# Surface EMG Evaluation of Sonographer Scanning Postures

**Susan L. Murphey BS, RDMS, RDCS, CECD**
**Sound Ergonomics, LLC**
**6830 NE Bothell Way**
**Suite C-236**
**Kenmore, WA  98028**
**Ph:  (877) 417-8151**
**Fax:  (425) 489-9030**
**Email: slmurphey@soundergonomics.com**

**Andy Milkowski  MS**
**Formerly of General Electric Medical Systems**
**Email:  amilkows@yahoo.com**

# Abstract

***Objectives***

This paper presents a technique for general quantitative evaluation of musculoskeletal impact through the evaluation of postural tests to assess two specific muscle groups. The two muscle groups chosen were the left upper trapezius, utilized while operating an ultrasound system's control panel, and the right suprascapular fossa, utilized while scanning. Surface electromyography (SEMG) was used to quantitatively measure muscular activity of these regions of the neck and shoulder.

***Methods***

Twenty-two sonographers subjects were evaluated using surface electromyography (SEMG) while performing standardized tasks typical of Diagnostic Medical Sonographers. SEMG was used to compare muscular activity in specific muscle(s) associated with postures employed to perform these tasks.

***Results***

This study shows large and statistically significant reductions in muscle activity by modifying scanning technique and workstation arrangement. The left upper trapezius muscle activity decreased 65% by changing from a 50˚ forward shoulder flexion (reach) to a neutral (0° reach) position. The right suprascapular fossa activity showed a reduction of 46% between a postural stance of 75° abduction and 30° abduction. There was an even more dramatic reduction of 78% by providing support under the forearm at the same 30° abduction. Consequently, the total reduction from the first position to the third position was demonstrated to be an 88% decrease in muscular activity.

***Conclusion***

The results of this study illustrate the benefit of optimized scanning technique, workstation utilization and use of adjustable workstation equipment. The overall reduction of 88% between 75° abduction, and a supported 30° abduction, shows the improvement possible with proper scan technique, support devices and versatile workstation equipment such as the ultrasound system, ergonomic chair and exam table.

***Keywords:*** *Ergonomics, Work-related-musculoskeletal-disorders (WRMSD), SEMG, Sonographer scanning technique*

# *Introduction*

In the field of diagnostic medical sonography, over 80% of sonographers surveyed suffer from some form of work related injury.[1, 2] The biomechanical risk factors for injury include awkward scanning postures, frequent repetitive motions, excessive exertion, faulty workspace and equipment design.[3, 4]

Non-industry specific ergonomic data emphasizes the importance of accommodating varied populations of workers within an industry through adjustability in the workstation, allowing employees to fit workstation equipment to their individual anthropometric requirements.[5] Studies in the field of visual display terminal and computer related industries show significant relationships between workstation design and WRMSD complaints. Specifically, pain and/or medical evidence of WRMSD is increased when keyboard levels are too high or low and when forearms are unsupported.[6] Data relating to the onset of fatigue associated with the forward shoulder flexion involved with reaching shows a more rapid onset of muscular fatigue with increased reaching distance. Similarly, increased abduction of the shoulder has been shown in numerous industries to cause excessive load on the shoulder and a more rapid onset of muscular fatigue. Shoulder abduction less than 30° is associated with reduction of muscle loading and, consequently, a slower onset of fatigue. Shoulder abduction of 60° corresponds to a muscle fatigue rate three times as fast as with a shoulder abduction angle less than 30º. [.14]

Symptoms of work-related pain in sonography were first described by Craig in 1985 with reference made to the "sonographer's shoulder".[7] Later studies showed that work-related musculoskeletal disorders (WRMSD) of the neck and shoulder area affect 74% and 76% of sonographers, respectively.[1 above, 2] Repetitive movement and prolonged, awkward positioning of the neck and shoulder are described as important factors for the development of WRMSD symptoms.[3,9] Identifying predictors for the development of musculoskeletal symptoms for such high-risk areas is vital for both the implementation of scanning control measures and equipment design. The most effective control measures to minimize or prevent WRMSD include both work methods and workstation considerations.

There is evidence that WRMSDs among ultrasound professionals results from repeated biomechanical stress due to ergonomic hazards prevalent in the workplace. Vanderpool et al. reported an increase in the prevalence of musculoskeletal symptoms with increasing volumes of studies performed and increasing exam times.[11] Among sonographers reporting pain, 97% relate their pain to the activities involved in ultrasound scanning, with the most severe symptoms occurring in the areas of the neck, shoulders, wrists, hand/fingers and back.[1] Relationships between occupational exposure and incidence of injury are demonstrated in literature reviews with specific correlation to the equipment components of the workstation.[3,12] Although numerous studies have reported the incidence and mechanism of injury among sonographers, there is little information available in the literature that specifically addresses how modifications in work practices and workstation equipment can affect the risk for WRMSD in the ultrasound setting. The purpose of this study was to apply the known principles of ergonomics to the practice of sonography in an effort to demonstrate that modifications of work practices, and the proper utilization of adjustable workstation equipment could effectively reduce biomechanical stressors associated with WRMSD in sonography.

The left upper trapezius muscle is chosen because of its active involvement in the action required to reach for the control panel of an ultrasound unit[2, 13]. Systems with a fixed keyboard and control panel often require an extended reach because of the inability to be positioned close to the sonographer. Studies have shown that the degree of forward shoulder flexion, or reach, significantly influences muscular fatigue, noting that as the horizontal distance is increased, the onset of fatigue is more rapid[14]. Ultrasound systems with keyboards and control panels that can be height adjusted, rotated, and extended away from the ultrasound system, towards the sonographer as well as height adjustable chairs allow the sonographer to achieve a "neutral" left arm position. This study was undertaken in an effort to confirm the efficacy of modifications in the sonography workstation related to forward reach.

The site selected as indicator of muscular activity required for abduction of the scanning arm in reaching for the patient is the suprascapular fossa. The suprascapular fossa reflects the activity of the supraspinatus and upper trapezius muscles and is used as a proxy for evaluating the muscular activity of the rotator cuff. Research shows that although shoulder strength remains fairly consistent at an angle of abduction between 30 and 90 degrees, fatigue increases dramatically when the shoulder is abducted greater than 30 degrees. Improvements in abduction of the scanning arm may be facilitated through changes in sonographer work practices, adaptive equipment, and adjustments in the exam table and chair height of the sonographer workstation. SEMG was used to validate these changes in the sonography setting.

SEMG has been used in numerous settings to measure voltage output of relative muscle recruitment, in ergonomic analyses when comparing musculoskeletal stress in a specific muscle(s) associated with postures and to evaluate the efficacy of ergonomic interventions[15,16]. This study utilized the average amplitude measurement from the SEMG to provide quantitative observation of recruitment intensity for specific muscle groups affected by a task. The analysis used average amplitude directly rather than the often-used percent of maximum voluntary contraction, because some subjects had active injuries and were unable to obtain a reliable maximum reading. An analysis of variance (ANOVA) can evaluate the mean difference between positions without the need for additional maximum voluntary contraction measurements.

Lastly, to minimize the variance from the SEMG readings, it was important to accommodate the differences in height and reach of sonographers as well as differences in dimensions of ultrasound machines.  This was done by “standardizing” the movements of sonographers in order to normalize the analysis for illustrating benefits of modified postures.  A goniometer was used to ensure a consistent angle of reach and abduction.

## *Materials and Methods*

The subjects were evaluated using SEMG while performing right and left handed tasks typical of Diagnostic Medical Sonographers.  Subjects were experienced sonographers recruited from an education class.  Years of experience and degree of musculoskeletal symptoms among subjects varied and were not included in study data.  The left arm tasks simulated the forward flexion of the left shoulder and extension of the left elbow while operating the control panel or keyboard of an ultrasound system.  The right arm postures simulated the sustained abduction of the right shoulder during sonography procedures.  Review of clinical worksite assessment data provided level of reach and abduction used as typical sonographer positions.  Improved postures were based on human factors fundamentals. Tasks were standardized to each subject by controlling the angle abduction and forward shoulder flexion through the use of a goniometer. The muscle activity of both the “standard” and “improved” postures on both the right and left side were measured in microvolts using surface electromyography.

The skin surface of each participant was cleaned with an alcohol prep pad, followed by application of a single EMG Triode Electrode to the left upper trapezius and another to the right suprascapular fossa region of the body, as shown in Figure 1. Muscle activity was assessed in each of the positions utilizing the MyoTrac 2 (Thought Technology, Ltd., Montreal, Canada). The SEMG sensor leads of the MyoTrac 2 were then connected to the electrodes. The MyoTrac 2 unit was programmed for Average & Actual display, with a range of 0-250 microvolts (+/- 0.1 μV) and signal processing was rectified and smoothed with a filter bandwidth of 20-500 Hz. By visual observation, signal was observed of low variance and quiescence with the arm in a rest position at the subject’s side.

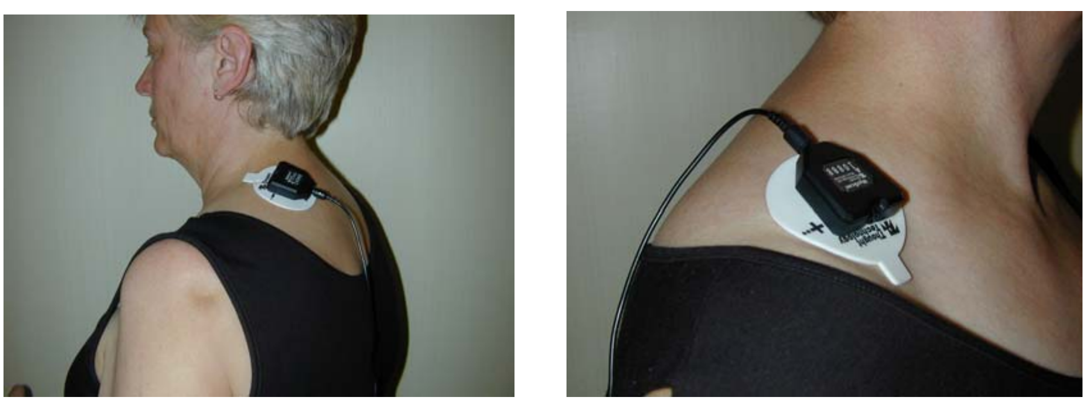

*Figure 1. Illustrating the placement of SEMG electrodes on the left upper trapezius and the right suprascapular fossa.*

Order selection of the left versus right upper extremities was done at random. Tasks performed with each extremity were also randomized in order and fully completed before testing the contralateral side.   Each position was held for 30 seconds to obtain an accurate reading of muscular effort.  Each position was verified using a goniometer prior to recording.  The positions are illustrated below:

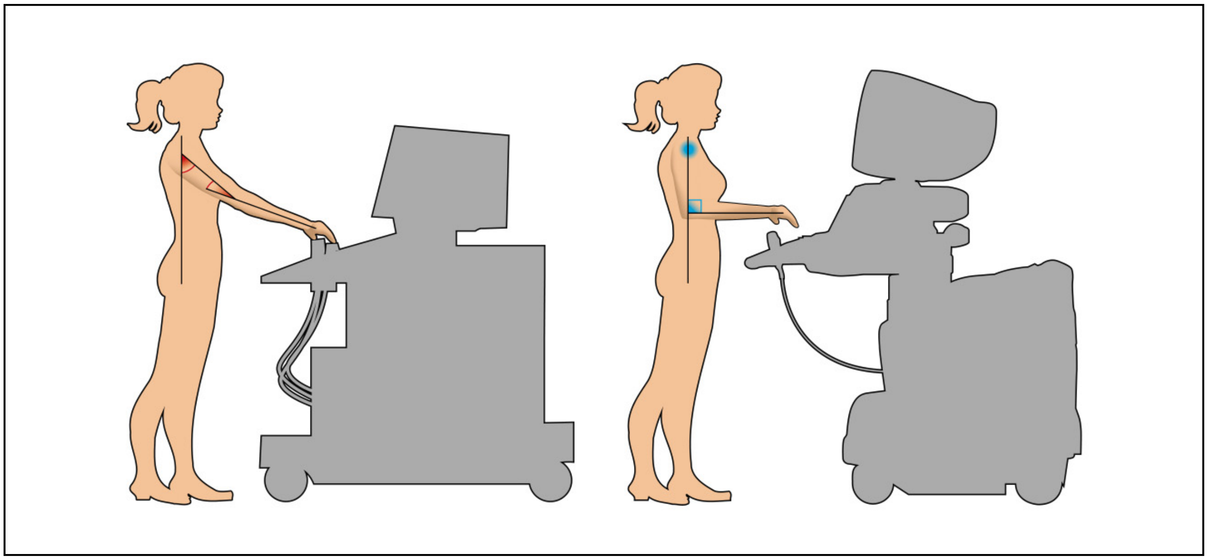

*Figure 2.  Illustrates the two positions for testing exertion of left upper trapezius. The first position shows shoulder flexion of 50˚ with and elbow flexed at 20˚.  The second position shows neutral shoulder position of 0˚ and elbow flexed at 90˚.*

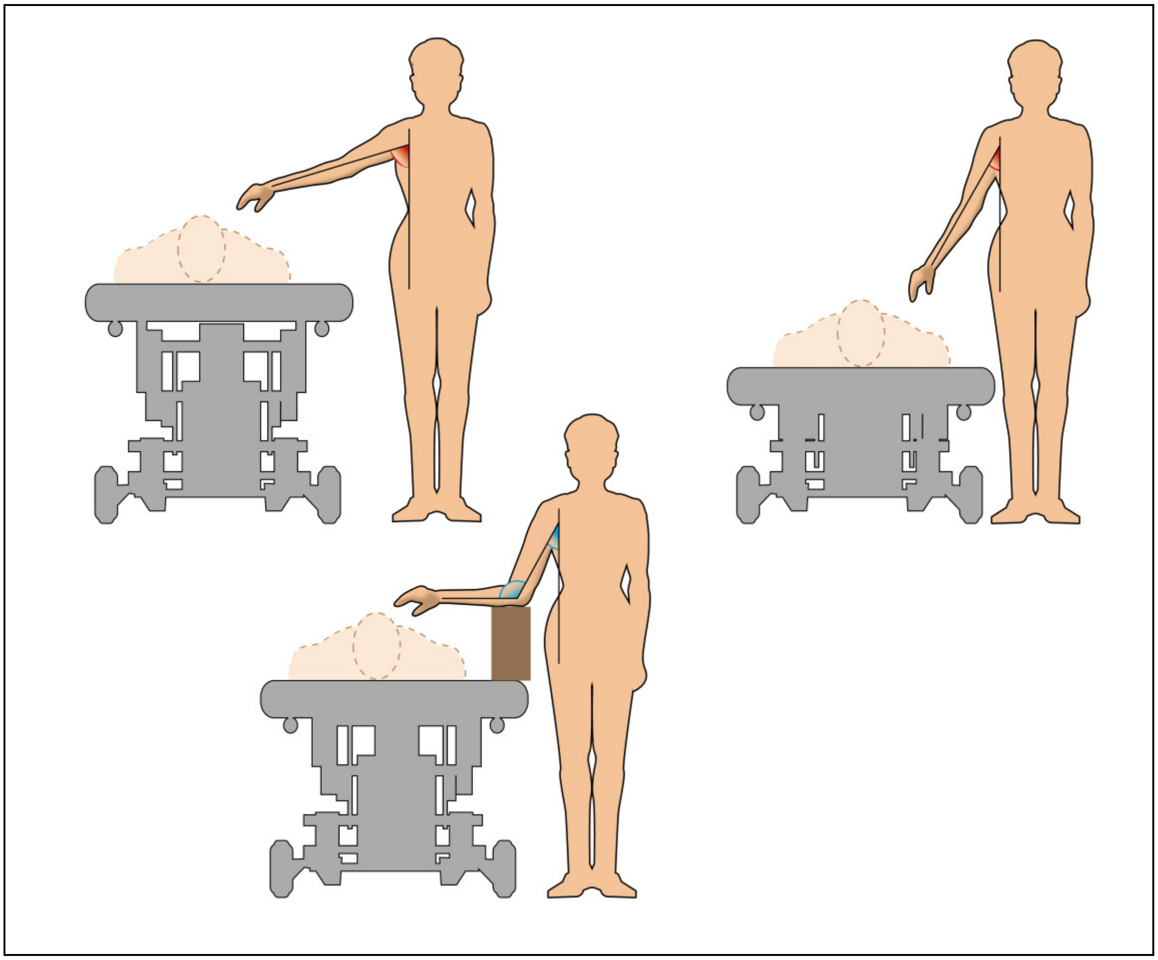

*Figure 3. Illustrates the three positions of the right supraclaviccular fossa. Specifically, the first position shows an unsupported arm abducted 75˚. The second position shows an unsupported arm abducted 30˚. The third position shows an arm supported on foam blocks abducted 30˚.*

Muscle activity was recorded as an average value of microvolts over the thirty-second period in each position. Subjects returned to a rest position between each trial. Resting state was verified by the return to original SEMG readings. Adaptive cushions utilized to support the scanning arm in the 30° supported position were Tumbleforms Block Modules (Sammons Preston Rolyan, Bolingbrook, IL.) Data, average microvolt values, from SEMG signals were analyzed in Minitab (Minitab Inc., State College, PA) using Analysis of Variance (ANOVA). ANOVA determines whether a statistical difference exists between the mean values of the compared groups – in this case, whether a difference exists between the original and modified positions. The ANOVA weighs the statistical significance by determining what random variables would affect the outcome. Statistical significance is represented by the p-value, with lower p-values corresponding to greater statistical significance.

# *Results*

Twenty-two subjects (6 male, 16 female) were selected for this study. The subjects were all diagnostic medical sonographers with different years of experience and, therefore, were familiar with the positions used in this study. The subject population was broken into the following number of male and female, right and left handed sonographers. (Table 1)

*Table 1. Number of female and male sonographers and number of right and left-handed sonographers*

| | Female Sonographers | Male Sonographers |
|---|---|---|
| Number of subjects | 16 | 6 |
| Right hand dominant | 13 | 5 |
| Left hand dominant | 2 | 1 |
| Ambidextrous | 1 | 0 |

**Left Trapezius**

The left upper trapezius muscle illustrates the difference in muscle activity in an extended reach posture as compared with a neutral posture. The result shows a mean of 19.5μV in the extended reach position and a mean of 7.0μV in the neutral position, resulting in a 64% reduction in mean exertion of the left upper trapezius muscle. (Table 2) A comparable work activity for sonographers would be use of a fixed control panel versus obtaining a neutral posture through utilization of an ultrasound system with an adjustable control panel.

*Table 2. Values showing average activity response in μV for the left trapezius with 50˚ extension (1st Position) and 0˚ extension (2nd position).*

| Subject | 1st Position | 2nd Position |
|---|---|---|
| Sono1 | 24.1 | 8.9 |
| Sono2 | 31.7 | 14.9 |
| Sono3 | 9.9 | 3.1 |
| Sono4 | 34.2 | 27.5 |
| Sono5 | 9.2 | 5 |
| Sono6 | 14.5 | 9.4 |
| Sono7 | 14.3 | 2.3 |
| Sono8 | 7.9 | 2.3 |
| Sono9 | 15.4 | 5.6 |
| Sono10 | 18.3 | 3.8 |
| Sono11 | 14.6 | 5.1 |
| Sono12 | 51.1 | 2.8 |
| Sono13 | 14.8 | 9 |
| Sono14 | 27.5 | 12.2 |
| Sono15 | 6.9 | 2.6 |
| Sono16 | 19.8 | 3 |
| Sono17 | 7.5 | 3.1 |
| Sono18 | 18.7 | 3.2 |
| Sono19 | 16.6 | 2.8 |
| Sono20 | 35.7 | 11.6 |
| Sono21 | 18.7 | 4.3 |
| Sono22 | 17.2 | 10.5 |
| Mean | 19.5 | 7.0 |

This 64% reduction in the mean exertion (19.5 – 7.0 μV) is shown graphically in Figure 4 and to be statistically significant ($p < 0.001$) in the following ANOVA (Table 3).

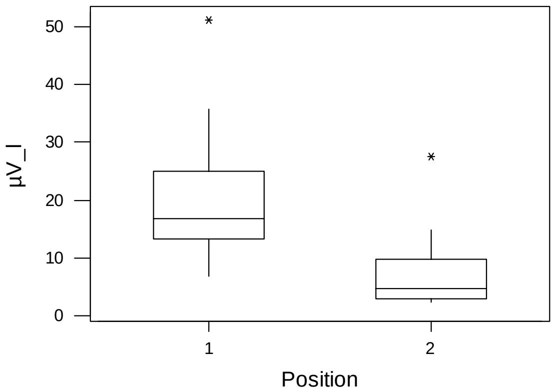


*Figure 4. Box-plot illustrating the decrease in muscle activity of the left trapezius muscle between the 1st position (50˚ extension) and 2nd position (0˚ extension)*

*Table 3. Analysis of Variance showing significance of position for left upper extremity*

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Sonographers | 21 | 2245.4 | 106.9 | 2.30 | 0.031 |
| Positions | 1 | 1726.3 | 1726.3 | 37.14 | 0.000 |
| Error | 21 | 976.0 | 46.5 | | |
| Total | 43 | 4947.6 | | | |

Sonographers=Number of subjects involved in the study

Positions=Number of conditions in which subjects were evaluated

Error=Number of subjects multiplied by number of conditions they interact with (sonographers x positions)

DF=Degrees of freedom; number of subjects available to vary

SS=Sum of squares; represents sample variance

MS=Mean of squares; estimate of population variance

F=Statistic signifying probability of variation between dependent variables

P=value representing the statistical significance of the study; lower p values represent increased statistical significance

**Right Rotator Cuff**

The right rotator cuff testing analyzes three different positions: The first position is a 75° abduction common to sonographers without knowledge of ergonomic principles or those working with an exam table or chair of limited adjustability. The second position is 30° abduction, a recommended work posture, and the third is a position of 30° abduction with the addition of support cushions placed under the right forearm. Reducing the angle of abduction from 75° to 30° demonstrated a 46% decrease in firing of the muscles tested. Muscle firing at 30° abduction was reduced further to 78% by supporting the forearm. The overall reduction between the first position of 75° abduction and the third position of 30°abduction supported on cushions demonstrated a decrease of 88% of muscle activity. Values for the average muscular workload are illustrated in Table 4.

*Table 4. Values for the average exertion in µV for the three right rotator cuff positions.*

| Subject | 1st Position | 2nd Position | 3rd Position |
|---|---|---|---|
| Sono1 | 45.5 | 24.4 | 4.1 |
| Sono2 | 21.6 | 15.5 | 2.4 |
| Sono3 | 47.3 | 31.3 | 7 |

| | | | |
|---|---|---|---|
| Sono4 | 42.3 | 28.6 | 10.9 |
| Sono5 | 11.5 | 7.6 | 1.9 |
| Sono6 | 59.9 | 33.5 | 18.8 |
| Sono7 | 18.3 | 7.9 | 1.9 |
| Sono8 | 30.1 | 10.1 | 2.2 |
| Sono9 | 39.9 | 18 | 2.2 |
| Sono10 | 27.1 | 12.5 | 1 |
| Sono11 | 20.9 | 9.9 | 3 |
| Sono12 | 44 | 17.6 | 5.7 |
| Sono13 | 20.6 | 8.1 | 2 |
| Sono14 | 43.1 | 23.5 | 5.1 |
| Sono15 | 50.2 | 27.1 | 2.4 |
| Sono16 | 36.3 | 22.7 | 4.7 |
| Sono17 | 13.8 | 8.4 | 1.3 |
| Sono18 | 39 | 22.9 | 1.3 |
| Sono19 | 29.1 | 21.2 | 3.3 |
| Sono20 | 39.7 | 23.3 | 3.7 |
| Sono21 | 22.5 | 6.5 | 3.5 |
| Sono22 | 18.7 | 14.5 | 2.7 |
| Mean | 32.8 | 18.0 | 4.1 |

The reduction in the mean muscle activity between the first, second and third positions is shown graphically in Figure 5 and is shown to be statistically significant ($p < 0.001$) in the following ANOVA Table 5.

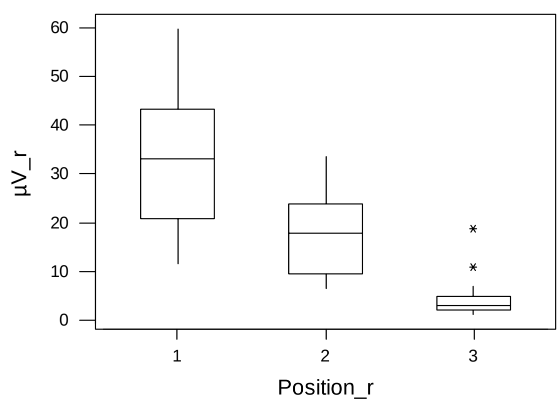


*Figure 5. Box-plot illustrating the decrease in muscle activity between the $1^{st}$ position (75˚ abduction), $2^{nd}$ position (30˚ abduction) and 3rd position (30˚ abduction with cushion)*

*Table 5. Analysis of Variance showing significance of position for right upper extremity.*

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Sonograper | 21 | 4008.2 | 190.9 | 5.42 | 0.000 |
| Positions | 2 | 9032.8 | 4516.4 | 128.25 | 0.000 |
| Error | 42 | 1479.0 | 35.2 | | |
| Total | 65 | 14520.0 | | | |

Sonographers=Number of subjects involved in the study

Positions=Number of conditions in which subjects were evaluated

Error=Number of subjects multiplied by number of conditions they interact with (sonographers x positions)

DF=Degrees of freedom; number of subjects available to vary

SS=Sum of squares; represents sample variance

MS=Mean of squares; estimate of population variance

F=Statistic signifying probability of variation between dependent variables

P=value representing the statistical significance of the study; lower p values represent increased statistical significance

## *Discussion and Conclusion*

When sonographers utilize extended reach and forceful muscular exertions with their scanning arm, it results in stressful forces of the muscles, especially those of the shoulder joint. The further away the subject is, the greater the force required by the shoulder muscles to counteract the efforts of the applied force. If the elbow is supported, or the arm held closer to the body, the neutralizing efforts of the shoulder muscles are reduced.

The results of the study on the right supraclavicular fossa evaluation of the rotator cuff show that the muscle activity can be dramatically reduced through proper technique and equipment. The effect is particularly dramatic between a “typical” diagnostic medical sonographer position of 75˚ abduction and the modified position of 30˚ abduction with the arm supported by adaptive cushions. This 88% (33.6µV – 4.0 µV) reduction suggests that the exertion of one patient exam utilizing the “typical” technique (75° abduction) is the equivalent of 8 to 9 patients with the improved technique and equipment. Biomechanical changes in work height through the use of adjustable ergonomic chairs and exam tables facilitate achieving improved positioning.

This study showed a significant reduction (64%) of muscle activity by the left upper trapezius muscle by eliminating the need to reach for the console of an ultrasound system.  The effect of this postural modification is intuitive and consistent with ergonomic training.  Additionally, this study suggests that an adjustable console (elevates, rotates and extends) used in conjunction with an adequately adjustable chair height could be a significant contributor to the reduction in WRMSD.

A note taken during the study between tests:  Each patient was verified to reach a "resting" state before moving to the next tested position.  Some of the patients did not reach a "resting" state until there was an active "shaking-out" of the arms and shoulders.  This would seem to indicate that some sonographers have chronic underlying conditions affecting the normal muscular function and recovery time.

In conclusion, this study shows a significant reduction of muscular exertion for two specific high-risk activities through the use of proper equipment and training.  This study also provides a procedural and analytical template for further investigation of system design and scanning posture evaluation.

## *Acknowledgement*

The authors would like to thank Alissa Garman, BS, of GE Medical Systems for her assistance in recording the data for this study.

This is a pre-publication manuscript. The final, peer-reviewed article, **Surface EMG Evaluation of Sonographer Scanning Postures**, was published in the *Journal of Diagnostic Medical Sonography*, Sept/Oct 2006; 22:298-305.

# *References:*


[1]Pike I, Russo A, Berkowitz J, Baker J, Lessoway V. The prevalence of Musculoskeletal Disorders among Diagnostic Medical Sonographers. JDMS. Sept.-Oct. 1997; 13(5): 219-27.

[2] Murphy C, Russo A. An Update of Ergonomic Issues in Sonography. Healthcare Benefit Trust Report, July 2000.

[3] Gregory, Val; Musculoskeletal Injuries: And Occupational Health and Safety Issue in Sonography; Sound Effects. September 1998;30.

[4] Occupational Safety and Health Administration (November 2002); Ergonomics: Recognition of Hazards, Scientific Basis for Ergonomics Regulation; HTTP: //www.osha-slc.gov/SLTC/ergonomics/recognition.html.

[5] Carson R, June 1994. Reducing Cumulative Trauma Disorders; Use of Proper Workplace Design, American Association of Occupational Health Nurses Journal. 1994: 42, 6, 270-276

[6] Kroemer KHE, Grandjean E; <u>Fitting the Task to the Human; Fifth Edition;</u> Taylor & Francis, London, 1997; chapter 5

[7] Craig M. 1985. Sonography: an occupational health hazard, Journal of Diagnostic Medical Sonography. 1, 121-125

[9] Baron S, Habes D; NIOSH Health Hazard Evaluation Report No. 99-0093-2749.

[11] Vanderpool HE, Friis EA, Smith BS, Harms KL. 1993. "Prevalence of carpal tunnel syndrome and other work-related musculoskeletal problems in cardiac sonographers," *Journal of Occupational Medicine*, 35: 604–610.

[12] Gregory V. September 1998. "Musculoskeletal Injuries: Occupational Health and Safety Issues in Sonography," *Sound Effects 30*.

[13] Kendall, F.P.; McCreary, E.K. Muscles-Testing and Function, Third Edition; Baltimore/London; Williams & Wilkins

[14] Salvendy, G. Handbook of Human Factors and Ergonomics: 2nd edition. New York, NY, John Wiley & Sons, 1997, pp 245-249.

[15] Aaras, A. Relationship between trapezius load and the incidence of musculoskeletal illness in the neck and shoulder. International Journal of Industrial Ergonomics. 1994;14: 341-348.

[16] Marras, W. Industrial Electromyography. International Journal of Industrial Ergonomics.1990; 6:89-93.