The Potential Reduction in Musculoskeletal Injury in the Nonscanning Arm by Using VoiceScan Technology During Sonographic Examinations

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Between 84% and 93% of sonographers in North America and Australia have reported musculoskeletal injuries related to their work activities. One type of occupational injury affects the nonscanning arm as sonographers reach for the control panel to manipulate the controls of the ultrasound equipment. A number of factors contribute to the reduction of these injuries, including improved ergonomic equipment designs. An important ergonomic design that targets the operator's nonscanning arm is a voice-activated control panel. The goals of this study were (1) to test the alternate hypothesis that there is significant difference in muscle activity of the upper trapezius muscle between three positions of forward flexion of the nonscanning arm and (2) to determine the efficacy of using voice activation technology to reduce the muscle activity required by the nonscanning arm to manipulate the keyboard of the ultrasound equipment.

Key words: ultrasound equipment, musculoskeletal injuries, sonographers, VoiceScan

Surveys conducted in the United States, Canada, and Australia have shown that between 84% and 93% of diagnostic medical sonographers suffer from some degree of occupational musculoskeletal injury.[1,2] Biomechanical factors, such as repetitive motions, static postures, and ultrasound equipment design, contribute to the risk factors for this type of injury, which can involve the worker's neck, back, and both upper extremities.[3] Extended reaches and static postures involved in manipulating the ultrasound equipment control panel can contribute to risk for injury in the nonscanning arm.

In this study, the left upper trapezius muscle was evaluated because of its function in elevating the shoulder, an action necessary to reach the ultrasound equipment control panel. One goal of this study was to achieve reproducible results for evaluating the efficacy of using voice-activated control

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panel controls as a method of reducing required muscular activity when manipulating the ultrasound equipment with the nonscanning arm.

Surface electromyography (SEMG) was used to compare muscular activity as the upper trapezius muscle was recruited to extend the left arm various distances from the trunk while reaching for the control panel. SEMG is used to analyze the musculoskeletal stress associated with certain body postures or limb positions and to evaluate the efficacy of ergonomic interventions.[4,5] Electromyography records the total electrical activity of a muscle, which is detected by surface electrodes, and a change in an SEMG signal can indicate muscle fatigue. The goal of these measurements was to determine the level of upper trapezius muscle activity required to access the control panel of the ultrasound unit while performing an examination. Repetitive reaching and maintaining the arm in a static posture while performing control panel functions increases a worker's injury risk; therefore, this study was undertaken to evaluate the nonscanning arm.

Keystroke data for lower extremity venous examinations without using a voice-activated control panel were obtained from a LOGIQ 9 ultrasound system (GE Healthcare, Milwaukee, WI) at Baptist Memorial Hospital Desoto (Southhaven, MS). The data showed the average number of keystrokes for the functions shown in Table 1.

LOGIQ 9 keystroke data obtained from Baptist Memorial Hospital Desoto (Southhaven, MS) for lower extremity venous examinations showed the average number of keystrokes required when using VoiceScan, GE Healthcare's voice-activated ultrasound control panel (see Table 2).

Materials and Method

Thirty-four subjects were enlisted from a customer education program. Years of scanning experience varied within the cohort. There were 4 men and 30 women with a variety of physical features and fitness levels. Four subjects were left-handed; 29 were right-handed. Only the left upper trapezius was evaluated in this study because most sonographers operate the control panel of the ultrasound system with their left hand while scanning with the right.

TABLE 1.
Average Keystrokes Necessary to Perform a Lower Extremity Venous Examination Without Voice Activation

Touch Panel	Doppler	Freeze/ Unfreeze	Print	Average Length of Examination
46	30	91	42	34 min

TABLE 2.
Average Keystrokes Necessary to Perform a Lower Extremity Venous Examination While Using VoiceScan

Touch Panel	Doppler	Freeze/ Unfreeze	Print	Average Length of Examination
4	2	14	2	26 min

For each subject, a single SEMG Triode electrode of the MyoTrac 2 (Thought Technology, Ltd., Montreal, Canada) was applied to the skin over the left upper trapezius muscle. The SEMG sensor leads of the MyoTrac 2 were then connected to the electrodes to measure the electrical activity of the muscle in microvolts (μV). The MyoTrac 2 unit was programmed for actual display. An average maximum voluntary contraction (MVC) of the upper trapezius muscle was determined for each subject. Each subject was asked to resist downward force against his or her left arm for six seconds while the arm was abducted 90 degrees from the trunk.[6] This action was repeated in each subject after a brief rest period, during which the upper trapezius muscle relaxed to a state of minimal electrical activity. These two measurements were then averaged together, providing the basis against which the three test measurements were compared. To normalize the results, SEMG test data were determined as a percentage of the MVC, representing the total effort in a percentage of maximum required for the task. When static postures are used, blood flow to muscles is reduced in proportion to the amount of force that is exerted. If static effort is less than 15% to 20% of MVC, blood flow to the muscles should be normal. Muscle fatigue due to static postures will occur more rapidly as increasing force is exerted.[7]

TABLE 3.
Electrical Activity of the Upper Trapezius Muscle in Three Different Degrees of Forward Flexion as a Percentage of the Electrical Activity of the Same Muscle During MVC

Degrees of Upper Extremity Forward Flexion	Mean Electrical Activity of the Upper Trapezius Muscle (μV)	% of MVC
44	22.4	5.56
55	28.67	7.12
70	36.12	8.97

Mean MVC = 402.7 μV, *n* = 33. MVC = maximum voluntary contraction.

TABLE 4.
Analysis of Variance Showing Significance of Position Changes for Left Upper Extremity

Source	*df*	SS	MS	*F* Value	Pr > *F*
Model	34	4208.56	123.78	35.59	>.0001
Error	64	229.05	3.58		
Corrected total	98	4437.62			

df = degrees of freedom; SS = sum of squares; MS = mean square; *F* value = probability distribution of the ratio of the mean square between groups to the mean square within groups.

TABLE 5.
Muscle Activity as the Angle of Forward Flexion Increased

Tukey Grouping	Mean	*n*	Position #
A	11.6004	33	70 degrees
B	8.9606	33	55 degrees
C	7.69	33	44 degrees

The difference in muscle activity as the angle of forward flexion increased was significant for each change in position as follows: between 44 and 55 degrees ($P = .0081$) and between 55 and 70 degrees ($P < .0001$).

FIG. 1. Excess reach of nonscanning arm without VoiceScan.

Each subject was then asked to perform a forward shoulder flexion (reach) at 44 degrees, 55 degrees, and 70 degrees from the trunk and to sustain each position for 10 seconds, which was arbitrarily determined as the length of time similar to that necessary to perform many of the control panel functions used during a sonographic examination. Elbow flexion was standardized at 160 degrees. A goniometer was used to verify forward shoulder flexion and elbow flexion prior to each recording. Each subject rested his or her arm between the three forward reaches for a period of time sufficient enough for the upper trapezius muscle to return to minimum electrical activity.

Results

SEMG data were analyzed using the analysis of variance (ANOVA) test. ANOVA is used to determine if there is a statistically significant difference between the means of two or more groups, requiring that the data are independent and normally distributed.[8] In this study, each subject was treated as a group, with the assumptions of independence and normal distribution.

As the forward shoulder flexion in this study was increased from 44 to 70 degrees in the majority of subjects, there was an associated increase in upper trapezius muscle recruitment. The mean change in voltage output for muscle recruitment was determined to be a statistically significant ($P < .0001$) difference between each of three angles of forward flexion as compared with the MVC for each subject.

Studies have indicated that expected time to reach maximum shoulder muscle fatigue decreases with increasing reach. At a 30-cm reach, the significant (severe pain) fatigue point has been established as 30 minutes, 20 minutes for a 40-cm reach, and 7 minutes for a 50-cm reach.[9]

The analysis thus supports the alternate hypothesis that there is an increase in muscle electrical activity with an increase in forward flexion. Muscle activity was measured as a percentage of the individual maximum voluntary contraction. In this co-

FIG. 2. Reduced number of reaches with nonscanning arm by using VoiceScan.

TABLE 6.
Percent Reduction in Reaches for the Most Frequently Used Keys on the Ultrasound Equipment Control Panel by Using VoiceScan During a Lower Extremity Venous Examination

	%
Overall reduction of reaches for all actions using VoiceScan	86.68
Overall reduction of touch panel reaches	91.30
Overall reduction of Doppler button reaches	93.33
Overall reduction of freeze button reaches	84.62
Overall reduction of print button reaches	95.24
Average reach reduction for touch panel, Doppler, freeze, and print	91.12

Keystroke data from Baptist Hospital, Southhaven, Mississippi.

hort, the mean percentage of maximum voluntary contraction at 44 degrees of forward flexion was 5.56%; at 55 degrees forward flexion, the percentage of maximum voluntary contraction was 7.12%; and at 70 degrees forward flexion, the mean percentage of maximum voluntary contraction was 8.97%. Of the subjects, 21% exhibited percentages of MVC recruitment at 70 degrees forward shoulder flexion that exceeded the recommended 15% to 20% of maximum voluntary contraction.[7] Nine percent of subjects showed percent MVC recruitments of greater than 15% at both 44 and 55 degrees of forward shoulder flexion. These percentages of MVC increase the subject's risk for muscle fatigue and injury by decreasing available blood flow and the removal of waste products.[7] This degree of reach often occurs when a sonographer reaches for the control panel of the ultrasound equipment to manipulate the controls during an examination. At an average distance of 20 to 25 cm from the ultrasound equipment control panel, it has previously been determined that the mean angle of reach for the time-gain compensation controls was 70 degrees, and the mean degrees of reach to annotate an image was 63.3 degrees.

Discussion

The two components of muscle activity that are involved in most work tasks are dynamic effort and static effort. However, the static component assumes greater importance because it is more strenuous. Dynamic effort is the alternation of muscle contraction and relaxation, whereas static effort is the prolonged state of muscle contraction. Common examples of static effort are those movements that require the arm to be held outstretched at or above shoulder level. Keyboarding is an example of the combination of both static and dynamic effort, with the shoulders and arms performing mainly static work to hold the hands in position over the keyboard, whereas the hands are performing dynamic movements. Normal flow of blood to muscles is required to maintain the oxygen supply and waste product removal. If static effort is 60% of the maximum voluntary contraction, blood flow can be almost completely interrupted.[7] Normal blood flow is maintained when muscle effort is less than 15% to 20% of maximum voluntary contraction. In static efforts, the constriction of blood flow is proportional to the muscle force exerted.[7] Constricted blood flow leads to decreased oxygen perfusion of the muscle and an accumulation of waste and carbon dioxide. This results in muscle fatigue and soreness resulting from static muscle contractions and awkward postures and can lead to injury if sustained for long periods. Improvements in postural alignment and frequent changes in positioning help to keep muscles and tendons flexible and well supplied with nutrients.

The goal is to maintain an upright posture while keeping the upper arms as close to the body as possible. The most common positioning error in many ultrasound studies is excessive reach. Excessive reach is generally related to improper positioning of the ultrasound system or patient. Critical issues for reducing risk factors related to shoulder and neck injuries include reducing reach and abduction of the upper extremity. This can be achieved by optimizing the relationship between the user and the equipment and using available technology such as VoiceScan as a means for reducing risk factors.

Comparison of keystroke data showed an overall reduction of 91% in forward reaches required while scanning by using the VoiceScan option. Through the use of this technology, there exists a potential for reducing the muscular effort required for forward flexion of the nonscanning arm by reducing the number of times the operator is required to perform extended reaches for the ultrasound equipment keyboard. In addition, the use of VoiceScan reduced the average length of time required to perform an examination by 8 minutes (see Tables 1-2), thus reducing the operator's "exposure time" to injury-producing scanning postures and limb positions. Further reduction of muscular effort may be realized by improvements in scanning technique designed to minimize awkward postures.

Conclusion

Occupational musculoskeletal injury risk is multifactorial and can be addressed through postural changes, ergonomic equipment design, and voice activation of ultrasound systems. Ergonomics strives to reduce or eliminate injury through different types of intervention. One of these, engineering controls, removes the presence of the hazard and can be implemented by redesigning workstation equipment. One such design change is a voice-activated control panel. This reduces the frequency of reaches for the control panel or the need to maintain extended, static reaches to access the most frequently used controls. Fewer required keystrokes can be directly related to reduced muscular effort. Reduction of muscular effort and a decrease in sustained postures have been shown to prolong muscular endurance during work tasks.

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