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Scientific/Clinical Article

Predictive value of metacarpophalangeal stabilization tests for simulated ulnar nerve lesion measured by a sensor glove



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ABSTRACT

Study Design: A within-subject research design was used in this study. The difference of the range of motion (ROM) with and without ulnar nerve block was analyzed.

Introduction: For the clinical evaluation of the functional effects of ulnar nerve palsy at the hand the relevance of clinical tests is in discussion.

Purpose of the Study: The aim of the study was to evaluate the predictive value of 2 clinical tests for a simulated ulnar nerve lesion by motion analysis with a sensor glove.

Methods: In 28 healthy subjects, dynamic measurements of the finger joints were performed by a sensor glove with and without ulnar nerve block at the wrist. In the 0° metacarpophalangeal (MCP) stabilization test, the subjects were asked to stabilize the MCP joints actively in 0° while moving the interphalangeal joints, whereas at the 90° MCP stabilization test, the subjects stabilized the MCP joints actively in the 90° position.

Results: In the 0° MCP stabilization test, no remarkable changes of the ROM were found at the MCP joints; at the proximal interphalangeal joints 2-5, the ROM decreased with ulnar nerve block, significantly at the index, middle, and ring fingers ($P < .05$). In the 90° MCP stabilization test, the average ROM of the MCP joints 2-5 significantly increased with ulnar nerve block ($P < .05$), whereas at the PIP joints, the average ROM decreased ($P < .05$).

Discussion: The 90° MCP stabilization test had a high predictive value for the discrimination between healthy subjects and subjects with a simulated peripheral ulnar nerve lesion.

Conclusions: The results could be relevant for the determination of the functional effect of ulnar nerve palsy and the quantification of clawing in hand rehabilitation.

Level of Evidence: II.

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Introduction

Lesions of the ulnar nerve are constituted to be the second most frequent nerve lesions in the upper extremities.¹ Ulnar nerve palsies are caused by injury or compression at various localizations, for example, as a result of a compression neuropathy of the nerve.² The functional deficit depends on the location of damage and can lead to characteristic changes in the grip function of the hand. One characteristic symptom, the so-called claw hand, consisting of a hyperextension of the metacarpophalangeal (MCP) joints with flexion of the proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints, predominantly in the fourth and fifth digits, has been reported by Bouvier.³ A clinical test described by Bouvier, also known as Bouvier test, requires the stabilization of the MCP joints in a 90° position (passive in the original description) while actively

flexing and extending both the PIP and DIP joints. It serves to clarify whether complete active extension of the PIP joints is still possible when intentionally preventing hyperextension of the MCP joints in an existing claw hand.⁴

In the present study, a test has been defined based on the Bouvier test's approach in which a subject is to stabilize the MCP joints actively in a 0° position, whereas at the same time an isolated active flexion and extension of the PIP and DIP joints is being carried out.⁵ The test has been named 0° MCP stabilization test; its suitability to test the intrinsic muscle function in an ulnar nerve lesion was examined.

For the clinical evaluation of the intrinsic muscles and therefore the diagnosis of an ulnar nerve lesion, Bourrel described an active stabilization of the MCP joints in a 90° flexion position during an active mobilization of the PIP and DIP joints.⁴ Based on this description, a 90° MCP stabilization test has been developed, testing the described movement pattern with the objective to verify the suitability of the test to diagnose a functional restriction of the intrinsic muscles in an ulnar nerve lesion.

As of yet, only few studies analyzing the dynamic sequence of finger movements in damaged hands exist. Direct methods have been developed recently, in which finger joint movements are tracked with multiple angle sensors located directly at the finger joints. The direct measurement has only been rendered possible by a significant reduction of the sensor size, so that they could be placed on the finger joints without disruption of the motion sequence. A sensor glove, developed at the Technical University of Berlin (TUB), enables the dynamic recording of the joint angles of all 3-joint fingers through 12 inductive motion sensors fitted on the extensor side, their own resistance being insignificant enough to not affect joint motion.⁶ The present study analyzed and compared the 2 specified metacarpal stabilization tests in healthy subjects and subjects with simulated ulnar nerve lesion and considered diagnostic importance they may hold for the evaluation of the functional effect of ulnar nerve palsy, especially the evolution of increasing clawing with time.

Material and methods

About 28 male right-handed subjects with a mean age of 34.8 years (21–41) participated in the study. A clinical examination showed no pathologic functional disorder of the hands in any of the subjects. The hand span averaged 23.5 cm (19.2–26.6), and the hand length averaged 20.4 cm (18.1–22.3) from the rascetta to the tip of the middle finger. To preclude habitual effects in all subjects, the order of measurements with and without ulnar block on different days, respectively, was randomized. To block the ulnar nerve, Mepivacaine hydrochloride was used as local anesthesia in all 28 subjects, injecting 5 mL of Mepivacaine 1% (50 mg Mepivacain hydrochlorid in 5 mL, HEXAL Inc., Holzkirchen, Germany) under aseptical conditions using a sterile 25-gauge short bevel needle directly radial to the flexor carpi ulnaris tendon (Fig. 1). Before and after the nerve block, the sensitivity and motor skills were clinically examined. Criteria used for successful ulnar nerve block were loss of sensation in the area innervated by the ulnar nerve and a reduced abduction and adduction of the fingers. Within approximately 6–10 hours, all subjects regained their normal motor and sensory hand function by 100% and without permanent damage. The utilization of local anesthesia in healthy subjects was approved by the ethical committee of the University of Ulm (application 36/2003). All subjects gave their written consent for participation in the study.

Each measuring process extended for more than 15 seconds. During this time, the respective grip sequence was repeated at least 5 times. All the gripping experiments were conducted in a standardized sitting position. In the present study, a test has been



Fig. 1. Ulnar nerve block proximal to the Loge de Guyon with 5 mL of Mepihexal 1% (50 mg Mepivacain hydrochlorid in 5 mL, HEXAL Inc., Holzkirchen, Germany).

defined based on the Bouvier test's³ approach, in which the subject is to stabilize the MCP joints actively in a 0° position, whereas at the same time, an isolated active flexion and extension of the PIP and DIP joints is being carried out. The test has been named 0° MCP stabilization test (Fig. 2). In the 90° MCP stabilization test, the MCP joints were actively stabilized in a 90° flexion, whereas PIP and DIP joints were flexed and extended to their maximum (Fig. 3). Test series were performed in every subject without anesthesia and with nerve block, respectively, for both tests at different days by random order. The motion pattern was recorded with the TUB sensor glove. The glove was made of cotton and elastane weighing approximately 200 g. It was equipped with 12 inductive length measuring sensors at the extensor side of the fingers through which the joint angles can be measured after calibration. All sensors were connected to the analog-digital converter attached to the forearm through cable connections located on the extensor side. The connections and devices in question were attached in a way that limits the gripping motion as little as possible.⁶ Joint-angle-time diagrams were created from the raw data, which were initially evaluated on their quality (Fig. 4). From the diagrams, the maximum ranges of motion (ROMs) of the joints were graphically identified, and the average and standard deviation for the 5 movements were calculated. The differences between the average with and without ulnar nerve block were statistically tested within the same subject by a paired *t* test ($P < .05$). Statistical evaluations were calculated with StatView (SAS; Abacus Corporation). For all three-joint fingers, out of the amplitudes of movement of the MCP and PIP joints, the difference of MCP-PIP was calculated and the difference with and without ulnar nerve block was tested by *t* test for the 0° MCP stabilization test and 90° MCP stabilization test ($P < .05$).

Results

Both tests monitor the function of the intrinsic muscles; therefore, only the 3-joint digits were examined.

In the 0° MCP stabilization test, the MCP joints were held in an actively extended position, and the PIP and DIP joints were flexed and extended repetitively. The average ROM of the MCP joints 2–5 was 13.2 (± 13.9), 29.8 (± 11.6), 17.6 (± 8.0), and 2.5 (± 6.6). With ulnar nerve block, the average ROM of the MP2–MP5 was 14.7 (± 15.3), 28.0 (± 16.5), 22.3 (± 16.0), and 13.7 (± 14.7) with significant change only at the MCP joints of the small finger. However,

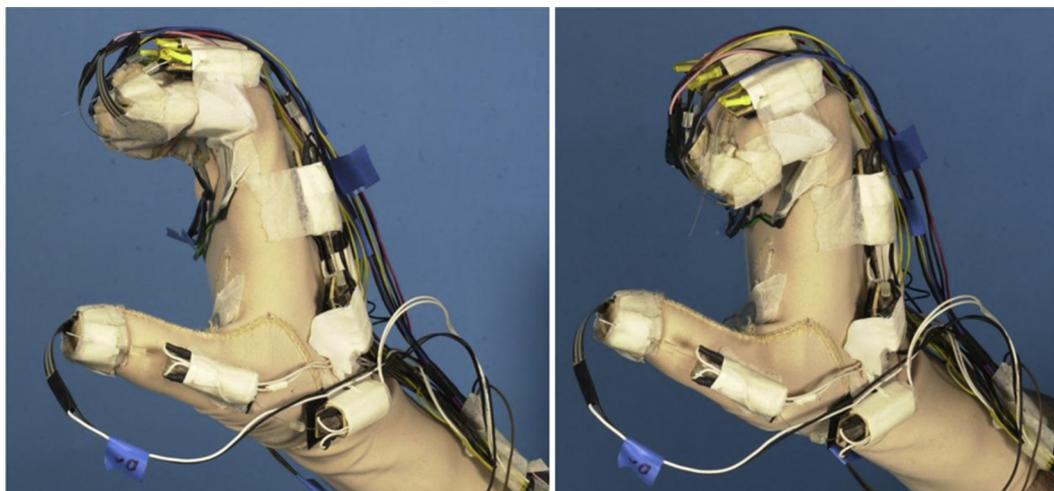


Fig. 2. A 0° metacarpophalangeal stabilization test.

there was an increase of the standard deviation for all fingers (Fig. 5). The PIP joints were flexed and extended almost completely; from index to little fingers, they went through an ROM of the PIP 2-5 of $73.8 (\pm 7.1)^\circ$, $76.2 (\pm 9.8)^\circ$, $72.2 (\pm 5.6)^\circ$, and $59.4 (\pm 14.2)^\circ$ on average. The DIP joints went through similar amplitudes of movement between 57° and 71° on average. In comparison to the ROM with ulnar nerve block, significant differences could only be found in the PIP joints of the index, middle, and ring fingers; the remaining joints showed no noteworthy changes (Fig. 5; $P < .05$). This also held true for all the differences of the ROM MCP-PIP (Fig. 6).

In the 90° MCP stabilization test without ulnar block, the MCP joints could be held consistently in approximately an 80° position. During the tests, the ROM of the MCP joints averaged MCP 2-5 $9.7 (\pm 4.5)^\circ$, $7.8 (\pm 6.0)^\circ$, $9.1 (\pm 3.6)^\circ$, and $8.5 (\pm 7.2)^\circ$ (Fig. 7). With ulnar block, the ROM increased almost uniformly in all MCP joints 2-5 to $23.8 (\pm 10.9)^\circ$, $19.3 (\pm 11.4)^\circ$, $20.5 (\pm 11.2)^\circ$, and $22.4 (\pm 9.6)^\circ$ on average. The difference was even more obvious in the PIP joints. Where they ranged at PIP 2-4 from $60.7 (\pm 21.2)^\circ$, $68.1 (\pm 12.6)^\circ$, $62.2 (\pm 12.9)^\circ$, and $51.1 (\pm 17.8)^\circ$ on average without ulnar block, the ROM decreased to $41.4 (\pm 22.0)^\circ$, $52.3 (\pm 17.2)^\circ$, $40.9 (\pm 15.9)^\circ$, and $29.5 (\pm 16.9)^\circ$ on average with ulnar nerve block. The difference in all fingers was significant ($*P < .05$, $**P < .005$, $***P < .0005$; Fig. 7).

In the DIP joints, there was no significant change in the amplitude of movement with ulnar block, ranging between 43° and 55° on average. The changes in the ROM of the MCP and PIP joints were contrary. There was an increase of the ROM in the MCP joints and a decrease in the PIP joints. Hence, the difference of the MCP and PIP joints, MCP-PIP, was significant in all fingers with $P < .0019$ at the index, $P < .008$ at the middle, $P < .0007$ at the ring, and $P < .0001$ at the little finger (Fig. 6).

Between the physiological movement amplitudes and those with ulnar nerve block, the results showed a significantly greater difference in the 90° MCP stabilization test than in the 0° MCP stabilization test.

Discussion

The relative contributions of the intrinsic and extrinsic muscles are clinically important to the understanding of the hand dysfunction seen in patients with ulnar nerve palsy. Ulnar nerve palsy results in considerable flexion moment decrease at the MCP joint. This altered mechanical equilibrium results in the claw hand deformity.⁷ Only few data exist on the dynamic movement patterns in existing palsies of the ulnar nerve. Hahn et al⁸ analyzed the movements of the finger joints with a 3-dimensional ultrasound

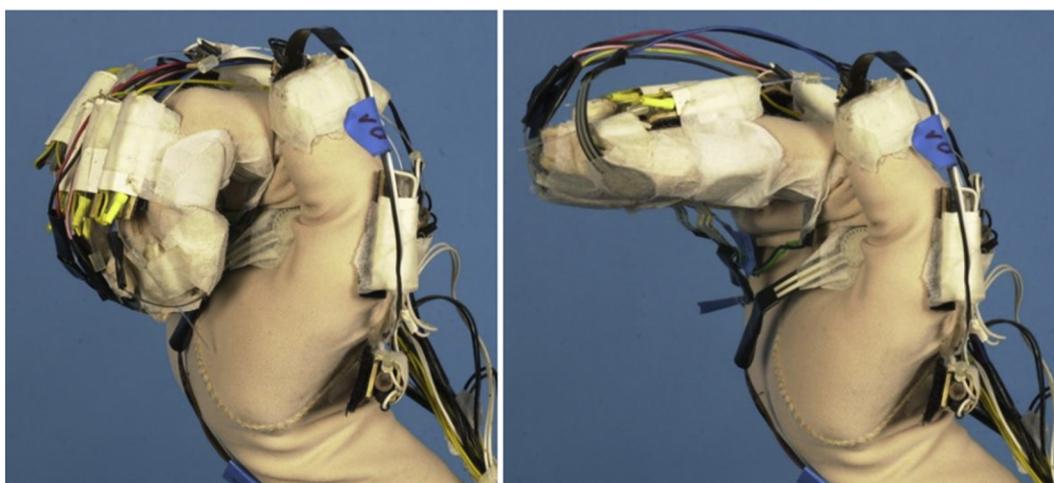


Fig. 3. A 90° metacarpophalangeal stabilization test.

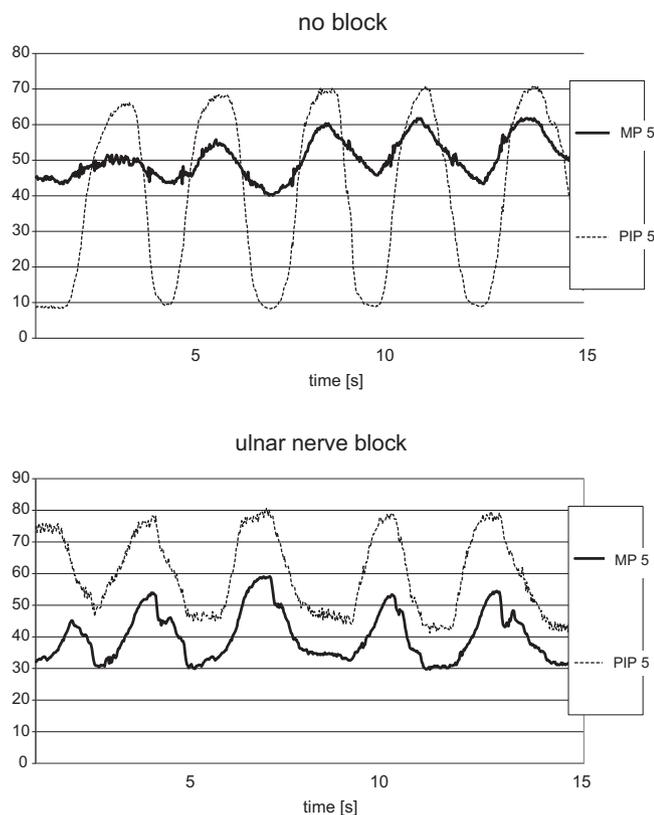


Fig. 4. Joint-angle-time diagram performing the 90° metacarpophalangeal (MCP) stabilization test with and without ulnar nerve block. MCP5 and proximal interphalangeal (PIP5) of subject 5.

that made a real-time recording of the finger joint movements possible. A pathologic motion pattern could be identified in 90% of patients with ulnar nerve entrapment in comparison to movement patterns of healthy hands with intact neural networks. However, it was not analyzed in detail which finger joints or digits of the hand in particular were responsible for these pathologic movement patterns. Brandsma et al⁹ examined a clinical test holding actively the MCP joints in a flexion position and the PIP joints in an extended position, described as intrinsic-plus position, and then giving resistance to the volar side of the proximal phalanx by the examining person. When testing the strength of intrinsic muscles in the intrinsic-plus position, the examiner is primarily assessing the strength of the interosseous muscles. In the clinic, the test has been established as reliable in the diagnosis of an ulnar nerve pathology for all 3-joint fingers. They suggested that specific movements be tested and graded when assessing and evaluating muscle or nerve function. In the present study, we evaluated the 0° MCP stabilization test, in which the subject is to stabilize the MCP joints actively in a 0° position, while at the same time, an isolated flexion and extension of the PIP and DIP joints is being carried out. However, differences in ulnar nerve block were not very pronounced. In the analysis of a similar grip through electromyography and movement analysis, Darling and Cole¹⁰ found strong simultaneous activation patterns in the flexor and extensor muscles. This could be explained by the necessity of the extrinsic extensors to partially antagonize the flexion movement to maintain a neutral position in the MCP joints. Hence, the data of the present study allow the conclusion that the intrinsic muscles are not as involved in the stabilization of the MCP joints in a 0° extended position as in the stabilization in a 90° flexion position, or the extrinsic muscles are compensating the weakness of the intrinsic muscles at the 0° MCP

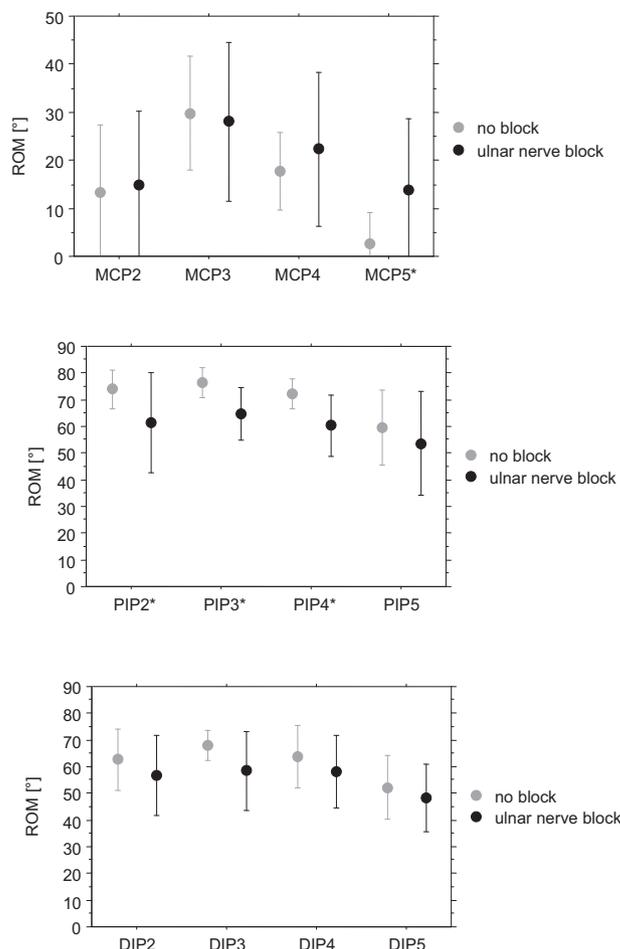


Fig. 5. A 0° MCP stabilization test. ROM of the finger joints (**P* < .05). ROM = range of motion; MCP = metacarpophalangeal; PIP = proximal interphalangeal; DIP = distal interphalangeal.

stabilization test. Therefore, the 0° MCP stabilization test is of minor importance in distinguishing subjects with and without ulnar nerve block.

Based on Bourrel,¹¹ a 90° MCP stabilization test has been defined in the present study. The active execution of this movement pattern can be managed if the intrinsic muscles are intact, resulting in small amplitudes of movement of the MCP joints and maximum amplitudes of the PIP and DIP joints. With an ulnar nerve block, the changes in the ROM of the PIP and DIP joints are contrary, resulting in an increase in the ROM of the MCP joints and a decrease in the PIP joints. This is due to the fact that the MCP joints can no longer be stabilized in the flexion position, which leads to significant discrepancies in the difference between ROM of the MCP and PIP joints (MCP-PIP) in all fingers. In the present study, this was most obvious in the movement analysis of the little finger. The declining strength of the intrinsic muscles, which contribute to a great extent to the moment of force of the flexion of the MCP joint during an extension of the PIP joint, can be identified as the responsible cause.¹² Schreuders and Stam¹³ measured the strength of the lumbrical muscles in 12 patients with complete ulnar nerve paralysis. In these patients, it was possible to measure directly the strength of the first and second lumbricals because the interosseous muscles are innervated by the ulnar nerve and, therefore, paralyzed. Thus, when the MCP joint is flexed, the lumbricals are the only muscles controlling PIP and DIP joint extensions. A dynamometer was used to press

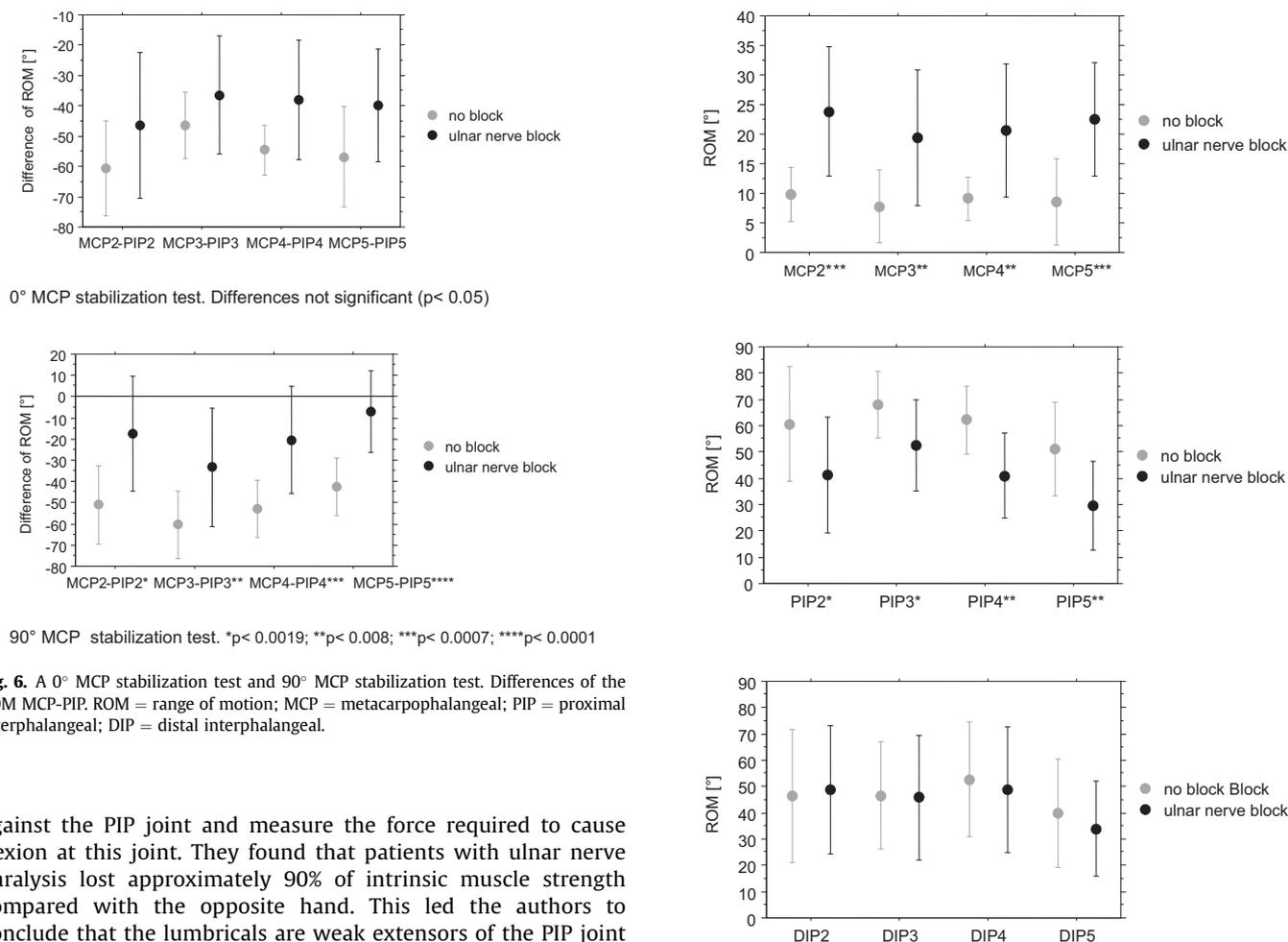


Fig. 6. A 0° MCP stabilization test and 90° MCP stabilization test. Differences of the ROM MCP-PIP. ROM = range of motion; MCP = metacarpophalangeal; PIP = proximal interphalangeal; DIP = distal interphalangeal.

against the PIP joint and measure the force required to cause flexion at this joint. They found that patients with ulnar nerve paralysis lost approximately 90% of intrinsic muscle strength compared with the opposite hand. This led the authors to conclude that the lumbricals are weak extensors of the PIP joint compared with the interosseous muscles.¹³ Koh et al⁷ determined the flexion moment losses at the MCP joint in low ulnar nerve palsy where the interosseus, hypothenar, and third and fourth lumbrical muscles would be paralyzed, but the second lumbrical muscle, which is innervated by the median nerve, would be spared. Therefore, the moment losses were calculated as 7%, 13%, and 28% in the middle, ring, and small fingers, respectively. They stated that the interosseous muscle contributes to about 22% of flexion at the MCP joints, whereas the lumbricals contribute to only 2%–3%.⁷ Radhakrishnan and Nagaravindra¹⁴ depicted a declining grip force in patients suffering from leprosy due to the loss of function of the intrinsic muscles through a lesion of the ulnar nerve by approximately 50%. Through experiments on the hands of cadavers, Ketchum et al¹² discovered that the intrinsic muscles of the index finger could supply 80% of the power of the superficial and the deep digital flexor tendon and that the intrinsic muscles supply 73% to the moment of force for the flexion of the MCP joint of the index finger.

The influence of ulnar nerve palsy has been measured by motion analysis by Hahn et al⁸ with a 3-dimensional ultrasound technique, enabling a real-time recording of the finger joint movements. A pathologic movement pattern of the index finger could be identified in 90% of patients with ulnar nerve entrapment; however, it was not analyzed in detail which finger joints in particular were responsible for these pathologic movement patterns. Thus, for the detailed real-time motion analysis of the finger joints, a sensor glove was developed at the TUB, which enables the dynamic recording of the joint angles of all fingers through 12 inductive motion sensors fitted on the extensor side, their own resistance being insignificant enough to not affect the joint

Fig. 7. A 90° MCP stabilization test. ROM of the finger joints (* $P < .05$, ** $P < .005$, and *** $P < .0005$). ROM = range of motion; MCP = metacarpophalangeal; PIP = proximal interphalangeal.

movements. The validity and reliability of the measurements were confirmed by Mentzel et al⁶ in healthy subjects. In another step, Mentzel et al¹⁵ analyzed various primary grip patterns in healthy subjects. In the present study, the suitability of this method to measure the joint angles of the fingers was confirmed. However, the study design implicates some limitations. In our setting, an immediate postulnar nerve block effect was assessed. The long-term effect of an ulnar nerve palsy leads to a stretching of the volar structures at the MCP joints as a consequence of the repeated tendency of hyperextension at the MCP joints to attempt full finger extension. Further studies are required to proof the reliability of the 90° MCP test at that clinical stage of ulnar nerve lesion. Effects can also be expected to be different when given an ulnar block at different sites, as for example, at the elbow, so this study is limited to a distal ulnar nerve block. The sensor glove measurements for subjects with an ulnar nerve block showed much greater differences between the physiological ROMs in the 90° MCP stabilization test than in the 0° MCP stabilization test. The 90° stabilization test is an easily executed test. It complements other measurement methods, like the measurement of strength of the intrinsic muscles in the diagnosis of dysfunction of the hand in ulnar nerve lesions. It can be performed to easily monitor the motor function of the hand in evaluation and rehabilitation of ulnar nerve palsy. As this study focused on the short-term effects of the ulnar nerve

block, further clinical studies are required to evaluate the value of the test for monitoring the evolution of increasing clawing in ulnar nerve palsy with time.

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Quiz: # 591

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- # 1. In an ulnar nerve injury there is typically
- an increased flexion moment at the MP joint
 - a decreased flexion moment at the MP joint
 - a decreased flexion moment at the PIP joint
 - a decreased flexion moment at the DIP joint
- # 2. The so-called 0° MCP Stabilization Test is used to assess
- MP ROM in patients with isolated ulnar nerve laceration at the wrist level
 - combined ulnar/median nerve function
 - global ulnar nerve function
 - intrinsic muscle function
- # 3. The Bouvier Test calls for
- PIP stabilization at 90°
 - PIP stabilization at 0°
 - MP stabilization at 90°
 - MP stabilization at 0°
- # 4. With the nerve block the following were found
- in the 0° MP stabilization position, decreased MP & PIP ROM
 - in the 0° MP stabilization position, no change in MP ROM and decreased PIP ROM
 - in the 90° MP stabilization position, no change in MP ROM and decreased PIP ROM
 - in the 90° MP stabilization position, decreased MP & PIP ROM
- # 5. The 90° stabilization test showed a high predictive value for discriminating between groups
- true
 - false

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