Available online at www.sciencedirect.com
ScienceDirect
International Journal of Industrial Ergonomics 37 (2007) 781–789
International Journal of INDUSTRIAL ERGONOMICS
www.elsevier.com/locate/ergon

Ergonomic analysis of postural and muscular loads to diagnostic sonographers

Judy Village*, Catherine Trask

University of British Columbia, School of Occupational and Environmental Hygiene, 3rd Floor, Library Processing Center, 2206 East Mall, Vancouver, British Columbia, Canada V6T 1Z3

Received 20 April 2007; received in revised form 14 June 2007; accepted 19 June 2007
Available online 17 July 2007

Abstract

Musculoskeletal disorders are prevalent in diagnostic sonographers. This study quantifies the postural and muscular loads during ultrasound scanning. Video-based stop-motion postural analysis at 4 samples/minute for 24 full scans (527.5 minutes) by 11 sonographers showed sonographers spend 68% of scanning time with $>30^{o}$ shoulder abduction, 63% with $>30^{o}$ shoulder outward rotation, and 37% with the neck bent forward, laterally or twisted $>20^{o}$. The shoulder was observed to be unsupported, or static, for 73% of scanning time and this was significantly higher for carotid scans compared with abdominal, obstetrical or leg scans ($p<0.05$). Electromyography (EMG) was collected for seven scans performed by three sonographers on three shoulder muscles: Supraspinatus, infraspinatus, and trapezius; as well as for flexor carpi ulnaris. Static (0.10) amplitude probability distribution functions (APDFs) for all three shoulder muscles exceeded 3% MVC corresponding to a "medium" risk rating for shoulder–neck disorders. Mean forearm flexor EMG was 3.96 kg (SD 2.94), with occasional peak forces as high as 27.6 kg.

Relevance to industry

Diagnostic sonographers experience long durations in static shoulder abduction and outward rotation, with high peak and sustained grip forces. These risk factors are consistent with the high prevalence of neck and upper limb musculoskeletal disorders and symptoms reported by many sonographers.

Keywords: Sonographers; Electromyography; Postural assessment; Risk assessment; Ergonomic analysis

1. Review of literature and objectives

1.1. Musculoskeletal pain and injuries among sonographers

Numerous studies have been conducted in the past decade documenting musculoskeletal injuries and symptoms among sonographers in the US (Smith et al., 1997; Pike et al., 1997), and Canada (Muir et al., 2004; Wihlidal and Kumar, 1997; Russo et al., 2002). Although the point prevalence for neck and upper limb pain for the general population is 13–22%, for sonographers it is between 63% and 91% (Brown and Baker, 2004). Wihlidal and Kumar (1997) reported three clusters of pain syndromes: Neck and interscapular pain; shoulder and upper arm, elbow and hand/wrist pain; and frontal headaches and visual discomforts. There is a considerable level of disability associated with these injuries: 80% of sonographers seek treatment for MSIs (Muir et al., 2004); 46% use physiotherapy or medication to control the pain (Smith et al., 1997); 16.7% missed work due to symptoms while a further 9.4% reduce their hours, 14.6% reduce their regular duties, 21.2% use sick leave, and 11.75% use vacation days (Wihlidal and Kumar, 1997). Although an estimated 20% of sonographers leave the profession due to persistent pain (Brown and Baker, 2004), only 12.9% of Canadian (Wihlidal and Kumar, 1997) and 4% of US (Vanderpool et al., 1993) sonographers reported the injuries to Workers' Compensation.

*Corresponding author. Tel.: +1 604 929 7243; fax: +1 604 929 7280.
E-mail address: village@interchange.ubc.ca (J. Village).

0169-8141/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.ergon.2007.06.005

1.2. Risk factors for neck/shoulder and upper limb injuries

Musculoskeletal symptoms or discomfort have been found to be correlated with a number of workplace factors: Long scan duration (Muir et al., 2004; Vanderpool et al., 1993), high scan frequency (Muir et al., 2004); a higher number of obstetrical scans (Muir et al., 2004); and the use of manually propelled devices (Smith et al., 1997). Studies of sonography work suggest shoulder risk factors include habitual arm abduction and isometric static loading, forceful gripping and applying pressure through the transducer, and habitual rotation of the upper spine (Brown and Baker, 2004). Constrained work involving repetitive movements with the hands and static muscle loading of the neck and shoulder have been shown to be risk factors for the neck/shoulder (Winkel and Westgaard, 1992a, b), and neck and intrascapular pain has been shown to be significantly related to sustained shoulder abduction, twisting of the neck and trunk, repetitive twisting of the neck and trunk and clerical activities in sonographers (Wihlidal and Kumar, 1997). Risk factors for hand/wrist and elbow disorders include forceful or sustained gripping, high repetitions and awkward bending/twisting postures (Silverstein, 1985). Although these hand/wrist risk factors have been studied extensively in short-cycle tasks of assembly lines and meat processing work, to our knowledge they have not been studied in sonographers.

1.3. Mechanism of injury at the shoulder

Three mechanisms have been suggested for shoulder injury. The first is mechanical compression of the supraspinatus tendon between the humeral head and the acromion process (Garg et al., 2006). The second is a reduction in the blood supply to the supraspinatus and infraspinatus muscles and tendons due to an increase in intra-muscular pressure when the arm is elevated (Garg et al., 2006); fatigue and reduced blood flow occur at moderate levels of abduction (30°), even without a load in the hands. The third mechanism occurs when prolonged static contractions (as little as 3–5% MVC) of the trapezius muscle result in an overload of type I muscle fibers (Jonsson, 1988), which may lead to selective motor unit fatigue and damage (Hagberg et al., 1995).

1.4. Objectives

This study will investigate the postural and muscular loads involved in performing ultrasound sonography scans, specifically the extent of abduction and outward rotation of the shoulder, neck bending/twisting and unsupported shoulder postures, and electromyography (EMG) of three neck/shoulder muscles (trapezezius, supraspinatus and infraspinatus) as well as the gripping force of the flexi carpi ulnaris holding the transducer. These will be compared with guidelines and studies of other workers from the scientific literature.

2. Methods

2.1. Postural assessment

Numerous authors have developed postural recording systems to facilitate observational data collection (Armstrong et al., 1982; Keyserling, 1986) and several of these have been tested for validity and reliability using video-based systems (Keyserling, 1986), inclinometers (Paquet et al., 2001; Village et al., 2007, submitted April 2007), or postural analysis systems (Leskinen et al., 1997). Fransson-Hall et al., (1995) found good agreement between observers for shoulder posture using their real-time (PEO) observational technique. Paquet et al., (2001) also found good inter-observer reliability for the shoulder and they reported no significant differences in the frequency of exposure of three shoulder postures when their observational assessment technique (PATH) was compared with inclinometer data (kappa of 0.8). Since most of these observational systems collect data in real time, the authors suggest that validity can be improved with video recording and playback capabilities (Fransson-Hall et al., 1995; Burt and Punnett, 1999). To optimize the validity and reliability of the postural assessment for this study, video recordings were used with stop-motion playback. A limited number of postures were chosen for the shoulder and neck and all observations were performed by a single-trained observer. Measures of shoulder abduction could be verified with on-screen measurement using a goniometer.

Postural assessments were carried out at six hospital facilities involving a total of 11 different ultrasound sonographers. Sonographers agreeing to participate were provided an explanation of the study purpose and procedures for observation and videotaping. They in turn explained the study and procedures to patients assigned to them that day. Consent forms from the Health Region were completed by both sonographers and patients willing to participate. A total of 24 complete scans were observed and videotaped. Sonographers were instructed to perform their scans as they normally would. Videotape was recorded directly behind the sonographer to optimize capture of shoulder abduction and outward rotation, as well as neck twisting and lateral bending. The videotapes were played back and stop-motioned four times per minute (every 15 s). At each stop motion, shoulder abduction and outward rotation was categorized by a single-trained observer in one of six categories: 0–15°, 16–30°, 31–45°, 46–60°, 61–75°, and 76–90°. Neck posture was categorized as either 'neutral' or 'bent/twisted'. 'Bent/twisted' was defined as more than 20° flexed, laterally flexed or rotated. Because neck posture often involves a combination of postures and the image was from the rear; for example, if there was uncertainty as to the angle of flexion, no data was recorded. Shoulder loading was also recorded as either static (i.e. supporting the weight of the arm and transducer), or relaxed (leaning on the patient, stretcher or keypad). The percentage of scan time in each postural