Journal of Diagnostic Medical Sonography
2024, Vol. 40(1) 4–18

DOI: 10.1177/87564793231205612
journals.sagepub.com/home/jdm
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Work-Related Musculoskeletal Disorders and Associated Work Systems Factors: Are There Differences Between Sonography Practice Areas?

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Abstract

Objective: Explore the differing associations of Sonography Work Systems (SWS) model factors with work-related discomfort outcomes among sonographers in four sonographic practice areas.

Materials and Methods: Survey data from a national cross-disciplinary cohort of sonographers was analyzed to explore experiences of work factors and work-related discomfort in sonographers across four practice areas: abdominal (ABD+), adult echocardiography (Echo), obstetrics/gynecology (OB/GYN), and vascular technology (VT). One-way analyses of variance (ANOVAs) and chi-square tests were conducted on SWS factors and work-related discomfort to examine differences across practice area groups. Associative analyses were conducted between upper extremity musculoskeletal discomfort and hand used during sonography examinations. For each practice group, regression analyses examined associations of SWS factors with work-related discomfort (i.e., musculoskeletal and visual discomfort, headaches).

Results: 2924 survey respondents (n = 1747 ABD+, n = 519 Echo, n = 351 VT, and n = 307 OB/GYN) were identified. Descriptive differences were identified in SWS factors and discomfort across practice area groups. Significant differences were noted in distribution of upper extremity pain compared with the hand used to complete sonography examinations ($P < .001$).

Conclusion: This study identified multiple organizational, tool, and process factors commonly associated with discomfort across specialties, which underscores the need for multidimensional approaches to worker health that include effective administrative and engineering controls.

Keywords

Occupational health, sonography, and worker health

Users of sonography perform many diagnostic examinations every day, sometimes under less-than-ideal conditions. As a result, among sonographers, echocardiographers, and vascular technologists, there is a substantial risk of work-related musculoskeletal disorders (WRMSD), especially in the shoulder, neck, wrist, and hands.[1] Prevalence of WRMSD has been at a substantially high level for more than two decades, affecting from 60% to 90% of sonographers, as well as other users, based on responses to surveys in the United States,[2,3] Canada,[4,5] and Europe.[6,7]

Several risk factors have been associated with the development of WRMSD among those who use sonography. The literature primarily identifies awkward work

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Received June 16, 2023, and accepted for publication September 18, 2023.

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postures, lack of incorporation of ergonomics design principles in the work environment, and physical layout of examination equipment as critical risk factors contributing to the development of WRMSD.[8,9] In addition, the length and number of examinations have long been a concern related to the health and well-being of sonographers.[10] In addition to physical strain, psychosocial stressors in the workplace, including lack of control over workflow and low support from management, have been associated with burnout, anxiety, and WRMSD in sonographers.[11] Beyond these traditional foci, additional holistic factors, such as failing to accommodate the diversity of workers' abilities and experiences, are important considerations for the well-being of all workers, not just sonographers.[12]

The WRMSD Grand Challenge Alliance, composed of representatives from the leading professional societies and accrediting agencies within the sonography and medical imaging fields, was convened to eliminate WRMSD among all users of sonography. Multiple initiatives have been associated with the Grand Challenge, including the development of a research registry of ultrasonography users to explore, through longitudinal data collection, how work contexts affect workers' health and well-being outcomes. A general description of the entire cohort of sonographers, echocardiographers, and vascular technologists, an analysis of the prevalence of WRMSD, and associated risk factors across the entire cohort have been reported.[3]

Although general information across all sonographers, echocardiographers, and vascular technologists provides a useful snapshot of the status of worker health and well-being, adequately addressing WRMSD also requires considering how work factors and processes unique to different sonographic practice areas impact workers within those settings. For example, an outpatient can be sonographically examined in a designated imaging suite with ergonomically designed equipment, whereas bedside sonographic examinations are often conducted in acute settings and involve restricted transducer positioning due to the limited space at the patient's bedside.[13] To this end, data analyses reported in this article are focused on differentiating the experiences of, and factors associated with, work-related physical discomfort among sonographers, echocardiographers, and vascular technologists who work within one of the four common sonographic practice areas: abdominal (radiology), echocardiography, obstetrics/gynecology, and vascular technology.

Materials and Methods

Data were obtained using survey methods as part of a longitudinal data collection effort that has engaged a cross-disciplinary cohort of those who use ultrasonography in their work. The project was reviewed and approved by the host university's Institutional Review Board (IRB# 2021B0113). Participants were initially recruited via emails to Grand Challenge Alliance members who chose to receive email notifications from the organizations. Two screening questions were used to identify respondents who met the inclusion criteria of working in a job requiring ultrasonography in the United States or Canada. To be included, respondents had to provide a job title and contact information for longitudinal follow-up. A detailed description of all questions included in the survey and analyses of findings across the full cohort of 3659 participants has been published elsewhere.[3] Data analyses reported in this manuscript include associations among work systems factors and work-related discomfort among respondents working in one of the four sonographic practice areas: abdominal (ABD), adult echocardiography (Echo), obstetrics/gynecology (OB/GYN), and vascular technology (VT).

Data Collection

After participants reviewed an electronic consent form, responses were gathered from anyone who volunteered to provide information using a questionnaire available through Qualtrics from June 8 to 28, 2021. The questionnaire consisted of close-ended questions aimed at understanding associations among the components of the Sonography Work Systems (SWS) model[3] and work-related discomfort. Personal characteristics obtained from respondents included gender, racial and ethnic identities, age, height and weight, work status, sonography-related credentials, history of ergonomics training, and geographical location. Workplace settings (i.e., hospital, outpatient clinic/lab, physician's office, urgent care, education setting, or other workplaces) and sonographic practice areas were collected using multiselection questions.

Participants also responded to general questions across other work system components, including using adjustable equipment/spaces and taking breaks. In addition, implementation of seven common ergonomic policies/procedures in the workplace by employer/medical practice (written policies to follow proper ergonomic principles, monitoring whether employees follow proper ergonomic principles, performance of detailed ergonomic assessments to ensure sonography equipment/work environment are safe, limited portable/bedside exams to reduce staffs' physical exposure, support of other reasonable accommodations based on patient considerations, equipment with exam-specific features, and implementation of task/exam rotations among employees) were assessed. Five questions on workplace culture and one question on trust in management were adapted from the WellBQ questionnaire. Two work process factors of

interrupted workflow timing/pacing and the hand(s) used to hold the transducer (i.e., left, right, or both) and one work outcomes factor of work pressure and performance were also investigated. Work-related discomfort outcomes included experiencing musculoskeletal discomfort, visual discomfort, or headaches directly attributed to work in the past 12 months and a series of questions regarding experiences of musculoskeletal discomfort across nine body regions.

Data Analyses

Among the 3659 study participants, 1177 reported working exclusively in one area: Echo, OB/GYN, or VT. Participants who identified one of these three practice areas as their singular area of practice were included in the analyses as part of their respective practice groups. Conversely, although abdominal imaging was one of the most frequently selected imaging tasks, respondents rarely identified abdominal as an exclusive practice area. Thus, any respondent who selected ABD as a practice area, regardless of other selections, was identified as a general sonographer and included in the ABD+ practice area for all analyses.

Various descriptive and associational analyses were completed. Differences in SWS factors and work-related discomfort outcomes among the four sonographic practice groups were examined using one-way analyses of variance (ANOVAs) for all continuous independent variables and chi-square tests for nominal categorical variables. Additional associative analyses and chi-square tests were conducted between the location of musculoskeletal discomfort (e.g., body region and laterality) and the hand(s) used to hold the transducer for exam completion. Further chi-square tests were conducted to examine differences in the distribution of hand(s) used to complete sonograms (e.g., left hand, right hand, or both hands) and laterality of pain (e.g., no pain, left-sided pain, right-sided pain, or bilateral pain). Histograms were created to visualize the distribution of upper extremity 7-day pain laterality by hand(s) used to complete sonograms for each of the four practice groups. These detailed data analyses were focused on areas with the highest prevalence of work-related discomfort and injury among ultrasonography users (i.e., neck and upper extremity).

Logistic regression analyses examined associations of all SWS factors with the three work-related discomfort outcomes (i.e., musculoskeletal, visual, and headaches) across the four sonographic practice groups. First, individual associations were calculated for each SWS variable with the discomfort outcomes by sonographic practice area, both as a primary association and interactions among the practice areas. The variables of using adjustable equipment, taking breaks, and interrupted workflow were measured as a percentage of the time (i.e., 0%–100%) and were divided by 10 to model changes for every 10% of the time rather than 1%. Due to the multitude of tests, the significance for individual models was set at $P < .01$ to minimize the risk of type II error. No statistically significant interactions were identified between the practice areas and individual variables, but differences were noted between practice areas in the main effects of significance for the individual SWS factors. Therefore, individual multivariable logistic models were created for each discomfort outcome by practice area (i.e., three outcomes by four practice areas resulted in 12 models). Each model was built using the SWS variables with significant odds ratios at a $P < .05$ level in the individual modeling of variables by practice area. Any variable with an odds ratio at $P < .05$ within these final multivariable models was identified as a critical factor, where odds ratios >1.0 indicated the variable was related to *experiencing* work-related discomfort, and odds ratios <1.0 indicated an association with *not experiencing* discomfort.

Results

Descriptive Characteristics of Primary Practice Groups

Of the 3659 survey respondents, 2924 either selected abdominal or indicated exclusively working in one of the three other primary sonographic practice areas. ABD+ sonographers represented 59.7% of the sample (n = 1747), followed by individuals working exclusively in Echo (17.7%; n = 519), VT (12.0%; n = 351), and OB/GYN (10.5%; n = 307). RDMS was the most common credential among ABD+ sonographers (96.1%; n = 1679), followed by RVT (60.8%; n = 1062) and RDCS (14.6%; n = 255). RDMS and RVT were also the primary credentials within the OB/GYN group at 97.7% (n = 300) and 13.0% (n = 40), respectively. Fewer vascular technologists or cardiac sonographers indicated having an RDMS credential (i.e., 19.9% and 8.9%, respectively); instead, 96.7% of the adult cardiac group had an RDCS and/or RCS, and 91.2% of the vascular sonographers had an RVT credential. No other credentials were reported by more than 8% of respondents within any of the four practice groups.

Few differences were noted in demographics among the four sonographic practice groups (Table 1). Most respondents in each group were female (87%–89%), white (83%–89%), non-Hispanic (85%–89%), and right-handed (86%–90%). Although statistically different, the differences in age, height, and weight were small and not considered to be meaningful. The geographical distributions of the respondents varied slightly among the groups. ABD+

Table 1. Sonography Work Systems Factors (Mean [SD] or Frequency [%]) Compared Among Four Primary Practice Groups.

	ABD+ (N = 1747)	Echo (N = 519)	OB/GYN (N = 307)	VT (N = 351)	*P*-value[a]
Age, years	47.9 (11.8)	49.0 (11.7)	51.3 (10.7)	49.3 (11.3)	**<.001**
Height, inches	65.1 (3.3)	65.5 (3.6)	64.7 (2.6)	65.6 (3.6)	**<.001**
Weight, pounds	166.0 (37.9)	170.7 (40.7)	162.0 (33.0)	174.9 (43.0)	**<.001**
Body mass index	27.5 (5.9)	27.9 (6.2)	27.3 (5.5)	28.5 (6.5)	**.028**
Gender					.936
Female	1544 (88.4%)	457 (88.1%)	274 (89.3%)	305 (86.7%)	
Male	190 (10.9%)	58 (11.2%)	31 (10.1%)	45 (12.8%)	
Nonbinary	2 (0.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Prefer not to say	11 (0.6%)	4 (0.8%)	2 (0.7%)	1 (0.3%)	
Race					.088
American Indian/Alaska Native	6 (0.3%)	5 (1.0%)	1 (0.3%)	1 (0.3%)	
Asian	50 (2.9%)	10 (1.9%)	7 (2.3%)	6 (1.7%)	
Black	53 (3.0%)	8 (1.5%)	5 (1.6%)	5 (1.4%)	
Hawaiian	1 (0.1%)	0 (0.0%)	0 (0.0%)	1 (0.3%)	
White	1454 (83.2%)	457 (88.1%)	264 (86.0%)	312 (88.9%)	
Other	28 (1.6%)	10 (1.9%)	4 (1.3%)	3 (0.9%)	
Two or more	34 (1.9%)	5 (1.0%)	10 (3.3%)	6 (1.7%)	
Prefer not to say	121 (6.9%)	24 (4.6%)	16 (5.2%)	17 (4.8%)	
Ethnicity					.081
Hispanic	97 (5.6%)	22 (4.2%)	24 (7.8%)	15 (4.3%)	
Not Hispanic	1485 (85.0%)	463 (89.2%)	261 (85.0%)	307 (87.5%)	
Prefer not to say	165 (9.4%)	34 (6.6%)	22 (7.2%)	29 (8.3%)	
Handedness					.220
Left	160 (9.2%)	37 (7.1%)	21 (6.8%)	39 (11.1%)	
Right	1506 (86.4%)	456 (88.0%)	275 (89.6%)	302 (86.0%)	
Ambidextrous	77 (4.4%)	25 (4.8%)	11 (3.6%)	10 (2.9%)	
Ergonomic training, yes	946 (54.2%)	290 (55.9%)	164 (53.4%)	187 (53.3%)	.855
Work status					**<.001**
Full time	1365 (78.1%)	431 (83.0%)	213 (69.4%)	307 (87.5%)	
Part time	244 (14.0%)	64 (12.3%)	64 (20.9%)	36 (10.3%)	
Other	138 (7.9%)	24 (4.6%)	30 (9.8%)	8 (2.3%)	
Work region					**<.001**
Canada	87 (5.2%)	28 (5.9%)	3 (1.0%)	9 (2.7%)	
US Midwest	410 (24.7%)	147 (30.9%)	83 (28.0%)	98 (29.3%)	
US Northeast	273 (16.5%)	93 (19.5%)	45 (15.2%)	72 (21.5%)	
US South	538 (32.4%)	146 (30.7%)	120 (40.5%)	117 (34.9%)	
US West	351 (21.2%)	62 (13.0%)	45 (15.2%)	39 (11.6%)	
Workplace setting					
Hospital	1083 (62.0%)	344 (66.3%)	76 (24.8%)	182 (51.9%)	**<.001**
Outpatient clinic/lab	801 (45.9%)	236 (45.5%)	109 (35.5%)	185 (52.7%)	**<.001**
Physician's office	225 (12.9%)	118 (22.7%)	164 (53.4%)	106 (30.2%)	**<.001**
Educational setting	176 (10.1%)	29 (5.6%)	8 (2.6%)	14 (4.0%)	**<.001**
Tools, organizational factors, and work processes					
Ergonomic policies/procedures, [0–7][b]	2.0 (1.8)	2.0 (1.8)	1.8 (1.6)	2.0 (1.8)	.457
Positive work culture, [1–4][c]	2.9 (0.8)	2.9 (0.8)	2.9 (0.7)	2.9 (0.7)	.843
Trust in management, [1–4][c]	2.6 (1.0)	2.7 (1.0)	2.6 (0.9)	2.6 (1.0)	.463
Taking work breaks, [0%–100%]	64.9 (27.6)	66.0 (26.6)	63.5 (28.5)	66.7 (28.1)	.4760
Using adjustable equipment, [0%–100%]	73.5 (20.8)	75.5 (20.2)	73.6 (22.9)	73.5 (21.4)	.273
Interrupted workflow timing/pacing, [0%–100%]	46.6 (24.7)	46.4 (23.3)	47.2 (25.1)	46.4 (25.1)	.976

(continued)

Table 1. (continued)

	ABD+ (N = 1747)	Echo (N = 519)	OB/GYN (N = 307)	VT (N = 351)	*P*-value[a]
Transducer hand					**.032**
Left	312 (17.9%)	123 (23.8%)	59 (19.3%)	76 (21.7%)	
Right	1191 (68.5%)	330 (63.8%)	205 (67.0%)	216 (61.5%)	
Ambidextrous	237 (13.6%)	64 (12.4%)	42 (13.7%)	59 (16.8%)	
Outcomes					
Work pressure and performance, [0%–100%]	45.1 (26.1)	45.5 (25.5)	45.9 (25.4)	42.8 (27.0)	.505
Work-related musculoskeletal discomfort, yes	1505 (86.2%)	455 (87.7%)	266 (86.6%)	298 (84.9%)	.689
Work-related visual discomfort, yes	789 (45.2%)	237 (45.8%)	138 (45.1%)	142 (40.5%)	.398
Work-related headaches, yes	685 (39.2%)	216 (41.6%)	136 (44.3%)	135 (38.5%)	.297

Sonographic practice groups are noted as ABD+, Echo, OB/GYN, and VT. *P*-values in bold font indicate factors that had a statically significant differnece among the four practice groups ($P < .05$).

Abbreviations: ABD+, Abdominal; Echo, Adult Echocardiography; OB/GYN, Obstetrics/Gynecology; VT, Vascular Technology.

[a]*P*-values from analysis of variance (ANOVA) or chi-squared test based on data type.

[b]Count of ergonomic and worker health policies and procedures in place at employer of seven possible.

[c]Higher scores (i.e., 4) indicate stronger agreement that the organization has a positive work culture and respondents have a higher trust in management.

sonographers had a slightly higher percentage of individuals from the West (21.2%) compared with others (11.6%–15.2%) and a lower percentage of individuals from the Midwest (24.7%) compared with others (28%–30.9%). The Northeast was represented by a larger percentage of respondents among Echo (19.5%) and VT (21.5%) compared with ABD+ (16.5%) and OB/GYN (15.2%), while the South accounted for a slightly higher percentage of respondents within OB/GYN (40.5%) than other practice areas (30.7%–34.9%). The majority of respondents across all four sonographic practice groups were full-time employees (>69%); however, the OB/GYN group had a higher distribution of workers in part-time positions (21%; n = 64), while Echo and VT had relatively smaller percentages of respondents indicating other work statuses (e.g., per diem, travel, and contract; $P < .01$). Finally, differences were noted in workplace settings ($P < .01$), whereby OB/GYN sonographers primarily reported working in physician's offices compared with respondents in the other groups working primarily in hospitals (52%–62%) or outpatient clinics (46%–53%).

Among the work system, process, and outcome factors, the transducer hand was the only variable that differed between the sonographic practice groups ($P = .032$). Across all groups, the right hand was most frequently used to hold the transducer (61.6%–68.5%), and ambidextrous scanning was least reported; however, a higher percentage in Echo reported using their left hand (23.8%; n = 123) than did other groups (17.9%–21.7%), and VT more frequently reported using both hands to hold the transducer (16.8%; n = 59) than did other groups (12.4%–13.7%). Across all groups, approximately half of the respondents had previously received sonography-related ergonomics training (53.3%–55.9%). Respondents in all groups reported using adjustable equipment in the workplace approximately three-fourths of the time within the 7 days preceding the survey (73.5%–75.5%), taking regular work breaks two-thirds of the time (63.5%–66.7%), experiencing interruptions to workflow timing and pacing almost half of the time (46.6%–47.2%), and experiencing negative work pressure and performance slightly less than half of the time (42.8%–45.9%). Ergonomic policies and procedures were implemented in the workplace at similar rates, with approximately two out of seven common policies and procedures implemented by employers in each practice area, and all work cultures were rated as generally positive with moderate perceptions of trust in management.

Work-Related Discomfort

There were no differences among the practice areas in the frequency of individuals that reported experiencing work-related musculoskeletal discomfort (84.9%–87.7%), visual discomfort (40.5%–45.7%), and headaches (38.5%–44.3%) within the prior 12 months. Similarly, no statistically significant differences were observed among the four practice areas in the frequencies of individuals experiencing musculoskeletal discomfort within the past 7 days across all body regions (Figure 1). The highest prevalence of discomfort was in the shoulders (71.1%–72.6%), followed by the neck (59.8%–61.9%) and wrist/hand (57.2%–60.4%). Fewer than 30% of respondents across all practice areas reported discomfort in the lower extremity regions in the past 7 days.

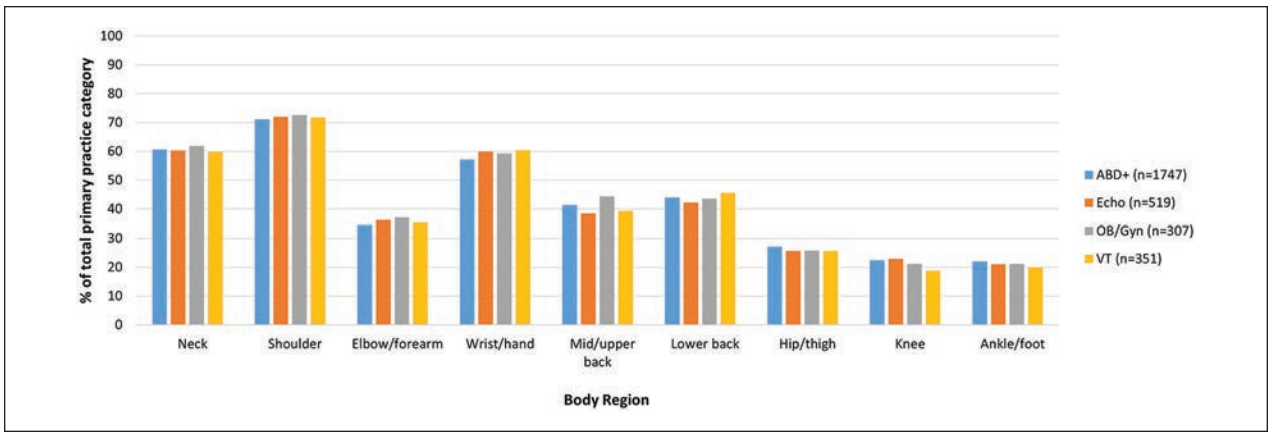

Figure 1. Seven-day prevalence of musculoskeletal discomfort in each body region by primary practice group. Sonographic practice groups are noted as ABD+, Echo, OB/GYN, and VT. ABD+, Abdominal; Echo, Adult Echocardiography; OB/GYN, Obstetrics/Gynecology; VT, Vascular Technology.

Scanning Hand and Location of Work-Related Discomfort

When comparing the hand(s) used to hold the ultrasound transducer during exam performance to the laterality of musculoskeletal discomfort across the shoulder, elbow, and wrist, there were statistically significant differences in the distribution of pain laterality when compared with the hand used to complete an examination ($P < .001$). Reports of discomfort in the past 7 days in the shoulder, elbow, and wrist were higher on the ipsilateral side of the hand used to hold the transducer when completing sonograms (Table 2). Sonographers using their left hand experienced relatively low rates of right-sided upper extremity discomfort (3.7%–8.8%) and higher rates of left-sided discomfort (22.5%–37.4%). Similarly, sonographers who used their right hand experienced low rates of left-sided discomfort (2.8%–6.5%) and higher rates of right-sided discomfort (26.3%–43.6%). The higher distribution of pain on the ipsilateral side of the hand used to complete a sonogram was consistent across all four primary practice groups in all three upper extremity regions of the shoulder, elbow, and wrist (Figure 2). Reports of shoulder discomfort were most common in sonographers who completed examinations left-handed. Sonographers who used both hands to complete sonograms had a similar overall prevalence of musculoskeletal discomfort as individuals who used either the right or left hand only to hold the transducer; these respondents who scanned using both hands most commonly reported right-sided and bilateral pain across all upper extremity regions.

Factors Associated With Work-Related Discomfort by Primary Practice Area

Results of the multivariable models to identify SWS factors significantly associated with experiencing musculoskeletal discomfort, visual discomfort, and headache among respondents within each practice area are presented in Tables 3 to 5. Individual multivariable logistic regression was conducted for each primary practice group, for each of the three work-related discomfort outcomes. The following paragraphs summarize the key findings of these regression models for each practice specialization.

ABD+ group. The ABD+ group had the most factors significantly associated with experiencing work-related discomfort. Among ABD+ sonographers, after adjusting for each of the other factors in the model (which prefaces the presentation of each significant factor), being female was associated with an up to 2.3 times higher likelihood of experiencing discomfort ($P < .05$). Identifying as white was associated with 80% higher odds of experiencing musculoskeletal discomfort than those who did not identify as white ($P = .011$). Two work processes were also associated with experiencing work-related discomfort among ABD+ sonographers. First, a higher percentage of time experiencing interruptions to workflow timing and pacing in the last 7 days was associated with an increased likelihood of experiencing discomfort across all three outcomes ($P < .01$). Second, compared with ABD+ sonographers who only use their right hand to hold the transducer when conducting sonograms, using only the left hand was associated with an 11% increase in the odds of reporting experiencing visual discomfort ($P = .005$). Two organizational factors were found to be protective for ABD+ sonographers. First, the implementation of more ergonomic policies and procedures reduced the odds of reporting experiencing musculoskeletal discomfort by 13% for each additional policy/procedure ($P = .002$), and second, each 10% increase in the percentage of time taking work breaks was protective of visual discomfort (odds ratio [OR] 0.92, 95% confidence interval

Table 2. Comparison of the Distribution of Laterality of 7-Day Musculoskeletal Discomfort in Upper Extremities and Handedness During Ultrasound Sonography Task (Frequency [%]).

Body part	Left-handed	Right-handed	Ambidextrous	Total	*P*-value[a]
Shoulder					**<.001**
No pain	134 (23.6%)	570 (29.4%)	123 (30.6%)	827 (28.4%)	
Left	213 (37.4%)	126 (6.5%)	58 (14.4%)	397 (13.7%)	
Right	50 (8.8%)	844 (43.6%)	112 (27.9%)	1006 (34.6%)	
Bilateral	172 (30.2%)	398 (20.5%)	109 (27.1%)	679 (23.3%)	
Elbow					**<.001**
No pain	375 (65.8%)	1250 (64.4%)	262 (65.5%)	1887 (64.8%)	
Left	128 (22.5%)	55 (2.8%)	30 (7.5%)	213 (7.3%)	
Right	21 (3.7%)	510 (26.3%)	62 (15.5%)	593 (20.4%)	
Bilateral	46 (8.1%)	126 (6.5%)	46 (11.5%)	218 (7.5%)	
Wrist					**<.001**
No pain	230 (40.4%)	804 (41.4%)	180 (44.8%)	1214 (41.7%)	
Left	193 (33.9%)	70 (3.6%)	48 (11.9%)	311 (10.7%)	
Right	29 (5.1%)	753 (38.8%)	67 (16.7%)	849 (29.6%)	
Bilateral	117 (20.6%)	314 (16.2%)	107 (26.6%)	538 (18.5%)	

[a]*P*-values from chi-squared test.

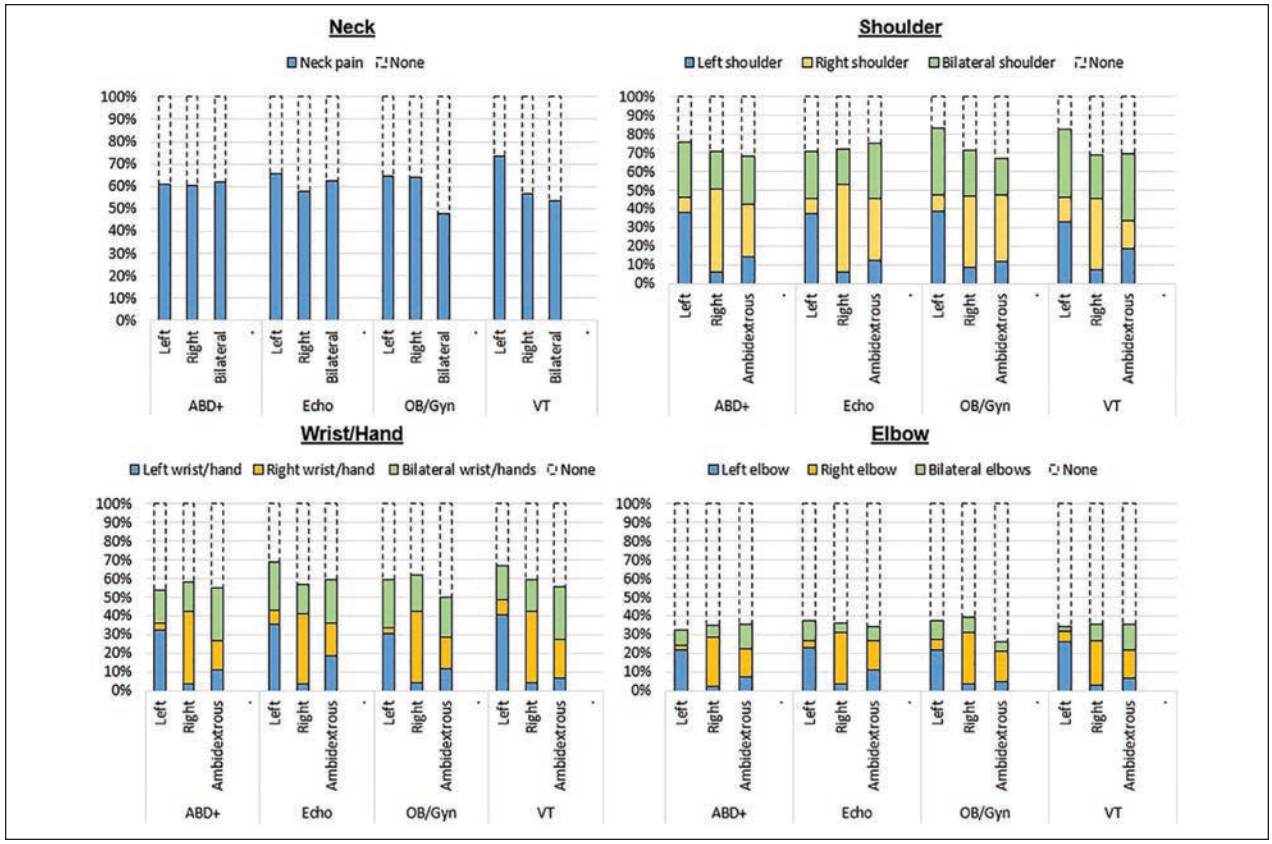

Figure 2. Neck and upper extremity 7-day pain prevalence for left, right, and ambidextrous ultrasound scanners by primary practice group by the hand(s) used to scan. Sonographic practice groups are noted as ABD+, Echo, OB/GYN, and VT. The three bars within each practice group indicate the hand(s) used to complete scans. The colors within each bar indicate the percentage of respondents reporting no pain or pain within the left, right, or both sides for each body region. Examples to aid in graph interpretation: The first bar in the upper left graph indicates that the prevalence of neck discomfort in Abdominal+ sonographers who scan left-handed is 61%; In the upper right graph, the first bar indicates that Abdominal+ sonographers who scan left-handed have a prevalence of 39% for left shoulder pain, 8% for right shoulder pain, 30% bilateral shoulder pain, and 23% for no shoulder pain. ABD+, Abdominal; Echo, Adult Echocardiography; OB/GYN, Obstetrics/Gynecology; VT, Vascular Technology.

Table 3. Odds Ratios of Reporting Experiencing Work-Related Musculoskeletal Discomfort Across Work System and Work Process Factors by Primary Practice Group.

	ABD+ (n = 1341)		Echo (n = 454)		OB/GYN (n = 249)		VT (n = 311)	
	OR [95% CI]	*P*-value	OR [95% CI]	*P*-value	OR [95% CI]	*P*-value	OR [95% CI]	*P*-value
Work systems								
Person								
Gender, female (ref: not female)	**2.34 [1.54–3.52]**	**<.001**	**4.05 [2.01–8.16]**	**<.001**	—	—	**3.39 [1.51–7.62]**	**.003**
Race, white (ref: non-white)	**1.83 [1.15–2.91]**	**.011**	—	—	—	—	—	—
Ergonomics training, yes	—	—	—	—	—	—	**2.27 [1.13–4.57]**	**.022**
Organization								
Ergonomic policies/procedures, [0–7][a]	**0.87 [0.79–0.95]**	**.002**	0.92 [0.78–1.09]	.314	0.97 [0.74–1.28]	.83	**0.79 [0.63–0.98]**	**.032**
Work culture, (1[negative]–4[positive])[b]	0.76 [0.53–1.12]	.172	0.81 [0.43–1.53]	.513	1.08 [0.40–2.93]	.879	0.77 [0.45–1.32]	.334
Trust in management, (1[low]–4(high))[b]	0.92 [0.69–1.23]	.584	0.73 [0.44–1.21]	.218	0.78 [0.37–1.64]	.51	—	—
Taking work breaks, % of time[c]	0.95 [0.88–1.02]	.126	0.94 [0.82–1.07]	.325	0.87 [0.74–1.04]	.12	—	—
Tools								
Using adjustable equipment, % of time[c]	**0.86 [0.78–0.96]**	**.006**	0.89 [0.74–1.07]	.222	**0.68 [0.50–0.91]**	**.011**	0.93 [0.76–1.14]	.486
Work processes								
Interrupted workflow timing/pacing, % of time[c]	**1.13 [1.05–1.21]**	**<.001**	—	—	1.14 [0.97–1.34]	.123	**1.22 [1.05–1.41]**	**.010**

Sonographic practice groups are noted as ABD+, Echo, OB/GYN, and VT. Individual logistic regression models were conducted using valid responses among the predictors within each factor for each of the three work-related discomfort outcomes. Significant predictors ($P < .05$) are indicated in bold font. Odds > 1.00 indicate increased likelihood (risk) and odds < 1.00 indicate decreased likelihood (protection) against experiencing work-related discomfort.

Abbreviations: ABD+, Abdominal; CI, confidence interval; Echo, Adult Echocardiography; OB/GYN, Obstetrics/Gynecology; OR, odds ratio; VT, Vascular Technology.

[a]Count of ergonomic and worker health policies and procedures in place at employer of seven possible.

[b]Higher scores (i.e., 4) indicate stronger agreement that the organization has a positive work culture and respondents have more trust in management.

[c]Average factor scores rated as 0% to 100% of the time across the last 7 days, divided by 10 to represent odds based on a factor change of 10%.

Table 4. Odds Ratios of Reporting Experiencing Work-Related Visual Discomfort Across Work System and Work Process Factors by Primary Practice Group.

	ABD+ (n = 1391)		Echo (n = 426)		OB/GYN (n = 233)		VT (n = 290)	
	OR [95% CI]	*P*-value	OR [95% CI]	*P*-value	OR [95% CI]	*P*-value	OR [95% CI]	*P*-value
Work Systems								
Person								
Age, years	—	—	—	—	**0.97 [0.94–0.99]**	**.019**	—	—
Body mass index	0.98 [0.96–1.00]	.066	—	—	—	—	—	—
Gender, female (ref: not female)	**1.59 [1.10–2.30]**	**.013**	—	—	—	—	—	—
Race, white (ref: non-white)	—	—	—	—	0.50 [0.20–1.26]	.141	—	—
Ergonomics training, yes	—	—	—	—	—	—	1.59 [0.97–2.63]	.068
Organization								
Ergonomic policies/procedures, [0–7][a]	0.97 [0.90–1.04]	.352	—	—	0.96 [0.78–1.18]	.707	0.94 [0.80–1.11]	.48
Work culture, (1[negative]–4[positive])[b]	0.92 [0.72–1.17]	.495	0.76 [0.51–1.14]	.189	1.09 [0.57–2.09]	.791	—	—
Trust in management, (1[low]–4(high))[b]	1.06 [0.88–1.28]	.568	1.03 [0.76–1.40]	.832	0.83 [0.52–1.33]	.432	—	—
Taking work breaks, % of time[c]	**0.92 [0.88–0.96]**	**<.001**	0.95 [0.87–1.04]	.255	0.96 [0.86–1.08]	.501	0.93 [0.85–1.03]	.177
Tools								
Using adjustable equipment, % of time[c]	**0.89 [0.84–0.95]**	**<.001**	0.93 [0.87–1.04]	.181	**0.85 [0.73–0.99]**	**.034**	0.90 [0.78–1.03]	.126
Work processes								
Interrupted workflow timing/pacing, % of time[c]	**1.11 [1.06–1.16]**	**<.001**	**1.17 [1.07–1.27]**	**<.001**	1.08 [0.96–1.21]	.193	**1.14 [1.03–1.27]**	**.012**
Transducer hand (ref: right)								
Left	**1.52 [1.13–2.03]**	**.005**	—	—	—	—	—	—
Both	1.00 [0.72–1.39]	.984	—	—	—	—	—	—

Sonographic practice groups are noted as ABD+, Echo, OB/GYN, and VT. Individual logistic regression models were conducted using valid responses among the predictors within each factor for each of the three work-related discomfort outcomes. Significant predictors ($P < .05$) are indicated in bold font. Odds > 1.00 indicate increased likelihood (risk) and odds < 1.00 indicate decreased likelihood (protection) against experiencing work-related discomfort.

Abbreviations: ABD+, Abdominal; CI, confidence interval; Echo, Adult Echocardiography; OB/GYN, Obstetrics/Gynecology; OR, odds ratio; VT, Vascular Technology.

[a]Count of ergonomic and worker health policies and procedures in place at employer of seven possible.

[b]Higher scores (i.e., 4) indicate stronger agreement that the organization has a positive work culture and respondents have more trust in management.

[c]Average factor scores rated as 0% to 100% of the time across the last 7 days, divided by 10 to represent odds based on a factor change of 10%.

Table 5. Odds Ratios of Reporting Experiencing Work-Related Headaches Across Work System and Work Process Factors by Primary Practice Group.

	ABD+ (n = 1421)		Echo (n = 423)		OB/GYN (n = 247)		VT (n = 311)	
	OR [95% CI]	*P*-value	OR [95% CI]	*P*-value	OR [95% CI]	*P*-value	OR [95% CI]	*P*-value
Work systems								
Person								
Gender, female (ref: not female)	**2.33 [1.54–3.52]**	**<.001**	1.83 [0.92–3.66]	.086	**3.60 [1.22–10.61]**	**.020**	2.18 [0.98–4.88]	.058
Ergonomics training, yes	—	—	**1.67 [1.10–2.53]**	**.016**	—	—	—	—
Organization								
Ergonomic Policies/Procedures, [0–7][a]	0.98 [0.91–1.05]	.538	0.98 [0.85–1.13]	.757	—	—	0.90 [0.76–1.07]	.234
Work Culture–(1[negative]–4(positive))[b]	0.96 [0.75–1.24]	.773	0.72 [0.48–1.09]	.12	0.96 [0.51–1.80]	.893	0.97 [0.59–1.59]	.902
Trust in Management, (1[low]–4(high))[b]	0.85 [0.70–1.03]	.094	1.15 [0.84–1.59]	.386	0.90 [0.56–1.44]	.654	0.88 [0.62–1.26]	.497
Taking Work Breaks, % of time[c]	**0.92 [0.88–0.96]**	**<.001**	0.94 [0.86–1.03]	.177	1.03 [0.92–1.15]	.625	—	—
Tools								
Using Adjustable Equipment, % of time[c]	**0.91 [0.85–0.96]**	**.002**	**0.87 [0.77–0.97]**	**.014**	**0.77 [0.66–0.89]**	**<.001**	0.92 [0.81–1.05]	.214
Work processes								
Interrupted Workflow Timing/Pacing, % of time[c]	**1.11 [1.06–1.17]**	**<.001**	**1.11 [1.02–1.22]**	**.022**	**1.19 [1.07–1.33]**	**.002**	**1.12 [1.02–1.23]**	**.022**

Sonographic practice groups are noted as ABD+, Echo, OB/GYN, and VT. Individual logistic regression models were conducted using valid responses among the predictors within each factor for each of the three work-related discomfort outcomes. Significant predictors ($P < .05$) are indicated in bold font. Odds > 1.00 indicate increased likelihood (risk) and odds < 1.00 indicate decreased likelihood (protection) against experiencing work-related discomfort. Abbreviations: ABD+, Abdominal; CI, confidence interval; Echo, Adult Echocardiography; OB/GYN, Obstetrics/Gynecology; OR, odds ratio; VT, Vascular Technology.

[a]Count of ergonomic and worker health policies and procedures in place at employer of seven possible.

[b]Higher scores (i.e., 4) indicate stronger agreement that the organization has a positive work culture and respondents have more trust in management.

[c]Average factor scores rated as 0%–100% of the time across the last 7 days, divided by 10 to represent odds based on a factor change of 10%.

[CI] [0.88, 0.96], $P < .001$) and headaches (OR 0.92, [0.88, 0.96], $P < .001$). Finally, more time using adjustable equipment reduced the likelihood of all three types of discomfort for ABD+ sonographers.

VT group. Among the VT respondents, visual discomfort and headache were only associated with one factor, while musculoskeletal discomfort was associated with several factors. An increase in interruptions to the workflow timing and pacing was associated with increased odds of visual discomfort and headache ($P < .05$), as well as increased odds of experiencing musculoskeletal discomfort. Female members of the VT group had higher odds of experiencing musculoskeletal discomfort (OR 3.39, 95% CI [1.51, 7.62], $P = .003$), and having ergonomics training was uniquely associated with increased odds of reporting experiencing musculoskeletal discomfort in this group (OR 2.27, 95% CI [1.13, 4.57], $P = .022$). Like the ABD+ group, working for an employer with more ergonomic policies and procedures reduced the likelihood of experiencing work-related musculoskeletal discomfort (OR 0.79, 95% CI [0.63, 0.98], $P = .032$).

Echo group. Within the Echo respondents, the only factor associated with increased odds of reporting experiencing musculoskeletal discomfort was the female gender (OR 4.05, 95% CI [2.01, 8.16], $P < .001$). A higher percentage of time experiencing interruptions to workflow timing and pacing was the only factor associated with increased odds of reporting experiencing visual discomfort (OR 1.17, 95% CI [1.07, 1.27], $P < .001$) in this group. Experiencing workflow interruptions was associated with an increased odds of experiencing headaches (OR 1.11, 95% CI [1.02, 1.22], $P = .022$), as was having ergonomic training (OR 1.67, 95% CI [1.10, 2.53], $P = .16$). Working with adjustable equipment was associated with lower odds of headaches (OR 0.87, 95% CI [0.77, 0.97], $P = .014$). Unlike other practice groups, no organizational factors were associated with the three discomfort outcomes for cardiac sonographers.

OB/GYN group. The same was true for OB/GYN sonographers, whereby no organizational factors were significantly associated with the three discomfort outcomes. Reduced odds for all three outcomes were associated with an increased percentage of time using adjustable equipment ($P < .05$) in this group. Older OB/GYN sonographers indicated some slight visual discomfort ($P = .019$), while female sonographers had an odds of experiencing headaches that were 3.6 times those of other sonographers in the OB/GYN group ($P < .02$). As with all other practice areas, increased interruptions to workflow timing and pacing were associated with increased odds of headaches (OR 1.19, 95% CI [1.07, 1.33], $P = .002$) among OB/GYN sonographers.

Discussion

This data analysis deliberately focused on participants who self-reported working primarily in ABD+, Echo, OB/GYN, or VT. While previous studies have been completed on differing experiences of sonographic practice groups, the exclusion of multimodality sonographers was not mentioned.[14,15] The exclusion of multimodality sonographers in these analyses provides a pure estimation of associations between health outcomes and sonography work systems factors when working in a dedicated sonography discipline. Self-reported work-related musculoskeletal discomfort was highly prevalent across all the sonography practice groups in this study (85%–88%) and followed a similar distribution across all body regions across the practice areas. These rates and distributions are similar to other recent studies of musculoskeletal discomfort[16,17] and scanning in pain[18] among sonographers, echocardiographers, and vascular technologists. The prevalence of headaches (39%–44%) and visual discomfort (41%–48%) was also similar across the four areas of specialization, and all prevalence values are higher than earlier reports, which may point to an area of increasing concern worthy of further attention. Some similarities and other important differences were noted among the sonography work systems factors associated with the three types of work-related discomfort across the practice areas.

Organizational and Work Process Factors

Interruptions to workflow timing and pacing was the most frequent factor significantly associated with experiencing all three types of work-related symptoms. Across all practice specialties, interruptions occur about 46% of the time within a typical workweek, including interruptions due to exam or procedural challenges (e.g., patient habitus and equipment issues), administrative barriers (e.g., physician orders and insurance), and late patients.[3] The odds of experiencing musculoskeletal discomfort, visual symptoms, and headaches increase by 10% to 20% for each additional 10% of the time workflow is interrupted. These data suggest that a sonographer with the average amount of interruptions would be 1.5 to 2.0 times more likely to experience physical symptoms. Efforts in sonography workflow have primarily focused on improving exam efficiency through equipment features[19] and computing technologies to improve exam-specific workflow.[20,21] Limited evidence suggests that workflow management systems that consider additional facilitators and barriers beyond exam-specific factors can reduce stress

among sonographers.[22] Given the findings of the current analysis that align with other previous studies describing work process challenges,[23] identifying solutions to improve both exam and non-exam workflow is vital to support sonographers' health and well-being.

In addition to the need for more efficient exam processes, findings suggest that ergonomic policies and the effective use of work breaks are two important administrative controls at the organizational level. Specifically, sonographers within the ABD+ and VT practice areas whose employers had more ergonomic policies had a lower likelihood of experiencing musculoskeletal discomfort, and ABD+ sonographers who reported adhering to regular breaks throughout their workweek (e.g., lunch and between exams) had a lower likelihood of experiencing headaches and visual discomfort. Despite widely available recommendations,[13,24] employers across all practice areas only have two of the seven common ergonomic policies in place. Once in place, attention is also required to ensure policies are effectively implemented. Work breaks are a familiar example of fragile policy implementation, as breaks are often ignored and skipped when workloads are high or treated as optional and nice to have when the schedule permits. In addition to the direct implications of breaks for headaches and visual discomfort suggested in findings here, previous literature has demonstrated a dose-response association between the frequency of headaches and eye complaints with neck/shoulder discomfort in sonographers.[6]

Scanning Hand and Work-Related Musculoskeletal Discomfort

The statistically significant difference in the distribution of which hand or hands were used to hold the transducer across the specialization groups was small in magnitude and likely not meaningfully different. Surprisingly, the percentage of sonographers in the Echo group who scan left-handed (24%) was only slightly higher than the percentages in the other three groups (18%–22%). Across the four groups, the percentage of those who reported operating the transducer ambidextrously was 12% to 17%. Laterality of shoulder, elbow, and hand/wrist discomfort matched the scanning hand for those who reported using only the right or left hand to hold the transducer. Similarly, Barros-Gomes et al.[16] found that hand pain laterality corresponded with the scanning hand in 98% of their sonography participants.

Published evidence related to scanning hand and discomfort is highly mixed with some reports indicating no differences in discomfort associated with scanning hand use[25] and others reporting a positive effect of two-handed/alternating scanning.[6] In this study, compared with ambidextrous or right-handed scanning, left-handed scanning was associated with a higher prevalence of neck, shoulder, and hand/wrist discomfort (≥10% higher prevalence) in the VT group, wrist/hand discomfort in the Echo group, and shoulder discomfort in the OB/GYN group. Although there were musculoskeletal discomfort associations with left-handed scanning in the ABD+ group, individuals in this group who scanned with the left hand were more likely to experience visual discomfort. The proportion of individuals without pain in the upper extremity regions was similar among individuals who performed ambidextrous scanning to those who scanned left-handed and right-handed in the entire study sample. However, among OB/GYN sonographers, ambidextrous scanning was associated with lower prevalence of neck and upper extremity discomfort (≥10% lower prevalence) compared with left or right-handed scanning.

Findings in this study must be interpreted with caution due to the lower proportion of ambidextrous scanning within specialty groups compared with the use of the left and right hand, and because cross-sectional research cannot determine causality due to the lack of an unambiguous temporal relationship between factors. Prospective investigations are needed to further explore these relationships between discomfort and hand use. In particular, there may be value in examining interventions to promote ambidextrous scanning. Implementation of alternating scanning with right and left hands had been successfully reported.[26] Factors that can encourage practicing sonographers to learn to scan with their other hand include training programs, practice time with a volunteer, implementation with patients who have uncomplicated pathology or are physically easier to examine, allotting more time per exam, and providing exam rooms designed to support both left- and right-handed exams.[27]

Ergonomics Training and Adjustable Equipment

Over the last 30 years, a great emphasis has been placed on providing ergonomics training to sonographers, echocardiographers, and vascular technologists at the student and practitioner levels.[28] This emphasis on providing ergonomics training is an important and positive step to address WRMSDs. In ergonomics training, participants learn how work can produce adverse effects on their health and well-being, are encouraged to report work-related injuries and illnesses, and learn how relevant engineering controls (e.g., use of adjustable equipment) and administrative controls (e.g., rest breaks during work) can have mitigating and beneficial effects. Yet, this assertion could be questioned given the lack of a positive association between training and health outcomes and apparent associations between training and adverse health outcomes in this study. Most study participants received

sonography-related ergonomics training (53.3%–55.9%); however, their ability to practice the knowledge imparted during training may be constrained. For those who had ergonomics training, the odds of reporting MSK discomfort were greater in the VT group, and the odds of reporting headaches were greater in the Echo group. Although these data cannot be interpreted as a causal relationship between training and adverse health outcomes, individuals experiencing work-related symptoms may be more likely to seek training. Similarly, training participation can improve recognition of the connection between work and symptoms and therefore be associated with increased reporting of health outcomes.[29,30]

Alarmingly, as noted previously, only two of the seven common policies and procedures related to ergonomics are implemented in the work environments of the study participants. Raising awareness is only one objective of ergonomics training, with the most important goal being the application of training in practice to have the intended effect of reducing the risk of WRMSDs and increasing worker well-being. Alexander and Orr wrote about success factors and common flaws that impact ergonomics programs, including the need for training accompanied by supportive infrastructure and timely accommodation of ergonomic problems before employees stop seeking solutions.[30] In their investigation of the effectiveness of health and safety training for young workers, Laberge et al.[31] illustrate the importance of offsetting constraints with resources to influence work activities and work system outcomes that include worker health and their work products, which can be applied to all workers.

One example of resources that can positively affect worker health and work products is the availability and use of adjustable equipment. The reported use of adjustable equipment approximately three-fourths of the time by respondents in this sample is promising, particularly when noting that increased use was associated with a lower likelihood of experiencing musculoskeletal discomfort, visual discomfort, and headaches among sonographers in multiple specialties. However, those resources can be offset by other organizational and process constraints, such as interruptions to workflow timing and pacing and limited ergonomics policies and procedures. Workplace productivity demands on sonographers, echocardiographers, and vascular technologists can create the need for shortcuts and workarounds, which are not commensurate with the proper practice of ergonomics. Training has a documented effect on worker behaviors, and providing sufficient resources to offset the constraints encountered in dynamic work environments is important to a sustainable occupational injury prevention program.[31] However, as demonstrated in this study and stated in literature, training and equipment provision alone are insufficient to directly impact health outcomes.[32]

Limitations

This study was cross-sectional and based on self-reported demographic, exposure, and health information, and participants were invited through affiliations with sonography credentialing and professional organizations in the United States and Canada. Cross-sectional analyses of subjective reporting and non-random sampling strategies limit the ability to infer causation, risk over- or under-estimation of associations between the variables of interest, and limit the generalizability of the findings. While age was not statistically significant in most of our models, the survey did not include years of experience, which may have had a significant effect on work-related discomfort. In addition, we did not survey respondents on specific sonography devices or other acillary tasks, such as the use of contrast medias like Definity, and therefore we are unsure how these factors may have been associated with experiences of work-related discomfort among our participants. The large sample size provides sufficient power and increases confidence in the findings across the areas of specialization and the hand used to perform examinations. Confidence in proper group assignment to a primary practice area was increased by demonstrating that common specialty credentials aligned with the reported area of practice for each group. This analysis excluded participants who reported working in multiple areas for the Echo, OB/GYN, and VT groups, and as such, the findings may or may not apply to sonographers working in more than one area.

Conclusion

Leveraging the data from a large cohort of sonographers, this study examined the experiences of work-related discomfort in four primary practice areas. This investigation provides a degree of understanding of some of the interrelations between SWS factors and work-related discomfort in sonographers practicing in various primary practice areas. While external work factors of work tools and work processes were among the most common significant SWS factors, the degree and significance of these effects on work-related discomfort outcomes varied. Further study on the similarities and differences in SWS factors across primary practice areas is needed to understand and strategize the most effective intervention(s) for work-related discomfort. This work underscores the need to understand the value and limits to ergonomics training and recognize that training is one component of an ergonomics program that should also include other administrative controls (e.g., work practices and procedures) and engineering controls (e.g., adjustable equipment). Furthermore, to effectively address the continued risk of

acute and chronic WRMSD, employer and health system administrators need to engage with their sonographers, echocardiographers, and vascular technologists to explore and provide worker-centered and effective solutions, such as training, administrative controls affecting breaks and scheduling, and engineering controls to protect employees and their patients.

Acknowledgments

The authors thank A. Nicole Stigall-Weikle for her contributions to the development of data collection tools and the interpretation of study findings.

Ethics Approval

The project was reviewed and approved by Ohio State University's Institutional Review Board (IRB# 2021B0113).

Informed Consent

Informed consent was not sought for this study because all case data were de-identified and/or aggregated and followed ethics committee or IRB guidelines (also referred to as the Honest Broker System).

Animal Welfare

Guidelines for humane animal treatment did not apply to the present study because no animals were used.

Trial Registration

Not applicable.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Financial support for this study has been provided by the following members of the WRMSD Grand Challenge Alliance with additional financial support from Biodex, part of Mirion Technologies. The views presented in this study are the authors and do not necessarily represent those of the supporting organizations: American Institute of Ultrasound in Medicine, American Registry for Diagnostic Medical Sonography and Inteleos, American Society of Echocardiography, Intersocietal Accreditation Commission, Joint Review Committee on Education in Cardiovascular Technology, Society for Vascular Ultrasound, Society of Diagnostic Medical Sonography, and Society of Diagnostic Medical Sonography Foundation.

Peer Reviewer Guarantee Statement

The Editor/Associate Editor of JDMS is an author of this article; therefore, the peer review process was managed by alternative members of the Board and the submitting Editor/Associate Editor had no involvement in the decision-making process.

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SDMS CME Credit – Work-Related Musculoskeletal Disorders and Associated Work Systems Factors: Are There Differences Between Sonography Practice Areas?

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Article: Work-Related Musculoskeletal Disorders and Associated Work Systems Factors: Are There Differences Between Sonography Practice Areas?
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Category: Other [OT]
Credit: 1.00 SDMS CME Credit

Objectives: After studying the article, you should be able to:

- Identify the risks of work-related musculoskeletal disorders (WRDSD).
- Discuss the work-related discomfort outcomes in four sonographic practice areas.
- Recognize the value and limits of ergonomics training.

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1. Which of the following is a risk factor associated with the development of a work-related musculoskeletal disorder (WRMSD)?
   A. Skill and support when ergonomic incorporation is needed
   B. Ability to manage and control workflow
   C. Unable to incorporate ergonomic design principles in the work environment
   D. Ability to accommodate the diversity of workers

2. Although _____ imaging was one of the most frequently selected imaging tasks, respondents rarely identified this specialty as an exclusive practice area.
   A. Abdominal
   B. Echocardiography
   C. Obstetrics and Gynecology
   D. Vascular Technology

3. Which work region area represented the largest percentage of respondents among Echo (19.5%) and VT (21.5%)?
   A. US Midwest
   B. US Northeast
   C. US South
   D. US West

4. What was the percentage of the highest distribution of workers in part-time positions?
   A. 4.6%
   B. 12.3%
   C. 20.9%
   D. 83.0%

5. According to Figure 1, where was the highest prevalence of discomfort?
   A. Lower extremity
   B. Wrist
   C. Neck
   D. Shoulder

6. The odds of experiencing musculoskeletal discomfort, visual symptoms, and headaches increase by _____ for each additional 10% of the time workflow is interrupted.
   A. 10% to 20%
   B. 26% to 30%
   C. 39% to 44%
   D. 41% to 48%

7. One example of resources that can positively affect worker health and work products is _____.
   A. Dismissing the need to learn relevant engineering controls
   B. Overlooking the need to report work-related injuries and illnesses
   C. Accepting all interruptions to workflow timing
   D. The availability and use of adjustable equipment