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Neck and upper extremity pain in sonographers – Associations with occupational factors

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A B S T R A C T

Sonographers have a high risk of musculoskeletal disorders. This study explores the associations between working conditions and musculoskeletal pain based on the frequency and intensity of pain in the neck and upper extremities. A questionnaire was answered by 291 female sonographers. High prevalence of neck/shoulder pain was associated with eye complaints and headache related to work on the computer, dissatisfaction with the computer workstation, high mechanical exposure index (MEI) and high demands. The possibility to adjust the keyboard and chair, and adequately corrected eyesight were positive factors. High prevalence of elbow/hand pain was associated with performing echocardiography, computer-related eye complaints, high MEI and high job and sensory demands. In echocardiography, working with a straight wrist and holding the transducer with a two-handed grip or alternating hands was associated with a low prevalence of elbow/hand pain. Thus, further improvements in the working conditions are possible and are recommended.

1. Introduction

Many sonographers experience musculoskeletal pain and discomfort in the neck, upper limbs and back (Morton and Delf, 2008; Muir et al., 2004; Pike et al., 1997; Roll et al., 2012; Russo et al., 2002). Sonographic scanning involves static postures and precise movements of the upper limbs (Kim and Roh, 2014; Pike et al., 1997; Wihlidal and Kumar, 1997), which are well known risk factors for neck and upper limb pain (Hagberg, 1996). Furthermore, it involves considerable computer work, in itself a risk factor for pain (Tornqvist et al., 2009). The scanning usually takes place in a dark room, which may lead to eye strain (Wihlidal and Kumar, 1997). However, the extent to which visual ergonomics affects the prevalence of work-related musculoskeletal disorders (WMSDs) is not known.

Sonography yields information on composition of i.a. internal organs, muscles, blood flow and is used in several specialities, such as cardiology, obstetrics, gynecology and radiology. It provides precise information and there is very little risk of adverse events for the patient (Douglas et al., 2007; Frank et al., 2015). Sonographic examinations have become more common over the past decades (Baker and Coffin, 2013; Schoenfeld et al., 1999), with an increase in the number of examinations and hours of scanning per day for sonographers (Baker and Coffin, 2013; Russo et al., 2002). This may lead to higher prevalence of WMSDs.

Sonography of the heart (echocardiography) has become an invaluable diagnostic tool in daily cardiology practice (Badano et al., 2009; Douglas et al., 2007). Echocardiography requires high grip forces in the transducer hand due to the depth of the scanned organ (Bastian et al., 2009). Increased force in the hand grip may lead to an additionally increased risk of developing musculoskeletal disorders (Vanderpool et al., 1993). Due to the set up in the examination room, echocardiography is performed in one of a limited number of working techniques, but it is not known whether any of these is more favourable in terms of the risk of WMSDs.

The aim of this study was to explore associations between physical and psychosocial working conditions and pain in the neck, shoulders, elbows and hands, in order to propose recommendations for improved working conditions for sonographers. Special attention was paid to the working conditions in echocardiography.

2. Participants and methods

2.1. Study design and population

This cross-sectional study comprised sonographers employed in

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clinical physiology and cardiology departments in hospitals throughout Sweden. A self-administered questionnaire was sent to all sonographers in all hospital departments where biomedical scientists performed sonography (45 departments). Female sonographers who worked at least 20 h per week and performed sonography for a minimum of four hours per week since at least three months were included in the analyses (N = 291, participation rate 86%). Male sonographers (N = 28) were excluded, due to the low number of participants.

For the studied population the ultrasonic equipment consists of a screen, a keyboard or a control panel and a transducer attached to a cable. The examiner usually sits on a chair during the examination and holds the transducer in one hand. With the other hand, she operates the keyboard and at the same time she watches the screen. The patient normally lies on an adjustable table and pressure is applied with the transducer to achieve optimal contact with the skin. During vein mapping of the legs the patient usually sits or stands. The transducers are usually palm sized (Lyon et al., 1997).

The examination room is darkened and the artificial light is low to facilitate viewing the images on the screen. The results are analysed by the sonographer, either on the ultrasound machine or on a separate computer workstation. Examinations are sometimes carried out in a ward with the patient in bed (bedside examination).

This study included echocardiography and other sonographic examinations. Other examinations involved mapping of veins, abdominal aorta scanning, examination of the neck vessels and screening for hip dislocation.

The study was approved by the Regional Ethics Committee at Lund University.

2.2. Data collection

2.2.1. Personal characteristics

The questionnaire included questions on personal characteristics: age, height, body mass index (BMI), smoking habits, personal recovery time, exercise, household work, children under 15 living at home and civil status.

2.2.2. General working conditions

The questionnaire included questions on seniority as a sonographer, working hours per week, number of hours of sonography per week, types of examinations and whether bedside examinations were performed. Questions were also asked about the equipment, for example the possibility of adjusting the position of the screen, the keyboard and the chair, the use of a specially designed examination table and where the analysis and reporting were carried out. We also asked about the use of and need for glasses or contact lenses and about eye strain and headache related to computer work.

Physical workload was assessed using a mechanical exposure index (MEI) and a physical exposure index (PHYI) (Balogh et al., 2001; Östergren et al., 2005). The MEI is based on 11 items concerning awkward work postures, static workload and precise movements. The PHYI is based on 7 items concerning material handling including lifting (Balogh et al., 2001). The participants answered each item on a three-point scale 1 = "hardly anything/not at all", 2 = "somewhat" or 3 = "a great deal". The total scores were calculated for each scale (MEI: 11–33; PHYI: 7–21) for each individual. The participants were then categorized according to the level of mechanical exposure: unexposed (11–12), low (13–15), medium (16–19) and high (20–33) and for physical score: unexposed (7–8), low (9–10), medium (11–13) and high (14–21), according to the recommendation of Balogh et al. (2001). The participants were also asked about satisfaction with ergonomic conditions during computer work.

We assessed the psychosocial conditions in terms of *job demands*, *job control* and *job support* using a Swedish version of the Job Content Questionnaire (JCQ) (Karasek et al., 1998; Karasek and Theorell, 1990). Job demands, job control and job support were calculated as the means of nine, nine and eight items, respectively. Each item was assessed using a four-point scale indicating the degree of agreement with various statements concerning conditions at work. Higher values on the scale indicated higher demands, better control and better support.

One dimension of the Copenhagen Psychosocial Questionnaire (COPSOQ) (Kristensen et al., 2005) was used to obtain an estimate of sensory demands, by the five questions that concern eye sight, precision, attention, focus and control of body movements. The participants answered the questions on a five-point scale (0 = hardly ever/to a very little extent, 25 = seldom/to little extent, 50 = sometimes/to some extent, 75 = often/to a large extent and 100 = always/to a very large extent) and the mean value was calculated for each participant.

2.2.3. Working conditions in echocardiography

Through the questionnaire, echocardiographers, i.e. sonographers who performed echocardiography at least ten hours per week, were identified. The questionnaire included detailed questions about echocardiographic examinations, such as the number of hours worked per week, the number of examinations per day and transducer time (the time during which the echocardiographer uses the transducer during an examination).

We also asked which hand was used to hold the transducer, dominant, non-dominant or two-handed/alternating grip. Further we asked whether the patient was lying towards or away from the examiner on the table. This led to four possible working techniques:

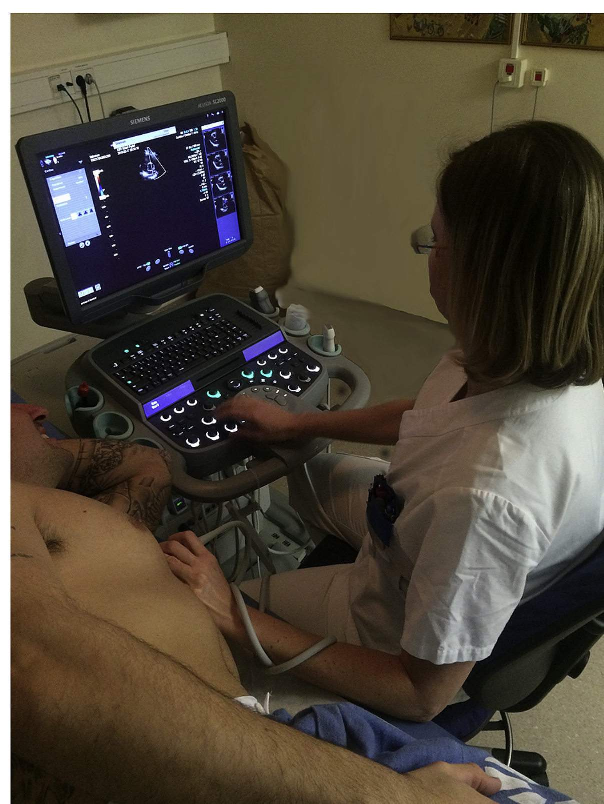

Fig. 1. Working technique 1: the patient was facing the examiner, who held the transducer in the left hand.

1, the patient was facing the examiner, who held the transducer in the left hand (Fig. 1), or 2, in the right hand (Fig. 2), or 3, the patient was facing away from the examiner, who held the transducer in the right hand (Fig. 3). In technique 4, the patient was facing the examiner, and either two sonographers examined the patient: one held the transducer with both hands and the other operated the ultrasound equipment (Fig. 4), or the sonographer alternated between hands.

Through the questionnaire, we also obtained detailed information on hand and wrist postures during examinations, such as how the transducer was held in different projections: apical (the heart tip), parasternal (left side of the sternum) and subcostal (below the ribcage). Four alternatives were considered: “like a pen”, “between the index and middle finger”, “with all fingers around the transducer” or “other grip” Three alternatives were used for wrist position: “straight wrist”, “bent forwards” or “bent backwards”.

2.2.4. Musculoskeletal pain

The participants were asked about musculoskeletal troubles (ache, pain or discomfort) in the neck, shoulders, elbows and hands during the preceding 12 months following the Nordic Questionnaire (Kuorinka et al., 1987). In addition, for each body region, information was collected about the frequency of complaints during the past year using a 5-point scale (never, seldom, sometimes, often or very often) (Holmström and Moritz, 1991), as well as the intensity of complaints on a ten-point scale from 0 (none at all) to 10 (very, very severe) (Borg, 1990). A participant was considered to have considerable musculoskeletal pain (subsequently referred to simply as “pain”) if reporting complaints at least “seldom” with an intensity of at least 7 (very severe), or “sometimes” with an intensity of at least 3 (moderate), or “often” or “very often” with an intensity of at least 2 (slight/mild) (Arvidsson et al., 2016). The condition was defined separately for the neck/shoulders and elbows/hands.

Fig. 2. Working technique 2: the patient was facing the examiner, who held the transducer in the right hand.

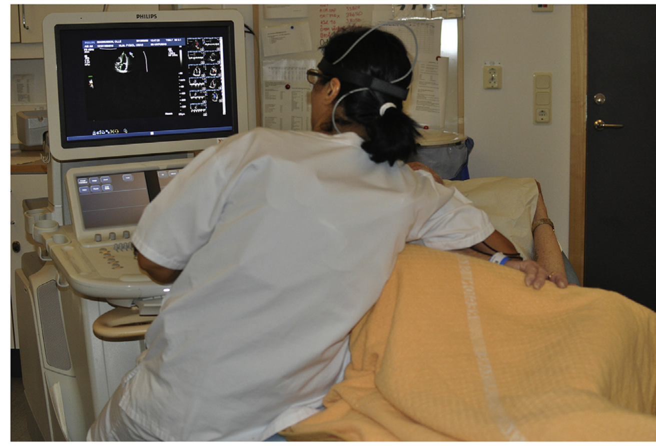

Fig. 3. Working technique 3: the patient was facing away from the examiner, who held the transducer in the right hand.

Fig. 4. Working technique 4: the patient was facing the examiner who held the transducer with both hands.

2.3. Statistics

The prevalence ratios (PRs) with 95% confidence intervals (CIs), estimated by Poisson regression, were used to assess associations with neck/shoulder and elbow/hand pain. PRs are given for personal, as well as work-related factors according to indexes or fixed categories used in the questionnaire. If the number of participants per category was ≤ 5 it was merged with an adjacent one. For working techniques and wrist positions a few participants reported divergent conditions that could not be merged with another one and were thus excluded. Continuous variables were trichotomized as there were no consistent linear effects. We calculated univariable PRs for personal factors and considered variables with overall p-values $\leq$ 0.20 for any outcome possible confounders. We then calculated associations between work factors and pain using crude PRs as well as PRs adjusted for possible confounders.

McNemar’s test was used to evaluate paired categorical outcomes, i.e. pain only in the hand or shoulder that handles the transducer ("transducer shoulder"), compared to the other hand or shoulder ("computer shoulder").

We used the statistical package for the social sciences SPSS 20 (SPSS Statistics, IBM and Armonk, New York, USA).

3. Results

The mean age was 44 years (standard deviation 13 years), mean height 167 cm (SD 6 cm), mean BMI 24 (SD 4) and mean seniority in sonography 12 years (SD 9 years). One hundred and sixty-nine participants (58%) met the criteria for neck/shoulder pain, 85 (30%) for elbow/hand pain and 189 (65%) in any or both body regions. Associations between personal factors and pain are shown in Table 1. Among personal factors only age showed an association with neck/shoulder pain. For elbow/hand pain, BMI and children at home were associated. These factors were used as possible confounders in the analyses.

3.1. Associations with work-related factors

High seniority in sonography, dissatisfaction with the computer work station and high MEI, were associated with reported pain in the neck/shoulders, as were high job demands and high sensory demands (Table 2). Associations were also found with inadequately corrected eye sight, as well as with eye complaints and headache related to computer work. The possibility to adjust the keyboard and chair was associated with less pain.

Echocardiographers showed a higher prevalence of pain in the elbows/hands than those who did not perform echocardiography. A high MEI, eye complaints and high job and sensory demands were also associated with pain in the elbows/hands (Table 2).

3.2. Associations with work-related factors in echocardiographers

Echocardiographers (N = 175) reported on average five echocardiographic examinations per day. More echocardiographers reported pain in the "transducer shoulder" only than in the "computer shoulder" only (33 vs 13, p = 0.005). Similar results were found for hand pain (30 vs 4, p < 0.001).

After adjustment, no specific factor in echocardiography was associated with neck/shoulder pain (Table 3). For the elbows/hands, to perform echocardiography 91–135 min per day (transducer time) was associated with pain, while more than 135 min was not. A

Table 1
Associations between pain[a] in the neck/shoulders and in the elbows/hands and personal factors in the total study population, calculated with Poisson regression. Number of subjects in each category (N), overall p-values (p) and prevalence ratios (PR) with 95% confidence intervals (CI).

	N	Neck/shoulders (N = 289)			Elbows/hands (N = 290)		
		p	PR	CI	p	PR	CI
Age (years)		0.07			0.24		
23–37	97		1			1	
38–53	92		0.87	(0.70–1.09)		1.45	(0.93–2.27)
54–66	99		0.76	(0.60–0.97)		1.17	(0.73–1.86)
Height (cm)		0.73			0.56		
153–164	93		1			1	
165–169	94		0.94	(0.74–1.21)		0.85	(0.56–1.31)
170–183	102		1.04	(0.83–1.31)		0.79	(0.52–1.22)
Body mass index (kg/m^2)		0.60			<0.001		
17.8–24.9	209		1			1	
≥25–29.9	62		1.06	(0.84–1.33)		1.32	(0.87–2.00)
≥30–37.8	16		1.19	(0.84–1.69)		2.43	(1.56–3.79)
Smoking habits		0.35			0.80		
Never smoker	220		1			1	
Former smoker	58		1.16	(0.94–1.44)		1.11	(0.73–1.70)
Daily smoker	10		1.17	(0.73–1.89)		0.77	(0.22–2.65)
Children living at home		0.74			0.14		
No	185		1			1	
Yes	104		1.16	(0.96–1.40)		1.06	(0.74–1.54)
Personal recovery time (h/day)		0.33			0.71		
Hardly any time at all	19		1			1	
<1	42		0.89	(0.60–1.32)		0.71	(0.33–1.55)
1	55		0.95	(0.66–1.37)		0.71	(0.34–1.49)
2	80		0.81	(0.57–1.17)		0.93	(0.48–1.80)
3	48		0.64	(0.41–1.00)		0.62	(0.28–1.36)
≥4	40		0.91	(0.61–1.35)		0.88	(0.42–1.85)
Physical exercise		0.53			0.69		
Never	22		1			1	
Occasionally	9		0.76	(0.40–1.45)		0.54	(0.15–2.04)
Once a week	49		0.85	(0.60–1.19)		0.65	(0.33–1.29)
2 – 4 times/week	163		0.76	(0.58–1.04)		0.73	(0.42–1.27)
≥5 times/week	46		0.81	(0.57–1.15)		0.64	(0.32–1.28)
Household work (h/week)		0.77			0.49		
0–2	6		1			1	
3–10	118		1.14	(0.50–2.57)		1.61	(0.26–9.90)
11–20	103		1.15	(0.51–2.61)		1.81	(0.30–11.07)
21–30	34		1.36	(0.59–3.11)		2.45	(0.40–15.45)
≥31	26		1.20	(0.51–2.28)		1.62	(0.24–10.78)
Civil status		0.80			0.60		
Single	44		1			1	
Married/Cohabitant	242		1.04	(0.80–1.36)		0.60	(0.31–1.15)

[a] Based on frequency and intensity of musculoskeletal complaints during the last 12 months.

Table 2
Associations between pain[a] in the neck/shoulders and in the elbows/hands, and work-related factors in the total study population. Number of participants (N) and prevalence ratios (PR) with 95% confidence intervals (CI), crude as well as adjusted for possible confounders, calculated with Poisson regression.

	N	Neck/shoulders[b] (N = 289)				Elbows/hands[c] (N = 290)			
		Crude		Adjusted		Crude		Adjusted	
		PR	CI	PR	CI	PR	CI	PR	CI
Seniority as a sonographer (years)									
1.1–6	95	1		1		1		1	
6.1–15	96	1.03	(0.80–1.31)	1.20	(0.93–1.55)	1.17	(0.75–1.81)	1.14	(0.74–1.77)
15.1–36	96	1.08	(0.85–1.37)	**1.51**	**(1.17–2.08)**	1.07	(0.68–1.68)	1.00	(0.64–1.57)
Working hours (h/week)									
20–39	134	1		1		1		1	
40–41	155	1.07	(0.89–1.30)	0.73	(0.51–1.04)	1.02	(0.90–1.15)	0.75	(0.52–1.07)
Sonography (h/week)									
1–14	82	1		1		1		1	
15–23	107	1.03	(0.79–1.35)	1.01	(0.77–1.31)	0.80	(0.51–1.24)	0.82	(0.53–1.27)
24–40	100	1.23	(0.97–1.58)	1.20	(0.94–1.53)	0.90	(0.59–1.38)	0.90	(0.60–1.11)
Type of examinations									
Other examinations only	70	1		1		1		1	
Echocardiography	106	0.97	(0.76–1.25)	0.91	(0.74–1.16)	1.74	(0.99–3.07)	1.71	(0.96–3.02)
Echocardiography and other examinations	112	1.01	(0.79–1.29)	0.98	(0.80–1.30)	**1.91**	**(1.10–3.32)**	**1.92**	**(1.11–3.32)**
Possibility to adjust screen height									
No	56	1		1		1		1	
Yes	229	0.91	(0.73–1.15)	0.91	(0.72–1.14)	1.44	(0.84–2.47)	1.43	(0.84–2.42)
Possibility to tilt screen									
No	24	1		1		1		1	
Yes	263	0.85	(0.63–1.14)	0.86	(0.65–1.14)	0.90	(0.50–1.66)	0.90	(0.46–1.76)
Possibility to adjust keyboard									
No	51	1		1		1		1	
Yes	233	**0.78**	**(0.63–0.96)**	**0.78**	**(0.64–0.95)**	1.01	(0.64–1.77)	1.18	(0.74–1.87)
Possibility to adjust chair									
No	24	1		1		1		1	
Yes	262	**0.70**	**(0.57–0.88)**	**0.72**	**(0.57–0.91)**	0.80	(0.46–1.39)	0.77	(0.43–1.37)
Use of special examination table									
No	30	1		1		1		1	
Yes	255	1.13	(0.80–1.57)	1.12	(0.80–1.58)	0.84	(0.50–1.40)	0.79	(0.47–1.33)
Computer work after examination									
In the examination room	186	1		1		1		1	
A workplace outside the examination room	71	1.16	(0.94–1.43)	1.17	(0.95–1.45)	1.17	(0.95–1.45)	1.44	(0.99–2.09)
None	15	0.82	(0.47–1.44)	0.82	(0.46–1.46)	0.82	(0.46–1.46)	1.32	(0.63–2.77)
Bedside examinations									
No	50	1		1		1		1	
Seldom	149	1.03	(0.78–1.36)	1.02	(0.77–1.35)	0.99	(0.59–1.66)	1.14	(0.68–1.89)
A few times per week	77	1.04	(0.76–1.42)	1.03	(0.75–1.40)	1.16	(0.67–2.01)	1.31	(0.76–2.27)
Daily	12	**1.49**	**(1.01–2.12)**	1.32	(0.92–1.90)	0.89	(0.31–2.62)	0.97	(0.36–2.61)
Eye complaints related to computer work									
Never	158	1		1		1		1	
Seldom	45	0.88	(0.62–1.24)	0.88	(0.63–1.23)	0.84	(0.46–1.53)	0.91	(0.50–1.65)
Sometimes	59	**1.28**	**(1.01–1.60)**	**1.30**	**(1.03–1.63)**	1.21	(0.77–1.90)	1.31	(0.85–2.04)
Often or very often	25	**1.80**	**(1.52–2.13)**	**1.84**	**(1.55–2.19)**	**1.96**	**(1.24–3.01)**	**2.22**	**(1.38–3.57)**
Headache related to computer work									
Never	170	1		1		1		1	
Seldom	60	**1.35**	**(1.05–1.73)**	**1.29**	**(1.00–1.65)**	0.90	(0.55–1.49)	0.92	(0.57–1.50)
Sometimes	34	**1.81**	**(1.47–2.24)**	**1.79**	**(1.45–2.20)**	1.28	(0.76–2.14)	1.26	(0.76–2.07)
Often or very often	22	**2.03**	**(1.69–2.44)**	**2.00**	**(1.66–2.41)**	1.64	(0.98–2.76)	1.54	(0.90–2.62)
Eyesight									
Good or adequately corrected	238	1		1		1		1	
Inadequately corrected	47	**1.34**	**(1.10–1.64)**	**1.39**	**(1.13–1.71)**	1.12	(0.70–1.78)	1.20	(0.75–1.92)
Mechanical exposure index score									
Unexposed/low (11–15 p)	44	1		1		1		1	
Medium (16–19 p)	131	**1.82**	**(1.17–2.82)**	**1.77**	**(1.14–2.74)**	1.67	(0.84–3.31)	1.72	(0.88–3.38)
High (20–33 p)	100	**2.18**	**(1.41–3.36)**	**2.20**	**(1.39–3.32)**	**2.03**	**(1.03–4.03)**	**2.00**	**(1.02–3.90)**
Physical exposure index score									
Unexposed (7–8 p)	74	1		1		1		1	
Low (9–10 p)	124	1.06	(0.83–1.34)	1.03	(0.81–1.31)	1.00	(0.63–1.58)	0.95	(0.61–1.49)
Medium (11–13 p)	55	0.89	(0.64–1.23)	0.86	(0.62–1.18)	1.12	(0.66–1.92)	1.14	(0.67–1.94)
High (14–21 p)	21	1.01	(0.73–1.59)	1.05	(0.72–1.53)	1.02	(0.47–2.20)	1.02	(0.47–2.18)
Computer work-station									
Very satisfied	35	1		1		1		1	
Rather satisfied	146	0.95	(0.69–1.31)	0.99	(0.72–1.36)	1.25	(0.65–2.41)	1.23	(0.63–2.38)
Neutral	67	0.97	(0.68–1.38)	1.00	(0.70–1.42)	1.06	(0.51–2.21)	1.07	(0.52–2.24)
Rather/very dissatisfied/	34	**1.49**	**(1.09–2.01)**	**1.54**	**(1.11–2.13)**	1.86	(0.92–3.83)	1.71	(0.81–3.58)
Job demands (cut-offs: 2.25 and 2.63)									
Lowest tertile	85	1		1		1		1	
Middle tertile	97	1.27	(0.95–1.70)	1.32	(0.99–1.77)	1.53	(0.91–2.57)	1.37	(0.82–2.31)

(*continued on next page*)

Table 2 (*continued*)

	N	Neck/shoulders[b] (N = 289)				Elbows/hands[c] (N = 290)			
		Crude		Adjusted		Crude		Adjusted	
		PR	CI	PR	CI	PR	CI	PR	CI
Highest tertile	105	**1.61**	**(1.24–2.10)**	**1.61**	**(1.24–2.10)**	**1.74**	**(1.06–2.86)**	**1.72**	**(1.10–2.79)**
Job control (cut-offs: 2.67 and 3.00)									
Lowest tertile	97	1		1		1		1	
Middle tertile	99	0.86	(0.70–1.07)	0.86	(0.69–1.07)	0.81	(0.55–1.19)	0.87	(0.58–1.26)
Highest tertile	91	0.90	(0.70–1.17)	0.88	(0.69–1.14)	0.66	(0.39–1.12)	0.70	(0.41–1.17)
Job support (cut-offs: 2.63 and 4.00)									
Lowest tertile	83	1		1		1		1	
Middle tertile	117	0.91	(0.72–1.14)	0.91	(0.73–1.15)	0.78	(0.52–1.19)	0.74	(0.49–1.11)
Highest tertile	86	0.93	(0.73–1.19)	0.90	(0.71–1.15)	0.77	(0.49–1.22)	0.75	(0.48–1.18)
Sensory demands (cut-offs: 70 and 87.5)									
Lowest tertile	87	1		1		1		1	
Middle tertile	113	**1.35**	**(1.01–1.79)**	1.30	(0.98–1.73)	1.24	(0.76–2.01)	1.17	(0.72–1.90)
Highest tertile	84	**1.70**	**(1.30–2.22)**	**1.69**	**(1.29–2.22)**	**1.68**	**(1.05–2.69)**	1.49	(0.93–2.40)

Results in bold face are statistically significant.
[a] Based on the frequency and intensity of musculoskeletal complaints during the past 12 months.
[b] Adjusted for age.
[c] Adjusted for BMI and children <15 living at home.

transducer grip with the wrist bent backwards was associated with a high prevalence of elbow/hand pain, while holding the transducer in a two-handed/alternating grip was associated with a low prevalence of elbow/hand pain (Table 3). No statistically significant association was found the in the other projections (data not shown).

4. Discussion

Two thirds of the sonographers met the criteria for pain in one

Table 3
Associations between pain[a] in the neck/shoulders and in the elbows/hands, and time and number of examinations and working techniques among echocardiographers (examinations $\geq$ 10 h/w). Numbers of subjects (N) and prevalence ratios (PR) and 95% confidence intervals (CI), crude as well as adjusted for possible confounders, calculated with Poisson regression.

	N	Neck/shoulders[b] (N = 174)				Elbows/hands[c] (N = 175)			
		Crude		Adjusted		Crude		Adjusted	
		PR	CI	PR	CI	PR	CI	PR	CI
Echocardiography (h/week)									
10–14	52	1		1		1		1	
15–19	50	0.85	(0.60–1.19)	0.80	(0.57–1.12)	0.99	(0.60–1.65)	1.00	(0.60–1.65)
20–40	73	1.02	(0.76–1.33)	0.95	(0.72–1.26)	0.80	(0.48–1.33)	0.78	(0.47–1.28)
Number of examinations/day									
2–3	30	1		1		1		1	
4	64	1.04	(0.74–1.48)	1.04	(0.74–1.48)	1.38	(0.74–2.56)	1.36	(0.74–2.50)
5	37	1.08	(0.74–1.58)	1.08	(0.74–1.58)	1.09	(0.55–2.22)	1.13	(0.55–2.31)
6–10	44	0.80	(0.52–1.22)	0.81	(0.53–1.23)	0.83	(0.39–1.76)	0.85	(0.41–1.77)
Transducer time (minutes/day)									
12–90	52	1		1		1		1	
91–135	58	1.03	(0.79–1.34)	1.04	(0.80–1.35)	1.54	(0.94–2.25)	**1.64**	**(1.00–2.70)**
136–400	64	**0.72**	**(0.52–0.99)**	0.73	(0.53–1.02)	0.71	(0.38–1.32)	0.75	(0.41–1.38)
Working technique									
1. Patient facing the examiner,transducer in left hand	80	1		1		1		1	
2. Patient facing the examiner,Transducer in right hand	37	0.97	(0.69–1.35)	0.98	(0.71–1.37)	1.11	(0.66–1.85)	1.17	(0.70–1.91)
3. Patient's back against the examiner, transducer in right hand	32	1.12	(0.82–1.52)	1.18	(0.87–1.64)	1.19	(0.71–1.98)	1.16	(0.68–1.95)
4. Patient facing the examiner, two-handed or alternating transducer grip	21	0.97	(0.64–1. 47)	0.99	(0.66–1.49)	0.28	(0.072–1.08)	0.29	(0.08–1.06)
Hand used to hold the transducer									
Dominant	69	1		1		1		1	
Non dominant	83	1.04	(0.80–1.50)	1.01	(0.77–1.31)	0.94	(0.62–1.43)	0.93	(0.61–1.42)
Two handed/alternating	21	0.99	(0.65–1.50)	0.97	(0.63–1.47)	**0.25**	**(0.07–0.98)**	**0.26**	**(0.07–0.94)**
Transducer grip in parasternal projection									
Like a pen	74	1		1		1		1	
Between index/middle finger	10	0.30	(0.09–1.05)	0.31	(0.09–1.07)	0.72	(0.27–1.92)	0.81	(0.30–2.22)
All fingers around the probe	79	0.86	(0.67–1.11)	0.86	(0.67–1.10)	0.64	(0.41–1.01)	0.63	(0.40–1.00)
Other grips	8	0.95	(0.54–1.65)	0.87	(0.49–1.52)	0.90	(0.35–2.28)	0.74	(0.34 – 1.62
Wrist position in parasternal projection									
Straight wrist	83	1		1		1		1	
Bent forwards	22	1.29	(0.90–1.83)	1.24	(0.88–2.39)	1.51	(0.72–5.94)	1.52	(0.79–2.91)
Bent backwards	62	1.19	(0.90–1.57)	1.12	(0.85–1.78)	**1.70**	**(1.05–2.77)**	**1.64**	**(1.01–2.68)**

Results in bold face are statistically significant.
[a] Based on the frequency and intensity of musculoskeletal complaints during the past 12 months.
[b] Adjusted for age.
[c] Adjusted for BMI and children <15 living at home.

or both of the studied body regions. This cross-sectional study is one of the first and to date the largest, to provide estimates of associations between musculoskeletal disorders and work-related factors in sonography. Echocardiographers had higher prevalence of elbow/hand pain than those who performed only other kinds of examinations. Dissatisfaction with the computer workstation was associated with a higher prevalence of elbow/hand pain, while adjustable equipment was associated with a lower prevalence of pain. Higher MEI, higher job demands and higher sensory demands were associated with pain in both body regions. In echocardiographers, pain was more common in the arm/hand that held the transducer than in the other arm/hand.

As the study includes almost all echocardiographers in Sweden and they reported fulfilling five examinations per day, we estimate that at least 100 000 such examinations are performed yearly in Sweden.

4.1. Methodological considerations

The present study is cross-sectional and based on self-reported exposure and on self-reported musculoskeletal pain. Overestimation of one or both of these may occur. Individuals with ongoing pain are prone to perceive their work to be more demanding than individuals without pain and therefore may overestimate the exposure (Hansson et al., 2001). Several of the exposure measures are objective (e.g. whether the chair can be adjusted) and thus unlikely to be misclassified. For those that are subjective, an overestimation of exposure among those with pain would lead to an overestimation of the association. The same effect would occur if subjects who perceive their work as too demanding overestimate bodily symptoms. However, in spite of these weaknesses, the observed associations are biologically plausible and in line with previous knowledge (Morton and Delf, 2008; Muir et al., 2004).

Several studies of sonographers have been reported in which various definitions of pain have been used (Horkey and King, 2004; Morton and Delf, 2008; Russo et al., 2002). Thus, comparisons with others studies must be made with caution. Pain may be troublesome both when it is severe and when it is frequent. Our definition of pain combines frequency and intensity, which we consider more relevant than most traditionally used definitions.

To the best of our knowledge we invited all clinical physiology and cardiology departments throughout Sweden where sonography is performed by biomedical scientists. They all agreed to participate. In each of these, the participation rate was high. Thus, we believe that there was no significant selection bias, neither on individual nor on regional level. However, since the study was cross-sectional, sonographers with pain may have left the profession and there may be selection towards more healthy workers (Shah, 2009). This would lower the prevalence of pain and possibly cause underestimation of the associations between occupational factors and pain.

Most of the sonographers also had other work tasks (e.g. spirometry, electroencephalography (EEG), work tests and administration). However, we judge from observations that these other activities in general caused a lower physical load and should not have influenced the results.

A previous study showed that discomfort of transducer design was a strong predictor of hand and wrist disorders (Vanderpool et al., 1993). We did not collect information on weight and dimensions of the transducers, thus we cannot draw any conclusion on the importance of the design of these.

Sonography is also used by other medical staff e.g. cardiologists, obstetricians, midwives ad gynaecologists (Eindhoven et al., 2015; Green et al., 2015; Kim and Roh, 2014; Tegnander and Eik-Nes, 2006). However, several work-related conditions are to a large extent similar to sonography performed in these specialities, e.g. light conditions, holding a transducer and watching a screen. Thus, the recommendations we propose are applicable also to other groups that perform sonography.

4.2. Risk factors and recommendations

The sonographers who reported high job demands had a higher prevalence of neck/shoulder as well as elbow/hand pain, with clear exposure-response relationships. This is in line with previously published results for health care professionals (Bernal et al., 2015)) and computer users (Tornqvist et al., 2009). High job demands as a cause of neck and upper limb symptoms is partly mediated by the stress symptoms they might give rise to (van den Heuvel et al., 2005).

The majority of the sonographers reported a high or moderately high MEI. As in previous studies there was a strong association between increasing MEI and pain (Balogh et al., 2001; Östergren et al., 2005). High sensory demands in terms of small and very precise movements and high sight demands, may lead to long time static postures in neck and shoulders as well as in wrists and hands. This may be an explanation to the strong associations between high sensory demands and pain in these regions. High sensory demands seem to be unavoidable in sonography, thus it is important to optimize work conditions concerning ergonomics.

We found a strong association between eye strain and pain in both body regions. There was an association between neck pain and headache related to computer work. Working with poor lighting may cause eye strain (Hemphälä et al., 2012), which in turn may increase trapezius muscle activity (Richter et al., 2015). This might be a causal factor for neck pain and headache. It is thus extremely important to ensure that all sonographers have adequate eye sight correction, and to optimize lighting conditions and contrast on the screen.

Dissatisfaction with the computer workstation was associated with neck/shoulder pain. This is most likely a proxy of poor ergonomics, including visual conditions. Indeed, similar associations were found for possibility to adjust chair and keyboard. Similar findings have been reported in two previous Swedish studies (Lindegård et al., 2012; Tornqvist et al., 2009). Hence, to decrease pain prevalence it is important that all available recommendations for good computer ergonomics are met (Goodman et al., 2012).

Sonographers who performed echocardiography showed a higher prevalence of pain in the elbows/hands and pain was more prevalent in the hand and shoulder used to operate the transducer. Keeping the wrist straight when pressing the transducer against the patient seemed protective, in accordance with basic ergonomic principles (Kuo et al., 2001; You et al., 2014). Holding the transducer two-handed/alternating grip was associated with a lower prevalence of pain and this should be encouraged. By using techniques1 and 2, i.e. with the patient facing the examiner, it is easier to hold the transducer with two hands when pressure is required in applying the transducer. Furthermore, voice activation has been shown to reduce the number of times the operator has to reach for the control panel (Bravo et al., 2005), and would make both hands available to handle the transducer. A robot arm holding the transducer has also been tested, which eliminates the problems with the handgrip (Arbeille et al., 2014; Boman et al., 2014).

Guidelines for prevention of work-related disorders in sonographers were developed more than ten years ago (Brown et al., 2003). These recommendations are well in line with the findings in this study, and should be more widely spread to encourage further improvements and interventions of the working environment. Since the prevalence of pain was high, we also suggest regular health screening for early detection and prevention of pain related to the working environment (Hagberg et al., 2012).

4.3. Conclusions

Ultrasonic examinations are becoming increasingly common. We estimate that at least 100 000 such are performed yearly in Sweden. This study has identified several ergonomic risk factors. Therefore it is important to ensure sustainable work conditions for sonographers. We recommend optimal visual conditions, adjustable components of the ultrasonic machine and the computer workstation, education concerning ergonomic guidelines and regular health screening, including eye sight. In echocardiography, other ways of holding and handling the transducer should be developed.

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