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How Does Level and Type of Experience Affect Measurement of Joint Range of Motion?

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OBJECTIVES: Comparison of range of motion measurements by 3 types of investigators with different levels and types of training using three different measurement techniques. The study hypothesis was that the accuracy and precision of range of motion measurements would vary based on (1) the level and type of experience of the investigator and (2) the measurement technique used.

DESIGN/SETTING: Descriptive laboratory study.

PARTICIPANTS: Ten fresh frozen cadavers (20 upper and 20 lower extremities).

INTERVENTIONS: Shoulder, elbow, hip, and knee motion were measured using 3 different measurement techniques (digital photography, goniometry, and visual estimation) by 3 groups of investigators (attending orthopedic surgeons, physical therapists, and residents). Accuracy was defined by the difference from the reference standard (motion capture analysis), whereas precision was defined by the proportion of measurements within either 5° or 10° of the reference standard. Analysis of variance, *t*-tests, and chi-squared tests were used.

RESULTS: Statistically significant ($p < 0.05$) differences in accuracy were found for hip flexion, abduction, internal rotation, external rotation, and knee flexion. However, none of these differences met the authors' defined clinical significance (maximum difference 3°). Precision was significantly ($p < 0.05$) different for elbow extension, hip flexion, abduction, internal rotation, external rotation, and knee flexion.

CONCLUSION: This study found that clinically accurate measurements of shoulder, elbow, hip, and knee motion are obtained regardless of technique used or the investigators' level and type of experience. Precision was equivalent for all shoulder motions, elbow flexion, and knee extension, but varied by as much as 7% to 28% between groups for all other motions. (J Surg Ed ■:■■■-■■■. © 2017 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: range of motion, digital photography, goniometry, visual estimation, training, resident

COMPETENCIES: Patient Care, Practice-Based Learning and Improvement, Interpersonal and Communication Skills

INTRODUCTION

Range of motion (ROM) is a common clinical parameter used for diagnosis, measurement of disease severity, determining fitness for return to work, and assessment of outcomes after therapeutic or surgical intervention.[1–3] It can be measured using a variety of techniques including, but

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not limited to, direct visual estimation, indirect visual estimation (i.e., measurements based on an image, such as digital photography), goniometric measurement (i.e., conventional, gravity, or digital), inclinometer, computerized motion analysis, or kinematics (i.e., 3-dimensional [3D] motion or position measured through infrared cameras using markers attached to the body).[4–6] The accuracy of these measurements is important as they may represent the primary determinant of treatment (including surgery) and level of impairment—both of which produce long-standing, sometimes permanent, effect on patients' lives.[3] The measurement accuracy is thought to vary based on the clinician obtaining the measurement (i.e., background and level of experience), the technique used, the particular joint examined (i.e., hip), the movement or position (i.e., internal rotation), and the number of times each sample is measured whether that be repeated measurements within a single clinic visit by one examiner, a single clinic visit with measurements by multiple examiners, or over multiple clinic visits separated by time or location.[1,3,5]

Prior studies have measured the intra-reliability and inter-reliability using these measurement techniques at the shoulder, elbow, hip, and knee, but these studies either (1) lack a well-defined gold standard used to assess the accuracy of measurements (i.e., radiographic or kinematic assessment of joint angles),[1,7] (2) focus on only one joint or even one joint motion (limiting comparison between motions and joints), or (3) do not quantify the effect that level or type of experience has on these measurements. Most of these prior studies have shown measurements to have high intra-rater reliability, but with an inter-rater reliability that varies considerably based on the technique used, the joint measured, and the level or type of experience, or background of the investigator.[2,5,8] In many clinics, measurements are often obtained by clinicians other than the attending physician, such as residents, fellows, physician assistants, occupational therapists, and physical therapists (PT).[3,5] Currently little information is available on the effect level or type of experience has on the accuracy of ROM measurements and whether different techniques can alter this accuracy.

The goal of this study was to compare the accuracy and precision of ROM measurements at the shoulder, elbow, hip, and knee between three groups of clinicians with different levels and types of experience (attending orthopedic surgeons, PT, and orthopedic surgery residents) using multiple measurement techniques (visual estimation, goniometric measurement, and photographic measurement). The study hypothesis was that the accuracy and precision of ROM measurements would be vary based on (1) the level and type of experience of the investigator and (2) the measurement technique used.

MATERIAL AND METHODS

Using G*Power software (Universität Mannheim, Mannheim, Germany) and assuming mean measurement error of $3° \pm 5°$ (effect size 0.6) between each group of investigators (attendings, PT, and residents), an a priori power analysis ($\beta = 0.20$, $\alpha = 0.05$) predicted that we would require 45 measurements by each investigator group (attendings, PT and residents). This requirement would be met with 3 investigators in each group (i.e., 15 measurements each) taking measurements on 15 extremities (or 8 cadavers).[9,10]

After institutional review board approval, ten fresh frozen human cadavers were obtained without specifying race, gender, ethnicity, age, or cause of death. The only exclusion criteria were gross limb deformity or amputated limbs. All specimens were stored at −5°C and thawed 24 hours before testing. Ten cadavers were used (20 upper and lower extremities, measured by 9 investigators [in 3 groups of 3] with 60 measurements of each motion using each technique by each group) for measurements in 2 different sessions (5 different cadavers were used in each session) separated by a 2-month period. For each of the 2 sessions, the 5 cadavers used were not refrozen after initial thawing and thus all measurements were obtained over a 3-day period.

All 9 investigators took measurements of 12 selected motions at 4 joints (shoulder, elbow, hip, and knee) using all 3 techniques (digital photography, goniometry, and visual estimation) on each cadaver (Figure 1A–L). The attending orthopedic surgeons included 2 sports medicine fellowship trained surgeons and 1 adult reconstructive fellowship trained surgeon with 8.5 years, 1.5 years, and 6 months in independent practice, respectively (following medical school, orthopedic residency, and fellowship). The PT included 1 PT in training to obtain his doctorate of physical therapy (DPT) and 2 PTs with DPTs in practice with 3 years and 6 months of experience, respectively. The orthopedic surgery residents included 1 in their third postgraduate year of residency training (PGY-3), 1 PGY-2, and 1 PGY-1.

Cadaver and Motion Analysis Setup

Before beginning each measurement session, specific sites on each of the 5 cadavers (to be used for that session) were dissected down to bone bilaterally where mounting plates were secured rigidly with screw fixation and cementation (using polymethyl methacrylate) to 6 sites. The 6 mounting sites used, included (1) the radial aspect of the radial midshaft, (2) the anterolateral aspect of the humeral midshaft, (3) the sternum, (4) the iliac crest, (5) the anterolateral aspect of the femoral midshaft, and (6) the anterior aspect of the tibial midshaft. Arrays of reflective markers (NDI, Waterloo, Canada—shown in Figure 1M) including 4 passive reflective spheres were attached to each mounting site to track 3D spatial location of each of these bones during the measurement session.

Prior studies have used radiographic (2D) measurements as their "gold standard" with which to compare with other