Work 47 (2014) 253–260
DOI 10.3233/WOR-121579
IOS Press

Contribution of positioning to work-related musculoskeletal discomfort in diagnostic medical sonographers

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Received 23 May 2012
Accepted 31 August 2012

Abstract.
BACKGROUND: Musculoskeletal pain and discomfort due to work exposure is experienced by 90% of sonographers. Survey research has provided a wealth of information to document this problem, but few studies have attempted to directly measure and identify the source of these disorders.
OBJECTIVE: This pilot observational study was conducted to obtain direct measures of the relationship of sonographers to their environment during the completion of sonographic examinations.
METHODS: The Rapid Upper Limb Assessment (RULA) was used to evaluate the positions of five sonographers during 24 sonographic examinations. The observed positions were compared among the various examinations and the association of these observed postures to discomfort, sonographer height, and exam table height was evaluated.
RESULTS: All participants reported an increase in musculoskeletal discomfort at the end of the workday. Overall RULA scores ranged from 3.11 to 5.00 with upper extremity venous Doppler and transvaginal pelvic examinations averaging the highest. Increasingly poor upper extremity positioning was positively associated with increased musculoskeletal discomfort ($r = 0.53$, $p < 0.01$).
CONCLUSIONS: Regardless of the examination being performed, sonographers are working in positions that require further evaluation and intervention. Longitudinal studies are needed that evaluate the inter-relationship of biopsychosocial risk factors of musculoskeletal injuries.

Keywords: Ergonomics, injury prevention, rapid upper limb assessment

1. Introduction

Sonographers work in a variety of clinical settings and perform a variety of examinations. On an average day, the majority of sonographers perform 9–11 examinations [1] that can last anywhere between 20–45 minutes [2]. This results in spending an average of 5–7 hours per day actively performing ultrasound examinations [2]. Obtaining a quality sonographic image can sometimes prove to be challenging and demands odd angles and increased pressure on the shoulder, elbow, hand and wrist. Due to the physical exposure, work-related musculoskeletal disorders have been a problem in the sonography profession for many years with incidence rates becoming increasingly widespread [3,4].

Up to 90% of sonographers are scanning in pain [1]. Shoulder pain is most common, occurring in 73% to

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90% of sonographers, with 69% reporting lower back pain and 54% having wrist and hand disorders [5]. Active myofascial trigger points, subacromial rotator cuff impingement, and dysfunctional movement of the scapulothoracic joint are consistently reported as disorders on the transducer side [6]. The onset of physical discomfort can be as early as within 6 months of employment (15% incidence), with rates increasing to 45% after three years, and 72% after ten years of employment [2]. Finger, hand, and wrist discomfort occur most often in this older, more experienced group of sonographers [1].

The increased incidence of musculoskeletal disorders in the profession has necessitated research of the work habits and environments of sonographers. A biopsychosocial approach that combines physical, psychological, and social has been suggested as a means for evaluating and understanding the contributory risk factors in work-related musculoskeletal injuries. Each of these factors can contribute individually or collectively along with the others. Factors may be predisposing (e.g. anthropometry, anxiety, job satisfaction), precipitating (e.g. trauma, long work hours), or perpetuating (e.g. poor ergonomics, poor health, fatigue, chronic pain) [6]. A long history of survey research has linked multiple predisposing factors, such as height, age, and gender differences among sonographers to increased musculoskeletal discomfort, but less evidence exists to support the relationship of precipitating and perpetuating factors to discomfort.

The primary perpetuating factor evaluated in musculoskeletal disorder prevention research is poor positioning. To complete evaluations, sonographers often work in sustained awkward positions that are a combined result of sonographer anthropometry and the work environment/equipment. One especially awkward examination is a portable neonatal neurosonogram in which sonographers must maneuver through numerous medical lines and tubes, twisting the scanning arm and hand into compromised positions to place the transducer on the fontanel of the premature infants inside isolettes [7]. As with the position required for this examination, sustained shoulder abduction, tight gripping of the transducer and twisting and bending of the wrist for long periods of time may be factors related to the onset of discomfort and disorders on the upper extremity in sonographers [8,9]. As the degree of shoulder abduction increases, the muscles fatigue quicker; in fact, when the angle of shoulder abduction increases from 30 degrees to 120 degrees, time to fatigue decreased from 60 minutes to 5 minutes [6].

In addition to the predisposing and perpetuating factors, the experience of musculoskeletal discomfort in sonographers is often mediated by other precipitating factors often outside the control of the individual sonographer. Because of the shifting focus in health-care settings toward productivity along with the streamlining of data processing due to technological advances, sonographers are being required to perform an increasing number of examinations each day with less break time between exams. The increasing number of examinations and disproportionate work/rest cycles can have a direct impact on the level of stress and the sonographer's physical and mental status [7]. Sonographers who hold two or more credentials may be required to perform an inordinate number of examinations due to their skill sets that may explain an increased incidence of wrist and hand injuries [5].

Sonographers believe that their own health and wellbeing is compromised because of their professional activities. The increase in physical discomfort lead to changes in home life, work responsibilities, sleep patterns, and psychosocial wellbeing [2]. Unfortunately, many sonographers accept that musculoskeletal discomfort is part of their job and the majority attempt to manage the situation on their own instead of reporting it. Absenteeism and lost-time can contribute to a significant loss of revenue (~$21,153/week), creates additional stress for co-workers trying to meet the workload, and can result in longer wait times for patients [10]. To compound the impact on employers, impaired presenteeism is likely to be occurring when employees continue to show up to work despite their discomfort. Work-related musculoskeletal discomfort can lead to a 5% to 7% decline in workers' productivity and abilities while present at work [11].

A gap in the literature exists with recording direct measurements of many of the factors that may be contributory to musculoskeletal disorders among sonographers. To date, most research that has attempted to relate the plethora of biopsychosocial factors to discomfort in sonographers has been through survey research with only two studies staging attempting to obtain objective measures [5,7]. While survey research has provided important indirect information, more studies are required to directly evaluate the exposure-incidence relationship. Therefore, the purpose of this research study was to pilot the collection of observational data to determine the relationship of the sonographer to the environment and aspects of positioning during various sonographic examinations to musculoskeletal discomfort.

2. Methodology

2.1. Design

A direct observation of sonographers in the work place was used to investigate factors that may increase their individual risk of work-related musculoskeletal disorders. This pilot study was a complimentary component of a larger research program being conducted to evaluate and adapt sonography equipment to mediate musculoskeletal disorders in sonographers. This research was approved by the Institutional Review Board.

2.2. Participants

Five participants were recruited into the study as part of an existing partnership with the academic research institution. All participants were credentialed, clinical preceptors with a minimum of 5 years of clinical experience. To minimize facility bias, participants were selected for observation from multiple clinical facilities. Data were collected as part of a student clinical internship.

2.3. Data collection

Data were collected via direct observation of participants in their work environment. Upon establishing first contact with the participant, the participant's height was recorded. For each date that a participant was observed, the participant was asked to provide a rating of their musculoskeletal discomfort. The participant provided their rating of musculoskeletal discomfort on a 10 cm visual analog scale (VAS) with anchors at either end (i.e. "no discomfort" and "agonizing pain"). Each participant provided a rating of musculoskeletal discomfort at the start of their work shift prior to performing any examinations and at the end of their work shift. One examination was randomly selected from the participant's schedule. The type of examination to be completed was recorded by the researcher.

The researcher observed the workstation and participant positioning throughout the sonographic examination. Each participant was allowed to set-up and adjust the workspace and equipment as they wished without interaction or influence of the researcher. An adjustable height patient bed was available in the workspace for every examination that was observed. During the examination the self-selected bed height was measured from the floor to the bed surface.

The Rapid Upper Limb Assessment (RULA) was used to quantitatively score the positioning of scanning arm and overall trunk posture of the participant [12]. The RULA is an observational tool that provides a means to quickly evaluate work positions and screen activities for exposure to physical risk. Non-neutral positions of the shoulder, elbow, forearm, and wrist are tallied to provide a sub-score for the upper extremity position and similar ranking is used to observe the neck, trunk, and legs resulting in a second sub-score. These scores are weighted based on repetitive or static muscle activity and the amount of muscle force being utilized. A final value from 1 to 7 is assigned to the overall activity position; a score of 1 is associated with a neutral or low strain posture and 7 denotes that changes in the workplace are needed immediately due to hazardous positioning [13].

2.4. Statistical analysis

Descriptive analysis was completed. Frequencies were calculated for each examination type. Sonographer height and patient bed height were used to calculate a height ratio by dividing the sonographer height by the bed height. The VAS ratings were scored and a discomfort change score was calculated by subtracting the end of shift score from the start of shift score. Even though verbal anchors were provided, VAS change scores were used as an additional means to reduce individual rater bias that may exist in the self-rating of discomfort. Means were calculated for the height ratio, all discomfort scores, and the relevant RULA scores (i.e. upper extremity sub-score; neck, trunk, leg sub-score; overall score).

Additional analyses were completed to examine the relationship among the various data. A one-way analysis of variance (ANOVA) was used to determine if differences existed in the bed height, change in discomfort or the RULA scores among the various examination types. The association among the participant height, bed height, change in discomfort and participant positioning was examined with a Pearson correlation. In addition to exploring the relationship of the overall RULA score and the two sub-scores, the individual scores for the position of each body part (e.g. shoulder, wrist, neck, legs) were analyzed for any relation to the change in discomfort and other variables. Statistical analyses were completed using IBM SPSS v.20. A p-value < 0.05 was considered significant for all statistical analyses.

Table 1
Average change in discomfort and positional scores for observed sonographic evaluations sorted by overall RULA score ($n = 24$)

	Bed height (cm)	VAS change	Upper extremity sub-score	Neck, trunk, legs sub-score	Overall RULA score
Upper extremity venous	68.67	1.67	4.00	5.00	5.00
Transvaginal pelvic	81.00	2.00	4.00	5.00	5.00
Transabdominal obstetric	81.00	2.00	3.67	4.67	4.67
Carotid duplex	83.00	2.00	4.00	4.17	4.50
Lower extremity venous	77.90	1.33	4.11	2.56	3.11

RULA, rapid upper extremity assessment; VAS, visual analogue scale.

Table 2
Comparison of bed position, bed to sonographer height ratio, change in discomfort, and sonographer positions among the five sonographic examination types ($n = 24$)

	Mean	df	F
Bed height (cm)	78.8	4	0.41
Height ratio	2.24	4	0.35
VAS change	1.71	4	0.65
Upper extremity sub-score	4.00	4	0.18
Neck, trunk, legs sub-score*	3.83	4	4.39
Overall RULA score	4.13	4	1.89

*$p < 0.05$; VAS, visual analogue scale; RULA, rapid upper extremity assessment.

3. Results

Five sonographers were recruited for participation in this pilot study. All sonographers were female with an average height of 168.1 cm (SD 6.7). A total of twenty-four examinations were observed across the 5 participants, but only one examination was observed per participant per day. Examination types were classified as lower extremity venous Doppler ($n = 9$), upper extremity venous Doppler ($n = 3$), carotid duplex ($n = 6$), transvaginal pelvic ($n = 3$), and transabdominal obstetric ($n = 3$). Bed heights ranged from 60 cm to 132 cm across the examinations and the average height ratio of sonographer height to bed height was 2.20.

Participants reported an average discomfort rating of 0.67 at the start of their workday and an average discomfort rating of 2.38 at the end of their shifts, resulting in an average overall change in discomfort of 1.71 across all participants regardless of examination type. Analysis of the RULA data indicated the muscle use and muscle force scores were 1 and 0 respectively for all examinations due to the static, low force positioning. Although the muscle force score of 1 was used to determine the overall RULA score, because these results were the same for every examination further analysis of these individual variables was excluded. The average upper extremity sub-score was 4.0 (SD = 0.72, [3.0–5.0]), the average neck, trunk, leg sub-score was 3.83 (SD = 1.52, [2.0–6.0]), and the average overall RULA score was 4.13 (SD = 1.54, [3.0–7.0]).

Average values for each of the observed variables by examination type are presented in Table 1. Minimal variation was noted to exist in the height ratio measure by examination with all examination types having a height ratio of 2.2 with exception of the upper extremity venous Doppler examination with an average ratio of 2.5. The difference in the calculated ratio for this examination is reflected in the lower bed height at 68.7 cm compared to 77.9 cm to 83.0 cm for all other examinations. Change in discomfort was similar among all examinations, ranging from 1.33 to 2.00. All overall RULA scores ranged from 3.11 to 5.00 with the upper extremity venous Doppler and transvaginal pelvic examinations averaging the highest for all RULA scores. Significant differences among these variables by examination type were only noted in the neck, trunk, and leg sub-score with the lower extremity venous Doppler examinations scoring significantly lower than the other examinations (Table 2).

The relationship of these variables, along with the individual body segment scores, were further evaluated to better understand how these selected predisposing and precipitating factors may be associated to each other and to changes in discomfort. Table 3 presents the correlation of the RULA scores to bed height, sonographer height, height ratio and changes in discomfort. There was a moderately negative correlation between the bed height and the score for the position of the neck ($r = -0.45$, $p < 0.05$) and trunk ($r = -0.46$, $p < 0.05$), indicating that as the height decreased the position becameincreasingly worse. Similarly, the positioning of the legs ($r = 0.52$, $p < 0.01$) and overall positioning ($r = 0.53$, $p < 0.01$) were worse in taller participants. The height ratio followed a similar pattern whereby the larger the ratio, the worse the positioning of the neck, trunk, and legs, leading to a higher overall RULA score. In contrast to the association of heights to the neck, trunk, and legs, the upper extremity sub-score was the only measure with a significant association to change in discomfort. A moderately positive association ($r = 0.53$, $p < 0.01$) was noted whereby as the upper extremity sub-score increased the change in discomfort also increased.

Table 3
Correlation of RULA scores to other independent variables

	Shoulder	Lower arm	Wrist	Upper extremity sub-score	Neck	Trunk	Legs	Neck, trunk, legs sub-score	Overall RULA score
Bed height	0.125	−0.124	−0.364	−0.257	−0.447*	−0.462*	0.100	−0.231	−0.285
Sonographer height	0.381	−0.083	−0.119	0.090	0.148	0.301	0.516**	0.485*	0.534**
Height ratio	0.041	0.111	0.313	0.357	0.415*	0.562**	0.085	0.411*	0.494*
VAS change	−0.016	0.023	0.398	0.530**	−0.137	−0.049	0.422*	0.215	0.369

*$p < 0.05$; **$p < 0.01$; RULA, rapid upper limb assessment; VAS, visual analogue scale.

4. Discussion

The objective of this study was to compare sonographer height, exam table/bed height, and sonographer positioning during examinations to discomfort that may lead to work-related musculoskeletal disorders. Although the only significant difference in these measures by examination type was in the positioning of the neck, trunk and legs for one exam type (lower extremity venous Doppler examination), all examination types were noted to have an overall average RULA score indicating further investigation might be required. Height measurements were noted to be related to changes in position for the neck, back and lower extremity, but did not have a relationship to the upper extremity position. However, the upper extremity positioning was the only measure that had a significant association with changes in discomfort.

The RULA scores for examinations in this study are similar to those previously reported for neonatal neurosonology examinations that were observed to have an average overall RULA score of 3.8 to 4.0 [7]. The RULA is meant to be a screening tool for the identification of high-risk postures. In the original version of this tool, McAtamney and Corlett [12] suggest that the overall scores indicate an action level: 1) 1–2 = acceptable; 2) 3–4 = may be harmful, investigate further; 3) 5–6 = investigate and change soon; and 4) 7 = investigate and change immediately. With sonography examinations consistently scoring over 3, and up to 5, further investigation and change within the profession is required soon.

Sonographers performing upper extremity venous Doppler and transvaginal pelvic examinations tended to have the worst positioning. Most sonographers stand on the right side of the supine patient when scanning, so he or she must reach over the patient in order to scan the left upper extremity. This places the shoulder of the scanning hand in abduction, causes bending and twisting in the neck and trunk, and often leads to an unbalanced stance through the lower extremities. In addition to this awkward sustained position, the completion of a venous Doppler examination requires the sonographer to have a tight grasp on the small transducer while applying additional pressure to coapt the vessel (Fig. 1).

Fig. 1. Depiction of the awkward grip position required to apply pressure through the transducer to coapt a vein during a typical venous Doppler exam.

Completion of the transvaginal pelvic examination was observed to have a unique set of positioning challenges. This exam requires using a long transducer with a handle that is inserted transvaginally. In order to obtain proper placement of the probe's scanning head, the sonographer must angle the probe up, down, and side to side to in order to obtain all the images. Because the patient and sonographer tend to stay stationary throughout the examination, the sonographer must move the wrist into extremes of flexion, extension, deviation and twisting (Fig. 2). In addition to the awkward wrist positioning, continued interaction with the sonography equipment is required; therefore, most sonographers will sit to the outside of the patient's legs requiring them to hold their shoulder in sustained abduction to reach overthe patient's leg that is being held in a stirrup.

Although there was no significant examination effect, an association with the upper extremity positioning observed during examinations was associated with increased musculoskeletal discomfort. While it is challenging to link the change in discomfort across an entire workday to observations that occurred in one examination, because this one sub-score was the only RULA data point that was noted to be significantly correlated with increased discomfort, further investigation

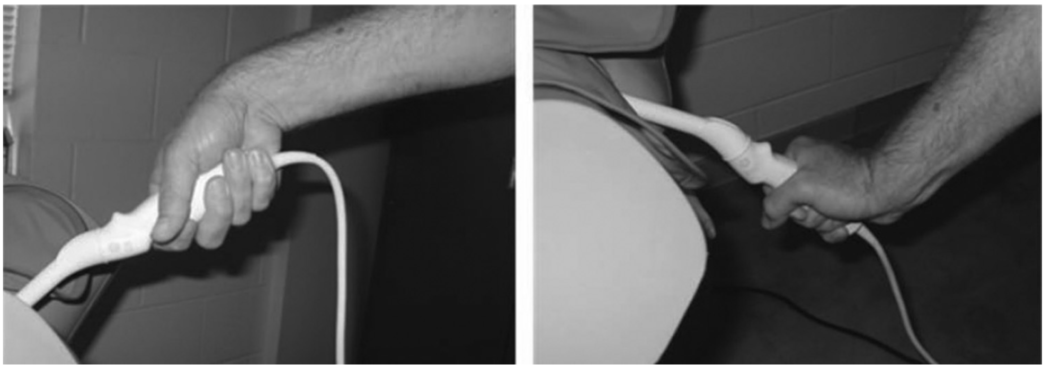

Fig. 2. Typical positioning of the wrist in ulnar deviation and flexion or radial deviation and extension during a transvaginal pelvic exam.

is indicated. Furthermore, a change in discomfort from the start to end of the work shift was noted for every sonographer. Despite the fact that 100% of the sonographers in our study indicated a daily increase in discomfort, as few as 26% of sonographers report their discomfort or injuries to supervisors [1]. This can create serious problems with inadequate presenteeism in the workforce, proving costly to employers [11].

To better understand the relative impact of discomfort on productivity, a continued investigation of the inter-relationship of the various predisposing, precipitating and perpetuating factors is needed. Hill, Slade and Russi [5] gathered anthropometric measures and psychological reports of job strain, to evaluate the association of these predisposing factors to musculoskeletal injuries. Based on this previous study, musculoskeletal disorders were less likely to occur in sonographers who were physically larger, had more favorable job strain scores, and spent less time standing. The authors concluded that increased body size might have a protective effect against the development of musculoskeletal disorders [5]. In contrast, the results of our study indicate that increased sonographer height may in fact be associated with increased poor positioning. However, height did not appear to contribute to differences in reports of discomfort, nor did it contribute to variability in positioning among the different examinations performed by our participants. Therefore, while important, the relationship of these predisposing factors requires further investigation as to how they may contribute to changes in perpetuating factors that may in fact be more directly related to increased discomfort and musculoskeletal injury.

Consideration of the work environment and equipment design is an additional factor that requires consideration. Portable examinations, i.e., taking the sonography equipment to the patient, have been linked with increased incidence of musculoskeletal disorders [14]. However, no significant differences were noted in exam efficiency when portable sonographic examinations were completed with laptop-style ultrasound scanners (compact, lightweight) versus conventional mobile ultrasound scanners (full-size ultrasound machine on wheels) [15]. This smaller equipment may lead to less physical strain on the individual during transport and although it may be more easily positioned in a crowded hospital room, if the sonographers maintain the poor positioning while completing examinations, this more mobile equipment may still be associated with musculoskeletal symptoms. In our study, all participants used adjustable height examination beds, yet the bed height continued to be associated with poor positioning. When individuals are known to be scanning in pain, they are willing to learn new techniques, such as training in ambidextrous scanning [16]; however, it is not clear that sonographers are willing to alter their positions and/or work environment prior to experiencing career threatening symptoms.

Since this was a pilot study, resources were not available to enhance the design; therefore, the interpretation of the data is limited due to the inability to follow one study participant and observe postures throughout an entire workday. Reports of pain based on visual analogue scale scores should be interpreted cautiously as these reports were collected at the beginning and at the end of the workday. Therefore, it cannot be implied that a single exam score contributed to a certain level of discomfort because all components of the participants' workday were not measured. Similarly, because the RULA scores are due to a combination of positions across multiple joints, the results of this study are not able to isolate the specific influence of improper positioning of one joint from another as it relates to discomfort ratings. It is further acknowledged that this study only observed a portion of all possible sonographic evaluations. Additional study is needed to determine the relationship of positioning during other frequent sonographic evaluations (e.g. abdominal, echocardiogram).

The small sample size in this pilot study limits the ability to make broad generalizations; however, the results of the data analysis provide valuable information that suggests that more significant relationships exist that require additional study with large samples. Future studies are needed that observe postures during sonographic scanning in addition to other physical activities completed across the entire workday to better analyze the contribution of each activity to changes in discomfort. Additionally, longitudinal studies would be beneficial in better understanding the effects of work components on acute versus chronic musculoskeletal symptoms. Once the impact of positioning to musculoskeletal discomfort is better understood, interventions, sonographer education and equipment modification can be developed and tested.

5. Conclusion

This observational pilot study is only the third known objective quantitative evaluation of the impact of sonographer positioning on reports of musculoskeletal discomfort, and only the second to attempt prospective measurement over time. Sonographers participating in this study always reported an increase in musculoskeletal discomfort at the completion of their daily schedule. Sonographers performing upper extremity venous and transvaginal pelvic examinations have the most problematic postures based on observation of joint positioning. Upper extremity positioning was noted to be similar during all evaluations; but a positive relationship exists between increasingly poor upper extremity positioning and increased musculoskeletal discomfort. The development of interventions and equipment modification aimed at reducing poor positioning is warranted. Expanded cross-sectional and longitudinal studies are needed to evaluate the inter-relationship of all predisposing, precipitating, and perpetuating biopsychosocial risk factors to musculoskeletal injuries while controlling for other components of sonography work.

Acknowledgements

Shawn C. Roll was funded by the National Institutes of Health Rehabilitation Research Career Development Program Grant K12 HD055929 at the time this manuscript was prepared. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the NIH.The authors wish to thank Carolyn Sommerich, PhD for allowing the collection of these data in coordination with her on-going research.

References

[1] Evans K, Roll S, Baker J. Work-Related Musculoskeletal Disorders (WRMSD) Among Registered Diagnostic Medical Sonographers and Vascular Technologists: A Representative Sample. Journal of Diagnostic Medical Sonography. 2009;25(6):287-99.

[2] Muir M, Hrynkow P, Chase R, Boyce D, McLean D. The Nature, Cause and Extent of Occupational Musculoskeletal Injuries among Sonographers. Journal of Diagnostic Medical Sonography. 2004;20(5):317-25.

[3] Pike I, Russo A, Berkowitz J, Baker J, Lessoway VA. The Prevalence of Musculoskeletal Disorders Among Diagnostic Medical Sonograhers. Journal of Diagnostic Medical Sonography. 1997;13(5):219.

[4] Vanderpool HE, Friis EA, Smith BS, Harms KL. Prevalence of carpal tunnel syndrome and other work-related musculoskeletal problems in cardiac sonographers. J Occup Med. 1993;35(6):604-10.

[5] Hill JJ, 3rd, Slade MD, Russi MB. Anthropometric measurements, job strain and prevalence of musculoskeletal symptoms in female medical sonographersf. Work. 2009;33(2): 181-9.

[6] Brown G, Baker J. Work-Related Musculoskeletal Disorders in Sonographers. Journal of Diagnostic Medical Sonography. 2004;20(2):85-93.

[7] Evans KD, Roll SC, Li X, Sammet S. A holistic evaluation of risk factors for work-related musculoskeletal distress among asymptomatic sonographers performing neurosonology: A pilot study. Journal of Diagnostic Medical Sonography. 2010;26(2):64-78.

[8] Evans KD, Roll SC, Hutmire C, Baker JP. Factors that contribute to wrist-hand-finger discomfort in diagnostic medical sonographers and vascular technologists. Journal of Diagnostic Medical Sonography. 2010;26(3):121-9.

[9] Roll SC, Evans KD, Hutmire CD, Baker JP. An analysis of occupational factors related to shoulder discomfort in diagnostic medical sonographers and vascular technologists. Work. 2012;42(3):1-12.

[10] David. Importance of sonographers reporting work-related musculoskeletal injury: a qualitative view. Journal of Diagnostic Medical Sonography. 2005;21(3):234.

[11] Campo M, Darragh AR. Work-related musculoskeletal disorders are associated with impaired presenteeism in allied health care professionals. J Occup Environ Med. 2012;54(1):64-70.

[12] McAtamney L, Nigel Corlett E. RULA: a survey method for the investigation of work-related upper limb disorders. Appl Ergon. 1993;24(2):91-9.

[13] Massaccesi M, Pagnotta A, Soccetti A, Masali M, Masiero C, Greco F. Investigation of work-related disorders in truck drivers using RULA method. Appl Ergon. 2003;34(4):303-7.

[14] Patel D, Satiani B, Mong R, Baetz L, Spiezio K. Appropriate resource utilization in portable noninvasive vascular studies:

the role of disruptive technology. Journal for Vascular Ultrasound. 2006;30(1):35-8.
[15] Pawaskar M, Balkrishnan R, Kiser D, Gray M, Satiani B. Work flow analysis: evaluation of conventional mobile versus portable ultrasound scanners in the noninvasive vascular laboratory. Journal for Vascular Ultrasound. 2008;32(2):85-8.
[16] Seto E, Biclar L. Ambidextrous Sonographic Scanning to Reduce Sonographer Repetitive Strain Injury. Journal of Diagnostic Medical Sonography. 2008;24(3):127-35.