Handedness and Hand Joint Changes in Rheumatoid Arthritis
(dominance, goniometry, deformity, joint protection)

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This study investigates the relationship of hand use to the deforming hand joint changes of rheumatoid arthritis. Measurements of metacarpophalangeal lateral mobility, loss of metacarpophalangeal hyperextension, thumb metacarpophalangeal range of motion, and lateral pinch strength were statistically compared across dominant and non-dominant hands of 51 adult subjects who had definite or classical rheumatoid arthritis. Incidence of boutonniere and swan neck deformities and distal radioulnar laxity was also recorded. Results of a multivariate analysis of variance of the difference scores between dominant and nondominant measures were not significant. The authors concluded that the relationship of hand use to joint destruction is not yet clearly defined and further study is needed. Implications for treatment principles of joint protection are presented.

Normal skeletal alignment and joint function in the human body depend on the integrity of the internal structures of the joint and the balance of external forces acting on the joint. The persistent inflammatory process of rheumatoid arthritis (RA) is destructive to the bony and soft-supporting intrinsic structures of an involved joint. The resulting pain and altered biomechanics predispose the joint to an imbalance of its external muscle forces (1, 2).

The synovial joints of the hands are typically involved in rheumatoid arthritis and, in time, frequently display characteristic joint deformities and changes in functional capacity. Bony erosions, weakening of the periarticular supporting structures, and muscle imbalance are all consequences of persistent destructive synovitis in the joints of the digits, the thumb, the metacarpals, the carpal, and the distal forearm.

A wide variety of assessment techniques has been used to measure hand deformity and joint changes. The three most common measurements are grip strength, range of motion, and pinch strength; however, the kaleidoscope of other assessments in the literature include roentgenograms, cadaver dissections, measurements of hand span and thumb web angle, hand profile tracings, finger-palm prints, joint circumference measurements, finger flexor strength measures, and dolorimeter measurements of pain (3-11).

A number of studies include test items of function such as tying knots, cutting wire, and buttoning (5, 12, 13). It is also possible to record categorical data such as presence of specific deformities, nodules, tendon dislocations or ruptures, intrinsic muscle tightness, crepitation, muscle atrophy, palmar erythema, and triggering (5, 9).

It has been suggested that the structural changes secondary to RA combine with the forces involved in the use of the hand to produce...
deformity (3, 14-19). Ellison, Flatt, and Kelly give equal weight to the deforming forces of usage and to the laxity of supporting joint structures (18). Flatt later states, “There must be aberrations of structure or function to initiate the deformity.” (14, p 266) Hakli and Tubiana, however, conclude that the external forces of hand use are only secondary to tissue destruction in the production of deformity in the rheumatoid hand (19).

A number of investigators have addressed the relationship of hand use to joint change in rheumatoid arthritis by comparing dominant and nondominant hand data (3, 9, 20, 21). They primarily studied the development of ulnar drift at the metacarpophalangeal (MCP) joints in the rheumatoid hand. Kemble demonstrated significantly larger angles of ulnar drift at the MCP joints of dominant hands than those of nondominant hands, and further stated, on the basis of X-ray data, that hand dominance “determines metacarpal head erosions and ulnar drift deformity.” (3, p 240) (italics for emphasis) Fearnley earlier stated, “In otherwise symmetrical cases with ulnar deviation more marked on the right, the greater use of the right hand will explain the deformity.”(20, p132) Treuhaft et al. (9), however, concluded that the joint changes of each hand in their subjects were nearly identical, and Lush concurred that there “appeared to be no correlation between the degree to which the hand was used or the nature of the patient’s work and the development of ulnar deviation.” (21, p 220)

Occupational therapists have traditionally taught joint protection to RA patients in an effort to minimize the dynamic deforming forces of the diseased hand. Treatment principles of joint protection that seek to reduce the joint stresses of daily hand use are based on the theory that the forces involved in the use of the hand contribute to structural joint changes and disease activity, thus fostering deformity (16, 17, 22-24). However, the equivocal results cited in the studies cited above mandate the need to further clarify the issues involved in the relationship between hand use and hand joint changes in rheumatoid arthritis.

The purpose of this study was to investigate the effects of hand use on the deforming joint changes of rheumatoid arthritis. Clinically observable hand joint changes were statistically compared across dominant and nondominant hands of 51 adult subjects who had definite or classical RA (25). In addition, categorical data on digital deformities and distal radioulna laxity were obtained. Based on the theory that the stresses involved in the use of the hand contribute significantly to joint changes and deformity in rheumatoid arthritis, and based on the assumption that the dominant hand is subjected to greater stress during daily activities than the nondominant hand, this study was designed to test the hypothesis that the dominant hand demonstrates significantly greater clinically observable joint changes than the nondominant hand in rheumatoid arthritis.

### Methods

Subjects for this study were 51 outpatients who had definite or classical rheumatoid arthritis as diagnosed by a physician. Subjects had no other connective tissue disease and no history of upper extremity surgical procedures. Ages ranged from 22 to 79 with a mean age of 54.15 years. There were 29 males and 22 females.

**Measurement Criteria.** An assessment battery measuring lateral laxity of the MCP joints in digits 2-5, loss of hyperextension of the MCP joints in digits 2-5, thumb MCP joint range of motion, and lateral pinch strength was administered to...
Table 2
Correlation Matrix of Hand Measurements: Rheumatoid Arthritis
(N = 51)

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<th>V5</th>
<th>V6</th>
<th>V7</th>
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$r$ of .273 significant at $p \leq .05$, $df = 49$

Each of the 51 subjects by the investigators. The presence or absence of swan neck and boutonniere deformities and distal radioulna joint laxity was also recorded.

Lateral laxity of the MCP joints was measured with a two-axis goniometer as described previously by Hasselkus, Kshepakaran, Houge, et al. (26). Swezey states that collateral ligament laxity is the primary component of ulnar drift (1). The two-axis goniometer enabled the investigators to measure the passive range of radial/ulnar movement at the MCP joint while maintaining the joint in flexion, that is, the joint position in which the collateral ligaments are normally taut (14, 17, 19).

Loss of hyperextension at the MCP joints (defined as 10° of motion beyond 0°) and range of motion of the thumb MCP were measured passively with a small finger goniometer that had been cut away to its axis to facilitate better clearance over bony protuberances. An OSCO pinch meter was used to measure lateral pinch force (27).

The presence of boutonniere deformity was defined as 10° or greater loss of extension of the proximal interphalangeal (PIP) joint in one or more digits on the hand. Swan neck deformity was defined as 10° or greater hyperextension of the PIP joint in one or more digits. The presence of radioulna joint laxity depended on testing for the "springboard" or "piano key" sign (24).

Analysis and Treatment of the Data. The data were analyzed using a multivariate analysis of variance (MANOVA). The ten dependent variables were passive MCP lateral mobility of digits 2-5, passive MCP hyperextension of digits 2-5, passive thumb MCP range of motion, and lateral pinch strength. The independent variable was hand dominance. Difference scores between dominant and nondominant measures for each variable were used to test the hypothesis. Distal radioulna joint laxity and boutonniere and swan neck deformities of the digits were descriptively analyzed.

Results
The results of this study are based on the measurement of 10 variables on both hands of each of the 51 subjects. Differences between group means using all the variables were used to test for the main effect of dominance.

Descriptive data from the MANOVA are presented in Table 1. The overall difference in clinically observable joint changes between dominant and nondominant hands was not statistically significant ($F(10, 41 = 1.3037); p = .261$). Thus the joint changes measured in the dominant hands were not significantly different from those measured in the nondominant hands. The hypothesis that the dominant hand demonstrates significantly greater clinically observable joint changes than the nondominant hand in rheumatoid arthritis was not supported.

The correlation matrix of the differences between the means of the ten variables is presented in Table 2. With an $r$ of .273, the strongest intercorrelations appear in Triangle II, that is, the measures of MCP hyperextension in digits 2-5. The highest coefficient, .8377 for $V_9/V_{10}$, indicates a very strong relationship.
between loss of MCP hyperextension in digit 4 and digit 5. Similarly, the correlation coefficient of .809 for \( V_r/V_s \) indicates a strong relationship between hyperextension measures in digits 3 and 4. In fact, all coefficients in Triangle II are high, suggesting significant relationships between the loss of hyperextension measures on all digits. Triangle I outlines the correlation coefficients for the measure of MCP lateral mobility in digits 2-5. The highest coefficient in this group is .4083 for \( V_r/V_s \), that is, the relationship between MCP lateral mobility measurements in digits 4 and 5.

Frequency of digital deformities and distal radioulnar joint laxity in dominant, nondominant, and bilateral hands is depicted in Figure 1. Of the 51 subjects, a total of 16 demonstrated radioulnar laxity, 23 had boutonniere deformities, and 14 had swan neck deformities. No pattern of dominant side involvement emerged; in fact, radioulna laxity was clearly more prevalent on the nondominant side.

Discussion

The results of this study on the relationship between handedness and hand joint changes in RA did not support the hypothesis that the dominant hand demonstrates significantly greater joint destruction than the nondominant hand. Thus, a clearcut relationship between hand use and the clinically observable joint changes measured in this study was not demonstrated.

It is assumed, when using a MANOVA for analysis of data, that the dependent variables are related and that they form a logical, conceptually meaningful set. "Multivariate analysis treats the data as a whole and considers correlations among measures," and the data are handled as "related aspects of a single response." (William C. Mann, Multivariate Analysis Institute, 1980 AOTA Conference, 515 Stockton Kimball Tower, Buffalo, New York 14214.)

The dependent variables in this study—MCP lateral mobility, loss of MCP hyperextension, thumb MCP range of motion, and lateral pinch strength—were selected on the basis of their logical interrelatedness in both the disease pathology and the theoretical dynamic forces of deformity in the rheumatoid hand. Smith et al. (16) link loss of MCP hyperextension and MCP lateral mobility together via the flexor forces exerted by the long finger flexors during hard grip and pinch activities. In the diseased hand, the flexor tendons tend to bowstring volarly and ulnarily at the mouth of the flexor tunnel at the MCP joints. As the supporting ligaments become weakened and elongated by the rheumatoid process, the volar and ulnar pulley of the long flexors during hand use becomes more and more forceful and the digits gradually move into a subluxed and ulnar-deviated posture. Ellison, Flatt, and Kelly (18) also relate MCP subluxation to ulnar drift, focusing on the deforming forces of the altered line of pull of the intrinsic muscles and the extrinsic extensors. Other studies provide further evidence for a strong relationship between loss of MCP hyperextension and ulnar drift (3, 6, 14, 20). In addition, prolonged synovitis of the most commonly involved joint of the thumb, the MCP joint, leads to joint instability and the classic thumb deformities described by Nalebuff (28). Laxity of the MCP joint and the laxity of the MCP joint of the index finger combine to result in a diminished pinch force (3, 4, 18). Thus the dependent variables chosen for this study did, in the authors' judgment, form a logical though unproven set.

The correlation matrix gives valuable clues on why the test of the mean differences among all the variables between dominant and non-dominant hands was not statistically significant. The correlations represent the strength of the rela-
the dominant and non-dominant hands for each variable. With 49 degrees of freedom, a correlation coefficient \( r \) of .273 is a value significantly different from zero. The higher the correlation, the greater the evidence of a meaningful strong relationship in the practical sense.

While a number of the variables demonstrate high correlations (especially \( V_3 - V_6 \), many do not. Most surprising were the low intercorrelations between many of the measures of MCP lateral mobility and those of loss of MCP hyperextension. Further, the authors had expected to find a strong correlation between lateral pinch strength and MCP lateral mobility, and these coefficients were very low. Passive range of motion of the thumb MCP did not correlate highly with any other variable.

To investigate the effect of the lack of relationship between many of the variables on the overall \( F \) value, two separate MANOVAs were run—one on the four variables that measured loss of MCP hyperextension, and one on the four variables that measured MCP lateral laxity. The results of the two separate MANOVAs were \( F(4,47) = 2.6771; p = .046 \) for the MCP hyperextension variable and \( F(4,47) = .2571; p = .904 \) for the MCP lateral mobility variable. This suggests that dominance is a major source of variance in the loss of MCP hyperextension, although its role in MCP lateral laxity continued to be statistically nonsignificant.

Other Factors to Consider. While a high correlation between MCP collateral ligament laxity and loss of MCP hyperextension is supported by a number of studies, the issue is far from clear. Treuhaft et al. (9) demonstrated a higher percentage of loss of MCP hyperextension than ulnar deviation in his hand study, so that the two variables do not necessarily occur in concert. Resnick (6) and Shapiro (15) both strongly implicate radial rotation of the wrist in ulnar deviation of the digits. Shapiro described the increased ulnar-volar force of the long flexors at the MCP joints with the wrist in radial rotation and the mechanical advantage this gave to the ulnar intrinsic, upsetting the normal delicate balance of the deep muscles during hand activity (15).

Ellison, Flatt, and Kelly (18) cite evidence that herniation of the proliferating synovium first occurs at the weakest anatomical point of the extensor expansion, that is, between the extrinsic extensor and the radial intrinsic insertion. Such a herniation changes the radial intrinsic line of pull so that the radio-ulnar balance is lost. The lumbricals are all radial intrinsics and, according to Eyler and Markee (29), the most important function of the lumbricals is to stabilize the MCP joint. Haktian and Tubiana state that it is conceivable that “capsular and ligamentous attenuation without involvement of the intrinsic muscles could produce a hand with very little ulnar-drift deformity.” (19, p 314)

Thus, the impact of persistent synovitis on the integrity of the intrinsic muscles and the subsequent implications on developing deformity need further investigation. A review of the factors that contribute to ulnar drift, as well as other hand deformities, is provided by Swezey (1).

Kemble (3) found significantly larger angles of ulnar drift, greater loss of MCP extension, and weaker pinch in sero-positive hands than sero-negative hands, regardless of dominance. He also found duration of illness strongly correlated with weak pinch and finger flexion forces. Neither of these variables was considered in this study. The use or nonuse of a cane or other walking aid might have proved to be another important variable in producing significant hand deformity; this information was not recorded. Further, one might speculate that persons with rheumatoid arthritis tend to shift much of their activity from a painful dominant hand to a less painful non-dominant hand, thus somewhat equalizing the resulting stress during hand use.

A number of subjects commented on this phenomenon.

**The Measure of MCP Lateral Mobility.** In retrospect, the method used to measure MCP collateral ligament laxity may have contributed to the nonsignificant results. The total range or arc of radio-ulnar movement of the MCP joint in the flexed position was recorded as the indication of collateral ligament laxity. The assumption was that as the arc of movement increased, so did the angle of ulnar drift. It is possible that this is not so. It may be that the range of laxity reaches a certain point and stabilizes, although its anatomical position continues to drift ulnarward. A 30° arc of radio-ulnar movement may be positioned in the midline of the articulation, or it may be from 10° to 40° of ulnar deviation. The total arc of movement is the same, but the second arc represents a more advanced stage of ulnar drift. In Lush’s study of ulnar deviation, 11 percent of the deviated digits could no longer be passively returned to the midline (21). Fearnley (20), in outlining the three stages of ulnar deviation, stated that the progression is toward gradual loss of the ability to actively or passively correct to the midline. If such is the case, a greater degree of ulnar deviation would not necessar-
The theories of joint protection are based on clinical observation, intuition, and logic. One concept imbedded in the principles of joint protection is that specific joint stress during daily activity can result in increased disease activity and can foster joint destruction and deformity. Patient education includes instruction to avoid activities that require hard grip and pinch, that subject joint ligaments and tendons to twisting and stretching, that create prolonged tension around a joint, and that rotate the digits in an ulnar direction. Resting splints, adapted self-care equipment, prescribed rest and exercise, and work simplification are all modes of treatment that are employed in occupational therapy (22-24, 30, 31).

The study was done in an attempt to test this theory of joint stress—that is, to explore the predictability of joint destruction and deformity and to ascertain to what degree actual data confirm or fail to confirm the theory. The data in this study failed to support the hypothesis, thereby failing to support the theory that links joint stress and hand changes in rheumatoid arthritis.

The interrelationships between the forces involved in the use of the hand and the joint changes of rheumatoid arthritis are very complex and need more precise and careful study to become better defined, both operationally and conceptually. Although the principles of hand joint protection make sense logically and intuitively, they are not yet strongly supported by clear-cut empirical data.

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REFERENCES