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User-Informed re-design of a sonography system to reduce Work-Related Musculoskeletal Disorders

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Abstract

The Prevalence of Work-Related Musculoskeletal Disorders is still increasing amongst professionals in ultrasound imaging departments. The significance of these injuries in the healthcare sector arises from multiple consequences: that they have a high financial impact causing huge costs to the NHS and other organisations, but also on the careers of professionals and their wellbeing. The objective of the work described here is to find possible solutions to this growing problem in order to advance the design of an ergonomic work environment for sonographers. This work is being done in collaboration with healthcare professionals as well as being supported by manufacturing companies, distributors and academia. The final deliverable is to have a mechanical prototype tested and ready to be used by a sonographers' focus group in order to get feedback from end users that would help to improve the design and following appropriate modifications, proceed with a final design to be developed and then evaluated under clinical conditions.

Keywords: Medical device design; Work-related Musculoskeletal Disorders; WRMSD; RSI; Sonography; Ultrasound; Shoulder Support; EMG; Electromyography

Introduction

Following a period of study of the importance of work-related musculoskeletal disorders amongst sonographers, comparing the collation of industry wide surveys (Quartly 2013), numerous on-site observations and meetings with professionals, the causes, effects and impacts of work-related musculoskeletal disorders in sonography (Burnett & Campbell-Kyureghyan 2010; Bastian et al, 2009; Murphy & Russo 2000) have been identified in this work. The information gathered to date has led to further research into possible solutions and the feasibility of proposed design ideas and products to reduce these negative effects. The gathered data suggests that the shoulder is the part of the body that is most prone to injury amongst practising sonographers (Figure 1). Therefore, it is decided to focus on shoulder and the support option.

The assessment and reports provided by the focus group have established a list of key areas for design focus. During this period different design aspects such as anthropometrics, comfort, materials, manufacturing practicalities and economic costs were taken into account. Special attention was paid to the issue of infection control, highlighted as an ever increasingly important consideration for medical departments.

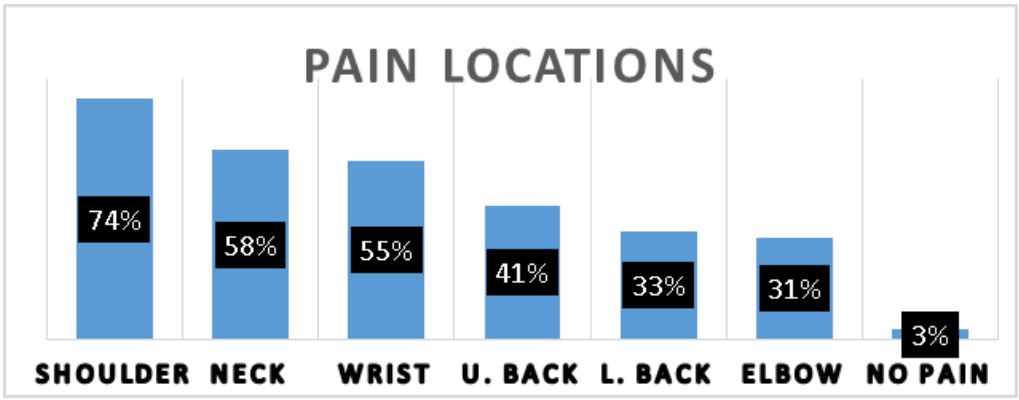

Figure 1. Results from prototype EMG experiment

This work on the shoulder support forms a part of a wider project aiming to significantly reduce the incidence of work-related musculoskeletal disorders in sonography which is focused on the design of a totally user-friendly and adjustable ergonomic environment to be installed in ultrasound workplaces.

Feasibility Study

> "Despite the introduction of several preventative methods, sonographers are still reducing their working hours or retiring early because of work-related injuries" (Quartly, 2013)

Was the conclusion reached by a recent study by the University of Sheffield, stated after analysing the results of a survey responded to by 128 UK-based sonographers (39% resp. rate), as well as

outlining the causes and impacts of the problem. The survey demonstrated that a large number of sonographers (97% of respondents) had suffered pain due to scanning procedures. 73% suffered a work-related injury but only 15% of them believed that their workplace did not reach the minimum industry standards for the prevention of these injuries. These all point to the notion that Work-Related Musculoskeletal Disorders (WRMSDs) are a common part of a sonographer's professional career.

Other information obtained from this survey was that most of them consider awkward postures and sustained muscular contraction as the most important causes of injuries, which are concentrated in shoulders (74%), neck (58%), wrist (55%) and lower back (41%). Other localised pain is suffered in areas such as upper back and elbow. Only 3% of those that answered stated that they hadn't suffered any pain at all.

A larger UK-based survey was completed by Sound Ergonomics in 2008 (Sound Ergonomics, 2008). On that occasion, the number of sonographers who had experienced any kind of pain during scans represented 90% of the 3024 respondents. Shoulder, neck and wrist were again the most common areas of pain. Sustained shoulder abduction, pressure application and neck and trunk twisting were the main reasons of pain given. Sonographers were asked about possible workplace improvements too, their most common responses concerned the adjustability of bed and couch, reduction on the number of scans and replacement of ultrasound machines with newer models.

Professionals' Feedback

Sonographers have reported several issues and opinions and some of them have been classified as a "wish list" for sonographers (Kinghorn RSI, 2012). The most important issues identified are:

- Reducing the effort needed to displace the adipose layer in high BMI patients.
- Avoiding having to bend their wrists too far away from the neutral position.
- Reducing the degree and frequency of abduction of the scanning arm, and finding an acceptable and non-restrictive way of helping to support its weight.

That is not the first time that aspects like the difficulties of scanning obese patients have arisen; in the mentioned above paper written for the University of Sheffield (Quartly, 2013), sonographers reported that more obese patients often induce more pain due to the extra effort that they have to apply to optimise imaging. Sometimes, sonographers have found an improvement by performing paired scans whereby two sonographers work together to complete the scan (Monningtom *et al*, 2012) but, of course, this solution increases the time needed for the scan and has cost implications.

Financial Impact

Repetitive strain injuries are said to cost European countries between 0.5% and 1.5% of the GNP (Kinghorn RSI, 2012). The monetary costs of work-related musculoskeletal disorders have been discussed by most of the authors that have researched this issue. There have been two primary

estimations, one each for both the UK and the US. The first one (NHS, 2009), states that MSDs *"Are the most common type of occupational ill health in the UK"* representing around 40% of all sickness absences and regarding to their accounts, it results in a cost of about £400 million each year. Most of the cases of absence due to MSDs are applying to sonographers and the cost can range between £2700 and £3700 per employee, plus the sick pay for the absent individual (Quartly, 2013). As can be seen, the economic impact of MSDs results in a large financial loss.

Another estimation analysed in a US-based report (Baker *et al,* 2002), establishes the costs attributed to a musculoskeletal disorder on the shoulder of a sonographer as much as $641,000, counting the worker's compensation, medical expenses (without surgery), staff replacement cost, revenue loss and recruitment of new sonographer costs. In the same document an estimated cost of implementing an ergonomic workstation for sonography was calculated being the total around $158,000 including examination table, chair, support cushions and a modern ergonomic ultrasound system.

Personal Impact

The benefits of investments in ergonomic instruments or devices are more than clear, all of this without counting other losses such as the productivity of an experienced sonographer and his/her ability to identify potential problems during scans or personal consequences. Tendon, muscular, and neurovascular related disorders are on the rise among sonographers and the damage may not reach its full effect until twenty or thirty years after the injury (Quartly, 2013), forcing about 20% of them (NHS, 2009) to leave the profession or take premature retirement because of the impact of their injuries over their quality of life. This impact can be very serious, in some cases causing depression or a high level of incapacity to perform activities of daily living (ADLs) such as driving or sports.

Solutions assessment

Shoulder as a key area

A considerable improvement regarding couches design seems to have been achieved. A large catalogue that offers different models to adapt for each kind of examination to be done will cover all the necessities of each department and there are even multipurpose models which reduce the number of couches needed for general examination departments.

Nevertheless, the largest gap identified after this technology review is the armrest. To date, nobody has developed a product that helps not only to support arms and shoulders, but to apply pressure over patients when required, even thought this is probably the kind of effort that causes the most and the worst injuries among sonographers. Based on this, and keeping in mind the previously mentioned list of most important areas of pain (Quartly, 2013), it is clear that the

shoulder should be the first target to point when attempting to design any potential device intended to help reduce musculoskeletal injury risks.

By reducing the effort on the shoulder, other areas are expected to have their stress reduced too. This is the case of the neck and back, since part of the effort sustained by the shoulder is usually transferred to these muscles due to a loss of strength in the arm.

To confirm this, an experiment has been designed in order to verify that by supporting the shoulder, muscular stress will be reduced.

Surface Electromyography (sEMG)

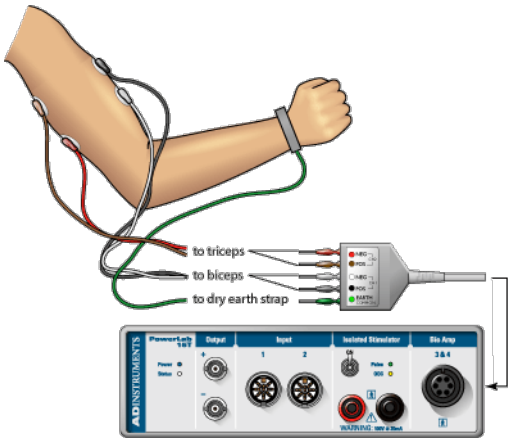

Figure 2. sEMG equipment. (Google images)

Electromyography (EMG) has been utilised before in other experiments for analysing issues related with sonography and, in other industries, to get information regarding performance associated with the workplace, principally to evaluate light, repetitive work where the activity of specific muscles is of interest. Ergonomic analysers often use this technique when comparing the specific musculoskeletal stresses associated with various work positions, postures or activities and for validation of ergonomic principles.

With this system we are able to collect muscular activity data in different scenarios, with the objective of comparing them and check that present improvements are truly successful, as well as test any potential prototype to confirm that the product can help to reduce the load and stress suffered by sonographers and avoid work related musculoskeletal disorders.

The first pilot experiment is performed in two different scenarios in order to obtain an estimation of possible improvement in terms of shoulder effort. The first scenario consisted of a normal range of motions including shoulder abduction at different degrees (0, 45 and 90 degrees) without any support. The second scenario includes an additional support under the arm intended to help during sustained shoulder abduction.

The muscles to be assessed are Upper Trapezius, Middle Trapezius and Lower trapezius, positions defined by Eleanor Criswell (Criswell, 2011).

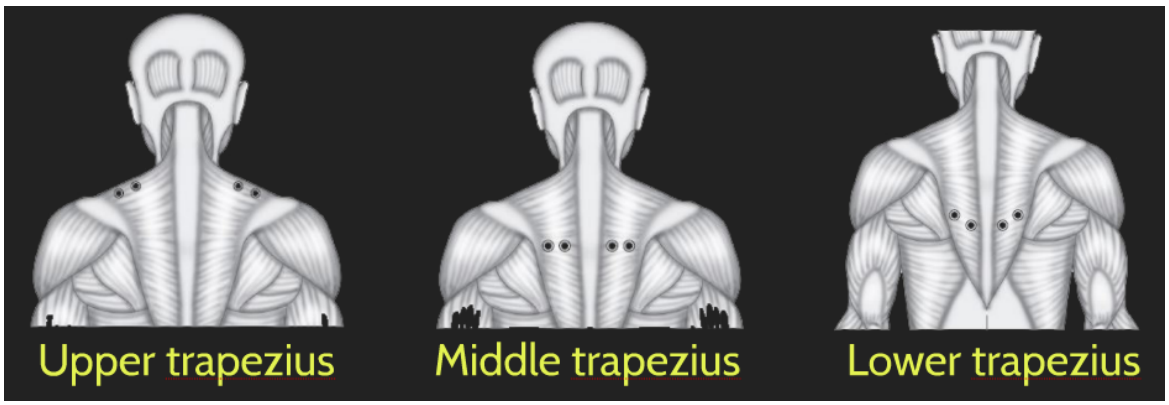

Figure 2. Sensor placement. (Criswell 2011)

The results (Figure 4) show an important improvement and muscular activity reduction not only in the shoulder area (upper trapezius), but in the back muscles too (middle and lower trapezius). This is taken as a validation and as a starting point to find a potential device that could be used as a support during ultrasound scans.

Design process

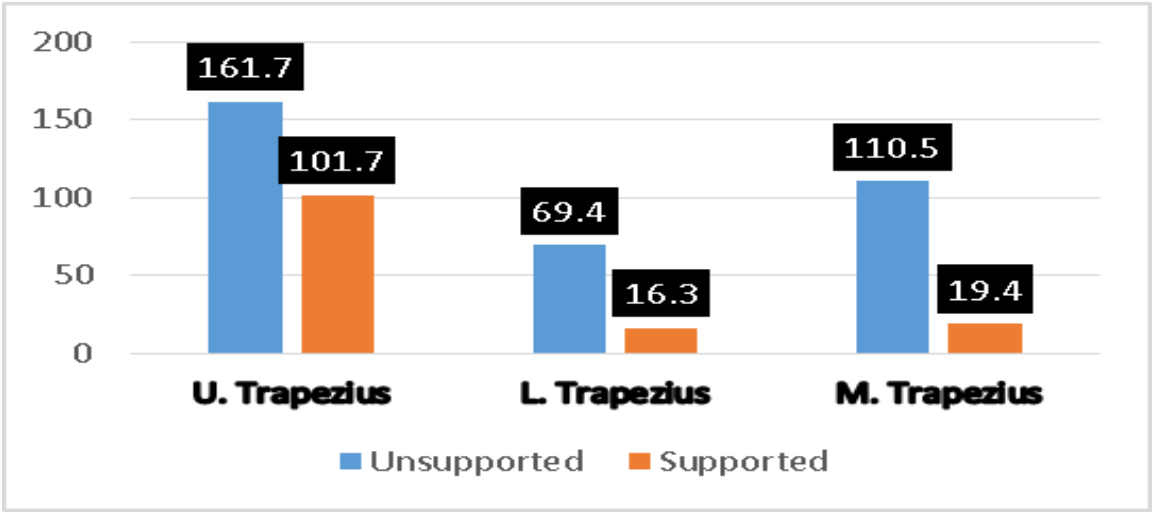

Figure 3. Results from pilot experiment

The objective is to find a system of supporting the shoulder without blocking any range of motion required in ultrasound scans. The device should keep the weight of the shoulder but without adding any extra effort requirement when moving the arm. This idea seems very close to the "zero

gravity" concept used in cinema when recording dynamic scenes to avoid vibrations during camera displacements, called "Steadicams".

Iso-Elastic concept

Steadicam is a device used by video makers to stabilise and eliminate shaking and rolling during video shooting. First introduced in 1976, its appearance has revolutionised the way movies and sports competition are recorded. There are three elements that make up of the device; an iso-elastic arm, a sled that holds the camera equipment and a supportive vest.

The specific system that is of interest to this project is the iso-elastic arm where it absorbed both the weight of the camera and vibration caused by user displacements. That system would be used to support sonographer's body weight and reduce shoulder abduction stress by attaching it to the shoulder. The spring in the system will pull the arm and hence provide an opposite force to neck, back and forearm muscles.

Figure 4. Support Device first prototype

The idea is to make one similar device like the Steadicam but with one single arm with one end attached to the sonographer's shoulder and another end attached to the chair or ultrasound scanning couch. Instead of being at front like Steadicam, the arm will be suspended from behind hence it wouldn't block any movement during scanning.

Prototype Assessment

Once a first prototype has been designed and manufactured, and before looking at other possible designs improvements or manufacturing methods, another experiment has been performed in order to validate the iso-elastic arm support idea.

In this case, the two scenarios consist again in normal scanning movements focusing on shoulder abduction, one without any support and another using the shoulder support device prototype.

Again, there is a clear muscular activity reduction when comparing both scenarios (Figure 6). The use of this device is helping the user to support the arm weight which reduces the effort required during sustained shoulder abduction.

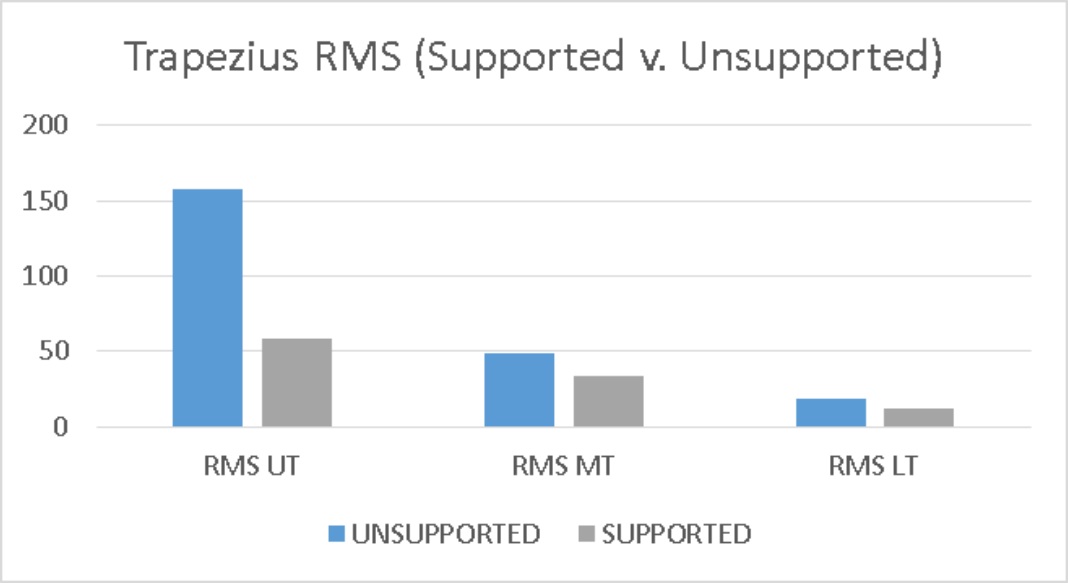

Figure 5. Results from prototype EMG experiment

Future work

The option of a device that helps reduce shoulder abduction-related effort will clearly reduce injury risks. The most important obstacle to achieve this, will be related with the design process since it is not easy to accommodate these kind of support in an ultrasound environment due to the huge amount of different movements that sonographers need to perform during scans.

Next steps include further re-design of the device in order to optimise it and to be able to perform a clinical test with professionals involved on it. Their feedback will be the most important to know before starting a final product design since their answers and questions will give the information required to continue with its development.

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