The Reliability of Goniometric Measurements of Active and Passive Wrist Motions

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Key Words: goniometry • measurement scales • wrist

A reliability study was conducted to determine (a) the intrarater and interrater reliability of goniometric measurement of active and passive wrist motions under clinical conditions and (b) the effect of a therapist's specialization on the reliability of measurement. Randomly paired therapists performed repeated measurements of active and passive wrist motions in 48 subjects who had been referred to one of four occupational therapy or hand management clinics for evaluation and treatment. The data were analyzed with an intraclass correlation coefficient. A posteriori data analyses were performed to determine the effects of identified sources of error on the reliability of measurement.

The results indicated that measurement of wrist motion by individual therapists is highly reliable and that intrarater reliability is higher than interrater reliability for all active and passive motions. Interrater reliability was generally higher among specialized therapists for reasons not immediately apparent from this study. With the exception of pain, identified sources of error were found to have surprisingly little effect on the reliability of measurement.

Wrist injury and pathology result in the functional limitation of the upper extremity, particularly during a person's working years. Although the incidence of impairment due to injury or disease of the wrist is difficult to determine, the results of an epidemiological study (Kelsey, Pastides, Kreiger, Harris, & Chernow, 1980) indicated that 16 million upper extremity injuries occur in the United States each year, with a total cost of $30 billion. Conditions affecting the wrist include (a) fractures; (b) dislocations, sprains, and strains; (c) open wounds; (d) burns; (e) nerve injuries; and (f) arthritis (Kelsey et al., 1980). Wrist motion may also be affected by damage to nonarticular structures or as a sequela to prolonged immobilization.

The measurement of active and passive wrist range of motion provides information on the muscle's ability to produce and transmit force and the condition of periarticular structures, respectively. Although occupational therapy assessment often includes the measurement of wrist motion, techniques are not standardized and measurements may vary for several reasons. Individual therapists may use consistent measurement methods and methods may be standardized within a clinic, but measurement practices may differ among clinics. Repeated measurements may not be performed by the same therapist, which may compromise the consistency of the clinical measurements. Additional variation may result from the patient's pain, fatigue, inconsistent voluntary effort, and affective and cognitive characteristics.

Researchers have studied the reliability of goniometric measurement of joint motion using normal subjects (Boone et al., 1978; Cobe, 1928; Hewitt, 1928; Low, 1976; Solgaard, Carlsen, Kramhoft, & Petersen, 1986), normal joints stabilized in external fixation devices (Fish & Wingate, 1985; Grohmann, 1983; Hamilton & Lachenbruch, 1969), and clinical subjects under rigidly standardized conditions (Hellebrandt, Duvall, & Moore, 1949). These studies, however, do not accurately represent range of motion measurements as they are conducted by occupational therapists in clinical settings. Rothstein, Miller, and Roettger (1983) suggested a protocol for the study of intrarater and interrater reliability of goniometric measurement under clinical conditions. This and subsequent studies have indicated that repeated measurements of the knee, elbow (Rothstein et al., 1983), and shoulder (Riddle, Rothstein, & Lamb, 1987) by the same therapist could be highly reliable, that individual measurements were no less reliable than the mean of three measurements (Rothstein et al., 1983), and that the reliability of the measurement was unaffected by the size of the goniometer used (Riddle et al., 1987, Rothstein et al., 1983). No clinical studies of the reliability of goniometric measurement of wrist
motions were found. Therefore, a reliability study was conducted to answer the following questions:

1. What is the intrarater reliability of the goniometric range of motion measurement of active and passive wrist motions in a clinical setting?
2. What is the interrater reliability of the goniometric range of motion measurement of active and passive wrist motions in a clinical setting?
3. What is the effect of a therapist's specialization on the reliability of goniometric measurement of active and passive range of motion of the wrist?

The study design was a modification of the method originally described by Rothstein et al. (1983).

Method

Definition of Terms

The following terms were operationally defined:

- **Active range of motion**—The maximum amount of joint motion attained by a subject during the performance of voluntary joint motion.
- **Passive range of motion**—The maximum amount of joint motion attained by a subject during the application of external force in the absence of voluntary muscle contraction.
- **Specialized therapist**—An occupational therapist or physical therapist at least 50% of whose treatment time was spent in the treatment of upper extremity injuries.
- **Nonspecialized therapist**—An occupational therapist or physical therapist less than 50% of whose treatment time was spent in the treatment of upper extremity injuries.

Subjects

The subjects were drawn from two occupational therapy departments and two hand management clinics. Criteria for inclusion in the study were that the subjects had been referred to the clinic for evaluation, treatment, or both and that the measurement of wrist range of motion would have normally been included in their assessments. Subjects undergoing periodic reevaluation were eligible for inclusion, but repeated measurement of the same extremity was not permitted. All subjects were at least 18 years old and signed a statement of informed consent.

Fifty wrist joints were measured in a sample of 48 subjects, 33 men and 15 women. The subjects ranged in age from 18 to 71 years, with a mean of 38.8 years. Forty-four subjects were of working age, 23 of whom had been injured in the course of their employment. Twenty-four subjects had injuries of the dominant hand, and 36 had undergone at least one surgical intervention. None of the subjects presented brain injury or upper motor neuron disorders.

Raters

Eleven registered occupational therapists and two licensed physical therapists participated in this study. The clinical experience of the 13 raters ranged from 2 months to 17 years, with a mean of 8.67 years. Six raters were specialists in hand therapy, with a mean of 3.75 years of specialty practice, and were employed at hand management clinics. The 7 nonspecialized raters worked in general physical disability settings. The 6 specialized raters had a mean of 8.08 years of clinical practice; the 7 nonspecialized raters had a mean of 9.41 years of clinical practice. In their daily work, the specialized raters measured wrist motions an average of five times per day; the nonspecialized raters measured wrist motions an average of three times per month.

Instrumentation

Active and passive range of motion measurements were performed with 8-in. blinded goniometers to which Vernier scales had been added (see Figure 1). A Vernier scale is a device used to increase the level of accuracy to which a linear or angular scale may be read; it eliminates the need for estimation of readings over a 5° interval. The accuracy of the goniometers and the Vernier scales was tested through the measurement of known angles. The goniometers used in this study were accurate to within 1°.

Procedure

The following procedure was used for the measurement of subjects by randomly paired sets of raters. For

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Figure 1. Blinded goniometer with Vernier scale.

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each rater pair, the first rater made sequential measurements of active wrist range of motion using the following sequence: extension, flexion, abduction, adduction. No techniques were specified, but the subject’s elbow, forearm, and finger positions were noted. The measurement was read and recorded, and the goniometer was reset to 0° before it was returned to the rater. The sequence was repeated so that there were two measurements of each active motion. After the first rater completed these measurements, the second rater measured the subject’s active wrist range of motion in the same sequence. Upon completion, the first rater returned and, using the same sequence, repeated the measurements for passive wrist range of motion, followed again by the second rater doing the same. To reduce the effect of muscle fatigue, a 2-min rest period was provided between the measurement of active motion by the first and second raters. After all of the data were collected for each subject, the raters were asked to note factors that might have affected the reliability of measurement for that subject.

The measurements required for this study preceded other evaluation procedures, and no treatment was provided until all of the data had been collected for the subject. None of the raters observed the measurement technique used by their paired raters during the data collection procedure. The raters were instructed to refrain from discussing the study until after its completion.

Data Analysis

A data analysis was performed with an intraclass correlation coefficient (ICC) (1, 1) (Shrout & Fleiss, 1979), which is based on the analysis of variance and provides an estimate of the agreement between ratings. The between-raters variance is included in the calculation of the ICC (1, 1), thus permitting generalization of the results beyond the raters in the present study. The standard error of measurement, which reflects the amount of error associated with individual measurements, was calculated for measurement of all active and passive wrist motions.

Results

Reliability

Descriptive statistics for each variable are displayed in Table 1. Intrarater reliability for the measurement of active wrist motions was determined through a comparison of the first and second measurements of each motion by each rater (see Table 2). Reliability coefficients for the measurement of active wrist range of motion exceeded .900 for all wrist motions. Intrarater reliability coefficients for passive wrist range of motion were similarly high. Agreement between measurements of motions in the sagittal plane (flexion and extension) was in both cases higher than that for measurements of motions in the frontal plane (abduction and adduction).

Interrater reliability was determined by a comparison of the first measurement of the first and second raters for each subject (see Table 2). Reliability coefficients for intrarater reliability of measurement of active wrist motions ranged from .783 for adduction to .905 for wrist flexion. Interrater reliability for measurement of passive wrist motions was generally lower, ranging from .662 for abduction to .855 for flexion. With the exception of adduction, the ICCs were lower for passive than for active measurement of all motions.

Specialty Practice

Intrarater reliability coefficients for the measurement of active wrist motions were higher among specialized than among nonspecialized raters (see Table 3). For active range of motion measurements, the coefficients for the specialized raters ranged from .909 for abduction to .974 for extension; those for the nonspecialized raters ranged from .860 for abduction to .890 for extension. Intrarater reliability coefficients for measurement of passive range of motion were slightly higher for the specialized than for the nonspecialized raters for flexion and extension. The reverse was true,
Table 2
Reliability for Measurement of Wrist Range of Motion

<table>
<thead>
<tr>
<th>Wrist Motion</th>
<th>Active ICC</th>
<th>95% CI</th>
<th>SEM</th>
<th>Passive ICC</th>
<th>95% CI</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Intrarater Reliability^b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extension</td>
<td>960</td>
<td>942</td>
<td>3.652</td>
<td>958</td>
<td>939</td>
<td>3.537</td>
</tr>
<tr>
<td>Flexion</td>
<td>974</td>
<td>935</td>
<td>3.528</td>
<td>958</td>
<td>940</td>
<td>4.136</td>
</tr>
<tr>
<td>Abduction</td>
<td>903</td>
<td>862</td>
<td>2.557</td>
<td>908</td>
<td>868</td>
<td>2.746</td>
</tr>
<tr>
<td>Adduction</td>
<td>921</td>
<td>887</td>
<td>5.485</td>
<td>935</td>
<td>830</td>
<td>5.017</td>
</tr>
<tr>
<td>Interrater Reliability^c</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extension</td>
<td>853</td>
<td>774</td>
<td>7.000</td>
<td>835</td>
<td>747</td>
<td>7.012</td>
</tr>
<tr>
<td>Flexion</td>
<td>905</td>
<td>851</td>
<td>6.579</td>
<td>855</td>
<td>777</td>
<td>8.242</td>
</tr>
<tr>
<td>Abduction</td>
<td>863</td>
<td>789</td>
<td>3.039</td>
<td>662</td>
<td>507</td>
<td>5.265</td>
</tr>
<tr>
<td>Adduction</td>
<td>783</td>
<td>673</td>
<td>5.777</td>
<td>851</td>
<td>742</td>
<td>4.849</td>
</tr>
</tbody>
</table>

Note. ICC = intraclass correlation coefficient; CI = confidence interval; SEM = standard error of measurement.
^b95% confidence interval denotes the lower bound of the ICC.
^cBased on 50 wrist measurements performed by each rater.

Table 3
Intrarater Reliability for Measurement of Wrist Range of Motion as a Function of Occupational Therapists' Specialty Practice

<table>
<thead>
<tr>
<th>Wrist Motion</th>
<th>Active ICC</th>
<th>95% CI</th>
<th>Passive ICC</th>
<th>95% CI</th>
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<tbody>
<tr>
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<tr>
<td>Intrarater Reliability^b</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Extension</td>
<td>974</td>
<td>.962</td>
<td>946</td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>958</td>
<td>.939</td>
<td>935</td>
<td></td>
</tr>
<tr>
<td>Abduction</td>
<td>909</td>
<td>.868</td>
<td>855</td>
<td></td>
</tr>
<tr>
<td>Adduction</td>
<td>932</td>
<td>.902</td>
<td>903</td>
<td></td>
</tr>
</tbody>
</table>

Note. ICC = intraclass correlation coefficient; CI = confidence interval.
^bDenotes an occupational or physical therapist at least 50% of whose treatment time was spent in the treatment of upper extremity injuries.

Table 4
Interrater Reliability for Measurement of Wrist Range of Motion as a Function of Occupational Therapists' Specialty Practice

<table>
<thead>
<tr>
<th>Wrist Motion</th>
<th>Active ICC</th>
<th>95% CI</th>
<th>Passive ICC</th>
<th>95% CI</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrarater Reliability^b</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extension</td>
<td>919</td>
<td>.872</td>
<td>901</td>
<td>835</td>
</tr>
<tr>
<td>Flexion</td>
<td>938</td>
<td>.896</td>
<td>902</td>
<td>836</td>
</tr>
<tr>
<td>Abduction</td>
<td>837</td>
<td>.734</td>
<td>637</td>
<td>446</td>
</tr>
<tr>
<td>Adduction</td>
<td>826</td>
<td>.717</td>
<td>808</td>
<td>690</td>
</tr>
</tbody>
</table>

Note. ICC = intraclass correlation coefficient; CI = confidence interval.
^bDenotes an occupational or physical therapist at least 50% of whose treatment time was spent in the treatment of upper extremity injuries.

However, for abduction and adduction. All ICCs for passive range of motion exceeded .900.

Discrepancies between the specialized and non-specialized raters were more marked for interrater reliability (see Table 4). Interrater reliability for measurement of active wrist motions by the specialized raters ranged from .826 for adduction to .938 for flexion. Reliability coefficients for the non-specialized raters were lower, ranging from .527 for extension to .896 for abduction.

Sources of Error

The factors most frequently cited by the raters as contributing to measurement error were pain (41 measurements in 28 subjects), external force application during passive range of motion (21 measurements in 15 subjects), and observable anatomical changes (16 measurements in 12 subjects). In no case was sensory or proprioceptive deficit considered to be a factor. Fatigue was cited infrequently (4 measurements).

Discussion

The reliability required of an instrument depends on the instrument and its intended use. The interpretation of reliability coefficients is thus somewhat arbitrary and is at the discretion of the reader. The following discussion is based on the guidelines provided by Fleiss (1986), who described a reliability coefficient (ICC) exceeding .75 as excellent, from .40 to 75 as fair to good, and below .40 as poor.
Reliability

Intrarater reliability for the measurement of both active and passive wrist motion was determined to be excellent for all motions. Reliability coefficients for active and passive measurements were similar for each motion, with the exception of adduction. The lower bounds of the ICCs were also in the excellent range. Thus, repeated measurements of wrist motion by the same therapist can be expected to be highly reliable under clinical conditions.

Interrater reliability coefficients were lower than those for intrarater reliability, although coefficients for all motions except passive abduction remained in the excellent range, as defined by Fleiss (1986). The lower bounds of the intrarater reliability coefficients, however, indicate that repeated measurements made by different therapists should be interpreted more conservatively than should measurements made by the same therapist. Thus, sequential measurements made by different therapists must show a greater disparity before the presence of clinical change in a patient may be assumed.

Specialty Practice

Although specialty practice was found to affect both intrarater and interrater reliability, the effect was greater in the case of interrater reliability. Intrarater reliability among specialized therapists was excellent for all motions except passive abduction. Intrarater reliability among nonspecialized therapists, however, was only fair for active extension, flexion, and adduction and for passive extension and flexion. Furthermore, the lower bounds of the ICCs for all motions except active abduction and passive adduction were close to 0, indicating that sequential measurements made by different therapists should be compared cautiously.

The source of lower interrater reliability among the nonspecialized therapists was difficult to determine with the data from this study. Three sources of error may have contributed to the discrepancies in reliability found between specialized and nonspecialized therapists. First, a practice effect may have resulted from more frequent measurement of wrist motion by specialized than by nonspecialized therapists. Second, differences in goniometer alignment, particularly during measurement of flexion and extension, may have affected the reliability of measurement. The literature supports alignment of the goniometer along either the radial (Moore, 1984; Scott & Trombly, 1983) or the ulnar (Esch & Lepley, 1973; Moore, 1984; Norkin & White, 1985) aspect of the wrist. All nonspecialized raters measured on the radial aspect of the wrist; all specialized raters measured on the ulnar aspect of the wrist. Thus, the presence of pain was associated with more marked reduction in the intrarater reliability of measurement at active, as opposed to passive, wrist range of motion. Interrater reliability of passive range of motion measurements did not appear to be systematically affected by the presence of wrist pain. This effect may have been the result of the order in which measurements were performed. The exacerbation of pain symptoms during measurement of active motion by the first rater may have affected measurements obtained by the second rater. Discrepancy might be expected between measurement of the asymptomatic joint by the first rater and the symptomatic joint by the second rater. Passive range of motion measurements followed active range of motion measurements in all cases. Pain levels during passive range of motion measurement of the first and second raters might then be expected to be more constant than during active motion. The presence or anticipation of pain by the subject, the rater, or both may have provided a more consistent end
Application of external force. The rater typically applied external force during measurement of passive range of motion. In 15 subjects (21 measurements), however, the subjects themselves applied external force, according to the rater's instructions. Intrarater agreement for passive wrist extension, flexion, and adduction was excellent regardless of the method of force application, as indicated by ICCs exceeding .920. Passive abduction was found to be measured less reliably when external force was applied by the subject. The ICCs for measurement of passive abduction, however, were generally lower than for those of other motions. Thus, with the exception of abduction, external force required for the measurement of passive wrist range of motion may be applied to the hand by the therapist or by the patient, according to the therapist's preference.

Anatomical changes. Anatomical landmarks used for goniometer alignment are easily obscured after injury to the hand or wrist. Hand edema is typically manifested dorsally, obscuring the contours of the metacarpals. Arthritic changes or posttraumatic wrist injuries may alter the orientation of the carpal bones, thus compromising the therapist's ability to locate the axis of motion. Finally, scarring may alter contours and obscure landmarks.

Although these features concerned the raters of 12 subjects in the present study (16 measurements), the presence of anatomical changes did not adversely affect intrarater reliability. In fact, intrarater reliability was higher for the subjects with observable anatomical changes. This associated improvement in reliability may be due to the raters' more careful goniometric alignment for what was presumed to be a difficult measurement situation.

Positioning. Riddle et al. (1987) found that among physical therapists, interrater reliability of measurement of passive shoulder motion was improved when the subjects were positioned similarly. A similar analysis in the present study was impeded by the fact that little variation in the positioning of subjects was noted.

Clinical Implications
The results of this study suggest that despite a lack of standardization of technique, the goniometric measurement of wrist motions is highly reproducible when performed under clinical conditions. Because interrater reliability was consistently lower than intrarater reliability, the same therapist should reevaluate patients whenever possible. These results are consistent with those of similar studies of measurement of the shoulder, elbow, and knee joints (Riddle et al., 1987; Rothstein et al., 1983).

The standard error of measurement provides an estimate of the amount of error associated with individual measurements; this is useful in determining the presence of meaningful clinical change in patients in response to clinical intervention. The standard error of measurement had not been presented in any studies on the reliability of goniometry that were reviewed.

The reliability of measurement of wrist motion during the present study was remarkably unaffected by such factors as variations in application of external force and anatomical changes due to trauma or deformity. Perhaps this was due to the raters' adequate control of these variables, which introduces implications for entry-level education. The control of such variables in changing clinical situations requires an understanding of the rationale for measurement techniques as well as competence in the psychomotor aspects of assessment. This level of understanding should be imparted in academic and fieldwork education programs.

The results of this study cannot be applied to measurements of wrist motion used for permanent disability ratings. The American Medical Association (AMA) stated that measurement techniques for the evaluation of permanent impairment should be "simple, practical, and scientifically sound" (AMA, 1984, p. 1). The AMA (1984) has provided detailed instructions for the measurement of each joint. None of the raters in this study used the AMA's suggested measurement techniques. Occupational therapists performing final disability ratings should therefore continue to use the techniques recommended by the AMA.

Only two reviewed studies addressed the amount of wrist motion that normal subjects required to perform functional activities (Brumfield & Champoux, 1984; Palmer, Werner, Murphy, & Glisson, 1985). The combined results of these two studies indicated that an arc of approximately 35° of motion in the sagittal plane and 25° in the frontal plane was sufficient for most activities of daily living. No studies have addressed the wrist range of motion requirements for occupational activities in an industrial environment, although the role of wrist positioning in the development of nerve compression and cumulative trauma disorders has been hypothesized (Armstrong, Fine, Goldstein, Lifshitz, & Silverstein, 1987; Gelberman, Szabo, & Mortenson, 1984; Silverstein, Fine, & Stevenson, 1987).

An effort was made to sample a broad range of clinical experiences and situations to make the results of this study more useful to occupational therapists in clinical practice. Nevertheless, the subjects in this study represent a limited sample, so the study results are not necessarily generalizable beyond the clinics.
and situations represented. In addition, the use of a
date recorder eliminated the potential error of a ther-
apist’s inability to accurately read and record measure-
ments from a goniometer scale.

Summary

The goniometric measurement of active and passive
wrist motions was found to be highly reliable when
conducted under clinical conditions. Intrarater reli-
ability was found to be consistently higher than inter-
rater reliability, although overall reliability remained
excellent. Speciality practice was found to affect in-
terrer more than intrarater reliability. Intrarater reli-
ability may have been influenced by frequency of
measurement, the knowledge base associated with
specialization of practice, or the method of
wrist motions was found

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ginia Commonwealth University, Richmond, Virginia.

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