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Abstract

Goniometric measurements are widely used in the field of occupational therapy to measure range of motion, define and describe movement, and predict the functional implications of joint limitations. These measurements are further used in documentation and as a means of justifying reimbursement. While goniometrics are a hallmark of our practice, therapist competency is rarely assessed. This study sought to evaluate whether a skill focused, simulation assisted training could lead to improvements in accuracy and consistency of goniometric measurements. Ten therapists at a single facility completed goniometric testing utilizing a simulation module to assess three joint motions (shoulder abduction, elbow flexion and neck extension). Testing was followed by extended, joint specific education prior to retesting. Estimates of consistency improved for all joint motions from pre to post training. Measurement accuracy improved in shoulder abduction and neck extension. Therapists reported improved level of comfort for specific joint measurements and for goniometry in general. Training laboratories such as the one described in this paper, can be an effective way of establishing a consistent departmental standard, assessing current competency, and providing hands-on training in a new and innovative way.

Keywords

Goniometry, simulation, training, competency, range of motion

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Acknowledgements

A Skill Focused Approach to Improving Therapist Goniometry Accuracy Using a Simulation Laboratory

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ABSTRACT

Goniometric measurements are widely used in the field of occupational therapy to measure range of motion, define and describe movement, and predict the functional implications of joint limitations. These measurements are further used in documentation and as a means of justifying reimbursement. While goniometrics are a hallmark of our practice, therapist competency is rarely assessed. This study sought to evaluate whether a skill focused, simulation assisted training could lead to improvements in accuracy and consistency of goniometric measurements. Ten therapists at a single facility completed goniometric testing utilizing a simulation module to assess three joint motions (shoulder abduction, elbow flexion and neck extension). Testing was followed by extended, joint specific education prior to retesting. Estimates of consistency improved for all joint motions from pre to post training. Measurement accuracy improved in shoulder abduction and neck extension. Therapists reported improved level of comfort for specific joint measurements and for goniometry in general. Training laboratories such as the one described in this paper, can be an effective way of establishing a consistent departmental standard, assessing current competency, and providing hands-on training in a new and innovative way.

INTRODUCTION

Goniometric measurements are one of the most widely used range of motion (ROM) evaluation methods in occupational therapy (OT). The universal goniometer (UG) is the instrument of choice for clinicians (Norkin & White, 2016). It has been found to have good to excellent reliability overall (Norkin & White, 2016) and for specific joints (Kooij, Fink, Nijhuis-van der Sanden, & Speksnijder, 2017; Mcveigh, Murray, Heckman, Rawal,

& Peterson, 2016; Meislin, Wagner, & Shin, 2016; Shamsi, Mirzaei, & Khabiri, 2019; Rijn, Zwerus, Koenraadt, Jacobs, Bekerom, & Eygendaal, 2018). Greater reliability is obtained when measures are taken by a consistent therapist and when using a standardized method (Blonna, Zarkadas, Fitzsimmons, & O'Driscoll, 2012; Boone, Azen, Lin, Spence, Baron, & Lee, 1987; Gajdosik & Bohannon, 1987; Norkin & White, 2016).

Accurate and consistent measurements are instrumental in identifying impairments, determining improvement or decline in joint motion and evaluating the success of therapeutic interventions such as ROM, orthosis fabrication, or casting. While having a consistent rater may be best practice, in reality, patients with extensive injuries are often treated by multiple members of a therapy team throughout their recovery. Inconsistencies in therapists' goniometric administration and skill can be troublesome when attempting to quantify a patient's ROM gains or losses and document change over time. The Guidelines for Documentation of Occupational Therapy mandate that documentation should "provide a clear and chronological record of client status" and "the client response to occupational therapy intervention and client outcomes" (American Occupational Therapy Association, 2018, p. 1). Without accurate and consistent goniometric measurements, it is difficult to meet this edict.

A survey of burn care therapists, who measure extremity contracture, indicated that 99% use goniometry often or sometimes (Parry, Walker, Niszczak, Palmieri, & Greenhalgh, 2010). Additionally, less than one-third of respondents checked the reliability of their measuring methods and only 37% checked staff competency for methods used to measure extremity contracture. The Accreditation Council for Occupational Therapy Education (ACOTE) Standards (2018) require students be provided with appropriate training on assessment tools. The National Board for Certification of Occupational Therapists (NBCOT) requires professional development units and continuing education is a requirement of many state-based licensure renewals. However, there are no standards governing specific therapist competencies for skill-based assessments, like goniometry, leaving policing competency to the discretion of the employer.

Skill based training allows the learner to focus directly on the components of the desired task, in this case goniometry. By directing the focus of education toward the desired skill and components of that skill (placement, positioning, normative values), learners can directly improve performance. Research has shown goniometric reliability is improved when the rater has been provided with more specific training in goniometric measurement (Chapleau, Canet, Petit, Laflamme, & Rouleau, 2011; Lewis, Fors, & Tharion, 2010).

The Society for Simulation in Healthcare (SSH) defines simulation as "a technique that creates a situation…to allow persons to experience a representation of a real event for the purpose of practice, learning, evaluation, testing, or to gain understanding of systems or human actions" (Lopreiato et al., 2016, p. 33). Many professions have turned to simulations to assist with training and competency assessment and to create a

bridge between learning and real-life clinical experience. Simulation training has implications for students, athletes, military, and civilian learners and has been shown to be effective with health care education. A systematic review of medical simulations found simulations to be more educationally effective than other reviewed educational interventions (Beal, Kinnear, Anderson, Martin, & Wamboldt, 2017).

Simulations can provide a standardized training experience for each learner and can be repeated for evaluation of change in skill over time. This active engagement in deliberate practice and its components of immediate feedback, time for problem solving and evaluation and repeated performance have been found to facilitate expert performance (Ericsson, 2008). Deliberate practice with the use of simulation has been shown to improve patient handoff (Pukenas, Dodson, Deal, Gratz, Allen, & Burden, 2014), facilitate an authentic learning experience for targeted outcomes (Welch & Carter, 2018) and improve specific treatment skills (Ahmed, Azher, Gallagher, Breslin, O'Donnell, & Shorten, 2018; Baird, Raina, Rogers, O'Donnell, & Holm, 2015). The SSH (2019) suggests the integration of simulation into healthcare training may also "raise the bar for objectivity and hence fairness in evaluation." Simulations are used widely in OT academic programs (Bethea, Castillo, & Harvison, 2014) and are often utilized during patient interventions. There is sparse literature on the use of simulations for skills training and competency of practicing therapists.

This paper describes one facility's use of a healthcare procedural simulation combined with practical in-services and didactic (direct lecture and demonstration) based instruction to provide focused training on goniometry with a goal of improving accuracy and consistency within the therapy department staff.

PURPOSE OF PROJECT
Differences in education, training, and measurement techniques among staff therapists decreased the accuracy and consistency of measurements and limited the ability to identify gains and losses in ROM for shared patients. This facility had no standard method for goniometry and no competency assessment program for ROM. To establish a training program and competency assessment for goniometric procedures, a multi-part laboratory, consisting of simulation-based assessment and joint specific training sessions, was developed.

DEVELOPMENT OF SIMULATION
Approval from the Institutional Review Board was completed prior to project initiation. In collaboration with the Simulation Education Center, goniometric measurements commonly assessed in OT practice were considered for inclusion. The SimMan 3G and Pediatric HAL S3005 Patient Simulator manikins were utilized. Available manikins did not allow for articulation of digits (flexion, extension, or opposition), wrists (flexion or extension) or radial ulnar joint (pronation or supination) and could not be placed in true plane shoulder flexion. Based on available motions and the presence of simulated landmarks, neck extension, shoulder abduction, and elbow flexion were selected for measurement.

Selected joints were stabilized at desired ROM. Neck extension stability was achieved using bolsters. Shoulder was positioned in abduction on a stable surface and elbow stabilization occurred with an external forearm and upper arm support. Alignment marks were made on the manikins to allow positions to be confirmed prior to each subsequent measurement. After stabilization, measurements were confirmed by three separate, experienced raters (20 years average experience) to establish the actual measurement for each joint.

Ten therapists completed pre- and post-education goniometric measurements and attended goniometric training sessions and staff in-services. These participants consisted of a convenience sample of actively practicing therapists at single facility. Participants were mostly female (90%; n=9) with an average age of 33.4 years, 8.9 years of total therapy experience, and 6.7 years of practice at this facility. Six out of 10 respondents (60%) graduated from the same OT program with each of the remaining four respondents attending separate programs.

PROCEDURE

Staff participation was voluntary. Consenting participants were scheduled in 15-minute time blocks during a single day laboratory in a simulated patient room within the Simulation Education Center. Each module was completed in a private session with only the participant and study assessor present.

Using a 7" Baseline ® Plastic Goniometer with a 360˚ blinded head, each therapist completed measurements of the three predesignated joints (shoulder abduction, elbow flexion, and neck extension). No cueing was provided for placement or measurement. After each measurement, the participant returned the UG to the study rater, who documented the obtained angle using a printed protractor and a coded results grid to allow confidentiality. The UG was closed and returned to the rating therapist. This process was completed three times for each of the three joints of interest for a total of nine measurements per therapist.

Results were compiled using the Research Electronic Data Capture (REDCap) software and blinded results were reviewed in a departmental in-service. Therapists were provided with group and individual results comparing acquired goniometric values to the actual value for each joint. Therapists participated in brainstorming sessions to discuss methods to improve intra and inter-rater accuracy. The group identified (1) group in-services, (2) practice with simulated patients, (3) education on goniometric standards, and (4) mentor guided practical application as techniques to improve departmental competence.

To improve consistency, the goniometric method described by Norkin and White (2016) was selected for departmental use. Initial in-services on goniometric technique and positioning were completed by therapy staff educators. Each participating therapist was then assigned a specific joint and movement, inclusive of all upper body joints and not limited to those assessed by the training laboratory. Therapists each completed a 15-minute staff in-service specific to the joint/movement they were assigned. In-service

components included: (1) joint arthrokinematics and landmarks, (2) normative range of motion values, (3) goniometric positioning and procedures, (4) joint and diagnosis specific special considerations, (5) demonstration of joint ROM and measurement, and (6) opportunity for staff to practice techniques. Fifteen goniometric related in-services were completed during the year between skill lab assessments. Opportunities were also provided for staff mentoring to address specific concerns or areas of difficulty in real and simulated patient experiences.

Approximately one year after initial assessment, a follow-up goniometric simulation laboratory was held. The lab was designed following the same methods described for the initial laboratory. Accuracy and consistency of obtained measurements were compared to determine improvement of individual therapists and of the team in its entirety. Results were reviewed with the therapy group and with individual therapists.

Data Analysis
To determine accuracy of each therapist's measurements to the true measure for each joint at pre- and post-training, the absolute percent error (APE) was calculated using the following formula: Absolute percent error = (|true value – observed value| \ true value) x 100%. The true value refers to the predetermined angle of each joint as described in the *Procedure* section of this paper. The observed value refers to each therapist's attempt at measuring the angle of each specified joint. The mean absolute percent error (MAPE) was used to describe absolute variation in angle measurement for each joint. Consistency of measurement (i.e., angle) within therapists for each joint was estimated using Cronbach's alpha (Bland & Altman, 1997). Alpha can range from 0 to 1 with greater values indicating greater consistency and reliability.

To determine if the overall MAPE differed significantly between pre- and post-training, a general estimating equation (GEE) was employed and analyses were conducted separately for each joint. Data on multiple measurements per therapist were included in the GEE model to account for the correlation structure of repeated measures (Stokes, Davis, & Koch, 2012). The GENMOD procedure in SAS version 9.4 (SAS Institute Inc., 2016) was employed to invoke the GEE method. A REPEATED statement was specified to account for the correlation among repeated measurements within therapists (Stokes et al., 2012).

RESULTS
Ten occupational therapists completed the skill focused training on goniometric measurements of elbow flexion, neck extension, and shoulder abduction and yielded joint measurements both pre- and post-training. The consistency of measurement was estimated via the Cronbach coefficient alpha. Estimates for alpha at both pre- and post-training are displayed in Table 1. Pre-training estimates for consistency of measurement ranged from .60 to .83. Estimates of consistency increased after training for each of the three joints measured. Consistency was the highest in the elbow flexion at baseline; thereby, it had the smallest increase in precision post-training. Consistency was the lowest in the shoulder abduction before training; thus, measurement consistency increased the greatest after training.

Table 1

Cronbach Alpha Estimates Pre- and Post-training

Joint	Pre-training	Post-training
Elbow Flexion	.83	.85
Neck Extension	.75	.83
Shoulder Abduction	.60	.86

The MAPE was the principal statistic used to evaluate the effects of training on the accuracy of joint measurements. Table 2 presents the MAPE for each therapist at pre- and post-training by joint. Sixty percent (n=6) of the therapists reduced their measurement error on elbow flexion post-training, while 80% (n=8) reduced measurement error on neck extension and shoulder abduction post-training. Figure 1 presents the overall MAPE for each joint at pre- and post-training. Measurements of elbow flexion yielded the least MAPE from the true measurement angle before skills-based training ($M = 8.7$, $SD = 4.7$). While the MAPE of elbow flexion decreased after training ($M = 5.8$, $SD = 2.3$), this decrease from pre- to post-training was not statistically significant ($p = .094$). Additionally, pre-training measurements of shoulder abduction yielded a MAPE of 12.4 ($SD = 7.2$) and decreased significantly post-training ($M = 4.9$, $SD = 2.1$, $p < .001$). Neck extension had the greatest MAPE before training ($M = 41.9$, $SD = 20.2$) and the largest decrease in MAPE post-training ($M = 25.2$, $SD = 20.2$). Accordingly, MAPE for neck extension differed significantly ($p = .041$) between pre- and post-training.

Table 2

Mean Absolute Percent Error at Pre- and Post-training by Therapist

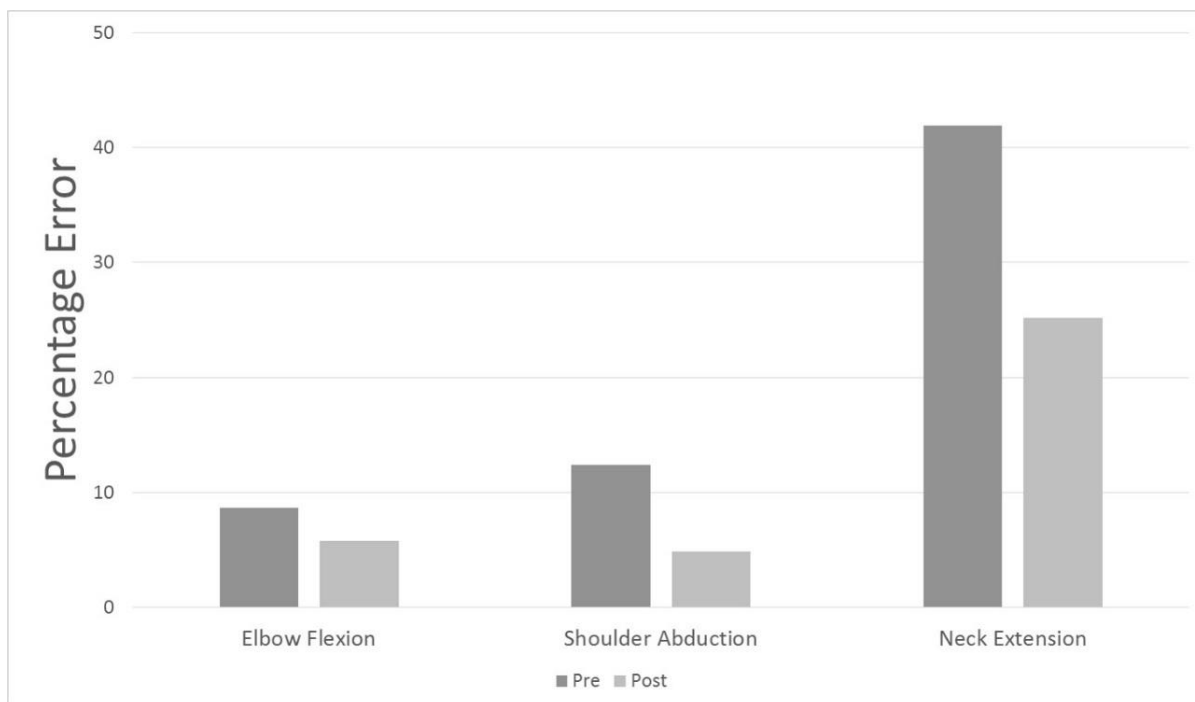| Therapist	Elbow		Neck		Shoulder	
	Pre	Post	Pre	Post	Pre	Post
1	5.6	2.2	56.7	11.1	5.7	2.2
2	11.5	4.4	27.8	24.1	13.3	3.3
3	3.0	9.6	77.8	9.3	18.3	8.3
4	8.2	3.7	51.1	24.1	2.2	5.0
5	4.4	5.9	35.6	11.1	23.3	7.2
6	20.0	9.6	57.8	57.4	20.0	7.8
7	10.9	5.9	27.8	9.3	16.9	3.9
8	5.2	5.9	51.1	57.4	4.4	4.4
9	15.6	5.2	15.2	42.6	11.7	3.3
10	3.0	5.9	17.8	5.6	8.3	3.9

Figure 1. Mean absolute percent error by joint for pre- and post- skills-focused training.

DISCUSSION

The use of practical laboratories is a common assessment method utilized by educators; however, once therapists begin professional practice, it is rare that these skill evaluations continue. Professional in-services often focus on "higher level" skills, facility requirements, or training in areas of specialization. It is often taken for granted that practicing therapists have competency in baseline therapy techniques such as goniometric measurements, manual muscle testing, or administration of therapy standardized tests. Therapist are expected to be proficient in the "basic" therapy skills and rarely are provided with or seek out training in these skill areas. With the challenges presented by reimbursement and the need to be strong advocates for our profession, therapists must be able to accurately assess limitations and speak to how these limitations directly impact a client's quality of life and performance of activities of daily living. Skill training programs, such as described in this paper, have the potential to facilitate skills in many areas of assessment and intervention.

Kirkpatrick and Kirkpatrick (2016) recommended evaluation of skill training programs based on the (1) reaction of the participants, (2) learning/skill acquired, (3) application of learned behavior, and (4) targeted outcomes/results of the program. This framework can be used to categorize the strengths and outcomes of this training method. Level 1 (Reaction): Participants were initially reticent when presented with this new format of education. After completion of the lab, participant feedback included, "It was less scary that I thought." "It was a great way to learn." and "I enjoyed practicing with the simulator". Therapists felt that the laboratory approach could be generalized to their current practice. Level 2 (Learning): Following this skill training method, therapists were found to more frequently carry UG tools and reported being more confident when using

a UG during patient evaluation. Level 3 (Behavior): During follow-up discussions, therapists reported a shift from visual estimates of joint angle measurement to actual UG measurements for patient assessment and documentation. Level 4 (Results): Overall departmental estimates of consistency improved for all joint motions from pre- to post- training. Overall measurement accuracy improved in shoulder abduction and neck extension. Of the 10 therapists involved, four demonstrated improvements in all joints measured and five demonstrated improvement in two out of three joints measurement. Rate of improvement did not correspond to experience level, but pre-training level did reflect area of practice with orthopedic focused therapists having more consistent pre-training goniometric skills.

Therapists in this grouping had self-professed experience and comfort with elbow flexion measurement but were, for the most part, less familiar with neck range of motion measurement. This was validated by the resulting high overall consistency and a low error in elbow flexion at pre-training assessment and a high MAPE pre-training and a high but improved MAPE at post-training assessment for neck extension. Improvement in both these areas suggests skills focused training has application for both new and previously learned skills. Post-training results highlighted areas where further directed training and evaluation were necessary for the group and for individual therapists.

The current study evaluated the effects of training, using a skill focused approach to goniometry for measuring joint ROM. While it is impossible to attribute improvements to the use of the simulation laboratory or to the increased focus on this specific skill, this training method did yield statistically significant improvements in the accuracy of shoulder abduction and neck extension measurements as well as in the consistency of measurements for all joints assessed. Additionally, this training increased attention to ROM and led to an increase in comfort and frequency in the use of UG as an assessment tool.

Implications for Occupational Therapy Education
Goniometric joint measurement is a hallmark part of occupational therapy practice. Goniometric training is routinely included in therapy education, is a standard part of assessment and documentation, and can be used as a qualifying metric for third-party payers. Various techniques are used when performing measurements and these techniques are often not standardized across therapists at a facility. Rarely do practicing therapists evaluate their accuracy and competence with standard therapy skills such as goniometry. Training laboratories, such as the one described in this paper, can be an effective way to establish a consistent departmental standard, assess current competency, and provide hands-on training in a new and innovative way. While this specific training process utilized manikins, similar procedures could be designed using actors or anatomical models which may be more readily available to occupational therapy practitioners.

With innovative training techniques comes the need to assess the effectiveness of such training. Tools such as the Kirkpatrick Model can be used to develop, evaluate and modify new educational methods. Education should also continue to take into

consideration the learning style of the target audience and should not allow the lure of technically advanced simulators to completely replace the hands-on, personal training which has been the backbone of occupational therapy education.

Regardless of the method of delivery, on-going competency assessment within a therapy department can encourage therapists to maintain proficiency in standard areas of therapy practice. Establishing an expectation of therapeutic skill and excellence can strengthen individual therapists, the overall therapy department and can lead to better patient experiences.

Limitations
Laboratory: Only the joint measurements of shoulder abduction, neck extension, and elbow flexion were assessed during this study. The design of the manikins determined joints available for assessment. Limited articulation at the digits, wrist, and forearm prohibited assessment of these measurements. While similar joint positions and landmarks are present, this simulation was performed using manikins and not on human subjects. While it is well documented in literature (Sexton, Stobbe, & Lessick, 2012) that skills learned in simulations generalize to actual practice, this laboratory design did not include accuracy testing on measuring live individuals.

Learning Style: This training did not assess the preferred learning style of individual participants prior to training. 1/10 of the participants demonstrated no change or an increase in MAPE at all three joints measured. This could be related to an incompatibility with this method of education and the learners preferred style.

CONCLUSION
Consistent and accurate measurements are essential throughout the continuum of rehabilitation for correct documentation of therapeutic progress. This skill can be improved by the controllable factors of having a standardized method of measurement and providing more training to the raters. This skill focused method of education and evaluation can be a valuable tool for employers seeking to improve confidence and competence and for those wishing to tailor education to the specific needs of the therapists.

While this model did not lead to improvement for 100% of the therapists involved, significant gains were seen for individual therapists and for the consistency of the department as a unit. This overall improved consistency can have a direct impact on direct patient care and continuity of service. Many standard occupational therapy procedures could potentially utilize simulation technologies for ongoing training. OTs are uniquely qualified to explore alternative approaches to promote clinical competence. Easily repeatable, non-laborious training methods are necessary as the professional responsibilities of therapists continue to increase. The breadth of the occupational therapy profession and the wide variety of technical skills utilized by the discipline lends to exploration of alternative methods of education, especially those that encourage multi-modal methods of learning.

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