Original Article

The Reliability Study of the Infrared Position Capture Device: A Novel Technique in Wrist Motion Measurement

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Background: Reliability in measurement of wrist range of motion (ROM) is necessary in clinical examination and evaluation. An infrared position capture device for detection and measurement of hand and finger movements without any physical contact with the device was introduced in 2013. No prior study has evaluated the reliability of this device relative to the measurement of wrist ROM.

Objective: To determine the reliability of the infrared position capture device, and to evaluate its agreement with universal standard goniometer for the measurement of wrist ROM.

Materials and Methods: A comparison of wrist ROM measurements was performed in 33 healthy subjects at the Department of Orthopaedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand. Candidates with previous wrist injury, wrist surgery, or severe obesity were excluded. Two examiners independently evaluated each participant using both measurement method. The results of both the two measurement methods and the two examiners were compared.

Results: Significant interobserver and intraobserver reliability were found in the measurement of wrist angle using the infrared position capture device and universal standard goniometer. Intraclass correlation coefficient (ICC) comparing infrared position capture device and goniometer was, as follows: flexion 0.86, extension 0.92, radial deviation 0.53, and ulnar deviation 0.76 for examiner 1; and, flexion 0.83, extension 0.92, radial deviation 0.69, and ulnar deviation 0.80 for examiner 2 (range: 0.53 to 0.92). Infrared position capture device measurements of wrist angle in all 4 positions were very similar to those of universal standard goniometer. The mean difference between methods for measurement of wrist angle ranged from 0.15 to 3.88 degrees.

Conclusion: The infrared position capture device was found to be a reliable tool for measurement of wrist motion. Measurements by infrared position capture device were found to be in agreement with measurements by universal standard goniometer, which is the current standard technique.

Keywords: Infrared position capture device, Leap motion controller, Goniometer, Wrist, Reliability, Range of motion

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The wrist is a joint of the upper extremity that facilitates flexion, extension, radial deviation, and ulnar deviation. Reliability in the measurement of wrist range of motion (ROM) is necessary for clinical examination, the evaluation of treatment options, and for treatment planning. Universal standard goniometer is considered to be a standard instrument for measurement of wrist ROM. Measurement by goniometer is a manual measurement that is performed by a clinician, and the result must be written down on paper or entered into a computer by the examiner.

In 2013, Leap Motion, Inc. (San Francisco, California, USA) introduced an infrared position capture device that is a small USB peripheral device that rests on a tabletop facing upward. This computer hardware technology is characterized by or described as a sensor device that detects and measures movements of the hand and fingers without any physical contact with the device. Frank Weichert, et al found the position accuracy of a infrared position capture device to be 0.2 mm(1). Guna J, et al reported that unidirectional measurement by infrared position capture device showed minimal standard deviation of measurement(2). Infrared position capture device further expands the opportunity for the use of 3-dimensional applications for motion analysis in the medical profession.

No prior study has evaluated the reliability of the infrared position capture device relative to measurement of wrist ROM. Therefore, the objective of this study was to determine the reliability of the infrared position capture device, and to evaluate its agreement with universal standard goniometer for the measurement of wrist ROM.

Materials and Methods

The protocol for the present study was approved by the Siriraj Institutional Review Board (SIRB) of the Faculty of Medicine Siriraj Hospital, Mahidol University

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(protocol number 209/2558 [EC2]).

Examiners

The two examiners that were selected for this study included one junior orthopedic resident and one senior orthopedic resident. Both examiners separately used universal standard goniometer and infrared position capture device to measure the wrist motion in each healthy subject. Both examiners were trained in session to ensure that they would be able to use both devices correctly.

Subjects

Thirty-three healthy adult subjects (21 males and 12 females) that met the inclusion criteria were recruited to participate in this study. The average age of subjects was 31±8.77 years (range: 20 to 60). Candidates were recruited via written communication. Candidates with previous wrist injury, wrist surgery, or severe obesity (body mass index ≥30 kg/m^2) were excluded. The dominant arm was defined as the arm/hand used for writing. Written informed consent was obtained from each subject before the study commenced.

Recorders

Individuals responsible for recording data from each measurement device (universal standard goniometer and infrared position capture device) were independent from the study so that the examiners would remain blinded to previous measurement results from other subjects.

Instrumentation

The infrared position capture device consists of two cameras and three infrared LEDs. Using this device, movements of the hand and fingers can be detected, and the position of the wrist can be measured by commutating advanced algorithms via stereo image of the infrared light spectrum, separated into the left and right cameras. Measurement of wrist position was performed in all directions, including flexion, extension, radial deviation, and ulnar deviation. The authors retained the services of a software programmer (HMC Prototype App, v 1.0, Bangkok, Thailand) to develop a program to calculate ROM. The infrared position capture device was positioned 5 cm from the front of the calibrator and connected to the computer via USB port (Figure 1).

Calibration

The authors developed and manufactured a calibrator designed to ensure a neutral wrist position in vertical and horizontal movement. The calibrator device consists of a stainless steel box with acrylic plastic on the top that functions as an armrest, and a T-shaped cylindrical stainless steel rod that rests against the top of the wrist ensuring neutral position during measurement (Figure 2).

Procedure

The present study was conducted at the Department of Orthopaedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand during the May 2015 to April 2016 study period. Subjects were asked to wear a short-sleeved shirt for full exposure of forearm and wrist. Subjects were then asked to sit in a standard-height adjustable chair. The subject's dominant shoulder was placed at 90-degree abduction, the elbow at 90-degree flexion, and the forearm in a neutral position. The calibrator was placed above the subject's wrist to ensure a standardized neutral position before measurements were taken (Figure 2). The dominant wrist of each subject was blindly measured in a random order of each direction of wrist motion with infrared position capture device by the first examiner followed by measurement with a universal standard goniometer by the second examiner. After a one-hour interval, subjects were blindly remeasured in each direction of wrist motion with infrared position capture device by the second examiner followed by measurement with universal standard goniometer by the first examiner. The measurement of wrist movement of all subjects was repeated randomly following the initial measurements after one week. For wrist ROM measurement, each subject was asked to hold a maximum static position in flexion, extension, radial deviation, and ulnar deviation (Figure 3). Once each maximum position was achieved and held, the measurement for that position was

Figure 1. Demonstration of infrared position capture device (red arrow) connected to computer via USB port.

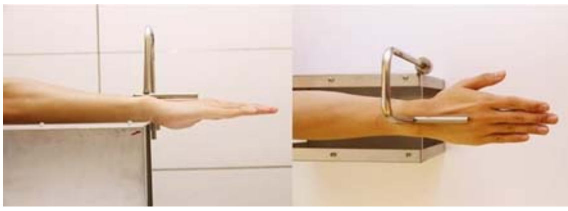

Figure 2. Demonstration of standardized neutral wrist position.

recorded. Hand position was reset to neutral position of the wrist after each measurement using our custom-designed calibrator. For universal standard goniometer measurement, the stationary arm of the device was placed parallel to the longitudinal axis of the dorsal surface of the forearm, and the movable arm of the device was placed parallel to the longitudinal axis of the third metacarpal bone (Figure 4).

Statistical analysis

Interobserver and intraobserver reliability between infrared position capture device and universal standard goniometer were measured by intraclass correlation coefficient (ICC), with an ICC >0.80 indicating strong reliability. Absolute agreement between infrared position capture device and universal standard goniometer measurements was assessed using ICC and 95% confidence interval (CI) for each of two examiners. ICC interpretations according to Landis and Koch were used, as follows: 0.00 to 0.20 = slight agreement; 0.21 to 0.40 = fair agreement; 0.41 to 0.60 = moderate agreement; 0.61 to 0.80 = substantial agreement; and, 0.81 to 1.00 = strong agreement[3]. The average ICC for each ROM measurement (flexion, extension, radial deviation, and ulnar deviation) was calculated for each measurement device. Bland-Altman method was used to assess agreement by calculating the mean difference between infrared position capture device and universal standard goniometer measurements, standard deviation of the mean difference, and 95% limits of agreement[4]. The Bland-Altman plots show patient distribution according to the mean of both measurement devices relative to the difference between the two measurement devices. If agreement is good, then differences should be randomly scattered around the zero-difference reference line.

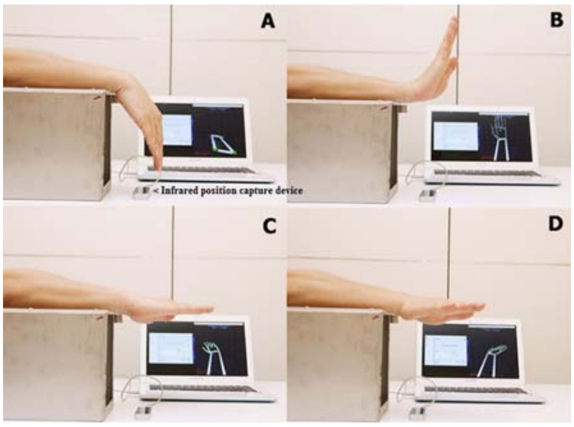

Figure 3. Demonstration of maximum wrist motion in four directions.

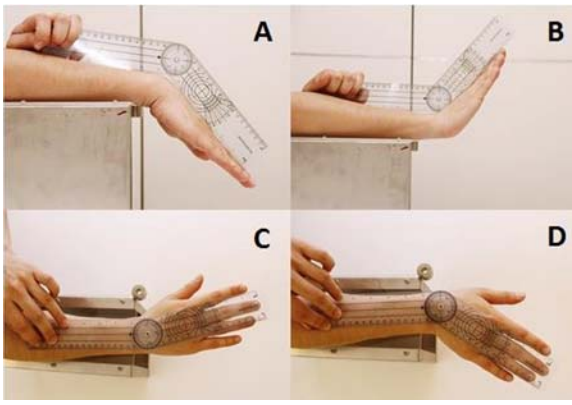

Figure 4. Demonstration of wrist motion measurement using goniometer

Results

Interobserver and intraobserver reliability of infrared position capture device and universal standard goniometer for measurement of wrist angle with ICC values are shown in Table 1. The infrared position capture device and the universal standard goniometer both had strong reliability for measurement of wrist angle in all four positions, as indicated by the reported high ICC values. For interobserver reliability, the infrared position capture device and the universal standard goniometer had strong reliability for measurement of flexion, extension, and ulnar deviation, but only substantial reliability for radial deviation.

As shown in Table 2, the ICC values ranged from moderate to strong agreement (range: 0.53 to 0.92). The mean difference between the infrared position capture device and universal standard goniometer for measurement of wrist angle ranged from 0.15 to 3.88 degrees. The 95% limits of agreement (LOA) between infrared position capture device and universal standard goniometer are shown in Table 2. Infrared position capture device measurements of wrist angle in all 4 positions were very similar to those obtained by universal standard goniometer. For examiner 1, the mean difference were -3.76±5.39 for flexion, -0.21±5.16 for extension, -3.88±4.89 for radial deviation, and -2.45±4.59 for ulnar deviation. For examiner 2, the mean difference were -3.21±6.2 for flexion, 0.45±5.13 for extension, -0.15±4.99 for radial deviation, and -0.15±4.6 for ulnar deviation. However, the 95% LOA for discrepancy between systems exceeded ±5°, which is defined as clinically significant.

Bland-Altman plots describe the mean of both measurement devices relative to the difference between the two measurement devices for wrist ROM in each position, including flexion, extension, radial deviation, and ulnar deviation. Each point on the Bland-Altman plots represents one subject (Figure 5).

Discussion

Universal standard goniometer is generally used to assess and diagnose prognosis of wrist motion. Paul C. LaStayo, et al measured 141 patients (141 wrists in a multicenter study) that showed significant differences in

Table 1. Intraobserver and interobserver reliability of wrist ROM measurements

Measurement	Intraobserver 1		Intraobserver 2		Interobserver	
	Mean ± SD	ICC (95% CI)	Mean ± SD	ICC (95% CI)	Mean ± SD	ICC (95% CI)
Universal goniometer						
Flexion	72.83±11.60	0.95 (0.91, 0.98)	74.12±10.63	0.96 (0.92, 0.98)	73.48±10.92	0.92 (0.84, 0.96)
Extension	61.03±12.10	0.97 (0.93, 0.98)	61.33±11.04	0.97 (0.94, 0.98)	61.18±11.40	0.94 (0.88, 0.97)
Radial deviation	27.89±5.67	0.82 (0.67, 0.91)	29.30±5.48	0.84 (0.70, 0.92)	28.60±5.16	0.70 (0.47, 0.84)
Ulnar deviation	43.39±6.88	0.91 (0.82, 0.95)	44.15±7.13	0.89 (0.78, 0.94)	43.77±6.76	0.86 (0.74, 0.93)
Infrared position capture device						
Flexion	77.06±11.94	0.95 (0.91, 0.98)	75.15±12.13	0.95 (0.90, 0.97)	76.11±11.82	0.92 (0.83, 0.96)
Extension	61.64±12.89	0.97 (0.93, 0.98)	61.12±12.77	0.94 (0.88, 0.97)	61.38±12.75	0.97 (0.95, 0.99)
Radial deviation	31.03±5.28	0.86 (0.74, 0.93)	28.76±6.35	0.87 (0.76, 0.94)	29.89±5.30	0.61 (0.32, 0.79)
Ulnar deviation	46.06±7.61	0.86 (0.73, 0.93)	44.27±7.00	0.94 (0.88, 0.97)	45.17±7.07	0.85 (0.68, 0.93)

ROM = range of motion

Table 2. Wrist ROM measurements compared between infrared position capture device and universal goniometer in 33 healthy subjects

Measurement	ICC	95% CI for ICC	Mean difference ± SD*	LOA	Agreement within 3° (%)	Agreement within 5° (%)
Examiner 1 (1st measurement)						
Position						
Flexion	0.86	0.58, 0.94	-3.76±5.39	-14.32, 6.81	55%	61%
Extension	0.92	0.85, 0.96	-0.21±5.16	-10.33, 9.91	58%	73%
Radial deviation	0.53	0.09, 0.77	-3.88±4.89	-13.47, 5.71	33%	58%
Ulnar deviation	0.76	0.51, 0.89	-2.45±4.59	-11.45, 6.54	36%	64%
Examiner 2 (1st measurement)						
Position						
Flexion	0.83	0.63, 0.92	-3.21±6.20	-15.37, 8.95	49%	61%
Extension	0.92	0.84, 0.96	0.45±5.13	-9.60, 10.51	58%	73%
Radial deviation	0.69	0.46, 0.83	-0.15±4.99	-9.93, 9.63	55%	79%
Ulnar deviation	0.80	0.63, 0.90	-0.15±4.60	-9.16, 8.86	58%	79%

* Mean difference = Goniometer (°) - Infrared position capture device (°)
LOA = Limits of agreement

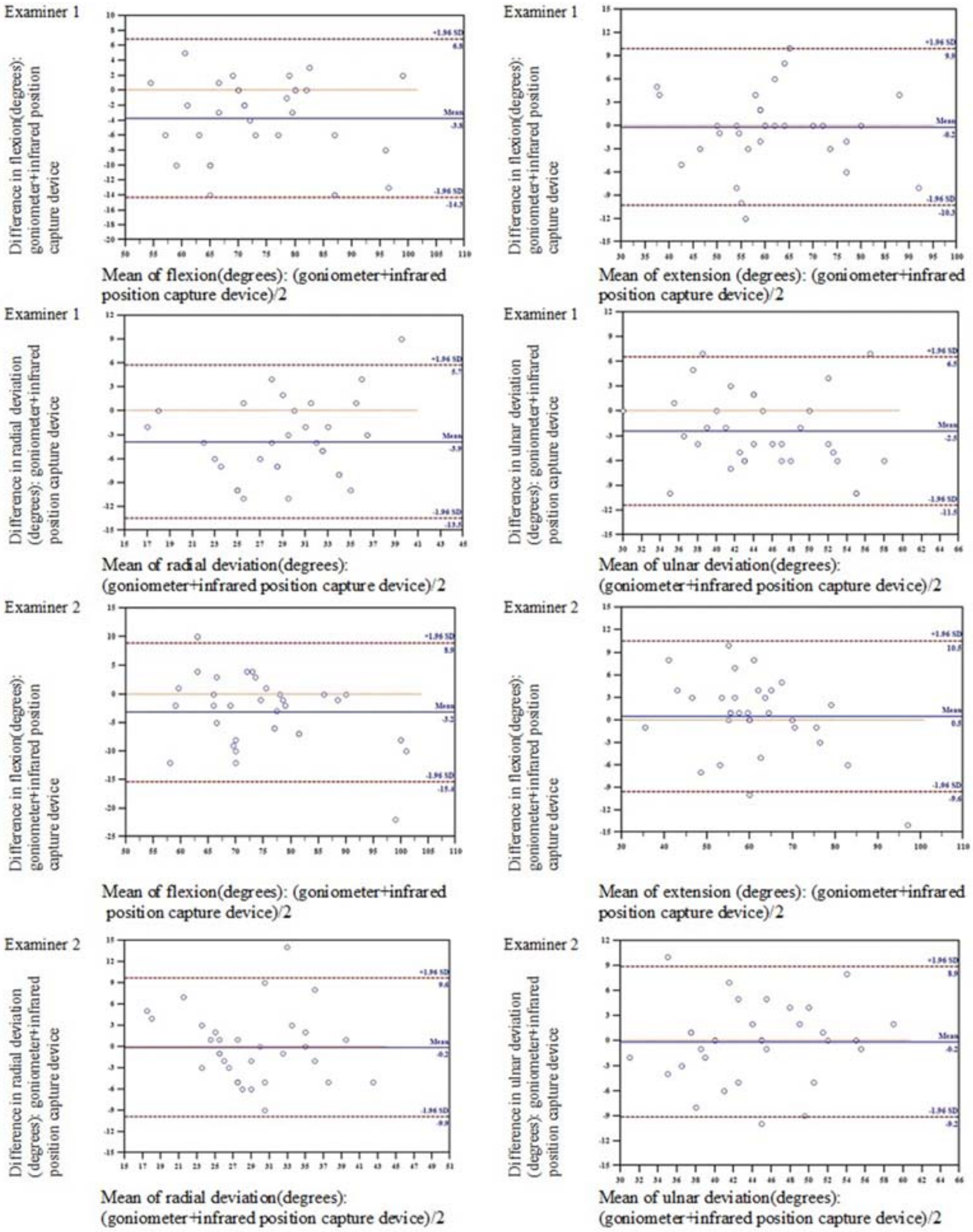

Figure 5. Bland-Altman analysis of flexion, extension, radial deviation, and ulnar deviation compared between examiners 1 and 2.

results among the various goniometric techniques[5]. Volar-dorsal alignment is recognized as having high reliability. The results of a study by Timothy I. Carter, et al support the reliability of the dorsal-volar technique for use among surgeons and hand therapists[6].

In the present study, we found that universal standard goniometer and infrared position capture device both demonstrated high reliability over repeated measurements of wrist angle independent of the skill level of the examiner (e.g., junior vs. senior orthopedic resident physician). In addition, high overall ICCs were observed for both intraobserver and interobserver assessment of all positions, except radial deviation. The authors hypothesize that the lowest ICC score in radial deviation measurement was caused by motion of wrist during angle calculation. Some subjects had to forcefully pronate their wrist to achieve the maximal radial deviation motion.

Infrared position capture device had strong agreement when compared with universal standard goniometer in all position, except radial deviation. Measurement data from the two instruments were closely similar in all measurement positions, with a mean difference less than 3.88 degrees and standard deviation less than 6.20 degrees.

Limitations of this study include that fact that all participants were healthy adults (age: 20 to 60 years), and none of them were severely obese (BMI: $\geq$30 kg/m^2).

Although the cost of an infrared position capture device (approximately $100 USD) is more expensive than a universal standard goniometer, the infrared position capture device promotes and facilitates greater efficiency due to less clinician involvement and data collection via electronic data capture.

Conclusion

The infrared position capture device was found to be a reliable tool for measurement of wrist motion. Measurements by infrared position capture device were found to be in agreement with measurements by universal standard goniometer, which is the current standard technique. Our finding supports the use of this technology in this clinical setting, and this technique may further promote the current trend toward increased electronic data collection.

What is already known on this topic?

The current standard measurement device for the measurement of wrist motion is universal standard goniometer. In 2013, an infrared position capture device for detection and measurement of hand and finger movements without any physical contact with the device was introduced.

What this study adds?

Infrared position capture device was found to be a reliable tool for measurement of wrist motion, and its results were found to be in agreement with those obtained by universal standard goniometer.

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Potential conflicts of interest

The authors declare no conflicts of interest.

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