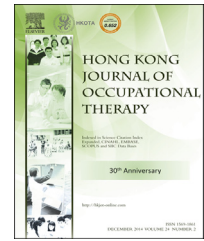Available online at www.sciencedirect.com

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ORIGINAL ARTICLE

Necessary Metacarpophalangeal Joints Range of Motion to Maintain Hand Function

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Summary *Objective/Background:* This study was conducted to ascertain the necessary flexion or extension range of motion (ROM) required for the finger metacarpophalangeal (MCP) joints to maintain hand function.
Methods: Twenty-one healthy adults were recruited for participation in this study. Each participant's right-hand function was evaluated using the Jebsen—Taylor hand function test and the O'Connor finger dexterity test. Experiment 1 was conducted to assess the influence of the orthosis on hand function. The function of each participant's right hand was measured without an orthosis, with all the finger MCP joints limited to 90° of flexion and 45° of hyperextension. Experiment 2 was conducted to evaluate the impact of limited flexion and extension of all the MCP joints on hand function. The movements of all the finger MCP joints were limited to 70°, 60°, 50°, and 40° of flexion and 20°, 30°, 40°, and 50° of extension lag using orthoses.
Results: No significant difference was found between a normal hand and a hand with either flexion of 90° or hyperextension of 45° in Experiment 1. In Experiment 2, no significant difference was found between a normal hand and a hand for which the flexion angle was 70°, with an extension lag of 30° or 20°.
Conclusion: The necessary ROMs of the MCP joints to maintain hand function are flexion ROM >70° with an extension ROM <30° of extension lag.
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Introduction

Hand injuries, burns, and diseases such as rheumatoid arthritis and scleroderma limit the range of motion (ROM) of finger joints and hamper hand function, thereby degrading activities of daily living (ADLs) and quality of life (Anzarut, Chen, Shankowsky, & Tredget, 2005). Hand function impairment is strongly associated with limited participation in ADLs, housework, education, etc. (Videler, Beelen, van Schaik, de Visser, & Nollet, 2009). Treatment goals for patients with impaired hand function are intended to eliminate dysfunction and to restore sufficient hand function for ADLs, work, and leisure activities by ensuring maximum functional improvement of the hand (Guzelkucuk, Duman, Taskaynatan, & Dincer, 2007; Michlovitz, Harris, & Watkins, 2004). Nevertheless, it is often difficult to regain ROM, muscular strength, perception, anatomical organization, and other functions completely. Finger contracture resulting from injury or disease of various kinds is one of the factors affecting hand function recovery (Clements et al., 1999, Sandqvist, Eklund, Åkesson, & Nordenskiöld, 2004). Therefore, occupational therapists need information indicating the extent of finger flexion or extension that is necessary to maintain hand function. Such information is useful for setting ROM goals for patients with impairment in finger joints.

The ROM necessary for the finger metacarpophalangeal (MCP) joints to perform activities has been assessed in people using an electrogoniometer (Hayashi & Shimizu, 2013). These reported values are useful for setting ROM goals for patients with finger MCP joints limitation. However, it does not mean that a person cannot perform activities beyond the suggested range. Moreover, diseases such as finger MCP arthroplasty, hand burns, and severe hand injury sometimes make it difficult to achieve the reported ROM. Although limitation in the finger ROM affects hand function, the degree to which a loss of finger flexion and extension adversely affects hand function are unknown. Therefore, ascertaining the ROM that is necessary for a finger to maintain hand function is important even if the finger ROM is limited.

Previous studies have demonstrated that limited ROM of the joints creates difficulties in performing activities for which specific movements such as holding and pinching are necessary (Clements et al., 1999; Estes, Bochenek, & Fasler, 2000; Holavanahalli, Helm, Gorman, & Kowalske, 2007). It has been demonstrated repeatedly that hand function is important for properly performing activities.

We studied the finger MCP joints because these joints are important for hand function (Moran & Berger, 2003). Motion of the MCP joints contributes to precision gripping and precision pinching. This study was performed to ascertain the flexion or extension ROM necessary for the finger MCP joints to maintain hand function. This study restricted the flexion or extension of all the fingers to simulate a burn injury, finger MCP joints arthroplasty, or severe hand injury, each of which can cause similar flexion or extension limitations in all the finger MCP joints.

Methods

Participants

The study participants were 21 undergraduate and graduate students recruited at Seijoh University (Tokai City, Japan). These 13 men and eight women (mean age 21.7 ± 0.7 years; range, 21–23 years) were all right handed, with no upper extremity condition. The study participants took part in Experiment 1 and Experiment 2. The study was approved by the Ethics Committee of Nagoya University, Nagoya, Japan (Approval Number 11-608). All participants provided written informed consent after being informed of the study aims and experimental procedures.

Instrumentation

We used two prefabricated orthoses for each participant according to the participant's hand size (Tomei Brace Co., Ltd., Seto, Japan; Fig. 1): one was used to limit flexion and the other was used to limit extension of the finger MCP joints. One orthosis was adjustable to limit only the flexion of the finger MCP joints of all four fingers at four predetermined angles of flexion without limiting the extension. The other orthosis was adjustable to limit only the extension of the finger MCP joints of all four fingers at four predetermined levels of extension without limiting the flexion. The angles of limitation of these orthoses were adjustable by turning a screw at the edge of the orthosis using a hexagonal wrench.

Measurement procedures

The hand function was evaluated using the Jebsen–Taylor hand function test (Jebsen test) and O'Connor finger dexterity test (O'Connor test). The Jebsen test consists of seven tasks for assessing hand function. The time necessary for executing each task was measured. These seven tasks assess different hand functions including writing, simulated page turning, picking up small common objects, simulated feeding, stacking checkers, picking up large light objects, and picking up large heavy objects. The test has been used to evaluate hand function in patients with widely diverse conditions including stroke, burn injury, and arthritis (Beebe & Lang, 2009; Holavanahalli et al., 2007; Stamm et al., 2007). Results of the Jebsen test are reportedly related to ADLs (Sharma, Schumacher, & McLellan, 1994). In addition, the O'Connor test was used to assess fine motor dexterity involved in manipulating objects by measuring the time necessary to place three pegs into a hole, repeated for 100 holes (Kirby, 1979). Results of the O'Connor test are also related to ADLs (Gloss & Wardle, 1981).

The study was conducted in two stages. Flexion and then extension of all the finger MCP joints of participants were limited using an orthosis. However, to rule out the possibility that the orthosis itself hampered the participants' hand function, Experiment 1 was performed to assess the influence of the orthosis on hand function. Using the Jebsen test and the O'Connor test, the function of the participant's right hand was measured without an orthosis (normal hand), with
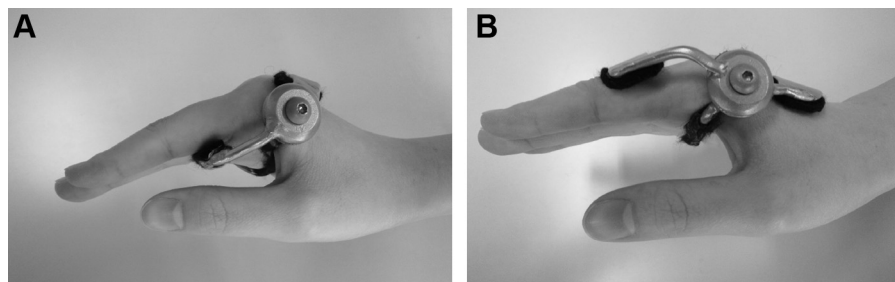
Figure 1 (A) Flexion-limitation orthosis and (B) extension-limitation orthosis. The flexion-limitation orthosis limits the flexion of the finger MCP joints. The flexion of all the finger MCP joints was limited to 70°, 60°, 50°, or 40°. The extension-limitation orthosis limits the extension of the finger MCP joints. The extension of all the finger MCP joints was limited to 20°, 30°, 40°, or 50° of extension lag. These orthoses can limit flexion or extension at varying angles. *Note.* MCP = metacarpophalangeal.

all the finger MCP joints limited to 90° of flexion (limited flexion trial) and 45° of hyperextension (limited extension trial). In other words, although all the finger MCP joints were limited to 90° of flexion and 45° of extension using an orthosis on the hand, the orthosis allowed free movement of the entire range of finger MCP joints. It is usual for the ROM of the MCP joints to fall within 90° of flexion to 45° of extension (American Academy of Orthopaedic Surgeons, 1965). Participants completed these three trials in random order. The time taken to complete each task was calculated. The results were reported as the sum of the time taken to complete seven tasks.

Experiment 2 was conducted to evaluate the impact of limited flexion and extension of all the MCP joints on hand function in healthy participants. Using the orthoses, movements of all the finger MCP joints were limited to 70°, 60°, 50°, and 40° of flexion and 20°, 30°, 40°, and 50° of extension lag. Participants performed the tasks of the Jebsen and O'Connor tests in random order with the normal hand and with the angle limited to the aforementioned eight levels.

Statistical analysis

The time necessary to perform the tasks of the Jebsen and O'Connor tests on the normal hand, limited flexion trial, and limited extension trial was compared using one-way analysis of variance. As a *post hoc* test, the Dunnett test was used to compare the time necessary to perform hand function tests in a limited ROM trial with a normal hand. Statistical analyses were conducted using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a modified version of R commander (version 1.6−3), a software that is commonly used in biostatistics. Significance was inferred for $p < .05$, unless noted otherwise.

Results

Experiment 1: Influence of an orthosis on hand function

The total mean time (seconds) necessary to perform the Jebsen test with a normal hand, with all the finger MCP joints limited to 90° of flexion, and with all the finger MCP joints limited to 45° of hyperextension was, respectively,

43.7 ± 4.0 seconds, 44.5 ± 4.1 seconds, and 44.1 ± 5.2 seconds. No significant difference was found between the results obtained for a normal hand and hands with the finger MCP joints limited to 90° of flexion ($p = .806$) or 45° of hyperextension ($p = .944$). The total mean time (seconds) necessary to perform the O'Connor test using a normal hand, with all the finger MCP joints limited to 90° of flexion, and with all the finger MCP joints limited to 45° of hyperextension was, respectively, 387.9 ± 43.8 seconds, 392.5 ± 55.2 seconds, and 396.8 ± 51.2 seconds. No significant difference was found between results obtained for the normal hand and hands with the finger MCP joints limited to 90° of flexion ($p = .901$) or 45° of hyperextension ($p = .740$). The study results show that application of an orthosis does not impair hand function.

Experiment 2: Influence of limited ROM of all the finger MCP joints on hand function

Jebsen test
The total mean time (seconds) necessary to perform the Jebsen test at 70°, 60°, 50°, and 40° of flexion was, respectively, 47.4 ± 4.9 seconds, 49.0 ± 5.4 seconds, 50.7 ± 5.5 seconds, and 53.5 ± 7.1 seconds. The mean total time (seconds) necessary to perform the Jebsen test at 20°, 30°, 40°, and 50° of extension lag was, respectively, 47.3 ± 5.8 seconds, 48.2 ± 5.1 seconds, 50.2 ± 6.3 seconds, and 51.0 ± 7.3 seconds. Regarding the limitation of flexion, significant differences were found between results for the normal hand and those of trials performed at 60° ($p = .027$), 50° ($p = .001$), and 40° ($p < .001$) in Jebsen test scores. No significant differences were found in hand function between a normal hand and hands limited to 70° of flexion ($p = .227$) in Jebsen test scores. Regarding the limitation of extension, significant differences were found between results obtained for the normal hand and those of the trials performed at 40° ($p = .004$) and 50° ($p < .001$) of extension lag in the total Jebsen test score. No significant difference was found in hand function between the normal hand and a hand for which the extension lag was 30° ($p = .088$) or 20° ($p = .241$; Table 1).

O'Connor test
The mean time (seconds) necessary to perform the O'Connor test at 70°, 60°, 50°, and 40° of flexion was,

Table 1 Total Mean Time (Standard Deviation) in Seconds Necessary for the Jebsen and O'Connor Tests Task Performance for a Normal Hand and for Eight Trials with Limited Flexion or Extension of all the Finger MCP Joints.

| | Jebsen test | | O'Connor test | |
	Time (SD)	p	Time (SD)	p
Normal hand	43.7 (4.0)		387.9 (43.8)	
70° flexion	47.4 (4.9)	.227	392.1 (43.9)	>.99
60° flexion	49.0 (5.4)	.027*	410.7 (45.6)	.716
50° flexion	50.7 (5.5)	.001*	434.9 (74.8)	.075
40° flexion	53.5 (7.1)	<.001*	475.3 (107.9)	<.001*
20° extension lag	47.3 (5.8)	.241	391.5 (42.1)	>.99
30° extension lag	48.2 (5.1)	.088	401.8 (47.7)	.962
40° extension lag	50.2 (6.3)	.004*	405.0 (46.8)	.901
50° extension lag	51.0 (7.3)	<.001*	432.8 (67.5)	.100

Note. MCP = metacarpophalangeal; SD = standard deviation.
* Significant difference on a limited ROM trial with normal hand ($p < .05$).

respectively, 392.1 ± 43.8 seconds, 410.7± 45.6 seconds, 434.9 ± 74.8 seconds, and 475.3 ± 107.9 seconds. The mean time (seconds) necessary to perform the O'Connor test at 20°, 30°, 40°, and 50° of extension was, respectively, 391.5 ± 42.1 seconds, 401.8 ± 47.7 seconds, 405.0 ± 46.8 seconds, and 432.8 ± 67.5 seconds. Significant differences were found between the normal hand and the results of trials performed at 40° of flexion ($p < .001$). At 50°, 60°, and 70° of flexion, the time necessary for the task performance was greater, but no significant difference was found. No significant difference was found in hand function between the normal hand and that of any other trial with an extension lag (Table 1).

Discussion

Occupational therapy plays an important role in reducing the limitations of activities such that the treatment goal of occupational therapy is to improve a patient's ability to perform activities. Therefore, understanding the degree to which the flexion or extension ROM of the finger MCP joints negatively affects hand function is important. This study evaluated the impact of limited flexion or extension of all the finger MCP joints on hand function in healthy participants. Results show that hand function does not decline by achieving flexion ROM >70° or an extension ROM <30° of extension lag. The findings of this study are applicable to occupational therapy practice for patients with limited ROM of the finger MCP joints.

No significant difference was found in this study in either the Jebsen test total time or the O'Connor test between a normal hand and a hand for which the flexion angle was 70°. Experimental results show that hand function might not be impaired by achieving flexion ROM >70°. A previous study described that the functional flexion ROM of the finger MCP

joints was 61° by measuring the joint position of participants' finger as they grasped objects (Hume, Gellman, McKellop, & Brumfield, 1990); by contrast, Hayashi and Shimizu (2013) reported that the maximum flexion angle of the finger MCP joints used in daily activities was much greater than 61°. Gülke et al. (2010) reported that the finger MCP joints flex from about 50—60° even while holding a 4-cm-diameter cylinder. The finger MCP joints require greater flexion to pick up small objects. Probably, to hold objects securely, fingers must flex more than the suggested position (Hume et al., 1990). The O'Connor test involves pinching with the index and middle fingers and the thumb. During pinching, the finger MCP, proximal interphalangeal (PIP), and distal interphalangeal (DIP) joints share the entire degree of flexion in the ratio of 59:32:9 (Nakamura, Miyawaki, Matsushita, Yagi, & Handa, 1998), which indicates that the ROM of the finger MCP joints is important for pinching. Therefore, it might take a longer time to perform pinching when the flexion of all the finger MCP joints is limited.

Reportedly, although the relation between total active extension and disability is significant, it is not strong (Zyluk & Jagielski, 2007). Nevertheless, few studies have found the extension ROM necessary to prevent a decline of hand function. The present study found no significant difference in either the Jebsen test total score or the O'Connor test between the normal hand and for those tests in which the extension lag was 30° or 20°. Therefore, hand function might not be impaired by achieving extension ROM <30° of extension lag. An earlier study found the extension lag to be significantly correlated with patient's satisfaction rate with hand function. Patients who achieved an extension lag of 30° of the MCP joints expressed satisfaction with hand function (Waljee & Chung, 2012). Our findings demonstrate that an extension ROM of <30° of extension lag for all the finger MCP joints does not signal a decline in hand function. We also observed that participants with limited extension of the finger MCP joints used their palms and thumbs for compensatory movements. However, such compensatory movements differ from normal movements. These might be reasons why the participants examined in this study took a longer time to complete these tasks. No significant difference was found in the O'Connor test scores of a normal hand and in the trials with extension limitation, probably because individuals need not open their hands wide while holding small objects (Gülke et al., 2010) and because the finger MCP joints remained flexed during the O'Connor test tasks. Results show that finger dexterity requires no finger MCP joints extension.

This study has some limitations. First, the flexion or extension of all the fingers was limited to simulate burn injury, MCP joints arthroplasty, and severe hand injury, each of which can cause similar flexion or extension limitations in all the finger MCP joints. Therefore, the study results might not provide useful information on finger fractures or tendon ruptures, which typically limit the flexion or extension of the finger MCP joints of a single finger. Second, participants with limited flexion or extension of the finger MCP joints used their palms and other joints such as a PIP joint or DIP joint for compensatory movements. However, we have not measured the ROM of the wrist and other joints. Finally, although previous reports show that the time recorded as necessary in

a functional assessment is correlated with hand function, we did not directly evaluate the participants' performance in ADLs or work.

Conclusion

This study revealed that hand function might not be impaired if flexion ROM is $>70°$ and extension ROM is $<30°$ of extension lag. Even in patients in whom the ROMs of finger MCP joints are limited, treatment improves hand function. The results of this study are expected to provide occupational therapists with valuable information that might help establish the flexion or extension ROM required for the MCP joints to maintain hand function for patients with limited ROM of the finger MCP joints.

Acknowledgements

References

American Academy of Orthopaedic Surgeons. (1965). *Joint motion: Method of measuring and recording.* Edinburgh & London: Churchill Livingstone.

Anzarut, A., Chen, M., Shankowsky, H., & Tredget, E. E. (2005). Quality-of-life and outcome predictors following massive burn injury. *Plastic and Reconstructive Surgery, 116,* 791–797.

Beebe, J. A., & Lang, C. E. (2009). Relationships and responsiveness of six upper extremity function tests during the first six months of recovery after stroke. *Journal of Neurologic Physical Therapy: JNPT, 33,* 96–103.

Clements, P. J., Wong, W. K., Hurwitz, E. L., Furst, D. E., Mayes, M., White, B., et al. (1999). Correlates of the disability index of the health assessment questionnaire: a measure of functional impairment in systemic sclerosis. *Arthritis and Rheumatism, 42,* 2372–2380.

Estes, J. P., Bochenek, C., & Fassler, P. (2000). Osteoarthritis of the fingers. *Journal of Hand Therapy, 13,* 108–123.

Gloss, D. S., & Wardle, M. G. (1981). Use of a test of psychomotor ability in an expanded role. *Perceptual and Motor Skills, 53,* 659–662.

Guzelkucuk, U., Duman, I., Taskaynatan, M. A., & Dincer, K. (2007). Comparison of therapeutic activities with therapeutic exercises in the rehabilitation of young adult patients with hand injuries. *The Journal of Hand Surgery, 32,* 1429–1435.

Gülke, J., Wachter, N. J., Geyer, T., Schöll, H., Apic, G., & Mentzel, M. (2010). Motion coordination patterns during cylinder grip analyzed with a sensor glove. *The Journal of Hand Surgery, 35,* 797–806.

Hayashi, H., & Shimizu, H. (2013). Essential motion of metacarpophalangeal joints during activities of daily living. *Journal of Hand Therapy, 26,* 69–73.

Holavanahalli, R. K., Helm, P. A., Gorman, A. R., & Kowalske, K. J. (2007). Outcomes after deep full-thickness hand burns. *Archives of Physical Medicine and Rehabilitation, 88,* S30–S35.

Hume, M. C., Gellman, H., McKellop, H., & Brumfield, R. H., Jr. (1990). Functional range of motion of the joints of the hand. *The Journal of Hand Surgery, 15,* 240–243.

Kirby, T. J. (1979). Dexterity testing and residents' surgical performance. *Transactions of the American Ophthalmological Society, 77,* 294–307.

Moran, S. L., & Berger, R. A. (2003). Biomechanics and hand trauma: what you need. *Hand Clinics, 19,* 17–31.

Michlovitz, S. L., Harris, B. A., & Watkins, M. P. (2004). Therapy interventions for improving joint range of motion: a systematic review. *Journal of Hand Therapy, 17,* 118–131.

Nakamura, M., Miyawaki, C., Matsushita, N., Yagi, R., & Handa, Y. (1998). Analysis of voluntary finger movements during hand tasks by a motion analyzer. *Journal of Electromyography and Kinesiology, 8,* 295–303.

Sandqvist, G., Eklund, M., Åkesson, A., & Nordenskiöld, U. (2004). Daily activities and hand function in women with scleroderma. *Scandinavian Journal of Rheumatology, 33*(2), 102–107.

Sharma, S., Schumacher, H. R., Jr., & McLellan, A. T. (1994). Evaluation of the Jebsen hand function test for use in patients with rheumatoid arthritis [corrected]. *Arthritis Care and Research, 7,* 16–19.

Stamm, T., Mathis, M., Aletaha, D., Kloppenburg, M., Machold, K., & Smolen, J. (2007). Mapping hand functioning in hand osteoarthritis: comparing self-report instruments with a comprehensive hand function test. *Arthritis Care and Research, 57,* 1230–1237.

Videler, A. J., Beelen, A., van Schaik, I. N., de Visser, M., & Nollet, F. (2009). Limited upper limb functioning has impact on restrictions in participation and autonomy of patients with hereditary motor and sensory neuropathy 1a. *Journal of Rehabilitation Medicine, 41,* 746–750.

Waljee, J. F., & Chung, K. C. (2012). Objective functional outcomes and patient satisfaction after silicone metacarpophalangeal arthroplasty for rheumatoid arthritis. *The Journal of Hand Surgery, 37,* 47–54.

Zyluk, A., & Jagielski, W. (2007). The effect of the severity of the Dupuytren's contracture on the function of the hand before and after surgery. *The Journal of Hand Surgery, European Volume, 32,* 326–329.