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THE UNIVERSITY OF ALBERTA

ASSESSMENT OF THE VALIDITY OF GONIOMETRIC MEASUREMENT OF FINGER JOINT RANGE IN NORMAL ADULT HANDS

by

DONNA MAE DAVIES

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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(SIGNED) Donna M. Davies

PERMANENT ADDRESS:

11115-36 Avenue,

Edmonton, Alberta,

Canada T6J 0C2

DATED: April 25th, 1988.

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled ASSESSMENT OF THE VALIDITY OF GONIOMETRIC MEASUREMENT OF FINGER JOINT RANGE IN NORMAL ADULT HANDS submitted by DONNA MAE DAVIES in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

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Supervisor

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DATED: ..... April 20th ..... 19 88.

DEDICATION

To my Mother, and to Terry Groves M.D., who have always had faith in my ability and determination to achieve, and who have always encouraged and supported me in my scholastic endeavors.

ABSTRACT

Criterion validity coefficients of three goniometers and a visual estimate, used for determination of finger joint range in thirty normal adult hands were established. Female and male subjects, 20 to 50 years of age were tested with each of the tools, and had one lateral hand x-ray.

The criterion measure of x-ray assessment of MCP and PIP joint range was compared with measures of joint range from 1) a plastic universal goniometer applied laterally, 2) a metal finger goniometer applied dorsally, 3) a flexible metal strip applied dorsally and traced onto paper, and 4) a visual estimate.

One therapist with less than one year of clinical experience and a reliability of 0.937 performed the measures blinded. The third fingers of each subject were stabilized with an aluminum splint to prevent movement.

The joint ranges tested were 0-60 degrees of MCP flexion, 1-10 degrees of MCP extension, and 0-70 degrees of PIP flexion.

Validity coefficients (ICC) were greater than 0.900 for all measures except the visual estimate of the PIP joint. The dorsal methods demonstrated the highest coefficients and were consistent over sub-groups differentiated by age and sex. The visual estimate and the lateral method had the largest standard error of mean difference scores.

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ABBREVIATIONS

DG - dorsal goniometer

DIP - distal interphalangeal

E - extension

FG - flexible goniometer

ICC - interclass correlation coefficient

IRCP - International Commission on Radiological Protection

MCP - metacarpophalangeal

mSv - millisievert

PIP - proximal interphalangeal

PT - physical therapist

ROM - range of motion

UG - universal goniometer

UGA - universal goniometer with the fingers separated in four different planes

UGT - universal goniometer with the fingers all together in one plane

VE - visual estimate

CHAPTER ONE

THE PROBLEM

A. INTRODUCTION

Goniometers are used clinically by health care professionals -- nurses, physicians, physical and occupational therapists; to measure joint range of motion.

Determining the range of motion of a joint can provide the clinician with valuable information. Comparison of active and passive range when joint motion is restricted allows the clinician to speculate on the cause of the dysfunction and treat accordingly. Limitation of range in one joint can be compared with the normal contralateral joint. This comparison provides a basis for judgement of the maximum range to be expected, with treatment, in the joint that is limited. Repeated measures of joints with restricted range, over time, following treatment, is one method used to illustrate the effectiveness of treatment and to indicate when the treatment plan should be altered.

Goniometers, then, are used for assessment, for assisting the diagnosis of causative factors, for prognosis, and for progression of treatment. It is therefore essential that this tool, so widely used, and for so many and varied purposes, be valid.

Due to the frequent use of goniometry by health care professionals, the research described hereafter was conducted in an attempt to reduce the deficit in our scien-

tific knowledge base, to improve clinical care of the injured hand, and to promote research in hand management.

B. STATEMENT OF THE PROBLEM

There is a need for validity and reliability in hand assessment instruments, in particular, goniometers, as important decisions are made based on joint angle measurements obtained from their use (Fess, 1986; Rothstein, 1985).

The quality of the information gathered is directly influenced by the instrument used for evaluation. A dependable precise tool measures accurately, diminishes subjective error and allows conclusions which are minimally skewed by extraneous factors (Fess, 1986). Therefore, the quality of the decision is contingent on the quality of the information gathered.

Hand injuries are a significant part of the rehabilitation caseload. As the hand is so important in daily functioning, it behooves the health professional to utilize the best and most accurate method to determine joint range and thus, to aid in the prognosis, and progression of treatment.

Once the validity and reliability of various tools used to assess finger joint range in normals have been established; normal contralateral limb comparisons can be evaluated with confidence. Once ascertained for normals,

the validity and reliability of these instruments can be further verified by testing individuals with various hand dysfunctions. Comparisons can then be made to the normal values. If the validity and reliability coefficients are sufficiently high, rehabilitation of the hand and clinical research for all of the various hand dysfunctions can be executed with increased confidence, and perhaps, a lower cost.

By first establishing which of the tools currently used are valid, time and research money is not wasted testing the reliability of instruments shown not to be valid. This study is the initial step in the definition of accurate, reliable tools for use in the assessment and treatment of hands. This study, when coupled with reliability studies of the validated tools should facilitate research in hand rehabilitation, and broaden the scientific base of the profession, with the ultimate goal being one of improved clinical care.

The problem was to assess the tools currently used by physical therapists clinically to measure metacarpophalangeal (MCP) and proximal interphalangeal (PIP) joint range of the finger in the normal adult hand, for criterion validity.

C. OBJECTIVES OF THE STUDY

The primary objective of this study was to assess the criterion validity of four different methods that are presently used to determine finger joint range. The four methods include three devices currently used clinically at the University of Alberta Hospitals plus visual estimation. Randomly selected angles throughout the range of motion, for both the MCP and PIP joints, were measured.

The criterion used was joint angles obtained from one lateral radiograph of both hands. Criterion validity was determined by comparing the scores of the four methods with scores obtained from the hand radiographs.

The second objective was to present a recommendation of the method to use clinically, when determining MCP and PIP joint range. This objective was achieved by determining the standard error of the mean difference scores.

D. RESEARCH HYPOTHESIS

For the purpose of this study, an assessment tool was designated as valid if there was a high degree of similarity, indicating a strong relationship, between measures obtained from the instrument to be validated, and the measures obtained from the criterion. A highly positive relationship between measures would indicate that the instrument tested was as capable as the criterion in obtaining the desired information.

The research hypothesis, therefore, was that there would be a strong relationship between the joint angle measurements obtained from the radiographs and those obtained from any one of the four clinically used methods.

The validity coefficient indicates the extent of the relationship between the two measures. Currier (1984), describes a high reliability coefficient as that area between 0.90 to 1.00 and suggests that validity coefficients can be thought of using the same scheme. Therefore, a high validity coefficient could also be defined as that area between 0.90 to 1.00.

Criterion validity of a method, would therefore be shown if the validity coefficient calculated, for each of the four methods, was equal to or greater than 0.900.

E. OPERATIONAL DEFINITIONS

The following words are defined as they were utilized in the study.

SUBJECTS: individuals (male or female) between and inclusive of the age of twenty to fifty years; who volunteered their time and their normal hands; met the inclusion and exclusion criteria; participated in all aspects of the study; and signed the informed consent.

NORMAL ADULT HAND: the hand of a subject who had no history of musculo-skeletal, congenital or nervous insult, or medical condition affecting the hand; and who with testing

did not display signs of, nor complain of, symptoms of pain, loss of range of motion, crepitus, obvious swelling or ligamentous instability in the hand; and could be radiologically examined.

FINGER JOINT RANGE: the measurement of range, as stabilized by a form, of the third MCP joint of one hand and the third PIP joint, of the alternate hand, of the volunteer.

GONIOMETER: a device used manually to measure joint range of motion.

UNIVERSAL GONIOMETER (UG): a small clear plastic device consisting of a half-circle protractor (2.7 cm in diameter) attached via a rivet at the center (base) of the protractor to two arms - one movable (6.2 cm in length) and one stationary (1.7 cm in length). See Plate 1.1.

DORSAL GONIOMETER (DG): a small stainless steel device with a hinged base (14.4 cm in length) attached perpendicular to a protractor (2.6 cm in diameter). The hinge of the base is attached to the center base of the protractor. The 3.0 cm movable section of the base accompanied the finger as it moved, which allowed a marker to be displaced the corresponding amount on the protractor. See Plate 1.2.

FLEXIBLE GONIOMETER (FG): a flat, 1.5 centimeter wide, 18 centimeter long, flexible piece of metal alloy, applied to the dorsum of the finger to correspond to the contour of the finger. The subsequent shape was traced onto paper and measured with a protractor from the paper. See Plate 1.3.

PLATE 1.1 Universal goniometer as used in the study, with a 15 centimeter ruler for scale

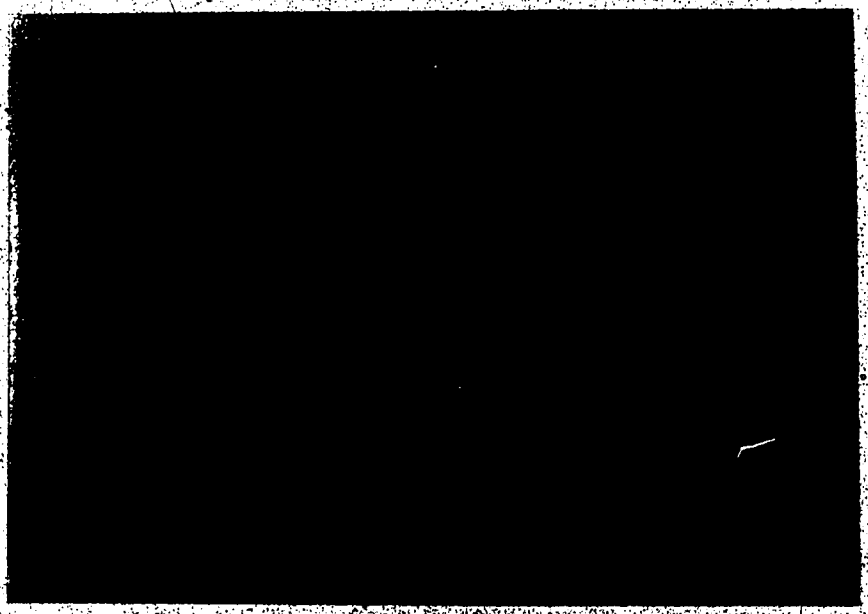


PLATE 1.2 Dorsal goniometer as used in the study, with a 15 centimeter ruler for scale

VISUAL ESTIMATE (VE): No mechanical device was used. A visual estimate was made of the joint range by the therapist viewing the joint angle of the joint to be measured and mentally determining the measurement. The visual estimate is colloquially equivalent to "eyeballing" to physical therapists.

BLINDED: inability of the physical therapist to read the measured angle from the goniometers during testing due to a substance that covered the engraved angles on the goniometers. The goniometers as they were blinded for the study are shown in Plate 1.4.

MEASUREMENT: the value obtained in degrees for the joint range as clinically assessed by the three goniometers or the visual estimate; or radiographically assessed with a radiograph and protractor.

MEASUREMENT POSITION: the position in which the subject was placed by the tester, and stabilized by a form, in order to obtain the measurements desired.

PHYSICAL THERAPIST: an individual who held a current Alberta license to practice physical therapy and; who, at the time of the study was employed at the University of Alberta Hospitals.

X-RAY TECHNICIAN: a qualified and experienced technician designated by the Radiology Department of the University of Alberta Hospitals, who followed an established protocol and produced one lateral radiograph of both hands, per subject.

PLATE 1.3 Flexible goniometer as used in the study, with a 15 centimeter ruler for scale

PLATE 1.4 The three goniometers, as they were blinded for use in the study

F. DELIMITATIONS OF THE STUDY

Thirty individuals with normal healthy hands from the University of Alberta and the University of Alberta Hospitals populations in the Fall of 1987 were subjects for the study.

If a homogenous study population had been used, one assumption of validity would have been violated (Crocker, 1976). Therefore, stratification of the sample for age and sex was necessary to produce a heterogenous sample. A sample of thirty may not be sufficiently large to qualify as a fully heterogenous group. However, in order to minimize the number of subjects exposed to radiation, the alternative, that of a larger sample, could not be justified.

One measure only was obtained with each of the four methods by one therapist. Although using only one measure, rather than repeated measures, may have increased the chance of error and therefore decreased the validity coefficient, doing repeated measures is not used clinically on a regular basis. As the intent of the study was to define assessment tools that are valid in the clinical setting, rather than in a laboratory setting, the use of one measure only was chosen.

G. LIMITATIONS OF THE STUDY

The accuracy of the joint angle measurements obtained from the radiographs was dependent on the skill of the x-ray technician producing the radiographs, the ability of the radiologist and investigator to correctly determine the correct bones on the radiographs, the reliability of the investigator to determine the radiographic joint angles, and the accuracy of the equipment used.

Evaluation of joint range by the physical therapist was dependent upon the accuracy and reliability of the blinded goniometers, the ability and reliability of the physical therapist determining the joint angle, the ability of the investigator and the assistant physical therapist to correctly and reliably read and record the blinded, measured angle, and the ability of the goniometer to maintain the selected position.

The physical therapists may have been more careful and thus may have obtained higher reliability coefficients as a result of being in the study. This alteration in behavior may lead to a slight overestimation of the validity coefficient of range of motion (ROM) measures as used in the clinical situation.

The accuracy of the measurements from the four methods and the radiograph was in part due to the ability of the stabilization form to perform its job adequately.

CHAPTER TWO

REVIEW OF THE LITERATURE

A. FINGER GONIOMETERS

Goniometry was used to measure finger joint range as early as 1919. Nutter (1919) used paper tracings of finger contours measured with a protractor, to determine finger joint range. Rosen (1922) elaborated upon Nutter's design and produced a platform on which the fingers rested, in order to standardize the measurement position.

Pollock and Brooks (1942) designed an elaborate spring balance to measure finger joint range. Although effective, the placement precision and instrumentation knowledge needed to obtain reliable results, made the device unsuitable for clinical use.

Hurt (1947) described a dorsal goniometer which fit over the dorsum of the finger and allowed flexion range to be measured. Noer and Pratt (1958) altered Hurt's dorsal goniometer to allow finger extension to be measured. A variation of these two goniometers is used today.

Glanville's (1964) technique for determining finger joint range utilized a rubber covered solder wire. The wire was placed over the dorsum of the joint and shaped to the joint contour. The shape of the configured wire was then transferred onto paper without distorting the angles. The traced angle could then be measured with a protractor. Glanville's method was similar to Nutter's (1922) paper

tracings but involved the use of a tool. In essence, Glanville's apparatus and method are still used today.

The Hines Digit-o-meter, reported by Brayman (1971), was used to measure the composite motion of finger flexion rather than individual joint motion. It was also used to evaluate thumb opposition.

Austin (1978) described a compact goniometer for the hand that used a modified protractor as its base. The protractor was reduced in size to allow only 110 degrees of motion to be measured. A short plastic measuring arm was added to register the degrees of movement obtained. The protractor was applied dorsally for flexion movements and palmarly for extension movements.

Hasselkus and Plautz (1981) reported on a two-axis goniometer which they used to measure MCP laxity and range of motion (flexion). Their main intent was to measure MCP joint laxity. As 70 - 90 degrees of flexion was needed at the MCP joint in order to accurately measure MCP joint laxity, their device of necessity had to have the ability to measure MCP joint range as well. The actual ability of this device to measure full joint range at the MCP joint was not reported.

The use of the universal goniometer for measuring joints other than the finger has been reported in the literature. However, Cambridge (1984) described a modified

universal goniometer that was appropriate for assessment of finger joint range.

Brand (1985) described the "rabbit ears" goniometer. It consisted of two wires and a protractor and utilized the dorsal technique. It was based on an electronic goniometer originally developed by Cantrell and Fisher (1982). Clinical use may have been limited as it was unwieldy.

Numerous devices designed to evaluate finger joint range have been disclosed over the past seventy years. As these devices have continued to evolve, the suspicion arose that none thus far developed have met all of the necessary criteria of scientific form and function. Evaluating the innate qualities of the devices currently in use could lead to an acknowledgment that those available are appropriate; or to the production of a device that is scientifically acceptable and is functionally practical.

B. RELIABILITY

Fess (1986) stated that reliability defines an instrument's ability to measure consistently and predictably; and that an instrument that has a high degree of reliability has been statistically proven to measure consistently between sessions, examiners and instruments.

The first major study on the reliability of goniometry was done by Hellebrandt, Duvall and Moore in 1949. They reached two conclusions. The first was that the average

physical therapist was very reliable when measuring joints responsive to reliable measurement using a reliable instrument. Secondly, they determined that the universal goniometer was more dependable than special devices. Unfortunately, the joints of the fingers and toes were not tested. All other peripheral joints were.

In 1969, Hamilton and Lachenbruch did the first and only study on goniometric reliability for the MCP, PIP and DIP joints. In a laboratory setting, seven testers, using three goniometers (universal, dorsal and pendulum), measured one normal index and middle finger. The hand to be measured was placed on a model for standardization of the test position. Intra-tester and inter-tester reliability coefficients were not provided. The variance was used to show that intra-tester reliability was significantly better than inter-tester reliability. A significant variance between the three goniometers could not be discerned.

Reliability studies on other joints addressed issues relevant to the study.

Low (1976) stated that the use of average measurements improved goniometric reliability. Boone et al. (1978) suggested that one measurement was as good as several for reliability. Low and Boone et al. both tested healthy subjects. Boone et al. used a standardized test protocol, but Low did not. Rothstein, Miller and Roettger (1983), utilized a clinical population and protocol. They

found that averaging measurements did not improve reliability. Theoretically, the size of the error decreases with repeated measurements. Clinically, the number of measurements needed to feasibly obtain maximum reliability is still undetermined and requires further study.

VALIDITY

Fess (1986) stated that validity indicates the truthfulness of an assessment tool, and that an instrument that has validity has been statistically proven to measure that which it purports to measure. Rothstein (1985) stated that a valid tool allows one to make inferences based on the information obtained from the tool. Validity can also be defined as "the extent to which measurements are useful for making decisions relevant to a given purpose" (Crocker, 1976).

Crocker (1976) identified five factors that might affect the results of a validation study. The factors listed by Crocker, were: 1) reliability of the instrument, 2) reliability of the criterion measure, 3) homogeneity of the sample, 4) appropriateness of the criterion, and 5) criterion contamination.

To obtain a high validity coefficient, the instrument(s) being validated, and the criterion measure, must each demonstrate high reliability. As the amount of variance due to error increases, reliability decreases. A

mathematical relationship exists between reliability and validity such that, validity is less than or equal to the square root of the reliability (Crocker, 1976). It follows, therefore, when reliability decreases, validity does as well.

Maximum validity depends also on the use of a heterogenous sample, with respect to the trait being measured (Crocker, 1976). A homogenous group leads to an underestimate of the instrument's validity. A heterogenous group, therefore, would provide a better estimate of the instrument's validity as well as allow for generalization to a larger group.

By choosing an appropriate criterion, it is ensured that the validity coefficient is representative of the instrument's intended purpose and ability.

Criterion contamination can occur if the individual providing the scores on the criterion has knowledge of the instruments' observed scores. This type of contamination can lead to an overestimation of the validity of the instrument.

Criterion contamination can also occur if the instrument being validated was actually used within the validation process to make decisions affecting the validation process. This type of contamination can lead to an underestimate of the instrument's validity.

With these factors in mind, the validation studies that have been published, and are reported below, have tended to violate at least one of the above five factors.

Literature reporting the validity of goniometers is scarce. In fact, to the knowledge of the investigator, there have not been any studies published, to date, on the validity of goniometers specifically used to measure finger joint range. Studies conducted on other joints have reported the following results.

Robson (1966) used trigonometry to show that misplacement of the goniometric axis could be reduced if goniometers with long arms were used, thus increasing the accuracy of the instrument.

Baldwin and Cunningham (1974) utilized an experienced physical therapist as their "gold standard" when they assessed the accuracy of physical therapists' ability to measure elbow joint range. Unfortunately, the validity and reliability of the "gold standard" was not first established, and thus their conclusion that the universal goniometer was not valid, may not be legitimate.

In a recent publication, Miller (1985) defended the use of radiographs, and stated that it remains the most accurate method of determining joint range. Only three studies to date, have utilized x-rays to determine the validity of their instruments.

Ahlback and Lindahl (1964) compared measurements obtained with a hip-joint specific goniometer with measurements obtained from x-rays. Statistical tests were not performed on the data. However, it was noted that the measurements were in close agreement. Their findings are irrelevant, however, as the instrument they tested is no longer used clinically to measure hip joint movement. The universal goniometer is most frequently used.

In two recent studies, Enwemeka (1986), and Gogia et al. (1987), determined the validity of the large universal goniometer for evaluation of knee joint range, through comparison with radiographs. Enwemeka (1986) found that the two methods were comparable except for the initial fifteen degrees of flexion. He failed, however, to note the reliability of the joint measures obtained by the goniometer. Gogia et al. (1987), found a high correlation (0.98) for the two methods throughout the joint range of 0 to 120 degrees. Intra-tester reliability coefficients were available for the goniometric measurements, but not for the radiographic measurements.

It is suggested by these two recent studies that the need for validation of instruments used in evaluation, is now being recognized; but careful attention to detail, to avoid violation of the factors listed above, is essential.

Rothstein et al. (1983), noted that the test position can be a major factor leading to variation in range of

motion measurements. Some researchers (Hellebrandt, Duvall & Moore, 1949; Hamilton & Lachenbruch, 1969; Boone et al., 1978; Hasselkus & Plautz, 1981), used standardized positions and instructions. They maintained that these standardizations were essential for maximum reliability. Other researchers (Baldwin & Cunningham, 1974; Mitchell, Miller & Sturrock, 1975), did not standardize their test positions. They allowed their testers to use familiar test positions, that were normally used, in order to replicate the clinical situation.

Ideally, standardized positions improve the reliability of the tool. In reality, clinical circumstances do not always allow for their use. A compromise suggests that a standardized position should be used whenever possible.

D. SUMMARY

When the need for tools to evaluate joint range was first recognized, numerous joint-specific devices were developed in a short period of time. The majority of these devices became obsolete, not as a result of scientific testing, but due to inefficient operation, handling difficulties and lack of durability. The few devices that did survive have been sporadically tested over the years on various joints; but the question of whether these devices display qualities of validity and reliability has not been adequately answered. This issue appears to be of little

concern to the majority of health care professionals who use these tools, with perhaps false confidence, on a daily basis.

Instruments used for evaluation should exhibit certain elements. These elements are reliability, validity, administrative instructions, equipment criteria, norms, instructions for interpretation, and a bibliography (Fess, 1986). Of these factors, reliability and validity are the most important. Fess (1986) stated that the reliability of the instrument must first be established before validity can be tested. Further therapist reliability and norming studies are then performed on the validated instruments.

There are only two recent studies (Enwemeka, 1986; Gogia et al., 1987) establishing validity of the large goniometer on the knee, both with minor faults (as previously described), so there is a demonstrated need for validity studies on other joints.

The one study that assessed the reliability of finger joint range measurement with goniometers (Hamilton & Lachenbruch, 1969) demonstrated that intra-rater reliability was greater than inter-rater reliability, but the study was not conducted with validated tools. The number of measures needed to obtain maximum reliability requires further study as well.

Perhaps validity and additional reliability studies have not been completed on the finger joints because of the

inherent difficulty of finger joint range measurement. A large number of small joints are located in a small area. The third and fourth MCP joints are not directly accessible. The long axes of the bones are, in fact, quite short and as Robson (1966) pointed out, long arms on the goniometers are required for accuracy.

In addition, fingers tend to be hypersensitive when injured, and are thus difficult to assess. Complex interrelated movements from tendons of two-joint muscles, edema, scarring, enlarged and malformed joints, joint deviation, multiaxial movements, difficulty of stabilization and force on bony segments and immature wounds are all factors listed by Hamilton and Lachenbruch (1969) which could affect results when obtained by goniometry.

Age, calibration, handling, maintenance and environmental conditions may also influence the measuring ability of assessment instruments even after they have been proven valid and reliable (Currier, 1984; Fess, 1986).

Ultimately, what is required clinically, is for each health care professional, who utilizes goniometry to assess finger joint range, to be able to demonstrate high intra-rater and inter-rater reliability on validated instruments appropriate for their use. As well, they must be able to accurately record their measurements and measurement positions so that other health care professionals can replicate these measurements. When these conditions have

been met, goniometric measurements obtained clinically in a serial fashion, will allow health care practitioners to make decisions based on scientific evidence.

CHAPTER THREE

MATERIALS AND METHODS

A. INTRODUCTION

Prior to the commencement of the validation study, a therapist reliability study was conducted to determine the identity and reliability of the therapist that performed the measurements for the validation study. A pilot study to confirm the appropriateness of the methodology and to determine the reliability of methods and materials used in the study was performed. The results of these studies were tabulated and considered acceptable prior to the commencement of the data collection for the validation study.

The materials and methods for the therapist reliability study and the pilot study, are presented prior to the presentation of the materials and methods for the validation study. The order of appearance is as follows: 1) therapist reliability study, 2) pilot study, 3) validation study.

B. THERAPIST RELIABILITY STUDY

The purpose of the therapist reliability study was to select the therapist who would measure the joint angles for the validation study.

Five therapists and five subjects participated in the reliability study. The experience of the therapists, both

in general practice, and with regard to their experience measuring finger joint range was obtained (see Table 4.1).

The joint range of the MCP joint of the third finger of one hand, and the joint range of the PIP joint of the third finger on the alternate hand, were measured on each of the five subjects, by each of the five therapists, with each of the defined methods.

Each therapist did eighteen measures in total (nine on the MCP joint, and nine on the PIP joint) on each of the five subjects. The visual estimate was performed first, and only once, on each joint. One repeated measure was done with the other three tools, on both joints. The universal goniometer was used to produce two additional measures on each joint. This goniometer was used to test the reliability of two different finger positions (fingers together in one plane or separated from each other). The two finger positions tested are presented in Plate 3.1.

The joint angles of the subjects' MCP and PIP joints were stabilized with a form. The forms used were adapted aluminum finger splints that were bent to a specific angle and taped in place. The splints ensured that the joint angles remained the same for each of the five raters. Plate 3.2 depicts a finger splint adapted, and bent for use in the study.

Intra-rater reliability coefficients were calculated for each of the five therapists, for three tools, and four

PLATE 3.1 Finger Position: Upper Hand (Right) - Together in one plane, Lower Hand (Left) - Separated

PLATE 3.2 Finger Splint - adapted for use and bent to a specific angle

methods (UG- UGA, UGT; DG; FG), for both joints, using the interclass correlation. These coefficients are presented in Table 4.2.

Inter-rater reliability coefficients were calculated for the five therapists, on all five methods, for both joints, using the interclass correlation. For the methods that had repeated measures, the average of the two measures was used in the calculations. These coefficients are presented in Table 4.3.

A composite reliability rating was calculated for each of the five therapists by averaging the eight intra-rater reliability values for each therapist (4 methods over 2 joints). The composite reliability ratings for the five therapists are shown in Table 4.4.

From the results of the therapist reliability study, one therapist was chosen who subsequently participated in the pilot study.

C. PILOT STUDY

A pilot study was conducted to test the following assumptions:

1. A true lateral x-ray of the designated hand could be taken (to rule out parallax error on the x-ray measurement).
2. The bones of the third finger could be clearly defined so that measurements could be taken from them.

3. The form devised to stabilize the testing position would perform its job without hindering the action of the therapist, or the x-ray beam.
4. Adaptations made to the goniometers for blinding purposes would not alter the measurements significantly.
5. The measured angle on the goniometer would not differ if viewed in place, or removed from the finger to be viewed.
6. The therapist recording the measured joint angles would read the same angles on the goniometers as the blinded therapist measuring them.
7. Altering the position of the forearm and hand used in the therapist reliability study, to the position to be used in the validation study, would not significantly alter the reliability of the therapist performing the measurements.

The hands of three subjects were x-rayed in the pilot study. The x-rays were examined by the radiologist and radiology technician to determine if 1) a true lateral x-ray of the hands could be achieved; and 2) that the bones of the third finger could be delineated on the x-ray with confidence.

Discussions between the investigator, the x-ray technician and the therapist, determined whether the stabilization form was appropriate.

The fourth assumption tested was that the goniometers blinded would measure the same angle unblinded. Only the universal and dorsal goniometers, when blinded, were altered from the state they would normally be used in clinically, so only these two goniometers were tested.

The dorsal goniometer was blinded using a felt hood to cover the protractor portion of the goniometer (see Plate 1.4). This hood was taped in place when in use. Seven angles were tested with the dorsal goniometer blinded, then unblinded, on both the MCP and PIP joints. Interclass correlation coefficients were calculated for the MCP and PIP joints combined.

The universal goniometer was initially blinded with a foam hood. Six angles were tested with the universal goniometer blinded, then unblinded, on both the MCP and PIP joints. The reliability coefficient (ICC) calculated using this method was unacceptable and non-significant, so a second method of blinding for the universal goniometer was tested. The universal goniometer was then taped on one side. This method of blinding is shown in Plate 1.1 and Plate 1.4. Eight angles were tested (four on the MCP and four on the PIP joint), using the second method of blinding. Interclass correlation coefficients were calculated on the MCP and PIP joints combined.

The fifth assumption tested was whether the angle measured on the goniometer would be equivalent, i[redacted]ad in

place (alongside the joint), or removed from the finger and read. The universal and dorsal goniometers were tested.

Three angles for the MCP joint and three angles for the PIP joint were measured for both the universal and dorsal goniometers. Interclass correlation coefficients were calculated on the MCP and PIP joints combined.

The therapist (PT2) responsible for measuring the angles in the validation study was blinded, so another therapist (PT3) read the angles from the blinded goniometers. To determine if PT2 and PT3 would read the same angles from the universal and dorsal goniometers, eleven angles were read on each of the two goniometers by PT2 and PT3. Interclass correlation coefficients were calculated.

The five therapists tested in the reliability study were allowed to measure the joints in whatever position they wanted to. They all chose to measure the joints with the olecranon process resting on the table, and the forearm perpendicular to the table. This position was not acceptable for the validation study however, as it would have necessitated a change of hand position between the goniometric measurements and the x-ray, so the chosen therapist measured six angles on the MCP, and five angles on the PIP joint, for both the universal and dorsal goniometers, in two positions. One position was as described above, with the forearm perpendicular to the table. The other position had the forearm resting on, and parallel to,

the table top. The two positions tested are shown in Plate 3.3. Interclass correlation coefficients were calculated for the MCP and PIP joints separately.

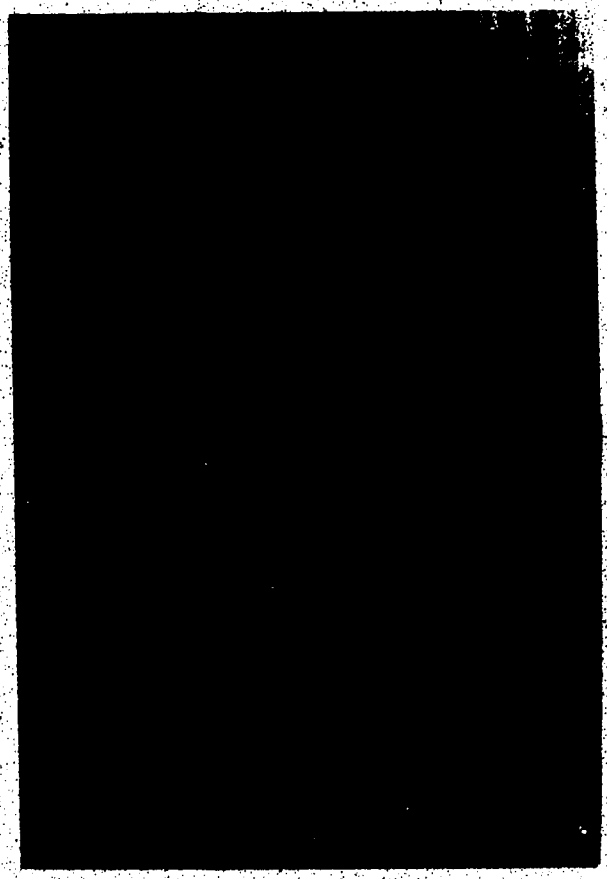


PLATE 3.3 Position of the forearm and hand used for the reliability study (right arm - background), and the pilot study (left arm - foreground).

D. VALIDATION STUDY

Subjects

Fifteen male and fifteen female volunteers, ranging in age from 20 to 50 years, served as subjects in this study. The subjects were questioned to determine if they had any history of musculo-skeletal, congenital or neurological insult to either hand. The subjects were assessed to ensure that they did not display signs of, nor complain of, symptoms of pain, loss of joint range, crepitus, swelling, or ligamentous instability in their hands. All subjects were given an information sheet and signed an informed consent (Appendix A).

Volunteers were excluded from the study if they were pregnant, did not fully comprehend the purpose and associated risks of the study, or were familiar with goniometry.

The thirty subjects were evenly distributed into three groups by age and sex. There were five female and five male subjects in each group. The subjects in one group were aged from 20 to 29 years, in the second group, from 30 to 39 years, and in the third group, from 40 to 50 years. The purpose of the distribution of subjects into groups, was to ensure that the sample was heterogenous and representative for age and sex of a healthy adult population.

A large heterogenous sample would support a recommendation of valid instrumentation more readily than a small

sample would (Crocker, 1976). However, as measurements from x-rays were used to determine the validity of the instruments, ethically, the fewer subjects exposed to radiation the better. The two recent studies that described the validation of the large universal goniometer for the knee joint used ten (Enwemeka, 1986) and thirty (Gogia et al., 1987) subjects. A sample size of thirty was tested for the above reasons.

Personnel

Three therapists were needed to obtain the measurements. One therapist (PT1) fixed the testing forms (one for the MCP and one for the PIP) to the randomly picked angles and secured the subject's fingers in the forms. The second therapist (PT2) determined the fixed joint ranges of each subject using the designated tools and methods. The third therapist (PT3) recorded the angles from the blinded goniometers and the visual estimate.

The selection of PT2 was based on the composite intra-rater reliability coefficients (see Table 4.4) achieved during the therapist reliability study, the results of the pilot study, and interviews by the investigator.

One x-ray technician, as operationally defined, was responsible for producing all of the x-rays required for both the pilot and the validation study.

One radiologist, from the Radiology and Diagnostic Imaging Department of the University of Alberta Hospitals, was responsible for ensuring the joint angles on the radiographs were determined correctly.

The investigator performed the duties of PT1 and discussed the study with each of the subjects, obtained the informed consent, and arranged the appointments.

Equipment

The three goniometers used in the study were new and were tested for reliability in their blinded and unblinded state. The goniometers were not used for general clinical practice until the completion of the study. The axes of the dorsal and universal goniometers were sufficiently tight to ensure that a selected position of the arms were maintained against gravity without manual assistance.

A standard engineer's protractor, as shown in Plate 3.4, was used to measure the angles on the x-rays, and on the tracings obtained from the flexible goniometer.

The goniometers and protractor were validated against angles of known accuracy. Computer-generated angles were produced for every five degrees between 0 and 110 degrees, and ten other randomly chosen angles. The accuracy of the goniometers and the protractor were then verified with these known angles. Plate 3.5 shows the protractor placed on an angle validation sheet of 30 degrees.

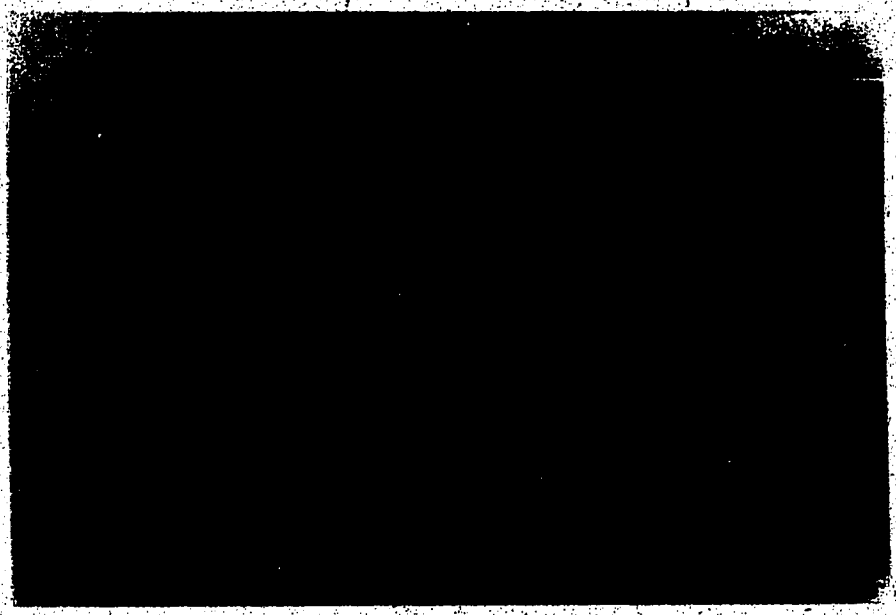


PLATE 3.4 Protractor used in the study, with a fifteen centimeter ruler for scale

PLATE 3.5 Angle validation sheet of 30 degrees with the protractor placed on it

The forms used to maintain the desired joint position were adapted from aluminum finger splints by removing the foam. These splints were then bent to randomly assigned angles by PT1, and checked with the universal goniometer to ensure the desired angles were achieved. Plate 3.2 shows the finger splint adapted, and bent for use in the study. Essentially, the forms maintained the position of the joints to be tested, but did not interfere with the measurements nor the x-rays.

Each subject had two splints - one for the third finger on each hand. The splints were not re-used on other subjects. Adhesive tape was used to maintain the forms securely in place on the subjects' fingers.

A three phase General Electric x-ray apparatus with a set focal film distance of 44 inches was used to obtain the lateral x-rays of the subjects' hands.

Procedure

One measure from each of the four methods was obtained on the MCP joint of the long finger in one hand. One measure from each of the four methods was obtained on the PIP joint of the long finger in the alternate hand. PT2 obtained these measurements and PT3 recorded them. Both hands were then x-rayed. The subject remained in the x-ray room for the entire procedure.

The four methods used were 1) the universal goniometer to one degree accuracy, 2) the dorsal goniometer to one degree accuracy, 3) the flexible goniometer to one degree accuracy and 4) a visual estimate to the degree of accuracy PT2 felt comfortable using. The degree of accuracy was not standardized over the four methods, as in effect it was the method, as well as the instrument, that was being validated. Using each method as it is used clinically provided a more appropriate representation of its accuracy.

The universal goniometer was placed on the lateral aspect of the radial side of the third digit to obtain the measurement of the PIP joint; and on the lateral aspect of the radial side of the second digit to obtain the measurement of the MCP joint.

The dorsal goniometer was placed on the dorsum of the third digit when measuring flexion ranges of the MCP and PIP joints; and was placed on the palmar aspect of the third digit when measuring extension ranges of the MCP joint.

The flexible goniometer was molded to the dorsal aspect of the third digit when measuring flexion ranges of the MCP and PIP joints; and was molded onto the palmar aspect of the third digit when measuring extension ranges of the MCP joint.

When flexion ranges were measured, the stabilization form was applied to the dorsal aspect of the digit. For

measurement of extension ranges, the stabilization form was applied to the palmar aspect of the digit.

In order to minimize systematic error in the study results, the following measures were taken: 1) The order of the joints tested (MCP, PIP), the order of the method used (UG, DG, FG), the hand used, the joint angle measured, and the subject to the procedure, were all randomly assigned. 2) The visual estimate was always the first method used of the four to prevent biased measures. The randomized order of testing, and the randomized angles fixed on the forms, are presented in Appendix B.

The finger tested was the middle or long finger. It was chosen to represent the "worst-case" scenario. This representation was due to the lack of accessibility of the middle finger. It was assumed that if the validity was high for measurements on the MCP and PIP joints of the middle finger, measurements on the joints of the other fingers would also have a high validity.

Due to the large temperature difference between outside temperatures of an Edmonton autumn and temperatures inside buildings, the temperature of the hand was allowed to acclimatize to indoor conditions prior to testing. This acclimatization was done by having the subject wait for fifteen minutes immediately prior to testing in the room designated for testing. During this time, the forms were positioned onto the fingers. A review of the literature

shows that waiting a period of 15 minutes prior to testing has been used frequently, but justification for doing so was not provided (Bacon et al., 1976; Engel et al., 1979).

Positioning of Subjects

The measurement position of the joints proximal to the joints tested was standardized within limits for all measurements. The elbow joint was positioned in approximately thirty degrees of flexion to allow the neutral forearm to rest on the surface of the x-ray table. The slightly flexed position of the elbow was chosen for comfort and to facilitate positioning of the forearm in neutral, as the x-ray table was high. A neutral forearm was required for a lateral x-ray. The wrist joint was also maintained in neutral. This position allowed balanced tenodesis action for all finger joint ranges tested, by preventing a resting-length insufficiency from occurring (Cambridge, 1984). The position used by the subjects in the study is shown in Plate 3.6.

The complex, inter-related movements of the joints and muscles prevent achievement of maximum range unless the fingers move together. As an important goal of the study was to replicate the clinical situation as closely as possible, it was desirable that all fingers of the hand being tested would be in the same position. Because the joint to be measured was fixed in a form, the position of

the fingers not being tested, was not as much an issue for the study, as for clinical situations where maximum range is desired.

Although the preferred method was for all fingers to move as a unit, the method chosen was with the fingers separated, to allow clearer definition of the third ray on the x-ray, and due to PT2's results in the reliability study (see Table 4.2).

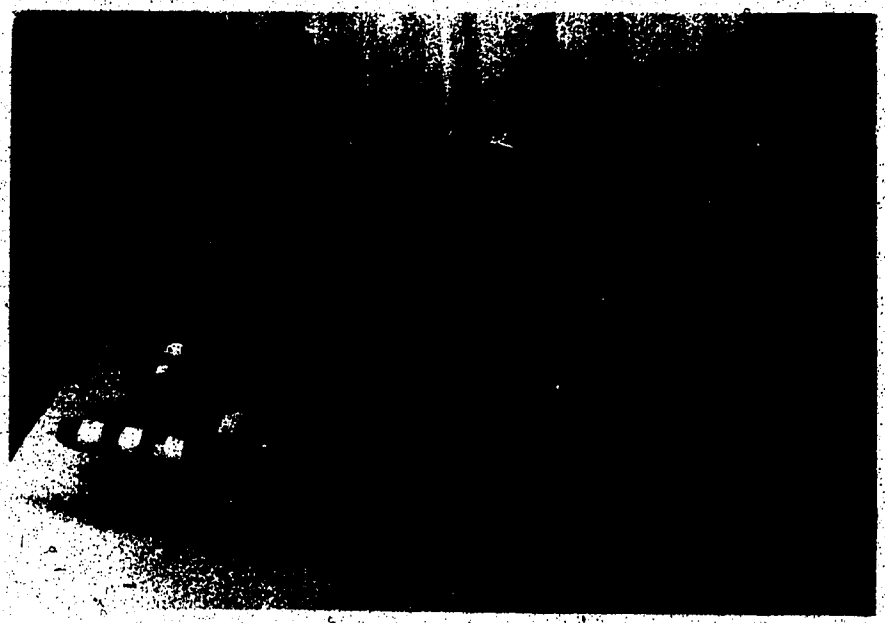


PLATE 3.6 Subjects' position for the study

Using both hands rather than just one, allowed the finger joints not being tested to assume the maximum loose-packed position. The MCP joint was tested with the PIP and DIP joints in the maximum loose-packed or resting position. The PIP joint was tested with the MCP and DIP joints in the resting position. The resting position for all joints of the fingers is slight flexion (Kaltenborn, 1974).

Clinically, the position of the joints of the finger, other than the one being tested, are varied, depending on the subject, the reason for testing, and the condition of those joints. The resting position for the non-tested finger joints was chosen so as to allow this procedure to be used with various dysfunctions, where muscle tightness may be present, allowing direct comparisons between this study and future studies.

It was important to validate the various instruments for all joint angles, as all joint angles are used clinically. The range of motion for the MCP joint is considerably variable, even among normal, healthy hands. Although Cambridge (1984) stated that extension of the MCP joint could be as much as 45 degrees in normals, it was important that every subject could attain the randomly selected joint angle. Therefore, the range of motion selected for testing for the MCP joint was 0 - 89 degrees of flexion and 1 - 15 degrees of extension. The range of

motion selected for the PIP joint was 0 - 109 degrees of flexion (Cambridge, 1984).

The total range of motion selected was sub-divided into groups to ensure that the angles tested were distributed evenly throughout the range. The actual joint ranges fixed on the position forms was determined through stratified random sampling, and varied from 13 degrees of extension through neutral and up to 89 degrees of flexion for the MCP joint, and from 0 degrees of flexion up to 108 degrees of flexion for the PIP joint. The angles chosen by this method are presented in Appendix B.

Reliability

Intra-rater and inter-rater reliability coefficients (ICC) of joint angle measurements from the flexible goniometer tracings were calculated. Written instructions plus a demonstration of how to obtain MCP and PIP joint measurements from the tracings were provided to the therapists performing the measurements. The therapists were instructed to draw two lines on each tracing (one for the proximal bony segment and one for the distal bony segment of the joint articulation) that would be representative of the long axes of the bones forming the joint.

One repeated measure from twenty tracings were used to determine the intra-rater reliability of PT1.

Three therapists - PT1, PT3 and a therapist not connected with the study (PT8) determined the angles on twenty tracings from the flexible goniometer. Their results were used to calculate inter-rater reliability coefficients. Four inter-rater reliability coefficients (ICC) were calculated - PT1 with PT3, and PT1 with PT8; for both the MCP and PIP joints.

Intra-rater reliability coefficients (ICC) for measurement of the angles on the radiographs were calculated for PT1. Measurements of the joint angle on fifteen MCP and fifteen PIP joints were repeated on fifteen radiographs for the reliability study. The radiographic joint angles were determined by first defining the outer margins of the shaft of the phalange or metacarpal in two locations. The mid-point between these outer margins was then calculated. A line drawn through these two mid-points was extended beyond the bony margins. The protractor was used to measure the angle at which the lines for the two bony segments crossed.

E. ETHICAL CONSIDERATIONS

Exposure to radiation from the process of procuring x-rays is known generally to be inadvisable.

In 1951, the International Commission on Radiological Protection (IRCP) identified the harmful effects that could

occur following exposure to ionizing radiation. The list that was published contained the following harmful effects:

"1) Superficial injuries.
2) General effects on the body, particularly the blood and blood-forming organs, e.g. Production of anaemia and leukemias.
3) The induction of malignant tumors.
4) Other deleterious effects including cataracts, obesity, impaired fertility, and reduction in lifespan.
5) Genetic effects."

This list still remains a reasonable representation of the harmful effects of ionizing radiation with the exception of obesity and a non-specific reduction in lifespan (Thorne, 1987).

In 1977, the IRCP further classified the effects of ionizing radiation into "stochastic" and non-stochastic" effects. Upton (1987) defined stochastic effects as "probabalistic phenomena which have no threshold and which vary in frequency but not in severity, with the dose." He defined non-stochastic effects as "deterministic phenomena which have thresholds and vary both in frequency and in severity with the dose."

Stochastic effects, then, include cancer and the induction of hereditary effects (mutations, chromosome aberrations, teratogenic effects) in the descendents of the irradiated individual (Thorne, 1987; Upton, 1987).

When radiation is used to make health care decisions; in order to attain a level of minimal risk with maximum benefit, the IRCP recommended a system of limitation of the

radiation dose. This system is based on the prevention of non-stochastic effects and the limitation of the probability of stochastic effects to levels deemed acceptable (Thorne, 1987).

The exposure limits for stochastic effects are ten times lower for the general public than for radiation workers. As well, susceptibility to these stochastic effects vary with age and are typically higher in children than in adults (Upton, 1987). Certain tissues are more susceptible to radiation damage. The extremities are generally less susceptible than are the more central tissues and organs (Thorne, 1987; Upton, 1987).

The majority of the total annual exposure to radiation per individual occurs due to natural background radiation and medical exposure to radiation. The effective dose equivalents of radiation from natural sources in the Edmonton vicinity, as estimated by the Radiation Protection Officer from the University of Alberta Hospitals in July of 1987, was approximately 1.5 millisieverts (mSv) per year (Trask, personal communication, July 22, 1987).

The amount of radiation required to obtain one adequate exposure for the purpose of this study was estimated to be equal to 0.08 mSv by the Radiation Protection Officer (Trask, personal communication, July 22, 1987). He further stated that the risk to the subject as a

result of participation in this study was so small as to be incalculable.

Two of the exclusion criteria dealt specifically with the issue of radiation exposure so that individuals not comfortable with being radiated were not accepted as subjects.

Unfortunately, the x-ray remains the only true method of determining the validity of joint measurements taken by goniometry. The paucity of literature in the area and the widespread use of goniometry clinically, justified the use of radiation on human subjects.

F. DATA ANALYSIS AND PRESENTATION

Criterion-related validity, for the purposes of this study, was defined as "the degree to which scores on one instrument are related to those on another" (Currier, 1984).

Pearson r correlation coefficients and interclass correlation coefficients have been calculated to show the relationships that are present between each of the four methods individually and the x-ray measurements, for both the MCP and PIP joints.

Two single factor analyses of variance have been calculated to determine if there were any significant differences between groups.

The standard error of the mean difference scores have been calculated for each of the four methods as compared to the criterion (radiographic measures), to provide clinically meaningful results. This technique provided a value in degrees that signified the amount of error that was likely to occur with each method.

A recommendation of the method to use clinically, based primarily on the ICC validity coefficient and the standard error of the mean difference scores was made.

The interclass correlation coefficient was also used to compute the required intra-rater and inter-rater reliability coefficients.

The equations used for the Pearson correlation coefficient and the standard error of the mean difference scores were those found in standard elementary statistic texts. Equations 1-4 from Bartko and Carpenter (1976) were used to calculate the interclass correlation coefficient.

The data was examined at the alpha level of 0.05 for significance. Where the significance was greater than 0.05, this level of significance was reported.

Tables of correlation coefficients, and tables of means, standard deviation and standard error of the mean difference scores, for each of the four methods, for both joints, are used to present the data. The angles that were measured, are presented in frequency distributions for both joints.

CHAPTER FOUR

RESULTS

A. THERAPIST RELIABILITY STUDY

Five therapists and five subjects participated in the therapist reliability study. The experience of these five therapists, both in general practice, and with regard to their experience measuring finger joint range, is noted in Table 4.1.

TABLE 4.1

Experience of Therapists in Reliability Study

Rater	Experience (Years)	
	GENERAL	FINGER JOINT RANGE MEASUREMENT
1	8.1	1.0
2	3.5	2.0
3	20.0	1.5
4	7.3	3.5
5	0.8	0.1

The five subjects used in the reliability study ranged in age from 22 - 50 years of age (mean age 30.4). Three females and two males were tested.

The ICC intra-rater reliability coefficients calculated for the five therapists, for the three methods, on both joints, are presented in Table 4.2.

The ICC inter-rater reliability coefficients calculated for the five therapists, for the four methods, on both joints, are presented in Table 4.3.

The composite reliability ratings calculated for each of the five therapists are shown in Table 4.4. Rater 5, as noted in Tables 4.1, 4.2 and 4.4, performed the tasks assigned to PT2 in this study.

TABLE 4.2

Interclass Intra-Rater Reliability Coefficients of Therapists in Reliability Study

Joint	Rater	Method			
		UGT	UGA	DG	FG
MCP	1	0.987	0.921	0.980	0.959
	2	0.918	0.902	0.960	0.953
	3	0.893	0.794**	0.944	0.968
	4	0.941	0.658*	0.980	0.972
	5	0.852	0.967	0.988	0.962
PIP	1	0.945	0.611*	0.972	0.971
	2	0.948	0.943	0.947	0.884
	3	0.751**	0.922	0.852	0.901
	4	0.947	0.828**	0.925	0.969
	5	0.939	0.927	0.952	0.909

All values are statistically significant at $p < 0.01$ except as noted (* not significant, ** significant at $p < 0.05$).

Abbreviations: MCP - metacarpophalangeal, PIP - proximal interphalangeal, UGT - universal goniometer - fingers together, UGA - universal goniometer - fingers apart, DG- dorsal goniometer, FG - flexible goniometer.

TABLE 4.3

Interclass Inter-Rater Reliability Coefficients of Therapists in Reliability Study

Joint	Method				
	VE	UGT	UGA	DG	FG
MCP	0.606	0.799	0.784	0.954	0.933
PIP	0.480	0.838	0.860	0.939	0.950

All values significant at $p < 0.01$.

Abbreviations: MCP - metacarpophalangeal, PIP - proximal interphalangeal, VE - visual estimate, UGT - universal goniometer - fingers together, UGA - universal goniometer-fingers apart, DG - dorsal goniometer, FG - flexible goniometer.

TABLE 4.4

Composite Reliability Rating of Therapists in Reliability Study

Rater	Reliability Rating
1	0.918
2	0.932
3	0.878
4	0.903
5	0.937

B. PILOT STUDY

The results of the assumptions tested in the pilot study are presented below. A validity coefficient equal or greater than 0.900 was the minimum value accepted.

The radiologist and radiology technician examined the x-rays and determined that a true lateral x-ray of the hands could be achieved; and that the fingers would need to be separated in order to delineate the third ray on the x-ray with confidence.

The form did not hinder the measurements or the x-ray beam in any manner; and did not allow movement of the joints measured, when taped on securely; and so the form was deemed acceptable.

The interclass correlation coefficient calculated for the dorsal goniometer, in blinded and unblinded states, for the MCP and PIP joints combined, was 0.982.

The interclass correlation coefficient calculated for the universal goniometer using the initial method of blinding (foam hood) was 0.604, for both the MCP and PIP joints combined. The reliability coefficient of 0.604 was both unacceptable and non-significant, and so a second method of blinding was devised.

The interclass correlation coefficient calculated for the universal goniometer using the second method of blinding (tape) was 0.980, for both the MCP and PIP joints combined.

When angles measured on the universal and dorsal goniometers were either read in place (alongside the joint), or removed from the finger and read, a combined (both the joints and goniometers) reliability coefficient (ICC) of 0.999 was obtained.

When PT2 and PT3 read the same angles from the blinded universal and dorsal goniometers, the interclass reliability coefficient for both tools was 0.999.

The interclass correlation coefficients calculated for the two positions used: 1) by the five therapists during the reliability study, and 2) by PT2 during the validation study, are presented separately for the universal and dorsal goniometers, in the following paragraph.

The reliability coefficient achieved by PT2 for the two positions with the universal goniometer was 0.976 on the MCP, and 0.991 on the PIP joint. For the dorsal goniometer, the reliability achieved by PT2 for the two positions was 0.941 on the MCP, and 0.994 on the PIP joint.

All interclass correlation reliability coefficients presented above were statistically significant at the $p < 0.01$ level except for one, as noted.

C. VALIDATION STUDY

The major purpose of this study was to determine if the tools clinically used by physical therapists to measure

MCP and PIP joint range of the finger in the normal adult hand had criterion validity.

Pearson product moment correlation coefficients were calculated to determine the relationship between each of the four methods on both joints and corresponding radiographs. The effect of age and sex on the coefficients was also calculated, both for the entire sample and for sub-groups divided on the basis of age and sex. Table 4.5 shows these correlations.

When all thirty subjects were used in the calculations all of the Pearson product moment correlation coefficients for all components were greater than 0.900. The significance of these coefficients are noted following Table 4.5.

Interclass correlation coefficients were calculated to determine if there was a non-biased relationship between each of the four methods on both joints and corresponding radiographs. Again, the effect of age and sex on the coefficients was also calculated, both for the entire sample and for sub-groups divided on the basis of age and sex. Table 4.6 shows these correlations.

When all thirty subjects were used in the calculations of the interclass correlation coefficients, all but one of the correlation coefficients were greater than 0.900. The significance of these coefficients are noted following Table 4.6.

TABLE 4.5

Pearson Correlation Coefficients Between Radiograph Measurements and Measurements On Each of the Four Methods For Both Joints, and for Sub-Groups Based on Sex and Age

Criterion Measure X-Ray				Method			
JT	N	SEX	AGE	VE	UG	DG	FG
MCP	30	B	20-50	0.933	0.937	0.964	0.966
	15	F	20-50	0.921	0.915	0.955	0.953
	15	M	20-50	0.944	0.959	0.974	0.978
	10	B	20-29	0.936	0.918	0.963	0.949
	10	B	30-39	0.889	0.879	0.920	0.967
	10	B	40-50	0.950	0.977	0.979	0.981
	5	F	20-29	0.974	0.872**	0.960	0.920**
	5	M	20-29	0.951	0.964	0.967	0.968
	5	F	30-39	0.583*	0.523*	0.735*	0.903**
	5	M	30-39	0.954	0.932	0.980	0.990
	5	F	40-50	0.976	0.991	0.965	0.968
	5	M	40-50	0.956	0.963	0.992	0.990
PIP	30	B	20-50	0.935	0.967	0.979	0.990
	15	F	20-50	0.902	0.947	0.962	0.988
	15	M	20-50	0.944	0.959	0.974	0.978
	10	B	20-29	0.950	0.982	0.983	0.993
	10	B	30-39	0.936	0.959	0.975	0.981
	10	B	40-50	0.931	0.954	0.976	0.996
	5	F	20-29	0.905**	0.981	0.966	0.989
	5	M	20-29	0.974	0.947	0.978	0.988
	5	F	30-39	0.951	0.972	0.976	0.985
	5	M	30-39	0.971	0.966	0.976	0.985
	5	F	40-50	0.884**	0.855**	0.949	0.996
	5	M	40-50	0.972	0.993	0.991	0.996

All values are statistically significant at $p < 0.01$ except as noted (* not significant, ** significant at $p < 0.05$).

Abbreviations: JT - joint, N - number of subjects used in calculations, VE - visual estimate, UG - universal goniometer, DG - dorsal goniometer, FG - flexible goniometer, MCP - metacarpophalangeal, PIP - proximal interphalangeal, B - both male and female, M - male, F - female.

TABLE 4.6

Interclass Correlation Coefficients Between Radiograph Measurements and Measurements On Each of the Four Methods For Both Joints, and for Sub-Groups Based on Sex and Age

Criterion Measure X-Ray				Method			
JT	N	SEX	AGE	VE	UG	DG	FG
MCP	30	B	20-50	0.916	0.919	0.951	0.964
	15	F	20-50	0.900	0.887	0.930	0.951
	15	M	20-50	0.930	0.948	0.970	0.974
	10	B	20-29	0.907	0.888	0.954	0.949
	10	B	30-39	0.872	0.878	0.913	0.967
	10	B	40-50	0.948	0.969	0.960	0.976
	5	F	20-29	0.873	0.819**	0.944	0.929
	5	M	20-29	0.937	0.959	0.966	0.968
	5	F	30-39	0.536*	0.521*	0.665*	0.864
	5	M	30-39	0.942	0.933	0.973	0.986
	5	F	40-50	0.973	0.989	0.946	0.973
	5	M	40-50	0.924	0.954	0.977	0.979
PIP	30	B	20-50	0.877	0.945	0.970	0.990
	15	F	20-50	0.809	0.917	0.960	0.987
	15	M	20-50	0.913	0.957	0.973	0.990
	10	B	20-29	0.948	0.978	0.973	0.991
	10	B	30-39	0.838	0.937	0.965	0.983
	10	B	40-50	0.839	0.917	0.965	0.993
	5	F	20-29	0.921	0.967	0.971	0.985
	5	M	20-29	0.857	0.955	0.936	0.987
	5	F	30-39	0.795**	0.934	0.974	0.985
	5	M	30-39	0.945	0.955	0.964	0.985
	5	F	40-50	0.800**	0.843	0.921	0.993
	5	M	40-50	0.863	0.942	0.979	0.992

All values are statistically significant at $p < 0.01$ except as noted (* not significant, ** significant at $p < 0.05$).

Abbreviations: JT - joint, N - number of subjects used in calculations, VE - visual estimate, UG - universal goniometer, DG - dorsal goniometer, FG - flexible goniometer, MCP - metacarpophalangeal, PIP - proximal interphalangeal, B - both male and female, M - male, F - female.

The absolute difference scores were used to calculate two single factor analyses of variance with repeated measures. This statistic was calculated for each joint separately to determine if there were any significant differences between the four methods. The tool used had a significant effect on the joint angle measured, for both the MCP ($p < 0.003$) and PIP ($p < 0.0000$) joints. Because a significant effect was shown, the Tukey Honestly Significant Different (HSD) test was applied to the mean values of the eight groups. The results of the Tukey HSD test are presented in Table 4.7.

TABLE 4.7

Tukey Pair-Wise Comparisons for the Four Methods for the MCP and PIP Joints

* Critical Difference (0.05) = 0.152
** Critical Difference (0.01) = 0.186

MCP JOINT					PIP JOINT				
	FG	DG	UG	VE		FG	DG	UG	VE
FG		**	**	**	FG		**	**	**
DG			**	**	DG			**	**
UG				NS	UG				**

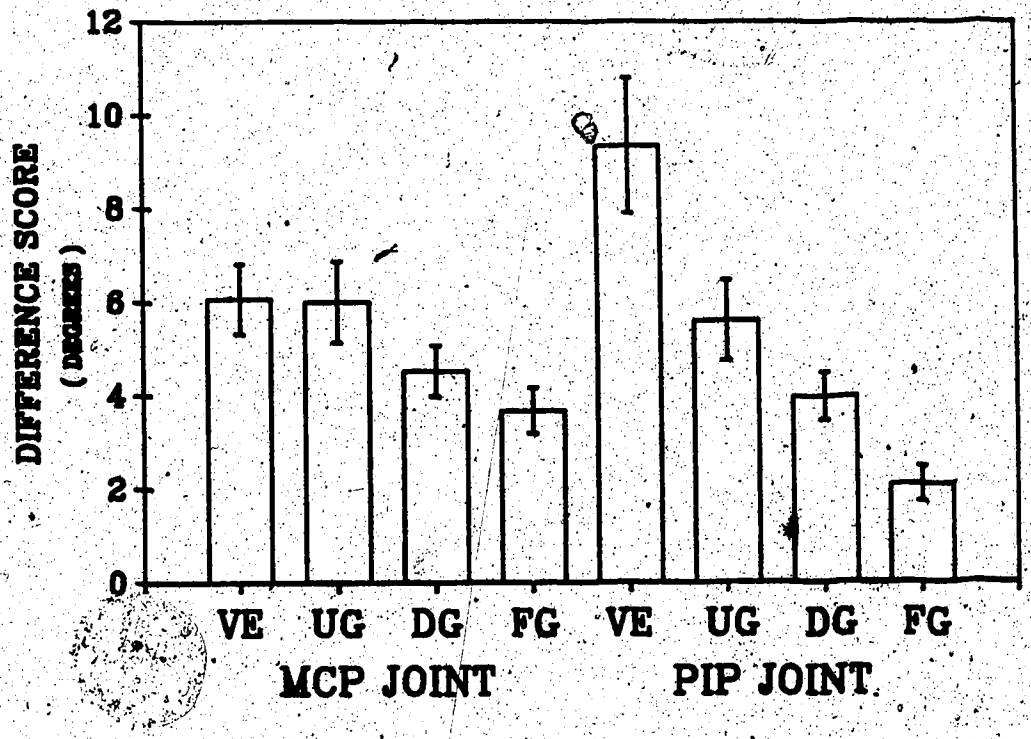
** Significant at the $p < 0.01$ level, * Significant at the $p < 0.05$ level.

Abbreviations: MCP - metacarpophalangeal, PIP - proximal interphalangeal, FG - flexible goniometer, DG - dorsal goniometer, UG - universal goniometer, VE - visual estimate, NS - not significant.

The mean values and standard error of the absolute difference scores for each of the eight groups are presented in Figure 4.1.

FIGURE 4.1

MEAN ABSOLUTE DIFFERENCE SCORE AND STANDARD ERROR FOR THE FOUR METHODS FOR THE MCP AND PIP JOINTS



Abbreviations: MCP - metacarpophalangeal, PIP - proximal interphalangeal, VE - visual estimate, UG - universal goniometer, DG - dorsal goniometer, FG - flexible goniometer.

The mean, standard deviation and standard error of the mean difference scores calculated for each of the four methods on both joints are presented in Table 4.8.

TABLE 4.8

Mean, Standard Deviation and Standard Error of the Mean Difference Scores for Each Method and Both Joints

Measure	Mean	Standard Deviation	Standard Error
VE:			
MCP	-2.2	7.063	1.290
PIP	-5.3	11.130	2.032
UG:			
MCP	-2.2	6.925	1.264
PIP	-4.0	6.187	1.130
DG:			
MCP	-2.5	4.769	0.871
PIP	-2.2	4.376	0.799
FG:			
MCP	-0.8	4.521	0.825
PIP	-0.4	2.944	0.538

Abbreviations: VE - visual estimate, UG - universal goniometer, DG - dorsal goniometer, FG - flexible goniometer, MCP - metacarpophalangeal, PIP - proximal interphalangeal.

The angles that were measured in the validation study were chosen randomly from a specified joint range. Although the forms were bent to correspond to these values, the actual angles tested were less than the full range expected, for both the PIP and MCP joints. The pre-set angles are presented in Appendix B. The angles actually measured by each method are presented in Appendix C.

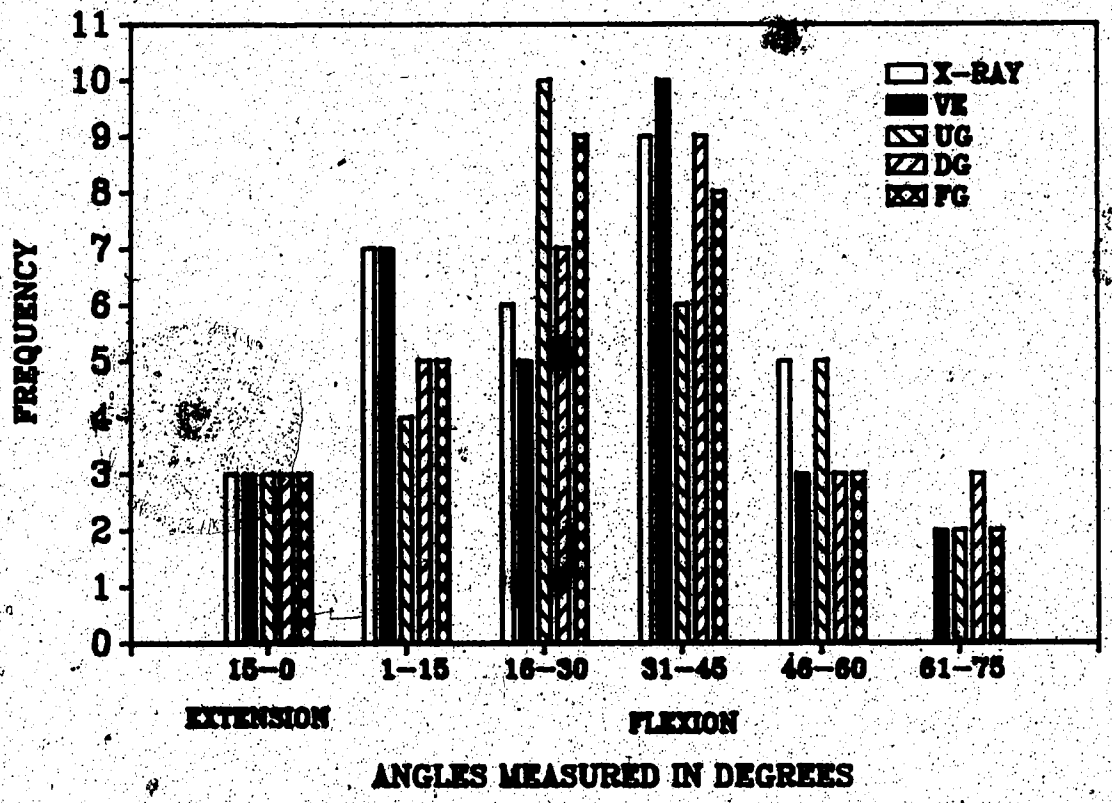
The frequency distribution of the angles tested for the MCP joint, divided into fifteen degree increments, starting in extension, and progressing through neutral and into flexion, are shown in Figure 4.2. The frequency distribution of the angles tested for the PIP joint, again divided by fifteen degree increments, and progressing from neutral into flexion, are shown in Figure 4.3.

The smallest and largest angles of flexion tested for all five methods, for both joints, are presented in Table 4.9. The smallest and largest angles of extension tested for all five methods, for the MCP joint, are presented in Table 4.10.

The raw data and subject characteristics for the validation study are presented in Appendix C.

FIGURE 4.2

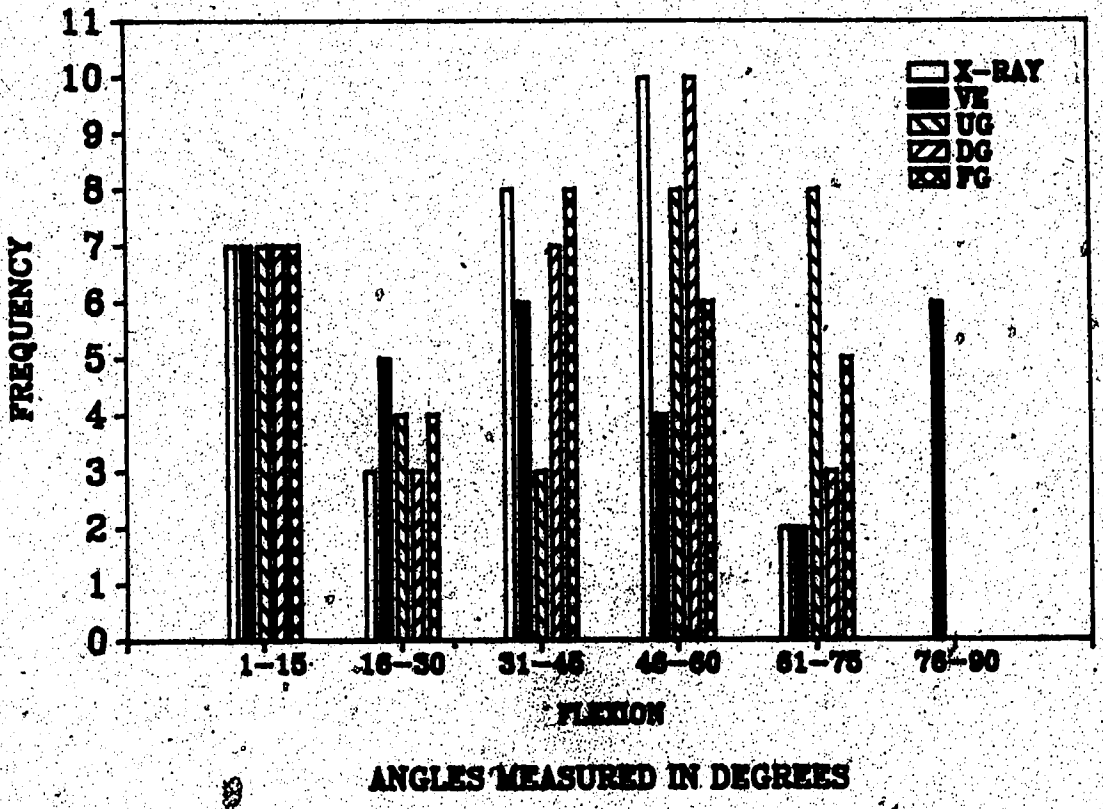
FREQUENCY DISTRIBUTION OF MCP JOINT ANGLES MEASURED



Abbreviations: VE - visual estimate, UG - universal goniometer, DG - dorsal goniometer, FG - flexible goniometer, MCP - metacarpophalangeal.

FIGURE 4.3

FREQUENCY DISTRIBUTION OF PIP JOINT ANGLES MEASURED



Abbreviations: VE - visual estimate, UG - universal goniometer, DG - dorsal goniometer, FG - flexible goniometer, MCP - metacarpophalangeal.

TABLE 4.9

Validation Study Flexion Range Tested
(joint angles in degrees)

Joint		X-RAY	VE	UG	DG	FG
MCP	HIGHEST	59	70	72	66	66
	LOWEST	5	0	3	3	5
PIP	HIGHEST	69	83	74	71	69
	LOWEST	3	3	4	6	6

Abbreviations: VE - visual estimate, UG - universal goniometer, DG - dorsal goniometer, FG - flexible goniometer, MCP - metacarpophalangeal, PIP - proximal interphalangeal.

TABLE 4.10

Validation Study Extension Range Tested
(joint angles in degrees)

Joint		X-RAY	VE	UG	DG	FG
MCP	HIGHEST	10	13	8	11	7
	LOWEST	5	5	3	3	6

Abbreviations: VE - visual estimate, UG - universal goniometer, DG - dorsal goniometer, FG - flexible goniometer, MCP - metacarpophalangeal.

The intra-rater reliability coefficients (ICC) calculated on PT1 for determination of the joint angles on the tracings from the flexible goniometer were 0.980 for the MCP tracings, and 0.978 for the PIP tracings. These values are significant at the alpha level of 0.01.

The inter-rater reliability coefficients (ICC) of three therapists - PT1, PT3, and a therapist not connected with the study (PT8), calculated for determination of the angles on tracings from the flexible goniometer, are presented in Table 4.11. Four inter-rater reliability coefficients (ICC) were calculated - PT1 with PT3, and PT1 with PT8; for both the MCP and PIP joints. Plate 4.1 shows a flexible goniometer tracing of the MCP joint that has been measured.

Intra-rater reliability coefficients (ICC) for measurement of the angles on the radiographs calculated for PT1 were 0.986 for the MCP joint, and 0.994 for the PIP joint. These values are significant at the alpha level of 0.01. Plate 4.2 depicts the x-ray of one subject from the validation study.

TABLE 4.11

Flexible Goniometer Tracings Interclass Inter-Rater Reliability Coefficients

Joint	PT1/PT3	PT1/PT8
MCP	0.976	0.963
PIP	0.937	0.943

All values significant at $p < 0.01$.

Abbreviations: PT - physical therapist, MCP - metacarpophalangeal, PIP - proximal interphalangeal.

PLATE 4.1 Measured MCP tracing of the flexible goniometer

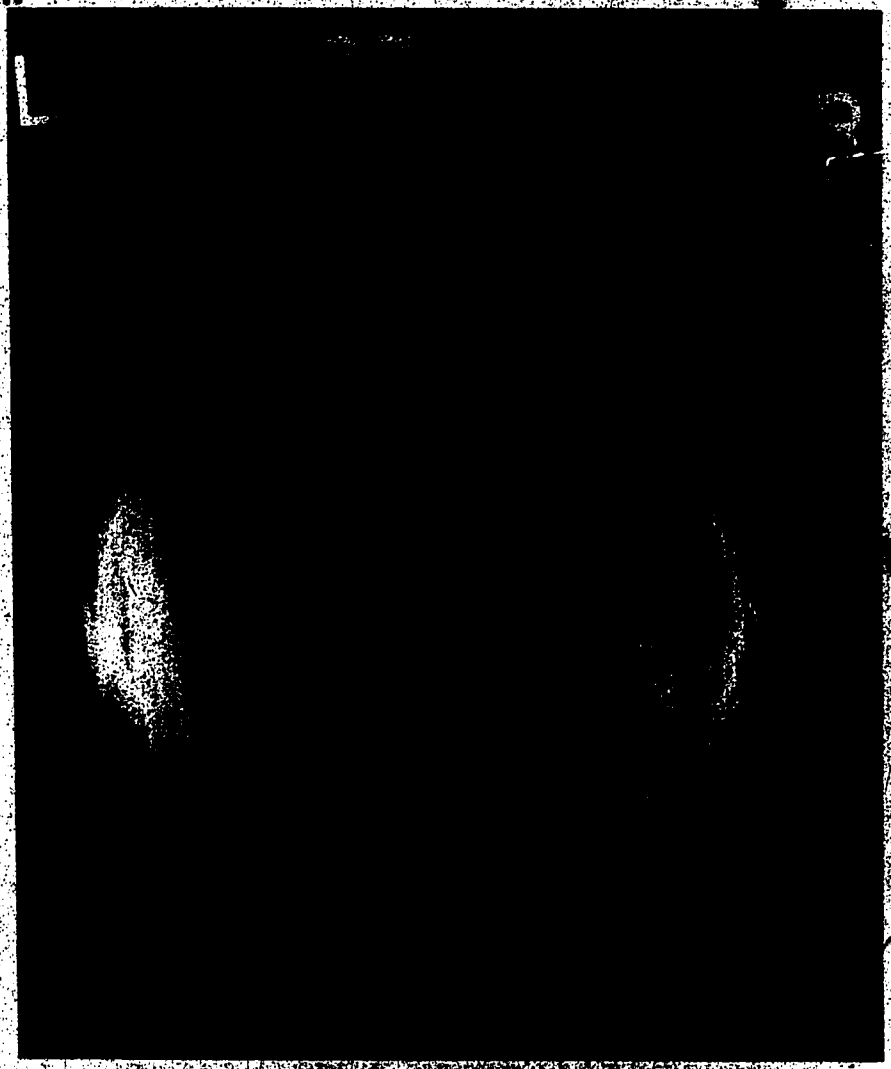


PLATE 4.2 X-ray of validation study subject #27

CHAPTER FIVE

DISCUSSION

A. THERAPIST RELIABILITY STUDY

Of the five therapists that participated in the reliability study, the two therapists with the highest reliability coefficients were the therapists with the least amount of experience. One of these two therapists had clinical experience measuring hands, which may explain her results. However, the other therapist was a new graduate with minimal clinical experience. Perhaps therapists become complacent when measuring joint range as they gain experience, thereby becoming less reliable. The method experienced therapists use to obtain joint range measurements may rely on observational skills rather than on mechanical devices. Intra-rater reliability coefficients could not be calculated for the visual estimate as only one measure was obtained, so this possible explanation can not be substantiated.

Comparing the intra-rater reliability coefficients of PT2 with four therapists that have different levels of experience enhanced the ability to generalize the results to the majority of physical therapists. Determining the relative ability of PT2 with respect to four of his colleagues provided an indication of his proficiency. This comparison will allow speculation of the value of the validity coefficient if other therapists were used.

Measurement of finger joint range using the universal goniometer laterally was less reliable when the fingers were together (so that the index finger was alongside the middle finger), than when they were separated. This decreased reliability held true for the PIP joint, but not for the MCP joint. Separating the fingers allowed the therapists to clearly define the long axes of the bones and the joint axis when measuring the PIP joint. This visualization enhanced the reliability of the therapists. Because the proximal phalanx of the index and middle fingers could be aligned parallel to each other, having the index finger alongside the middle finger enhanced the reliability of the therapists, when the MCP joint was measured.

B. VALIDATION STUDY

The a priori criterion for establishing validity of the four methods was achievement of a validity coefficient of 0.900 or greater. Based on the interclass correlation coefficients, all four methods/instruments are valid tools for measurement of MCP joint range between the angles of 10 degrees of extension and 60 degrees of flexion. For the PIP joint, all methods/instruments are valid tools for measurement of PIP joint range between 0 and 70 degrees of flexion, with the exception of the visual estimate.

The ICC, unlike the Pearson product moment correlation, takes the variance of the scores into consideration.

Coefficients calculated using the Pearson product moment method tended to produce higher values than did the inter-class correlation. This relationship was particularly true for those coefficients approaching 0.900. The lower ICC results suggests that the variance element is an important factor when determining validity.

Only the visual method applied to the PIP joint demonstrated a statistically significant coefficient that was not valid. As validity and reliability are directly related, as discussed in Chapter 2, and as the inter-rater reliability of the visual estimate was very poor (see Table 4.3), improving the reliability of the visual estimate may produce a valid method. The reliability of the visual estimate for the MCP joint was poor, but not as low as for the PIP joint. As the visual estimate for the MCP was shown to be a valid tool, this improved reliability may have been the cause. However, as the reliability of the visual estimate for both the MCP and PIP are unacceptably low, another factor may be involved, such as, the anthropometric characteristics of the subjects.

The proximal and middle phalanges of the third ray are relatively short. As long axes are required for accurate results, as discussed by Robson (1966), the short phalanges forming the PIP joint may be a factor in the reduction of accuracy of the visual estimate at the PIP joint. The

longer metacarpal on the proximal aspect of the MCP joint may aid in the visual estimate of the MCP joint.

Although statistically significant, the results obtained from the analyses of variance and Tukey HSD test were not clinically meaningful. Measurement of joint range varies significantly with the tool used, but the validity coefficient and standard error of the mean difference score are of primary importance, and must also be considered.

I[illegible]epts an error variance of five degrees as a clinically [illegible]table standard, the standard error of the mean d[illegible]e scores, of approximately two degrees or less, are clinically acceptable values. With the exception of the visual estimate, the standard error value was less for the PIP joint than for the MCP joint. The two methods using the dorsal approach (DG, FG) had the least standard error, whereas, the visual estimate had the largest amount of standard error.

The standard deviation was greater than five degrees for the visual estimate and universal goniometer, but less than five degrees for the dorsal and flexible goniometers. As standard deviation is a measure of variance, the results suggest that the dorsal and flexible goniometers would be the most appropriate instruments to use clinically.

In this study, the universal goniometer was applied to the lateral aspect of the joints to obtain the desired measurements. Clinically, some therapists utilize this

The risk involved with this protocol is very small. This protocol has been reviewed by several committees, and in particular, has received approval from a committee composed of knowledgeable scientists and physicians who are your advocates regarding the level of the proposed radiation.

All records will be the property of the principal investigator. No records or property which would reveal your identification will be made public without your written consent. Access to all pertinent records will be restricted to those individuals directly associated with this study.

If concerns or questions arise regarding the study, prior to or during the study, please feel free to contact or question the principal investigator, Donna Davies at 432 - 2068, or the physician responsible for authorization of the x-rays, Dr. DC Reid at 432 - 6233.

Please retain this explanation of the reasons for and procedures for the study for your own records.

INFORMED CONSENT FORM:

ASSESSMENT OF THE VALIDITY OF GONIOMETRIC MEASUREMENT OF FINGER JOINT RANGE IN NORMAL ADULT HANDS

Subject Consent (retained by investigator)

I, _____ do hereby agree to
(please print name)
participate in the study entitled "Assessment of the Validity of Goniometric Measurement of Finger Joint Range in Normal Adult Hands" to be conducted by physical therapist Donna Davies and her colleagues - another physical therapist, a x-ray technician, and a radiologist, under the supervision of Dr. DC Reid.

I acknowledge that the nature of the study, its purpose, its possible effects and the research procedures, of which I have a copy, have been explained to me, and that any questions I have asked have been answered to my satisfaction. I understand the lack of direct benefit and the implications of being a subject in this study. I know that I may ask now, or in the future any questions about the study or the research procedures. I have been assured that personal records relating to these experimental protocols will be kept confidential and that no information will be released or printed that would disclose personal identity without my permission.

I understand that the performance of the study is not intended as a form of remedial treatment. I have also been advised that I may withdraw from participation in the study at any time without providing a reason for doing so.

_____ _____

Subject's Signature Date

_____ _____

Address Phone Number

I was witness during the explanation referred to above and to the signature.

_____ _____

Signature of Witness Date

APPENDIX B

RANDOMIZED ANGLES AND TESTING ORDER

RANDOM ASSIGNMENT OF TESTING ORDER

SUBJ	ORDER	JT1	JT2	M1	M2	M3	M4	HAND-M	HAND-P	ANG-M	ANG-P
21	1	MCP	PIP	VE	FG	DG	UG	R	L	28	25
17	2	MCP	PIP	VE	FG	UG	DG	L	R	60	56
26	3	PIP	MCP	VE	FG	UG	DG	R	L	4E	17
20	4	MCP	PIP	VE	FG	UG	DG	L	R	75	108
14	5	PIP	MCP	VE	DG	UG	FG	R	L	6E	84
7	6	MCP	PIP	VE	DG	FG	UG	L	R	56	68
22	7	MCP	PIP	VE	DG	FG	UG	R	L	0	30
10	8	PIP	MCP	VE	UG	DG	FG	L	R	38	60
9	9	PIP	MCP	VE	FG	DG	UG	L	R	23	90
29	10	MCP	PIP	VE	UG	FG	DG	R	L	84	53
24	11	MCP	PIP	VE	UG	DG	FG	L	R	51	11
2	12	MCP	PIP	VE	DG	UG	FG	R	L	46	49
16	13	PIP	MCP	VE	DG	UG	FG	R	L	68	105
19	14	MCP	PIP	VE	DG	UG	FG	L	R	13E	28
8	15	PIP	MCP	VE	UG	DG	FG	L	R	87	38
15	16	MCP	PIP	VE	UG	FG	DG	R	L	3	94
12	17	PIP	MCP	VE	FG	DG	UG	R	L	89	3
5	18	MCP	PIP	VE	DG	FG	UG	L	R	27	39
6	19	MCP	PIP	VE	UG	FG	DG	L	R	58	51
23	20	PIP	MCP	VE	UG	DG	FG	L	R	13	100
25	21	MCP	PIP	VE	DG	UG	FG	R	L	6	71
27	22	MCP	PIP	VE	FG	UG	DG	R	L	12	65
3	23	MCP	PIP	VE	UG	FG	DG	R	L	70	76
1	24	PIP	MCP	VE	DG	FG	UG	R	L	33	97
30	25	MCP	PIP	VE	FG	DG	UG	R	L	43	87
28	26	PIP	MCP	VE	FG	DG	UG	R	L	64	43
18	27	PIP	MCP	VE	UG	DG	FG	L	R	30	78
11	28	PIP	MCP	VE	DG	FG	UG	L	R	72	5
4	29	PIP	MCP	VE	UG	FG	DG	L	R	47	10
13	30	PIP	MCP	VE	FG	UG	DG	L	R	16	15

Abbreviations used above:

SUBJ - subject
JT1 - first joint measured
JT2 - second joint measured
M1 - first method used
M2 - second method used
M3 - third method used
M4 - fourth method used
HAND-M - hand MCP joint tested on
HAND-P - hand PIP joint tested on
ANG-M - angle MCP splint set at
ANG-P - angle PIP splint set at
MCP - metacarpophalangeal
PIP - proximal interphalangeal

E - extension
L - left
R - right
VE - visual estimate
UG - universal goniometer
DG - dorsal goniometer
FG - flexible goniometer

RANDOM ASSIGNMENT OF JOINT RANGES

PIP JOINT RANGES:			MCP JOINT RANGES:		
0-10	1)	10	0-9	1)	6
	2)	5		2)	3
	3)	3		3)	0
11-21	1)	17	10-19	1)	13
	2)	11		2)	12
	3)	15		3)	16
22-32	1)	28	20-29	1)	27
	2)	30		2)	23
	3)	25		3)	28
33-43	1)	38	30-39	1)	38
	2)	43		2)	30
	3)	39		3)	33
44-54	1)	53	40-49	1)	46
	2)	51		2)	43
	3)	49		3)	47
55-65	1)	65	50-59	1)	51
	2)	60		2)	56
	3)	56		3)	58
66-76	1)	71	60-69	1)	60
	2)	68		2)	68
	3)	76		3)	64
77-87	1)	87	70-79	1)	75
	2)	78		2)	70
	3)	84		3)	72
88-98	1)	97	80-89	1)	89
	2)	94		2)	84
	3)	90		3)	87
99-109	1)	108	0-15E:	1-5 1)	4
	2)	105		6-10 2)	6
	3)	100		11-15 3)	13

All angles above are flexion except as noted with an "E".

Abbreviations used above:
E - extension
MCP - metacarpophalangeal
PIP - proximal interphalangeal

APPENDIX C

VALIDATION STUDY RAW DATA

[illegible]	F	37	MCP	21	35	26	29	25
[illegible]	F	43	MCP	05	05	03	03	07
[illegible]	F	44	MCP	32	30	35	36	32
8	F	44	MCP	54	50	55	61	56
9	F	49	MCP	22	15	23	20	16
18	F	50	MCP	16	20	21	28	23
4	M	20	MCP	39	25	30	35	30
11	M	27	MCP	52	60	60	56	59
26	M	29	MCP	10	05	05	03	07
28	M	29	MCP	34	35	39	42	35
22	M	29	MCP	05	00	04	08	05
23	M	30	MCP	13	15	18	19	16
24	M	31	MCP	41	40	50	38	39
2	M	31	MCP	38	40	36	38	36
27	M	34	MCP	12	06	06	12	10
17	M	37	MCP	35	45	31	34	33
16	M	40	MCP	40	48	50	46	45
19	M	45	MCP	09	13	08	11	06
10	M	45	MCP	25	35	29	28	28
20	M	46	MCP	49	45	44	49	48
12	M	50	MCP	59	70	67	66	66

Abbreviation used above:
ID - identification
JT - joint
VE - visual estimate
UG - universal goniometer
DG - dorsal goniometer
FG - flexible goniometer
MCP - metacarpophalangeal

VALIDATION STUDY RAW DATA AND SUBJECT CHARACTERISTICS

PIP JOINT

CASEID	SEX	AGE	JT	XRAY	VE	UG	DG	FG
3	F	20	PIP	51	60	5	50	47
29	F	21	PIP	48	45	52	51	48
13	F	22	PIP	13	18	13	15	12
7	F	25	PIP	43	35	44	38	39
6	F	27	PIP	39	40	47	44	40
5	F	30	PIP	32	20	26	28	24
15	F	32	PIP	56	78	72	59	55
21	F	35	PIP	09	08	09	15	10
25	F	37	RIP	49	75	57	56	50
30	F	37	PIP	59	80	64	59	59
14	F	43	PIP	60	75	62	59	64
8	F	44	PIP	29	25	30	32	29
1	F	44	PIP	69	83	74	61	70
9	F	49	PIP	57	50	53	52	57
18	F	50	PIP	43	60	62	50	44
4	M	22	PIP	03	04	09	10	06
11	M	27	PIP	10	05	07	13	10
28	M	29	PIP	36	25	34	37	35
26	M	29	PIP	10	05	07	11	09
22	M	29	PIP	18	15	21	24	21
23	M	30	PIP	64	80	69	71	69
24	M	31	PIP	04	10	11	14	10
2	M	31	PIP	47	47	41	45	44
27	M	34	PIP	43	45	50	43	43
17	M	37	PIP	42	45	49	45	41
16	M	40	PIP	57	80	70	59	61
19	M	45	PIP	16	30	24	26	21
10	M	45	PIP	43	45	47	47	42
20	M	46	PIP	60	83	74	61	61
12	M	50	PIP	04	03	04	06	06

Abbreviation used above:
ID - identification
JT - joint
VE - visual estimate
UG - universal goniometer
DG - dorsal goniometer
FG - flexible goniometer
PIP - proximal interphalangeal