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# Effects of Work Experience, Patient Size, and Hand Preference on the Performance of Sonography Studies

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Reports to clinic managers of sonographer work-related musculoskeletal disorders, especially those linked to larger patient body sizes, are increasing annually. This study was conducted to determine if patient size, sonographer experience level, and hand preference affected image quality associated with ambidextrous scanning. Thirteen experienced and 11 novice sonographers performed right- and left-handed scans of target organs on three models (5th, 50th, and 95th percentile body weight). Estimated grip force was measured during each scan through the use of force matching with a digital dynamometer. Results revealed a significant ($P < .01$) interaction effect between specialty and handedness for general and echocardiography for shoulder abduction angle; a significant difference among patient model sizes for grip forces, with the 95th percentile producing the highest estimated grip force values; and a significant difference in shoulder abduction angle among patient model sizes. Image quality was not different across specialties or handedness, and estimated grip force did not differ between handedness across specialties. These findings suggest that both inexperienced and experienced sonographers could benefit from ambidextrous abilities without increasing risk factors for injury or decreasing scanning quality for clinical practice.

*Key words:* WMSD, ambidextrous, grip force, joint angle, sonographer

Work-related musculoskeletal disorders (WMSDs) are prevalent in most health occupations, particularly the field of sonography.[1] It has been estimated that approximately 80% to 85% of sonographers are

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working in pain, and 20% experience career-ending injuries.[2] Injury surveys of these sonography-related health professionals have established that the most common injuries occur in the neck, upper back, shoulder, wrist, and hand.[2] These injuries often occur from ergonomic risk factors such as sustained contractions, increased sitting and standing time, extended reaching, awkward body mechanics, and prolonged static posture.[3,4] The economic impact of these injuries is considerable, with the cost of absenteeism and loss of productivity among sonographers who report symptoms of WMSDs estimated to be in the millions of dollars per year.[5]

Research evidence regarding ergonomic or other interventions designed to reduce WMSDs among sonographers is limited, and few studies have used quantitative measures. Methodologies that have been used include surveys, interviews, and expert opinion for data collection concerning this problem. The 2003 Society of Diagnostic Medical Sonography Consensus Conference recommended transducer size and weight improvements and suggested the need to increase adjustability of the work space tools, including table, chair, and the sonography machine control panel.[6] Two other factors, patient size and experience of the clinician, have been hypothesized to play an important role in the musculoskeletal health risks for those who perform sonography studies. In addition, the use of both hands (ambidextrous scanning) has been suggested as an additional practice that might result in decreased exposure to ergonomic risk factors; recent research by Biclar and Seto[7] suggests that ambidextrous scanning may reduce sonographers' risk of developing repetitive strain injuries (RSIs). Thus, the purpose of this study was to examine the effects of patient model size, sonographers' experience, and handedness on the performance of three types (general, vascular, and echocardiography) of sonography studies. In addition, select kinematic and kinetic variables were measured to evaluate possible ergonomic and WMSD risk factors for sonographers under these conditions. Such information may allow ergonomists and other health care professionals to better design and implement performance safeguards or work guidelines that would reduce the incidence and severity of WMSDs for the sonography specialties.

## Methods

### PARTICIPANTS

Convenience sampling was used to obtain 24 sonographer participants (19 women, 5 men) from west Michigan from the sonography specialties of general ($n = 10$), vascular ($n = 4$), and echocardiography ($n = 10$). Across these specialties, 13 sonographer participants qualified as experienced (≥5 years), and 11 were novice sonographers (third- and fourth-year baccalaureate students in an entry-level professional education program). Sonographer participant data are summarized in Table 1. Only novice sonographers had received prior training in ambidextrous scanning as part of their curricular programs, whereas experienced sonographers' use of their nondominant hand was limited to their job experience. Therefore, no effort was made to control for the presence of ambidextrous scanning experience among sonographer participants in this study. All participants were instructed in the purposes of the study and then provided written informed consent according to the protocol approved by the Human Research and Review Committee of Grand Valley State University. All data collection sessions were performed at the Radiologic and Imaging Sciences sonography laboratory, Cook-DeVos Center for Health Sciences, Grand Valley State University, Grand Rapids, Michigan, during February-April 2008.

### STUDY DESIGN

General sonographers performed a long-axis right kidney scan, echocardiographers performed a scan of the apical views of the heart, and vascular sonographers performed views of the left mid-common carotid artery and proximal internal carotid artery. Test scans were performed on three different sizes of patient models—5th, 50th, and 95th percentile by body weight[8]—using both a right-handed and left-handed setup for a total of six scans, as shown in the study design outlined in Figure 1. Figure 2 notes how participants performed these scans according to a random order

**TABLE 1.**
**Sample Demographics**

| | Mean Age, y | Male | Female | Echo | General | Vascular |
|---|---|---|---|---|---|---|
| Novice (*n* = 11) | 22.7 ± 2.7 | 1 | 10 | 4 | 5 | 2 |
| Experienced (*n* = 13) | 39.2 ± 8.6 | 4 | 9 | 6 | 5 | 2 |
| Total | 31.6 ± 10.5 | 5 | 19 | 10 | 10 | 4 |

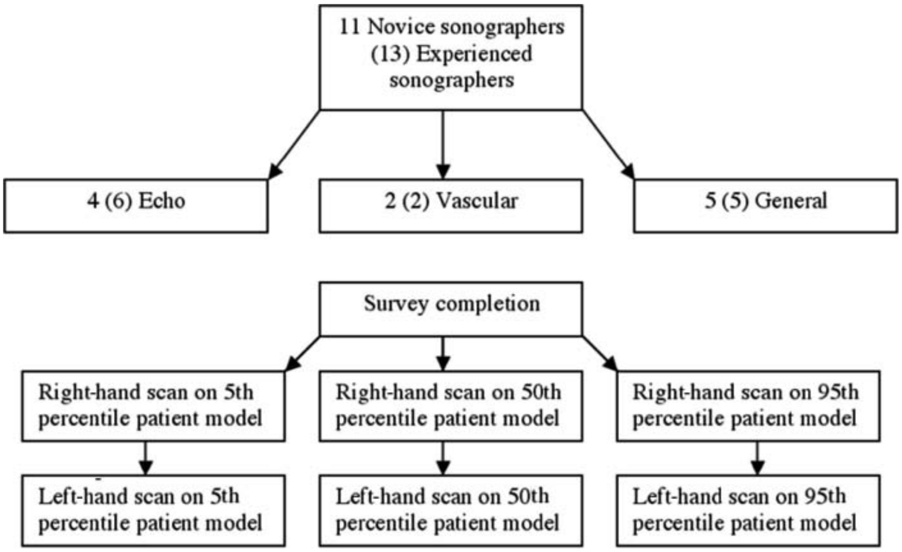


**FIGURE 1.** Study design overview.

based on their starting point to minimize order effects during data collection. Because scan quality was a variable of interest, the time to acquire each scan was not measured for the purposes of this study. All scans were videotaped for 2D motion analysis for shoulder abduction and wrist flexion/extension angle measurement. Grip forces were measured during each scan using the force-matching technique as described by Bao and Silverstein.[9] All test scan images were coded and saved to a PAC system to allow blinded assessment of quality by three expert credentialed sonographers who evaluated each scan in their respective specialty area in terms of professional standards.

#### INSTRUMENTATION AND MEASUREMENT

All scans were performed using Acuson Sequoia C512 (Mountain View, California) sonography machines, equipped with 4V1c, 6L3, and 6C2 transducers. Any sonographer participants unfamiliar with this equipment were provided instruction until proficiency and comfort with use were established. As illustrated in Figure 3, estimated grip force was measured using a Biometrics E-Link digital dynamometer (Evaluation System V800S) for both its measurement precision and zeroing capability.

During each scan, sonographer participants were instructed to obtain the best image while attending to the amount of grip force necessary to obtain that image. Once the image was obtained, the transducer was exchanged for the hand dynamometer without changing arm position to ensure an accurate force match, and participants were instructed to match the grip force they remembered as closely as possible. After the estimated grip force was measured, each sonographer participant was instructed to perform a maximum forceful grip in the same position to allow comparison of forces as

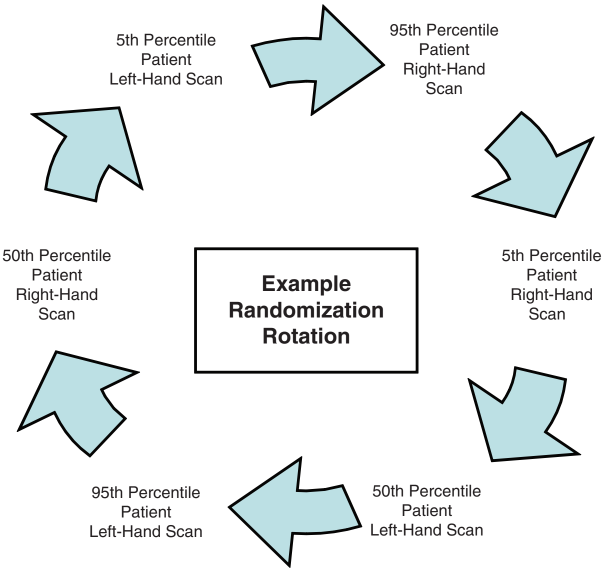


**FIGURE 2.** Example of a randomized scanning rotation sequence.

**FIGURE 3.** Grip force matching procedure.

a percentage of maximum grip force used during the scan. The grip used by each sonographer participant was assessed to ensure that each test scan protocol was performed in a similar fashion, maintaining approximately both the same grip type and force.

2D motion analysis was performed using two Sony DCR-VX2000 Digital HandyCam cameras and Dartfish Connect (V.4.5.2.0) software. Both cameras were handheld to best obtain all views because scanning postures were highly variable and dynamic; however, filming was performed at

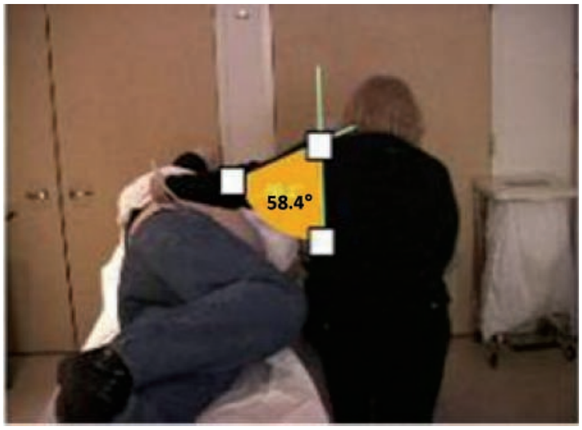


**FIGURE 4.** Joint angle measurement during scanning.

right angles to the plane of motion whenever possible. Both shoulder abduction and wrist flexion/extension angles were measured from the most advantageous position using this protocol. All anatomical landmarks were identified consistent with Norkin and White[10] in measuring these joint angles from the video records using Dartfish software. In addition, these angle measurements were taken from the actual positions in which sonographer participants captured the images, as illustrated in Figure 4.

Image quality was assessed on a three-point scale according to best practice criteria of overall echogenecity, focal zones, resolution, depth of field, angle of insonation, and optimization of scale evaluated by three expert credentialed sonographers who were blinded to sonographer participant experience, patient model size, and handedness. Table 2 illustrates the criteria and example scans in the general category.

Following completion of all test scans, sonographer participants completed a survey (adapted from Lamar[3]) to provide further demographic data and information regarding their injury history. Once all the test scans and survey were completed, each participant was given an opportunity to ask questions and then thanked for their participation in the study.

## DATA ANALYSES

All data were analyzed using SPSS Version 14 software. Grip force and joint angles were tested using univariate analysis of variance (ANOVA).

**TABLE 2.**
**Image Quality Grading Criteria With Examples for General Sonography**

| Example Image | Grading Criteria |
| --- | --- |
|  | **1**<br>Not acceptable for diagnostic use |
|  | **2**<br>Suboptimal: needs improvement |
|  | **3**<br>Optimal image |

Image quality was tested using Kruskal-Wallis and Mann-Whitney nonparametric tests. A *P* value ≤.05 was considered statistically significant for all tests.

## Results

Demographic survey data for the 24 sonographer participants in this study are shown in Table 3 and Figure 5. Of the 13 experienced sonographers, 7 participants reported working for 5 to 10 years, 2 for 11 to 15 years, 2 for 16 to 20 years, and 2 for more than 20 years. Their ages ranged from 20 to 54 years, with an average age of 32 years. In terms of stature, 1 sonographer participant was less than 60 inches in height, 5 were between 61 and 64 inches, 14 were between 65 and 69 inches, and 4 were between 70 and 74 inches. Of our convenience sample of participants, 100% of the experienced sonographers and 45.5% of the novice sonographers reported a history of a WMSD, as shown in Figure 5. As summarized in Figure 6, of those reporting a WMSD, 56% identified the anatomical region as the hand and wrist, 50% the shoulder, 44% the neck, and 28% the low back. These percentages overlapped because many of the sonographers reported multiple sites of pain. Our sample reflects similar characteristics as that for the most recent study published by Biclar and Seto[7] and is comparable to the literature in relation to age, gender, WMSD prevalence, and anatomical region of injury.[1,3–5,11–18]

**TABLE 3.**
**Demographic Information and Work Factors**

| Variable | Number of Sonographer Participants |
|---|---|
| Sonographer participant height, inches | |
| <60 | 1 |
| 61–64 | 5 |
| 65–69 | 14 |
| 70–74 | 4 |
| Years worked as a sonographer | |
| 5–10 | 7 |
| 11–15 | 2 |
| 16–20 | 2 |
| >20 | 2 |
| Student | 11 |
| Hours scanning per week | |
| 0–10 | 2 |
| 11–20 | 7 |
| 21–30 | 4 |
| 31–40 | 8 |
| >40 | 3 |
| Percentage of time scanning with nondominant hand | |
| 0%–12.5% (very little usage) | 14 |
| 12.6%–25% (little usage) | 3 |
| 25.1%–37.5% (moderate usage) | 2 |
| 37.6%–50% (frequent usage) | 5 |
| Percentage of obese patients per day | |
| 0%–20% | 0 |
| 21%–40% | 3 |
| 41%–60% | 10 |
| 61%–80% | 8 |
| 81%–100% | 3 |
| Expressed difficulty scanning obese patients | |
| Not at all difficult | 0 |
| Somewhat difficult | 8 |
| Very difficult | 16 |

### GRIP FORCE

Actual grip forces applied by sonographer participants ranged from a minimum of 0.3 kg to a maximum of 9.3 kg, with a mean grip force of 4.9 kg. The control variables of experience level of the sonographer, size of the model patient, and sonographer specialty all demonstrated significant ($P < .01$) differences in the percentage of maximum grip force used while performing the test scans, as illustrated in Figures 7 and 8.

Novice sonographers produced a mean value for percentage of maximal grip force of 22.0% ± 16.5%, as compared with 34.5% ± 19.8% for the experienced sonographers. As patient model size increased, this mean percentage of maximal grip force increased for the 5th, 50th, and 95th percentile sizes, respectively, as listed in Table 4. Mean percentage of maximal grip force was 31.3% ± 18.9% for echocardiographers, 13.8% ± 7.8% for vascular sonographers, and 32.2% ± 20.4% for general sonographers, respectively. However, no significant difference was found between hand use and the amount of grip force

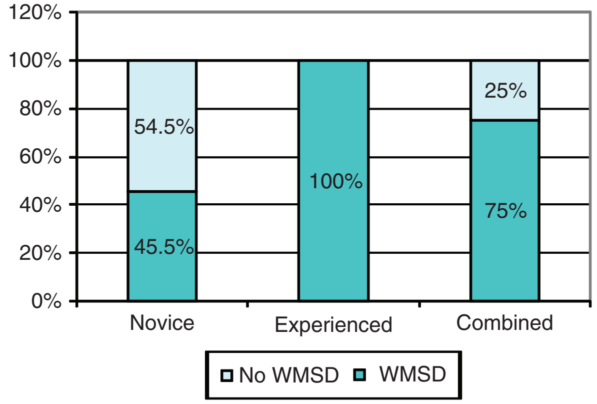


**FIGURE 5.** Prevalence of work-related musculoskeletal disorders (WMSDs) among novice and experienced sonographers.

applied. In addition, no interaction effect was detected between experience and patient model size, or specialty and patient model size, regarding mean percentage of maximal grip force.

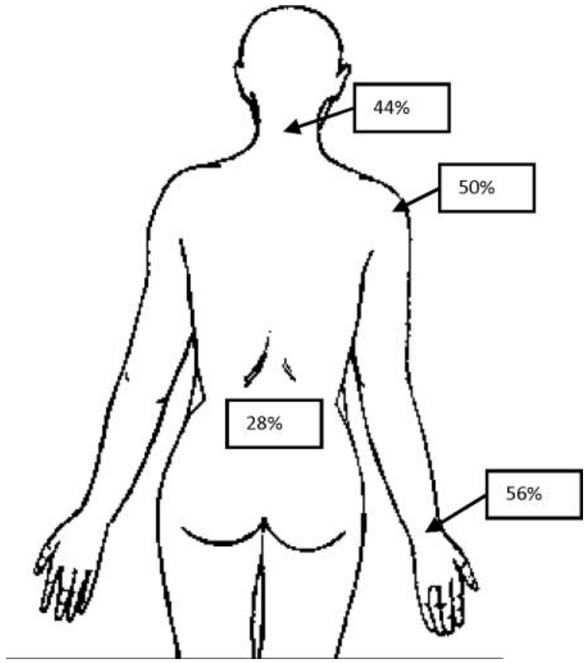


**FIGURE 6.** Summary diagram of symptom reports among participants.

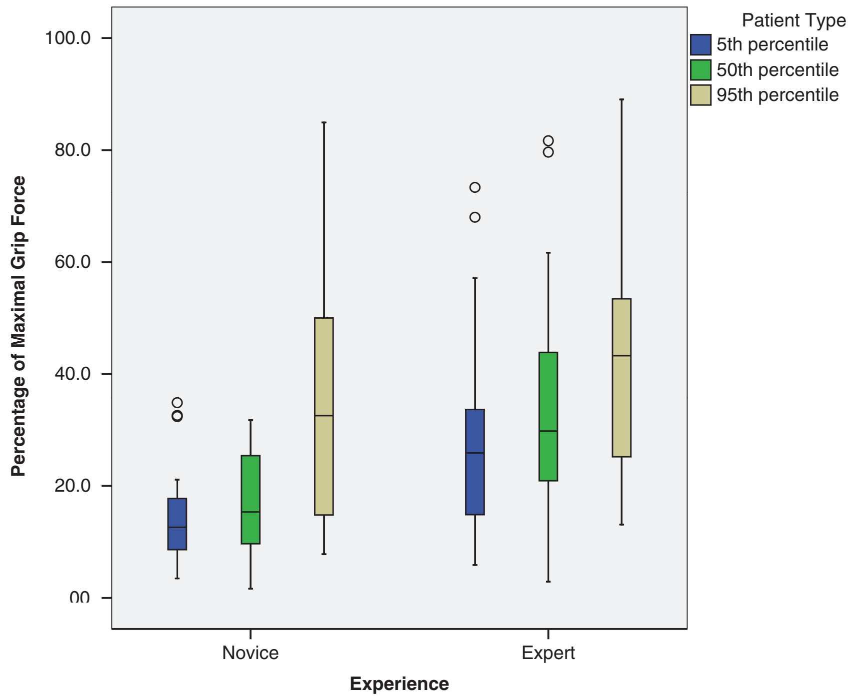


**FIGURE 7.** Percentage of maximal grip force for patient model sizes among experience levels.

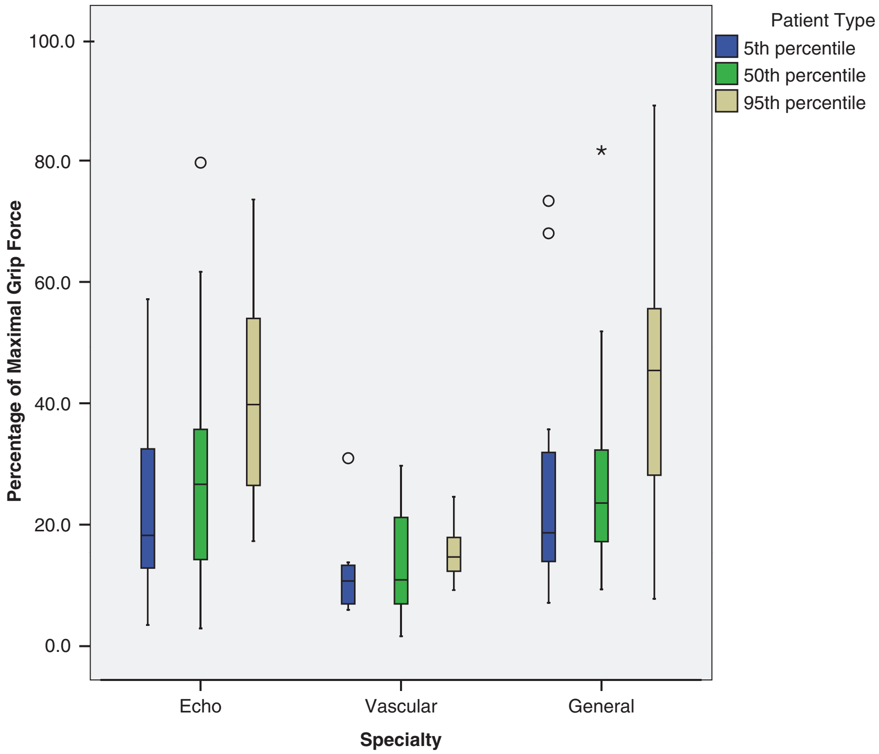


**FIGURE 8.** Percentage of maximal grip force for patient model sizes among specialty.

Survey data from our sample revealed that sonographer participants whose caseloads comprised 81% or more of obese patients used significantly higher grip forces throughout this study as compared with those who reported that they did not work with obese patients as much, as shown in Figure 9.

## JOINT ANGLES

*Shoulder*. Patient model size demonstrated a statistically significant ($P < .01$) difference for shoulder abduction while scanning, as shown in Figure 10. Average mean shoulder abduction angles were 36.6 ± 15.5 degrees when scanning the 5th percentile size, 32.8 ± 14.9 degrees when scanning the 50th percentile size, and 46.7 ± 19.7 degrees when scanning the 95th percentile size, as listed in Table 5. In addition, there was a statistically significant ($P < .01$) interaction effect between sonographer specialty and handedness for shoulder abduction angles between scanning hands with echocardiographers and general sonographers, as illustrated in Figure 11.

The interaction effect observed between specialties and handedness with regard to shoulder abduction demonstrates a difference in shoulder abduction angles between hand use only for general and echocardiography sonographer participants. This may be due to the simple fact that the target organs were on opposite sides of the body, thus affecting the preferred hand choice of the sonographer.

*Wrist*. No significant differences were found for the amount of wrist extension used while scanning across experience levels, patient model size, specialty, or handedness.

## IMAGE QUALITY

Nonparametric analysis of scan image quality approached statistical significance ($P = .051$) for both the 95th and 50th percentiles, as well as the 95th and 5th percentile model patient sizes; the Kruskal-Wallis mean ranks of the image quality scores for the 5th, 50th, and 95th percentile model patient sizes were 74.1, 78.5, and 60.4, respectively.

**TABLE 4.**
**Mean Percentage of Maximal Grip Force for Specialties, Patient Model Size, and Experience Level**

| | 5th Percentile | | 50th Percentile | | 95th Percentile | |
|---|---|---|---|---|---|---|
| | Nov | Exp | Nov | Exp | Nov | Exp |
| Echocardiography | | | | | | |
| Left hand | 13.2 | 27.3 | 19.3 | 36.1 | 37.6 | 45.4 |
| Right hand | 20.0 | 27.5 | 18.7 | 32.0 | 46.2 | 40.9 |
| General | | | | | | |
| Left hand | 15.0 | 36.5 | 16.4 | 37.6 | 43.1 | 53.6 |
| Right hand | 16.8 | 31.2 | 18.5 | 38.6 | 32.8 | 46.5 |
| Vascular | | | | | | |
| Left hand | 8.8 | 9.9 | 5.7 | 17.8 | 13.2 | 16.8 |
| Right hand | 9.6 | 21.3 | 10.4 | 20.9 | 11.9 | 20.0 |

Nov, novice; Exp, experienced.

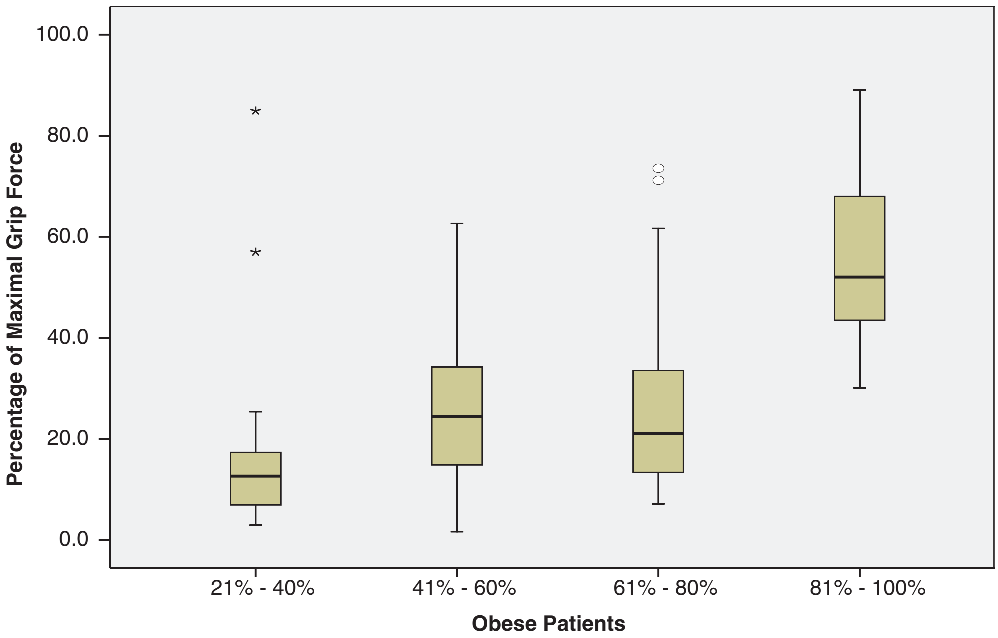


**FIGURE 9.** Percentage of maximal grip force in contrast to perceived percentage of caseload comprising obese patients.

No differences were found in image quality between right-handed and left-handed scans across all experience levels.

## Discussion

Previous research has emphasized the persistent prevalence of WMSDs among sonographers. Horkey and King[5] have suggested the necessity for appropriate quantitative biomechanical models that may further explain or justify ergonomic interventions. Commonly cited risk factors associated with these WMSDs include sustained grip pressure through the transducer, prolonged shoulder abduction without support, and scanning an increasingly obese patient population.[1,3,4,14,15] The use of ambidextrous scanning techniques recently has been suggested by Biclar and Seto[7] in their study concerning the

**TABLE 5.**
**Mean Shoulder Abduction Angle for Specialties, Patient Model Size, and Experience Level (in Degrees)**

| | 5th Percentile | | 50th Percentile | | 95th Percentile | |
|---|---|---|---|---|---|---|
| | Nov | Exp | Nov | Exp | Nov | Exp |
| Echocardiography | | | | | | |
| Left hand | 19.9 | 29.4 | 18.3 | 15.9 | 36.0 | 23.4 |
| Right hand | 28.5 | 49.8 | 31.9 | 39.2 | 63.4 | 71.0 |
| General | | | | | | |
| Left hand | 49.9 | 47.1 | 41.7 | 46.1 | 56.3 | 57.9 |
| Right hand | 25.3 | 30.8 | 21.8 | 34.0 | 28.2 | 38.0 |
| Vascular | | | | | | |
| Left hand | 38.0 | 42.9 | 40.1 | 36.6 | 52.6 | 57.5 |
| Right hand | 54.9 | 26.2 | 58.7 | 27.0 | 67.2 | 29.4 |

Nov, novice; Exp, experienced.

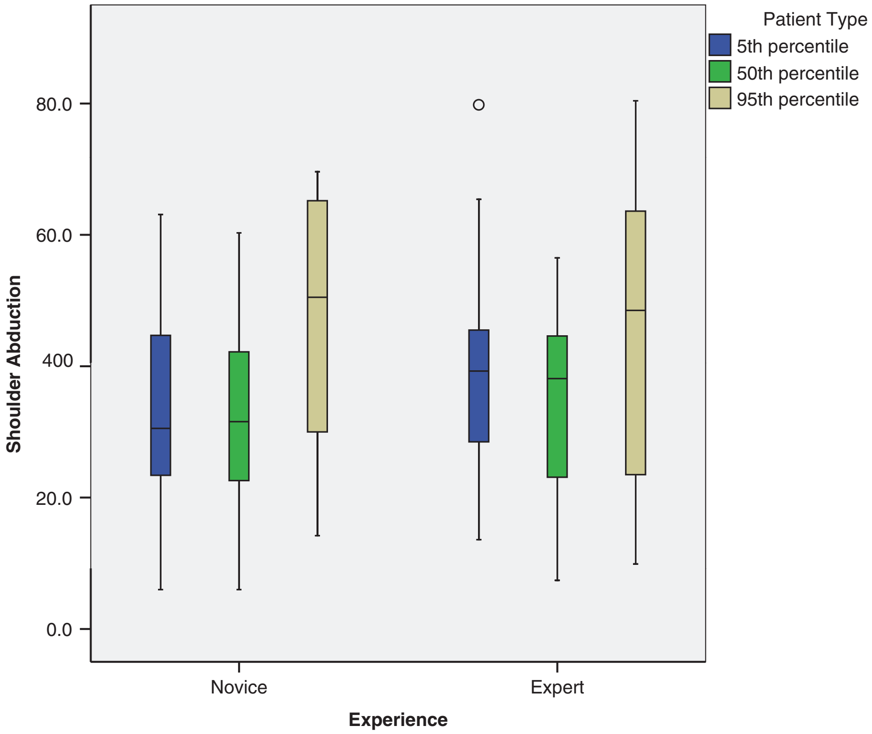


**FIGURE 10.** Degree of shoulder abduction for patient model size among experience levels.

feasibility of ambidextrous scanning for sonographers without loss in image quality as assessed by physician raters. The results of our study concur and also demonstrate that image quality is not significantly affected by the use of ambidextrous scanning for both experienced and novice sonographers among the three specialties of general, vascular, and echocardiography.

Despite our study findings, we observed that experienced sonographer participants demonstrated

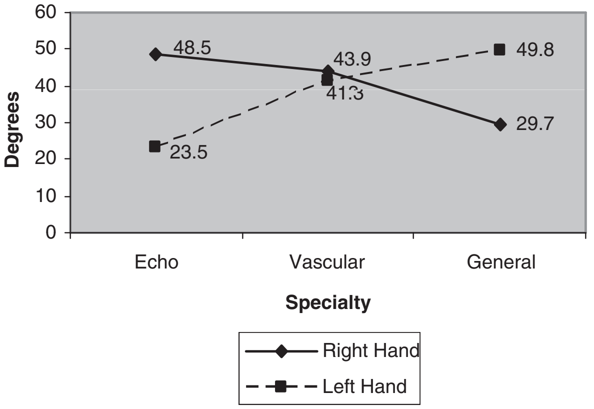


**FIGURE 11.** Shoulder abduction interaction effect between general and echocardiography sonographer participants.

hesitancy in performing scanning techniques with their nonpreferred hand. Informal feedback from study participants suggests that this attitude was founded on concerns about producing poor-quality images. Given the recent results of Biclar and Seto,[7] as well as what we found in our study, such concerns regarding image quality of scans performed ambidextrously are not supported. In addition, we found no differences among sonographers in the amount of grip force applied by either hand, lending further support to the recommendation that sonographers can benefit from use of ambidextrous scanning techniques in reducing the risk factors associated with overuse and work-related repetitive strain injuries. This benefit is amplified for those sonography tasks that involve repetitive and sustained activities. Although ambidextrous training of entry-level professionals has received some resistance in the profession, such an emphasis may be more beneficial than previously suspected. However, student and novice entry-level sonographers report difficulty in incorporating ambidextrous scanning into clinical settings because of traditional practice patterns and equipment that does not permit sonographers to be equally successful using both hands. Although ambidextrous scanning may share the workload between a sonographer's extremities, adoption of this practice is difficult unless sonography equipment can be properly adjusted to meet physical demands of performing scanning studies and sonography staff receive support for this practice from administrators and management staff.

Regarding the forces and measurements of grip strength, it is important to note that actual grip force data were not analyzed in comparison to the independent variables because of the variability in scanning positions and grip style. Because of this variability, we decided that use of percentage of maximal grip force was more meaningful as a force measure for our study, and use of force matching, as illustrated by Bao and Silverstein,[9] presented a more valid method of determining the effects of sonographer experience, model size, and handedness. We felt that these decisions allowed us to better evaluate individual differences among sonographers while permitting more realistic performance of the scans. Among specialties, the significant differences in percentage of maximal grip force used may be attributed to the uniqueness of individual scanning requirements, such as target organ and patient positioning. For example, it was not surprising to find that vascular sonographer participants demonstrated the least amount of percentage of maximal grip force as compared with the other specialties due to the superficial location of the carotid artery target, regardless of anthropometric differences across patient model sizes. The trend of increasing amount of percentage of maximal grip force, as patient model size increased, was observed across specialties, with the general and echocardiography specialties producing significantly higher values. This may be due to the depth of the scanned organs and the amount of adiposity associated with the larger patient models. Furthermore, in comparison to novices, experienced sonographer participants demonstrated significantly higher percentages for maximal grip forces. This finding may be influenced by the training received by the novice sonographer participants as part of their academic degree program. Further study of grip forces is warranted and should be evaluated for each specialty area of sonography to better understand the relationships that kinetic variables may have with scan performance and image quality.

The consensus of published evidence suggests that sustained shoulder abduction beyond 20 degrees, without arm support, is a notable risk factor for

WMSDs among sonographers.[14] Our findings reveal that our sonographer participants produced unsupported shoulder abduction angles greater, on average, than this 20-degree recommendation. Notably, when scanning the largest patient model, these values reached their highest, suggesting greater muscle forces required to perform the same scan. When combined with grip force requirements brought on by awkward shoulder postures, this finding may suggest that scanning larger patients may increase predisposition, or risk, for work-related repetitive strain injuries for sonographers.

### STUDY LIMITATIONS

We recognize that several study limitations may have affected our findings. Foremost among these was the use of 2D motion analysis techniques for what is essentially a 3D task. For example, calculation of joint angles from the video records provided us no more accuracy than using a universal goniometer or inclinometer with respect to reference points on the limbs. However, pilot testing indicated that our measurement precision was within acceptable limits, and the choice of 2D analysis permitted more realistic performance of the scans than 3D techniques would allow. In addition, the use of grip force matching as a technique for grip measurement was more indirect than force sensors directly mounted on the transducers. This latter technique may provide a more valid assessment of grip force through direct measurement of the actual forces used by the sonographer on the transducer. Finally, the choice of body weight as the sole indicator of patient model size may not have fully taken into account anthropometric differences as, say, body mass index (BMI).

## Conclusion

Patient size, particularly above the 90th percentile for body weight, carries an increased physical demand for performing sonography studies. Increased shoulder abduction angles, combined with increased grip forces on the transducer to obtain acceptable image quality, suggest an increased ergonomic risk that may increase the risk of work-related musculoskeletal disorders for sonographers, regardless of their experience level. Implementation of and adherence to appropriate ergonomic controls to reduce such risks may be necessary to ensure the future health of sonographers. One potential way to reduce such risks may involve training sonographers to scan ambidextrously as a way to relieve physical stresses on the preferred upper extremity. Future research should examine injury epidemiology and WMSD risk factor reduction associated with ambidextrous scanning, especially for bariatric and other large-sized patients. In addition, use of 3D motion analysis techniques that allow calculation of joint torque requirements for the upper extremity should be used to better understand muscle force requirements for scanning technique. Future research might focus on bilateral organ scans as a way to further test the relationships among handedness, image quality, and musculoskeletal risk across specialties.

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