Mod Rheumatol (2007) 17:322–326
DOI 10.1007/s10165-007-0590-y

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ORIGINAL ARTICLE

**Takafumi Yayama · Shigeru Kobayashi · Yasuo Kokubo
Tomoo Inukai · Yasutaka Mizukami · Masafumi Kubota
Jyunichi Ishikawa · Hisatoshi Baba · Akio Minami**

Motion analysis of the wrist joints in patients with rheumatoid arthritis

Received: January 12, 2007 / Accepted: May 1, 2007

Abstract We investigated the characteristics of the wrist joint motion in patients with rheumatoid arthritis (RA), using a biaxial flexible goniometer. Wrist joint range of motion and velocity were measured on the dominant hand in RA patients ($n = 22$) and normal individuals ($n = 5$). We investigated flexion–extension (FE) task, radial–ulnar deviation (RUD) task, and functional motion tasks, such as writing letters or unscrewing the lid of a jar. In normal individuals, there was cooperative coupling of FE and RUD during wrist movement, and this coupling motion was essential for normal wrist movements. On the other hand, in RA patients, wrist joint range of motion was restricted at various degrees, with reduced joint motion velocity that was severe on RUD. Functional wrist motion tasks indicated circumductive movement with both FE and RUD in normal individuals, whereas the direction of movement was limited in RA patients, and results revealed failure of cooperative coupling of FE and RUD. Our results indicate that disturbed coupling of FE and RUD results in difficulties in the cooperative movements and have great influence on the daily activities in RA wrist joint.

Key words Biomechanics · Motion analysis · Rheumatoid arthritis · Wrist joint

Introduction

The wrist joint is involved in rheumatoid arthritis (RA) especially in patients with advanced disease. In daily clinical practice, it is essential to assess the anatomical conditions and impairment of the rheumatoid wrist joint followed by appropriate medical and physical therapies to maintain the patient's daily activities. It is obviously important to treat pain and its associated joint movement limitations, including the selection of appropriate treatment option.

The available surgical treatments for rheumatic wrist joints include synovectomy, resection arthroplasty, and arthrodesis, with suitability of each dependent upon the patient.[1,2] These surgical procedures may be performed on the basis of destructive conditions of the wrist joints, with a particular goal of increasing joint motion and elimination of motion pain. Various resection arthroplasty procedures and their modifications have been described, but each carries both advantages and disadvantages. Total joint arthroplasty is useful for the replacement of joints in destructive disease involving the hip or knee joints, both in terms of pain control and preservation of range of motion. However, in the wrist joint, prostheses lacks longevity and histocompatibility.[3–5] Total wrist arthroplasty has also been found to be unsuitable for severe joint malformation, chronic subluxion, and collapse of the carpal bone.[6] It is clear that optimum treatments are required for each stage of RA joint destruction.

The purpose of this study was to describe the two-dimensional in vivo behavior of rheumatic wrist joints using a biaxial goniometer. This analysis and assessment of the dynamic function of the wrist joint may be useful for allowing the RA patient appropriate joint motion in daily activities.

Materials and methods

Subjects

We conducted a motion analysis of the wrist joint in 22 RA patients who complained of pain and swelling. Patients were 2 men and 20 women, with an average age of 60.1 years (range, 29–74 years) at the time of the current analysis. All subjects satisfied the American College of Rheuma-

T. Yayama (✉) · S. Kobayashi · Y. Kokubo · T. Inukai · Y. Mizukami · M. Kubota · H. Baba
Department of Orthopaedics and Rehabilitation Medicine, Fukui University Faculty of Medical Sciences, 23 Matsuoka Shimoaizuki, Eiheiji, Fukui 910-1193, Japan
Tel. +81-776-61-8383; Fax +81-776-61-8125
e-mail: yayama@u-fukui.ac.jp

J. Ishikawa · A. Minami
Department of Orthopaedic Surgery, Division of Advanced Medical Sciences, Hokkaido University Graduate School of Medicine, Sapporo, Japan

tology 1987 revised criteria for RA,[7] and had no history of trauma, surgical treatment for the wrist joint, or neuropathy in the upper extremity. With regard to Larsen's radiographic classification, five patients had grade II conditions, six grade III, nine grade IV, and two grade V. Control subjects were five women of an average age of 25.2 years (range, 22–27 years) who had no destructive joint changes. The study protocol strictly followed the Ethics Review Committee Guidelines of our University Hospital, and written informed consent was obtained from all patients and control volunteers.

Experimental procedures

Wrist joint range of motion and velocity were measured on the patient's dominant hand (all subjects were right handed) using a biaxial goniometer (M100; Penny & Giles Blackwood, Gwent, UK). Markers were attached to the skin with adhesive tapes. The distal goniometry marker was placed along the third metacarpal bone, and the proximal maker was placed on the dorsal surface of the forearm along the radius.[8] After the attachment of the markers, the subject was seated with their humerus positioned at 0° abduction in the frontal plane and 0° flexion in the sagittal plane. The elbow joint was held at 90° of flexion and the forearms positioned at 0° of pronation (Fig. 1). During the flexion–extension (FE) task, the patient performed maximal flexion and extension at one cycle per second, paced by a metronome. The radial–ulnar deviation (RUD) task was similar to the FE task, except that the motion was in the radial–ulnar direction. Patients performed functional motion tasks, such as writing letters and unscrewing the lid of a jar, at their own speed.

Data processing and analysis

A neutral wrist position is defined as the 0° FE and 0° RUD when the axis of forearm and middle finger are in parallel. The FE and RUD tasks were performed at a sampling frequency of 200 Hz, and the motion angle and motion angle speed for the 6th to the 15th cycle of a total of 20 cycles were used for analysis. Subsequent analyses were conducted with a 2-channel analogue amplifier (AD Instruments Japan, Tokyo, Japan) and a Power Lab system (AD Instruments Japan). Mann–Whitney *U*-test and analysis of variance were used to analyze the results. The level of significance was $P < 0.05$.

Results

Flexion–extension task

Figure 2a shows a representative case of a 38-year-old woman who presented Larsen's radiographic classification

Fig. 1. Goniometry markers were placed on the forearm and hand. The subject was seated with the humerus positioned at 0° abduction and 0° flexion. The elbow joint was held at 90° of flexion and the forearms positioned at 0° of pronation

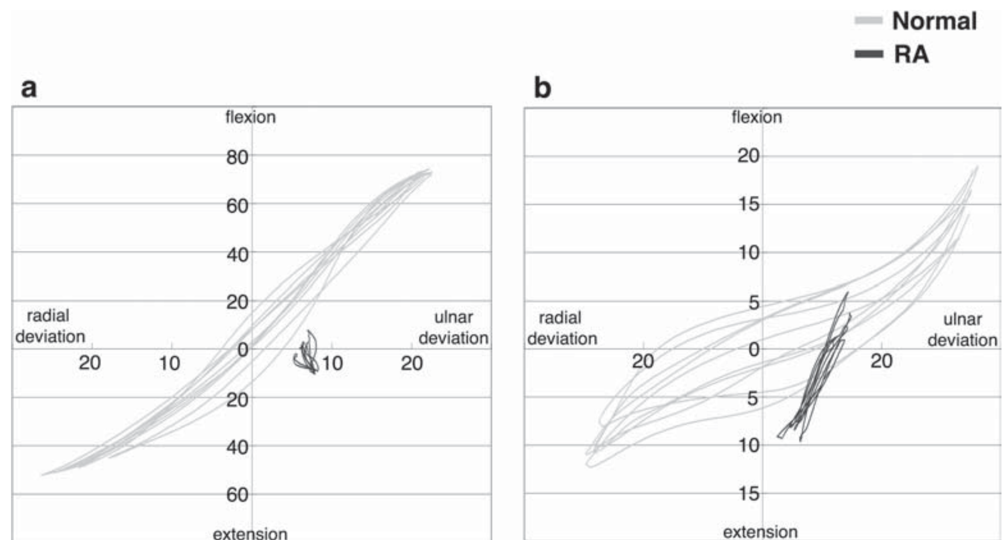

Fig. 2. Representative motion for angle–angle plots and their regression lines during flexion–extension (FE) (**a**) and radial–ulnar deviation (RUD) (**b**) trials. Rheumatoid arthritis (*RA*) patients (38 year-old woman, Larsen grade III) showed limited range of motion, and cooperative FE and RUD motion compared with normal individuals (22-year-old woman)

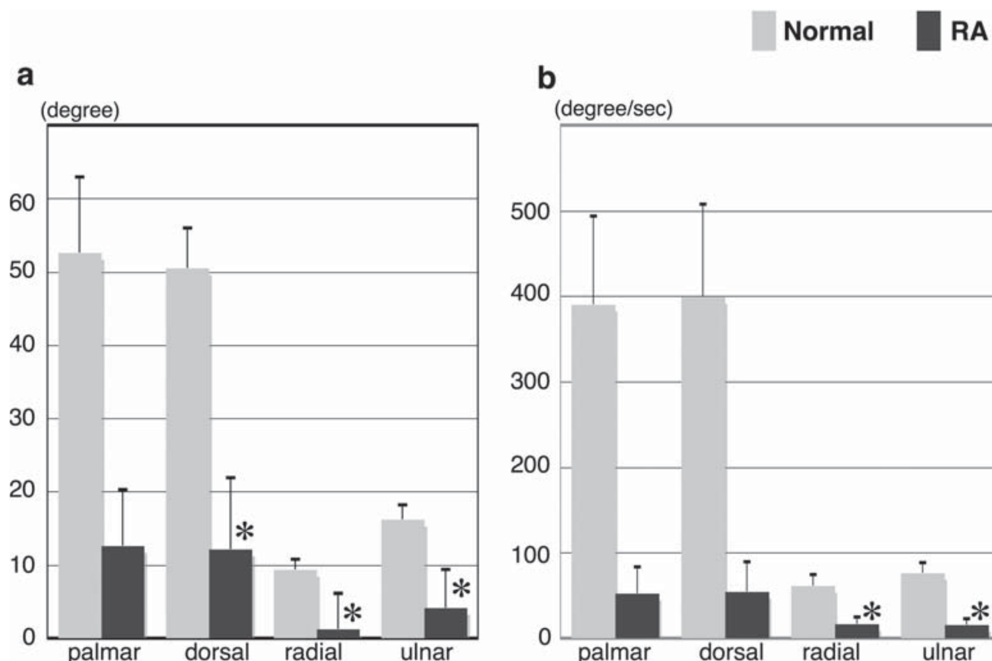

Fig. 3. Range of motion (**a**) and velocity (**b**) during FE tasks. There were significant differences in the range of motion on extension, radial-ulnar deviation and velocity on radial–ulnar deviation (* $P < 0.05$)

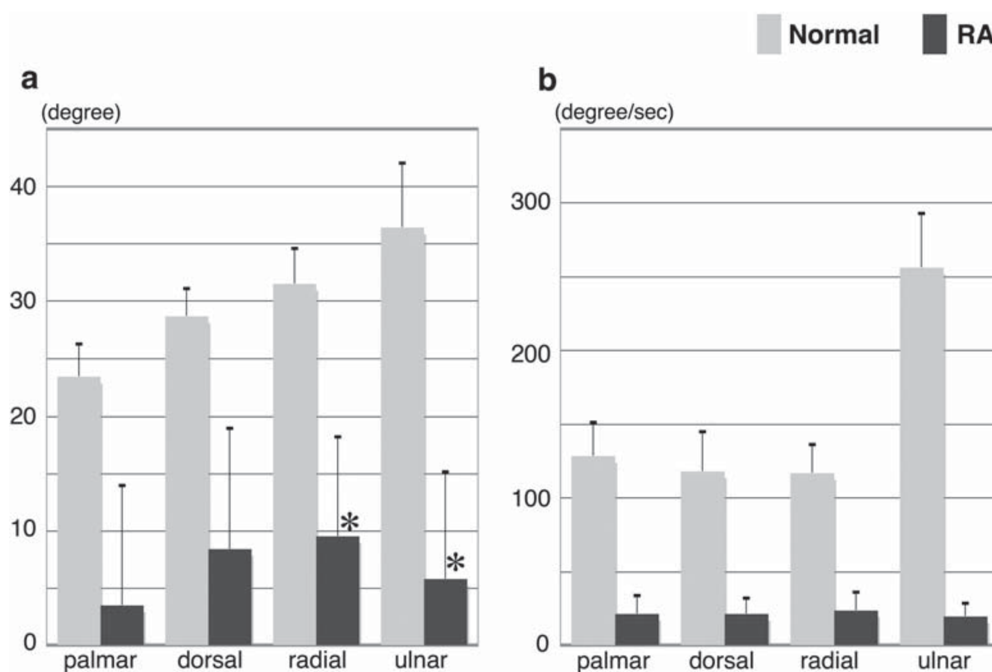

Fig. 4. Range of motion (**a**) and velocity (**b**) during RUD tasks. There was a significant difference in the range of motion on radial–ulnar deviation (* $P < 0.05$)

grade III. During the FE task, RA patients showed limited range of motion and cooperative FE and RUD motion of the wrist joint compared with normal individuals. Patients with RA exhibited a restricted wrist movement, especially for extension, radial deviation, and ulnar deviation (Fig. 3a). In addition, reduced performance in the FE task increased with the progression of joint destruction. Analysis of joint velocity showed marked impairment of directed radial-ulnar movement. The velocity of radial deviation was 15.8°/s in RA patients and 76.4°/s in normal individuals, while ulnar deviation was 16.7°/s in RA patients and 61.1°/s in normal individuals (Fig. 3b).

Radial–ulnar deviation task

During the RUD task, the control subject demonstrated a coupling of FE and RUD, which was reduced in the RA patient, similar to the findings in the FE task (Fig. 2b). Figure 4 shows the results of analysis of variance for RUD (Fig. 4a, range of motion; Fig. 4b, velocity). The average range of motion for radial deviation was 9.5° in RA patients and 31.5° in normal individuals, and radial deviation was 5.8° in RA patients and 36.4° in normal individuals. The velocity of RUD was reduced in all directions, though there were no significant differences between RA patients and

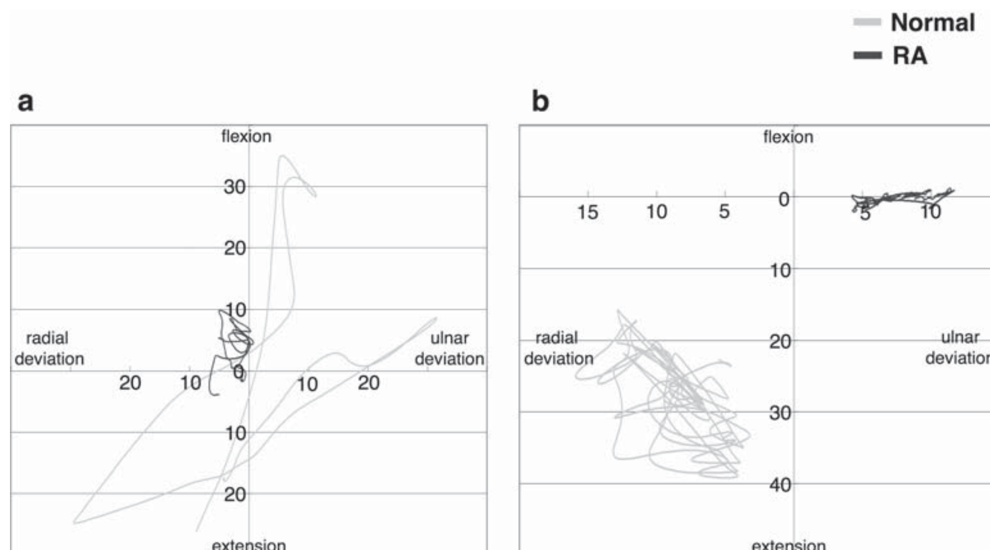

Fig. 5. Example of functional motion (**a**: unscrewing the lid of a jar; **b**: writing) in normal (22-year-old woman) and rheumatoid arthritis (*RA*) wrist joint (42-year-old woman, Larsen grade IV). Rheumatoid arthritis patient showed disturbance of the circumductory motion

control individuals. The range of motion and velocity tended to be reduced in proportion to the degree of joint destruction, and the relationship between Larsen's radiographic classification and RUD task parameters was insignificant.

Functional motion (unscrewing lid of a jar or writing letters)

In normal individuals, the wrist joint presented the boundary of motion in all directions, that the third metacarpal bone roundly moved to the axis of radius with circumduction cycles, when they unscrewed the lid of a jar. Figure 5a shows representative data of unscrewing from a 42-year-old woman with Larsen grade IV. The range of motion and velocity of wrist movement were severely limited in the study patients, and the wrist circumduction cycle was small. The RA patient tended to undergo a decrease of circumduction cycles to the extent of joint destruction. During writing, the normal wrist showed circumduction, with extension being the dominant direction of movement. Rheumatoid arthritis patients kept their wrist joint in a neutral or slightly flexed position, and writing was carried out by radial–ulnar deviation with an ulnar drift. The magnitude of the circumduction cycle was small or zero, as shown in the representative result illustrated in Fig. 5b.

Discussion

The wrist joint is a biaxial joint with two degrees of direction: a flexion–extension motion and a radial–ulnar deviation. The present study showed that cooperative coupling of FE and RUD was important for normal wrist movement.[9,10] Although a small amount of axial rotation may exist in FE and RUD, this motion has little effect and does not generally occur at the level of the wrist complex.[11,12] In our study, the primary FE motion necessitated comparable secondary motion in RUD, and the primary RUD also necessitated secondary motion in FE, as indicated by the slope of the regression line during FE or RUD tasks in the control wrist. These movements corresponding to extension with radial deviation and flexion with ulnar deviation (similar to the motion of a dart thrower) support a plane oblique to the anatomical planes and facilitate wrist mobility and agility. This coupling of FE and RUD has a large impact on the ability of patients to perform many activities of daily living, involved in many functional tasks such as hair combing, washcloth wringing, shoelace tying, and can-opening.[12]

The main factors that limit and affect wrist motion patterns include irregularity of articular carpal bone surfaces, constraints of carpal ligaments, and muscle contraction patterns.[13–15] Rheumatoid arthritis patients in the present study had a severely reduced range of motion and velocity of movement in the direction of radial–ulnar deviation during the FE task, and a restricted range of motion in radial deviation and ulnar deviation during the RUD task. These results indicate that the restriction of movement in the direction of radial–ulnar deviation caused by RA joint destruction may lead to imbalance of cooperative coupling of FE with RUD, and these imbalances are associated with difficulties in achieving smooth movement of the wrist joint.

The circumductive wrist motion, which was induced by cooperative FE and RUD coupling, also plays an important role in the capacity for daily activities. We presume that the velocity presented in this study may reflect the natural wrist motion of circumduction. Evans et al.[16] reported that the motion of the hand segment relative to the forearm segment during FE and RUD was of smaller magnitude in RA patients than in normal individuals. In our study, RA patients showed severely limited velocity in all directions of wrist motion and exhibited little wrist circumduction on writing or unscrewing of a jar. In addition, ulnar drift defor-

mity may also influence these motion impairments, because the wrist has the greatest range at the anatomically neutral position on circumduction.[17] These results indicate that appropriate stability of the radial-ulnar deviation is particularly important in the functional outcome of RA wrist joint movement. However, surgical stabilization of the radial–ulnar deviation may limit the range of wrist movement. Palmer et al.[12] showed that the range of wrist joint movement required for activities of daily living was 30° of dorsal flexion and 5° of palmar flexion. We consider that stabilization of radial-ulnar deviation is more important in reconstruction of the RA wrist joint than maximization of the flexion-extension range.

There are a number of limitations to this study. The wrist joint range of motion and velocity tended to be limited, and the wrist circumduction cycle was reduced in proportion to the degree of joint destruction in patients with RA. Because our study group was small, and pain and/or soft tissue imbalance may have affected wrist joint mobility, we could not assess the relationship between wrist joint function/kinematics and the stage of progression of destructive RA. Knowledge of the relationship between the grade of joint destruction and wrist kinematics is necessary for the determination of appropriate treatment. Further evaluation of the functional and dynamic motion of the wrist joint is needed.

In conclusion, the coupling motion of FE and RUD is important for natural wrist movement. There is a preferable wrist motion pattern that combines extension with radial deviation and flexion with ulnar deviation during daily tasks. Wrist joint destruction in RA severely affects the range of motion and velocity for RUD. We postulate that these imbalances of FE and RUD coupling motion greatly influence daily activities in RA wrist joint.

Acknowledgments This work was supported in part by a grant from the Investigation Committee on Rheumatoid arthritis, the Public Health Bureau of the Ministry of Health and Welfare of the Japanese Government.

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