Viability of Hand and Wrist Photogoniometry

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Abstract

Background: No goniometric technique is both maximally convenient and completely accurate, although photogoniometry (ie, picture taking to facilitate digital angle measurement) shows promise in this regard. Our purpose was to test the feasibility and reliability of a photogoniometric protocol designed to measure wrist and digit range of motion in general. **Methods:** Two independent observers examined a sample of joints in both normal and abnormal hands according to a photogoniometric protocol. Interrater and intrarater correlation were calculated, and these measurements were compared with measurements made by a third independent examiner with a manual goniometer. **Results:** The photo-based measurements were reliable within and between observers; however, only a minority of these measurements were in agreement with manually collected values. **Conclusions:** At present, photogoniometry is not an acceptable alternative to manual goniometry for determining wrist and digit range of motion in general. Joint-specific photogoniometry should be the subject of future study, as should relevant imaging and software technology.

Keywords: photogoniometry, digital angle measurement, manual goniometry, digit range of motion, wrist range of motion

Introduction

There is no perfect way to measure wrist and digit range of motion. Manual goniometers are often used; however, they are prone to error,^{2,4,10,15} time-consuming, and tedious to use, and they may transmit microorganisms. Other options have been described, ranging from the simple crossing paper slips¹⁴ and wire tracing,⁹ to the complex cell phone applications,¹⁷ video motion analysis,^{3,6,12,20} and goniometric gloves.^{13,19} None of these alternative techniques are ideal. Given the lack of a perfect option, some examiners simply “eyeball” joints, a technique that is intuitively inferior and has been proven ineffective.^{15,21}

An ideal technique would produce accurate, reproducible measurements, be easy for both examiners and patients, work equally well for normal and stiff joints, permit measurement of any number of joints, be hygienic, be inexpensive, and involve tools that are easy to maintain.

Photogoniometry—taking a picture to facilitate digital measurement—may be an ideal technique. This method has been studied previously; however, existing articles are limited to study of a wax hand model,⁸ eschew a global assessment of the hand and wrist,^{7,8,10,22} or rely on a complicated protocol.^{10,22} We therefore tested the ability of a simple photogoniometric method to make accurate and reproducible measurements of various wrist and hand motions in vivo.

Materials and Methods

Our institutional review board approved this study. Patients with upper extremity pathology were recruited from our hand therapy service, and healthy volunteers were recruited from our institution (8 patients, 7 volunteers). We obtained informed consent from each study participant. Only subjects uncomfortable communicating in English were excluded.

A set of joints and potential excursions at these joints was chosen to represent hand and wrist motion in general. One certified hand therapist (CHT), who remained independent of the other examiners, used a manual goniometer (Baseline Stainless Steel Finger Goniometer; FEI, White Plains, New York) and American Society of Hand Therapists–standardized technique to measure maximum active motion at each chosen point of potential excursion, for each subject. The same CHT

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Table 1. Concordance Correlation Coefficients.

Excursion	Average intrarater reliability	Interrater reliability (95% CI)	Agreement with manual goniometer (95% CI)
Wrist flexion	0.96	0.96 (0.89 to 0.99)	0.78 (0.47 to 0.92)
Thumb abduction	0.85	0.84 (0.70 to 0.92)	0.16 (−0.20 to 0.48)
Wrist extension	0.95	0.96 (0.91 to 0.98)	0.51 (0.23 to 0.71)
Thumb MP extension	0.88	0.80 (0.64 to 0.89)	0.60 (0.35 to 0.77)
Thumb IP extension	0.82	0.78 (0.60 to 0.88)	0.46 (0.18 to 0.67)
Thumb MP flexion	0.93	0.93 (0.87 to 0.97)	0.72 (0.52 to 0.84)
Thumb IP flexion	0.94	0.93 (0.87 to 0.97)	0.84 (0.72 to 0.92)
Index MP flexion	0.82	0.84 (0.69 to 0.92)	0.60 (0.34 to 0.77)
Index PIP flexion	0.68	0.70 (0.48 to 0.85)	0.46 (0.14 to 0.69)
Index DIP flexion	0.79	0.80 (0.62 to 0.90)	0.48 (0.18 to 0.70)
Ring MP flexion	0.93	0.93 (0.87 to 0.97)	0.53 (0.25 to 0.72)
Ring PIP flexion	0.89	0.90 (0.80 to 0.95)	0.82 (0.68 to 0.90)
Ring DIP flexion	0.73	0.74 (0.52 to 0.86)	0.06 (−0.26 to 0.37)

Note. CI = confidence interval; MP = metacarpophalangeal; IP = interphalangeal; PIP = proximal interphalangeal; DIP = distal interphalangeal.

then used a digital camera to take a predetermined set of photographs so as to visually capture the maximum active excursion at each chosen point of potential excursion, for each subject. We chose a dedicated digital camera, rather than a cell phone, only to allow for maximum data security. The only instructions given to the CHT were example photographs, recommended verbal cues to give to participants, and the request that each hand be photographed resting on a solid surface with the camera lens as parallel to that surface as possible (data sheet available in the Online Appendix). These photographs were made available to 2 independent reviewers, one a hand surgery fellow and the other an attending, board- and Certificate of Added Qualification-certified hand surgeon. Each photograph reviewer measured the same excursions digitally with ImageJ (US National Institutes of Health, Bethesda, Maryland) that had been measured manually. Each photograph reviewer made 2 such assessments, with at least a week intervening.

Concordance correlation coefficients within and between the photograph reviewers were determined for each excursion studied. Intrarater reliabilities calculated for each reviewer were averaged for each excursion studied. Photo-based measurements were averaged for each excursion studied before calculating correlation coefficients between these average values and their corresponding manual measurements.

Results

A mix of adult hands from both our hand therapy service patients and from healthy volunteers was studied. Results are shown in Table 1. Nearly all of the photo-based measurements had acceptably high intra- and interrater correlation. Four of the photo-based measurements were deemed to be in acceptable ($r \geq 0.70$) agreement with the manual

measurements and 9 were not ($r < 0.70$). Lack of agreement between photogoniometric values and manual values was influenced by manual measurements not being taken in the photogoniometric position.

Discussion

The suggestion that meaningful assessments of the hand and wrist may be obtained from carefully taken photographs is not new. Acheson et al, in 1966, described a “self-contained portable unit,” permitting “rigid standardization with regard to position, lighting, and focal length,” designed to take pictures of the hand to screen for joint disease.¹ More recent work has focused primarily on motion at more proximal body parts like the hip,⁵ knee,¹⁸ and elbow.^{7,16} The elbow, in addition to being large, is not subject to tenodesis, is relatively unobscured during photography, and produces motion in only 2 planes. The hand constitutes a complex collection of interconnected, closely located, small joints, many with several degrees of freedom, and therefore poses a unique challenge to both manual and photo-based goniometric techniques.

Our results indicate that photogoniometry, used in vivo and with a simple protocol, is viable for certain, although not all, joints of the wrist and hand. Intra- and interobserver reliability of photo-based measurements were high for nearly all observed joints. Certain photo-based measurements, however, particularly those pertaining to motion of joints affected by tenodesis, such as the index distal interphalangeal joint, or to joints that were difficult to photograph due to them being obscured, such as the ring metacarpophalangeal joint, were not in acceptable agreement with manual measurements. Both the examiner and the subject must be given freedom to precisely position these “problem” joints. Posing these joints for photographs

restricted this freedom and exposed a weakness of the photogoniometric technique in general.

Our findings expand on a small amount of related work evaluating photo-based measurement of wrist and hand range of motion. De Carvalho et al found good correlation between manual and photo-based measurements taken from 3 joints of a wax hand.⁸ Smith et al compared manual and photo-based assessments of proximal and distal interphalangeal joints in patients with Dupuytren disease. Reasonable correlation was noted even though the authors did not specify that the photographs be taken at a particular angle to the hand.²² Georgeu et al made measurements of ring and small finger range of motion with a manual goniometer and from reproducible digital photographs. Excellent correlation was found between the 2 methods, although other areas of the hand were not studied.¹⁰ Crasto et al noted “strong” correlation ($0.57 < r < 0.67$) between wrist flexion/extension measured manually and from photographs.⁷

In our study, we used manual goniometry as a convenient and familiar reference standard. Although manual goniometry is the empiric standard among hand surgeons and hand therapists, x-ray-based measurements may be most reproducible.^{4,11,12,15} We chose against x-ray in favor of the empiric standard, to eliminate the risk of radiation and to minimize cost and study burden. We studied only a sample of the motions of which the hand and wrist are capable. Sample motions were selected for clinical relevance (eg, abduction and adduction of the individual digits at the metacarpophalangeal joints were omitted), feasibility (eg, pronosupination through the carpus was omitted), and to expose what we saw as likely limitations of the photographic protocol (eg, the tendency of the ring finger to be obscured by adjacent digits). We feel our results can be fairly extrapolated to joints and motions not specifically studied. Also, given that our sample of joints exposed weakness of the technique in general, a larger or more varied sample seemed unnecessary. Likewise, although bias may have been introduced by asking the same examiner to both measure and photograph hands, this bias would tend to favor the photo-based technique, making our essentially negative result more robust.

We additionally acknowledge that a more complex photographic method might have allowed for more accurate measurement of excursion at certain joints. For example, photographing the hand from the ulnar side may have permitted better visualization of the ring finger. Our goal in this study, however, was to test the viability of photogoniometry to measure wrist and hand motion in general. With this in mind, we designed our protocol to be at least as convenient as manual measurement of multiple joints in a single setting. Were only a single joint or smaller number of joints of concern, such as in patients with Dupuytren contracture, a more complex but more accurate photogoniometric protocol

might be justified. Such a protocol could allow for ideal positioning of the subject’s hand, a distinct advantage of manual goniometry. Dedicated ring finger photographs, for instance, might produce more accurate, reproducible digital measurements than did our photographs, designed as they were to capture motion of several joints at once and otherwise for simplicity. Ideal photogoniometry of individual hand and wrist joints should be the subject of continued study.

Although our protocol was convenient, it was not universally accurate. Conversely, x-ray images may afford accurate measurements,^{4,11,12,15} but they are prohibitively cumbersome for the purpose of joint measurement in many clinics. We speculate that future technology will permit both accuracy and ease of use. Because cell phones are ubiquitous, provide a platform for ever-improving software, and may automatically upload information, the cell phone is a likely vehicle for photogoniometry.^{7,16} At present, however, as in our study, this method requires at least 2 steps: joints must be photographed and then measured; to our knowledge, no technology exists to simultaneously accomplish each. Although software applications do exist for measurement of joint range of motion, most of them have not been specifically validated for use in the hand, and most require the cell phone to be placed physically against the patient’s body. For instance, knee range of motion may be tested with a cell phone’s accelerometers and/or inclinometers by placing the cell phone against the proximal tibia.¹⁷ We see little advantage of this process, which is not true photogoniometry, over traditional manual goniometry. Other fields, such as video motion capture technology and 3-dimensional scanning may help accomplish what these apps have not—the development of an automatic photogoniometer.^{3,6,12,20} As this technology becomes cheaper and more refined, in other words, as it approaches the convenience of manual goniometry, it should be the subject of future investigation.

Our findings should not be interpreted as a denunciation of clinical hand photography or manual goniometry. Photography, and particularly a standard series of photographs, records much about a patient’s hand. Over time, and especially if they are incorporated into the medical record, these images are compelling markers of both disease and recovery, and may serve as teaching tools for doctor and patient alike.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Statement of Informed Consent

Informed consent was obtained from all individual participants included in this study.

Declaration of Conflicting Interests

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