Influence of Wrist Position on the Metacarpophalangeal Joint Motion of the Index Through Small Finger

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David Latz¹, Christos Koukos¹, Petra Boeckers¹, Pascal Jungbluth¹, Erik Schiffner¹, Robert Kaufmann², and Sebastian Viktor Gehrman¹

Abstract

Background: The metacarpophalangeal joints exhibit range of motion that is influenced by wrist position. Synergistic motion occurs between the wrist and the metacarpophalangeal joints with different static wrist positions affecting joints' motion capability. The aim of this study was to determine how different wrist positions influence the active range of motion of the index through small finger metacarpophalangeal joints. **Methods:** The active range of motion of the index through small finger metacarpophalangeal joints of 31 healthy subjects was measured in flexion/extension and radial/ulnar deviation in 5 different flexion/extension wrist positions, using biaxial electrogoniometers. **Results:** There was a difference in range of motion of all fingers depending on the wrist position. The minimum metacarpophalangeal joint range of motion was found in 80° wrist extension, the maximum in neutral wrist position. For the index finger, flexion/extension was 84.7° (±8.6°) to 25.9° (±10.2°) and radial/ulnar deviation was 32.1° (±11.3°) to 22.6° (±12.8°). For the middle finger, flexion/extension was 84.8° (±8.5°) to 25.9° (±10.1°) and radial/ulnar deviation 28.8° (±11.1°) to 22.1° (±8.9). The fourth finger showed a range of motion for flexion/extension of 87.2° (±11.5°) to 22.8° (±11.6°) and radial/ulnar deviation of 8.1° (±5.8°) to 32.3° (±12.4°). The highest range of motion was measured at the fifth finger with flexion/extension of 84.0° (±8.6°) to 32.1° (±16.8°) and radial/ulnar deviation of 15.1° (±12.9°) up to 54.6° (±18.7°). **Conclusions:** The range of motion of the index through small finger metacarpophalangeal joints was significantly influenced by wrist position. The highest metacarpophalangeal joint range of motion of all fingers was conducted in neutral wrist positions. Apart from ergonomic implications, we conclude that metacarpophalangeal joint motion should be assessed under standardized wrist positions.

Keywords: finger motion, metacarpophalangeal joint, range of motion, tenodesis effect, goniometer

Introduction

Several anatomic structures influence the active and passive motion properties of the metacarpophalangeal (MCP) joints. Intrinsic structures (joint capsule, ligaments, articular cartilage, synovial fluid, inactive intrinsic muscles) as well as extrinsic structures (extensor and flexor muscles of the fingers) contribute to their movement.⁵ Maximizing range of motion (ROM) of the MCP joints is of value as minor restrictions can result in functional deficits.³ Motion restriction may occur in degenerative and posttraumatic conditions.¹⁰ The MCP joints of the index through small finger contribute to a multilink kinematic chain whose motion is influenced by wrist position.⁷ Linear relationships govern the motion between the wrist and that of the distal interphalangeal, proximal interphalangeal, and MCP joints.¹² A synergistic wrist motion pattern occurs with wrist flexion being accompanied by finger extension and

wrist extension being accompanied by finger flexion. This suggests that MCP joint motion would exhibit restricted extension capability if the wrist were maximally extended and, vice versa, MCP flexion would be restricted when the wrist was maximally flexed. Given these relationships, it follows that MCP mobility would be decreased if the synergistic motion patterns of the wrist were to be prevented. The kinematic changes of the MCP joint caused by the position of the wrist may have important ergonomic implications. As we know, grip strength is maximized when the wrist is extended and the MCP joints are flexed.^{6,9,13}

¹University Hospital, Düsseldorf, Germany

²University of Pittsburgh Medical Center, PA, USA

Corresponding Author:

Erik Schiffner, Department of Trauma and Hand Surgery, University Hospital, Moorenstrasse 5, 40225 Düsseldorf, Germany.
Email: erik.schiffner@med.uni-duesseldorf.de

Maintaining the wrist in suboptimal positions such as maximal flexion and extension, while also requiring repetitive finger motion, has been implicated as contributors to cumulative upper extremity musculoskeletal disorders, such as extensor tendinitis and carpal tunnel syndrome.^{1,2} Wrist ROM is affected by the position of the finger joints with flexion of the aforementioned resulting in significantly reduced wrist ROM.⁴ The corollary relationship of how MCP joint ROM is influenced by wrist position has not been quantified. Knowledge of the active ROM limits of the MCP joints as a function of wrist position is crucial so as to avoid repetitive motion tasks that extend beyond these limits. So far, it is not known how much the ROM of the index through small finger MCP joints is possible when the wrist is positioned in different positions. The purpose of this study was, therefore, to determine the active ROM of the index through small finger MCP joints while maintaining the wrist in different positions of flexion/extension (FE) and radial/ulnar deviation (RUD).

Materials and Methods

In this study, 31 right-handed male and female subjects with an age between 18 and 70 years and without a history of musculoskeletal diseases or trauma of the upper extremity were asked to participate. An approval by the institutional review board and an informed consent from each subject prior the procedure was obtained. Only subjects who were able to move the right wrist at least to 80° extension and 80° flexion actively were included in the study.

The joint motion of the index through small finger was measured with a biaxial electrogoniometer (Biometrics, UK) recording FE and RUD. The goniometers were attached to the dorsal aspect of the metacarpal and the proximal phalanx with double-sided medical adhesive tape. Free active motion of the finger MCP joints without deviation of the goniometer was ensured. The distal and proximal interphalangeal joints were stabilized in extended postures. The subjects were seated on a height-adjustable chair adjacent to a table onto which a custom-made arm mount was placed (Figure 1). The fixture maintained the right forearm in a comfortable position while keeping the elbow at 90° of flexion and 90° forearm pronation. The index through small finger metacarpals were clamped to position the wrist in 5 different FE positions (−80°, −40°, 0°, 40°, 80°). Free rotation was allowed at the MCP joints. The thumb assumed a relaxed posture.

Bidirectional motion of the index through the small finger MCP joints with active FE and alternating RUD (Figure 2) at a self-selected speed was encouraged. The subjects were verbally instructed to initiate MCP joint movement beginning with full extension and then flexing the joint while also moving in RUD (ie, circumduction). The subjects were encouraged to maximize the motion capability of

Figure 1. The forearm was stabilized on an arm mount and the third to fifth metacarpals kept stable with a clamp to hold the wrist in stable position. The biaxial goniometer was placed on the dorsal aspect of the second metacarpal bone and the proximal phalanx.

Figure 2. The task consisted of an index finger metacarpophalangeal joint motion from full extension to flexion and oscillating from radial to ulnar deviation. The resulting motion path covered the complete motion area of the joint.

the MCP joint during this task. The data were collected using a biaxial electrogoniometer system at a sample rate of 20 Hz. A practice trial was performed before data collection.

Raw data of the electrogoniometer were transformed into angular data and further analyzed with a custom-made MatLab program (The MathWorks, Natick, Massachusetts). An envelope was derived from the motion path of the angle-angle plot of FE vs RUD data. The envelope represents the maximal motion boundary of the MCP joint motion in FE and RUD, and the enclosed area characterizes the full motion capability of the joint. Repeated-measures 1-way analysis of variance was used to analyze the effect of wrist position on the ROM and envelope area ($\alpha = 0.05$).

Results

The motion envelope of the finger MCP joints has a narrow cuneiform shape with a round margin in extension and a

Figure 3. Motion envelope of the metacarpophalangeal joint of the middle finger generated by a subject holding the wrist at neutral position. Units in radian.

pointed margin in flexion (Figure 3). The envelopes exhibited similar shapes regardless of wrist position. The MCP joint ROM of the index through small finger was significantly influenced by wrist position (Table 1).

Maximum MCP joint ROM for all fingers was found in neutral wrist position. The greatest reduction in MCP joint ROM occurred while holding the wrist extended at 80° extension, except the index finger where the greatest reduction occurred at 40° extension.

The highest MCP joint ROM, measured by the motion envelope area, was found at the fifth finger with an area of 6043.9 (± 2412.2) square angles at neutral wrist position, whereas the smallest was found at the ring finger with an area of 3418.7 (± 818.8) square angles at neutral wrist position. Holding the wrist in 80° extension showed the smallest enveloped area for all but the index finger, where the minimum value was found at 40° extension.

When the ROM of the MCP joint was divided into flexion and extension components, we observed a significant reduction of extension when holding the wrist at 80° extension compared with all other wrist positions for the index through fourth finger (index: $P < .01$, third: $P < .01$, fourth: $P \leq .01$) except from the small finger. In that case, a significant reduction was observed only between 80° extension and neutral position of the wrist ($p < 0.05$). MCP joint extension was significantly higher when holding the wrist at 80° flexion compared with holding the wrist in 80° extended position for all but the small finger (index: $P < .01$, third: $P < .01$, fourth: $P < .01$, fifth: $P > .05$). Positioning the wrist in either a neutral position or flexed posture (0°, 40°) did not

reduce MCP joint extension significantly compared with 80° wrist flexion. Holding the wrist in 80° flexion resulted only in a small but significant loss of maximum MCP joint flexion of the index finger (79.5° (± 9.3) in 80° wrist flexion vs 81.9° (± 6.8) in 80° wrist extension, $P < .05$).

In RUD, the MCP joint ROM was also dependent on wrist position. Dividing the RUD in radial/ulnar components, maximum ulnar deviation capability was significantly higher than the radial deviation capability for the middle through small finger (index: $P < .01$, third: $P < .01$, fifth: $P < .01$). On the other side, maximum radial deviation capability was significantly higher than the ulnar deviation capability for the index finger ($P < .01$). For the index finger, ROM in FE was 84.7° ($\pm 8.6^\circ$) to 25.9° ($\pm 10.2^\circ$) and in RUD 32.1° ($\pm 11.3^\circ$) to 22.6° ($\pm 12.8^\circ$). The middle finger ROM in FE was 84.8° ($\pm 8.5^\circ$) to 25.9° ($\pm 10.1^\circ$) and in RUD 28.8° ($\pm 11.1^\circ$) to 22.1° ($\pm 8.9^\circ$). The fourth finger showed a FE of 87.2° ($\pm 11.5^\circ$) to 22.8° ($\pm 11.6^\circ$) and a RUD of 8.1° ($\pm 5.8^\circ$) to 32.3° ($\pm 12.4^\circ$). The low capability of the RUD for the middle and fourth finger was expected due to the position of the index finger to the radial and of the fifth finger to the ulnar side. A high ROM was measured for the fifth finger with FE of 84.0° ($\pm 8.6^\circ$) to 32.1° ($\pm 16.8^\circ$) and a RUD of 15.1° ($\pm 12.9^\circ$) to 54.6° ($\pm 18.7^\circ$).

Discussion

Wrist position significantly influenced MCP joint motion capability of the index through small finger. Maintaining the wrist at 80° extension reduced the FE capability of the MCP joints.

The synergy that couples motion of the fingers and wrist reflects the changes that govern the functional equilibrium of these joints.¹³ Positioning the wrist in flexion exerts tension on the extensor mechanism which leads to a more extended passive posture of the finger joints.¹² Active MCP joint flexion is then reduced due the preexisting stretch on the extensor tendons. Positioning the wrist in flexion additionally shortens the flexor muscles and reduces finger force production capability.⁶

In a neutral wrist position, the tendon excursions are proportional during active extension and flexion of the MCP joints,⁸ but the tendon excursion on the flexor side is greater than on the extensor side.¹¹ This may be why wrist flexion was less restrictive on MCP flexion than wrist extension was on MCP extension. A higher passive stretch of the flexor muscles, when holding the wrist in extension may be responsible. By this mechanism, wrist position also affects force production of the fingers.⁶

A higher ulnar than radial deviation capability of the index MCP joint was identified in our study and concurs with previous findings.¹⁴ A decrease of MCP joint ulnar deviation while holding the wrist maximally extended can be explained by the increased pull on the lumbrical muscle, which is placed

Table 1. MCP Joint Ranges of Motion and Standard Deviations in FE and RUD at All Wrist Positions in Degrees.

	Wrist position	Ulnar deviation	Radial deviation	Flexion	Extension	MCP area
Index finger						
Extension	80	22.6 (±12.8)	29.8 (±15.0)	81.9 (±6.8)	16.8 (±10.5)	5499.7 (±1642.9)
	40	20.3 (±12.8)	30.3 (±13.3)	84.7 (±8.6)	8.4 (±9.7)	4912.8 (±1325.6)
	0	20.7 (±11.7)	31.2 (±9.8)	83.5 (±8.7)	23.4 (±10.4)	6040.5 (±1778.5)
Flexion	-40	20.4 (±11.9)	32.1 (±11.3)	79.7 (±9.3)	24.3 (±12.3)	5954.7 (±1958.2)
	-80	21.8 (±10.5)	28.8 (±11.1)	79.5 (±9.3)	25.9 (±10.2)	5735.2 (±1573.6)
Third finger						
Extension	80	16.3 (±8.2)	15.9 (±8.1)	84.8 (±8.5)	7.7 (±12.2)	3434.9 (±1028.7)
	40	20.4 (±6.8)	13.1 (±5.8)	83.4 (±8.1)	18.9 (±9.8)	3924.7 (±1308.1)
	0	21.8 (±10.5)	28.8 (±11.1)	79.5 (±9.3)	25.9 (±10.1)	5735.2 (±1573.6)
Flexion	-40	19.5 (±9.9)	12.6 (±7.0)	82.6 (±10.4)	23.7 (±13.6)	3855.6 (±1848.6)
	-80	22.1 (±8.9)	9.6 (±5.5)	80.8 (±9.5)	23.2 (±13.5)	3799.2 (±1360.0)
Fourth finger						
Extension	80	32.3 (±12.4)	3.3 (±5.8)	84.2 (±11.6)	9.2 (±9.5)	2912.6 (±900.0)
	40	28.9 (±9.8)	5.4 (±4.9)	87.2 (±11.5)	14.7 (±6.8)	3308.2 (±1168.2)
	0	28.0 (±10.7)	8.1 (±5.8)	83.4 (±10.6)	22.4 (±8.2)	3418.7 (±818.8)
Flexion	-40	29.4 (±13.3)	5.7 (±5.7)	82.7 (±8.9)	20.0 (±9.9)	3203.5 (±980.6)
	-80	30.4 (±11.7)	5.4 (±7.9)	83.9 (±8.6)	22.8 (±11.6)	3164.0 (±1126.1)
Fifth finger						
Extension	80	54.6 (±18.7)	14.4 (±11.7)	79.5 (±13.1)	23.3 (±13.2)	5432.1 (±1960.4)
	40	48.9 (±13.6)	15.1 (±12.9)	82.9 (±9.2)	25.4 (±13.2)	5655.5 (±2378.2)
	0	48.5 (±17.0)	14.8 (±12.8)	84.0 (±8.6)	31.3 (±15.3)	6043.9 (±2412.2)
Flexion	-40	49.2 (±14.1)	11.7 (±12.4)	77.6 (±13.7)	29.2 (±14.4)	5681.6 (±2161.9)
	-80	51.7 (±18.2)	11.3 (±11.6)	78.0 (±11.2)	32.1 (±16.8)	5806.7 (±2430.0)

Note. Bold numbers mark the maximum excursions in each direction, and the gray numbers mark the minimum excursions ($P < .05$). MCP = metacarpophalangeal joint; FE = flexion/extension; RUD = radial/ulnar deviation.

under more tension in extended wrist positions. Tension on the first lumbrical muscle, eg, which inserts on the radial side of the extensor hood, is likely the culprit in limiting ulnar deviation of the index finger's MCP joint.

From a functional point of view, reciprocal effects exerted between the wrist and MCP joints influence the human prehension, gripping, and throwing efforts. Holding objects

securely requires the finger joints to be flexed and this is facilitated by wrist extension. Releasing objects during a throwing motion requires the MCP joints to extend. Similarly, a precise throwing motion benefits from a stable grip around an object at an initial wrist extended phase. During this stage, the wrist extension restricts MCP joint extension. The wrist flexed phase occurs at the release portion of the

throwing motion at which time higher MCP joint extension capability assists a controlled release.

The ergonomic design of a computer mouse follows the same principle. Most mouse designs have a convex surface that, when cupped by a hand, dictates both wrist and index finger MCP joint positions. The second mouse button located on the “ulnar” side of the first button is ergonomically benefited by the increased index finger MCP joint ulnar deviation capability.

This study has several limitations. A major limitation relates to matching of the long axis of the metacarpal and proximal phalangeal bones with the proximal and distal arms of the goniometer. In this study, the long axes of the bones were determined by palpation, which we considered adequate. For any goniometer-based motion analysis, skin movement can also cause measurement errors of the underlying metacarpal bones, but most of the skin movement occurs in the long axis of the finger, so this effect did not change the results of measurements.

When measuring the MCP joint mobility, for diagnosis of pathology or post surgical evaluation of treatment outcomes, knowledge of the wrist position's influence of joint ROM is of import. Constraining the wrist in a 40° flexed posture will maximize the total ROM in FE of the MCP joint, while holding the wrist in neutral position will maximize total ROM in RUD.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

There is a positive vote from the ethics committee of the Medical Faculty.

Statement of Informed Consent

Prior to subject's participation, written informed consent was obtained.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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