EDITOR'S CHOICE

A Comparison of Elbow Range of Motion Measurements: Smartphone-Based Digital Photography Versus Goniometric Measurements

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Purpose The purpose of this study was to validate elbow flexion and extension measured from smartphone photography obtained by participants and compared them with photographs obtained by surgeons and goniometric measurements.

Methods We enrolled 32 participants with a total of 64 elbows, aged 25 to 68 years. Participants obtained smartphone photographs of full elbow flexion and extension. Then surgeons obtained the same photographs and goniometric measurement of elbow range of motion (ROM). We measured ROM from the photographs using Adobe Photoshop and calculated average ROM. Comparisons of manual goniometer versus digital measurements, participant versus surgeon photograph measurements, and interobserver measurements were statistically analyzed.

Results Average ROM measured by manual goniometer and digital photographs was 0° to 129° (range, 0° to 140°) and 0° to 129° (range, 0° to 145°), respectively. The goniometer versus digital measurements interclass correlation was 0.828 (L) and 0.740 (R). Pearson coefficient was 0.845 (L) and 0.757 (R). Bland-Altman plots demonstrated that 30 of 32 digital measurements (L) and 31 of 32 measurements (R) were within the 95% confidence interval. Participant-obtained photographs compared with researcher's photographs interclass correlation was 0.955 (L) and 0.941 (R), with a Pearson coefficient of 0.962 (L) and 0.957 (R), respectively. Reviewing interobserver reliability, concordance coefficients were 0.793 (L) and 0.767 (R) and Pearson coefficients were 0.811 (L) and 0.780 (R). Bland-Altman plots demonstrated that 28 of 32 digital measurements (L) and 26 of 32 measurements (R) were within the 95% confidence interval.

Conclusions Measuring elbow ROM using smartphone digital photography is valid and reliable. Participants were able to obtain accurate photographs and the measurements based on these photographs show no statistical difference from those taken by surgeons or goniometric measurement.

Clinical relevance This study validates using smartphone photography for measuring elbow ROM by laymen in a remote setting.

Type of study/level of evidence Diagnostic II.

Key words Digital photography, elbow range of motion, smartphone.

Additional Material at jhandsurg.org

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Received for publication May 5, 2015; accepted in revised form January 8, 2016.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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0363-5023/16/4104-0002$36.00/0
http://dx.doi.org/10.1016/j.jhsa.2016.01.006

A measure of outcomes in upper-extremity surgery is range of motion (ROM). Manual ROM measurements using a handheld goniometer have been the standard method of measurement of joint ROM because of their ease of use and accessibility. However, the accuracy and reproducibility of manual goniometer measurement have been questioned.[1–5] New methods including digital photographs have been investigated as a means to provide the same ease and accessibility while improving consistency of measuring ROM.[3,5–9]

Advances in smartphone technology, specifically the high-resolution cameras in smartphones, offer a potential platform for measuring patients' ROM. As a form of telemedicine, patients can use smartphone cameras to ascertain and send digital images and video clips to provide objective data to their physicians.[10] As the use of smartphones continues to increase, it affords an opportunity to use smartphone camera technology to perform remote evaluation of joint kinematics, especially for patients in remote areas or at a far distance from their physicians.

Photographs are a desirable form of communication because they provide recordable, documented information at specific time points. When added to the electronic health record (EHR), photographs provide an invaluable asset for evaluating patient outcomes. A few studies have examined the role of photography in evaluating joint ROM; however, none have validated measuring the elbow ROM using smartphone images.[8,9] The purpose of this study was threefold: to compare active elbow ROM measurements using smartphone photography compared with manual goniometer measurements; to determine whether there were differences between ROM measurements of smartphone photographs taken by participants or surgeons; and to validate the use of smartphone photographs for measurement of elbow ROM.

MATERIALS AND METHODS

After we received institutional review board approval, we invited participants to participate in this study; 32 people consented (a total of 64 elbows). No participants had an active or past injury involving the elbow. Age, gender, handedness, and type of smartphone were documented. All participants were comfortable with using smartphone technology and did not need instruction on the use of their smartphone's camera.

Active ROM assessment

Participants were paired and asked to watch an instructional video describing how to take photographs of the elbow at terminal extension and flexion (www.youtube.com/channel/UCpWxO6YnZgdCXfEUrPmmwjA/videos). They were given a handout reinforcing the information in the video (Appendix A, available on the *Journal's* Web site at www.jhandsurg.org). The video explained how the participant should stand and position the shoulders, elbows, and wrists. It showed examples of correct and incorrect photographs, reinforcing capturing the elbow with the shoulder and forearm in the photograph for accurate measuring. It also discussed how to obtain a correct perspective. This video was uploaded onto YouTube.com (Google, San Bruno, CA) to simulate using the video remotely. Paper handouts included the same information as the video, with diagrams to reinforce capturing optimal photographs.

After reviewing the video and handouts, partnered participants documented each other's active elbow ROM using their smartphone camera. Elbow flexion–extension photographs were captured of each extremity with the participants in profile, the shoulder in neutral position, and the arms adducted to the torso. The extremity of interest was profiled nearest to the camera. Terminal flexion–extension was defined as the extremes of tolerated active elbow motion. This process was repeated on the contralateral side. Each participant obtained a set of 4 photographs.

The authors of this study then obtained a second set of 4 photographs for each participant using the same positioning. Chronology was strictly maintained so that participants would not simply mimic the authors' technique but instead would follow the video and handout directions. Finally, we measured joint motion using a goniometer. The universal goniometer was placed on the lateral epicondyle; the stationary arm was placed in the center of the upper arm, pointing toward the middle third of the lateral edge of the acromion. The distal limb of the goniometer was placed along the dorsal surface of the forearm.[3] We used this method to measure both flexion and extension.

We measured elbow flexion and extension angles from photographs obtained by both the participants and authors using Adobe Photoshop (Adobe, Seattle, WA). The program's angle feature was used to measure all angles. The center of the angle was placed over the lateral epicondyle; if this landmark was not easily identifiable, the center of the angle was placed posterior to the bulge of the soft tissue mass of the extensor tendons originating from the lateral epicondyle at the level of the cubital fossa. The stationary arm of the angle tool was placed along the center of the upper arm, bisecting the shoulder. The mobile arm of the angle tool was placed along the middle of the dorsal surface of the forearm bisecting the wrist joint. Measurements were performed in a blinded fashion.