Teaching a Series of Mind-Body Techniques to Address the Risk of Work-related Musculoskeletal Disorders Among Sonography Students: A Pilot Study

THESIS

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Abstract

One population of healthcare workers for which the link between job specific activities and work-related musculoskeletal disorders (WRMSD) has been reported are sonographers. Existing literature on the topic has focused on self-reported survey data which has demonstrated that upwards of 80% of sonographers perform their jobs in pain. Many studies have identified risk factors for WRMSD relating to the micro-ergonomic interface between sonographer and equipment and the macro-ergonomic interface between sonographer and hospital organization. However, very few prospective or intervention studies which address these risks have been executed.

Recent research has demonstrated the feasibility of mind-body techniques in the improvement of micro- as well as macro-level ergonomic concerns for populations of professionals at-risk for developing WRMSD. The current study was designed as a prospective teaching pilot of a series of mind-body techniques for a group of student sonographers. The proposed research question is: What combination of mind-body techniques, taught to a cohort of novice sonography students, would provide exploratory reduction of the risk of WRMSD?

A pre-post experimental design was employed and longitudinal data were collected from a cohort of first year sonography students at The Ohio State University (n=12). In order to measure variables of self-reported health influenced by micro-and...
macro-ergonomic factors, a set of surveys was administered to participants at study baseline and upon completion of the interventions: the Short-Form Health survey, the Perceived Stress Scale, and the Visual Analog Scale for upper extremity pain. Students who participated in the study were exposed to two types of interventions: ergonomics education and mind-body techniques.

As ergonomics education is a curricular requirement of accredited sonography programs, this intervention was delivered to all participants. The two mind-body techniques employed were biofeedback and mindful sonography yoga and cueing. Participants were randomly assigned to a level of experimental treatment: ergonomics education + biofeedback (BF, n=4), ergonomics education + biofeedback + mindful sonography yoga and cueing (BFYM, n=4), or ergonomics education + mindful sonography yoga and cueing (YM, n=4). These interventions were delivered in a series of six sessions. Additional postural analysis was performed and muscle activity measures were collected for groups who received the biofeedback intervention.

While analysis of the self-reported survey data did not demonstrate statistically significant changes for any of the treatment groups over the study period, certain participants showed development in micro- and macro-ergonomic behaviors. The YM group demonstrated an improvement in mental health, stress level, and right upper extremity pain. Three of the study participants experienced a clinically significant reduction in right upper extremity pain, one from the BFYM group and two from the YM group. Also, biofeedback training was shown to improve posture in both groups who received this treatment, and to a greater extent for the BFYM group. While the statistical
power of the results was limited by a small sample size, the findings of this pilot study indicate the need for future, larger scale studies which investigate the use of ergonomics education and mind-body techniques to address micro- and macro-ergonomic risk factors of WRMSD for sonographers.
Acknowledgments

I would first like to thank my M.S. thesis committee, Dr. Carolyn Sommerich and Dr. Maryanna Klatt. Your professional expertise has been a pivotal part of the development of this thesis, and I value the feedback and advice that you have both given me along the way.

I would also like to express immense gratitude for my advisor, teacher, and friend, Dr. Kevin Evans. Your passion and dedication to your work is truly admirable, and you are a one-of-a-kind role model for our profession. I would not be where I am today without the unwavering support and mentorship you have given me over the past ten years.

Finally, I would like to say thank you to my family, Andy and Hunter. You guys are everything.
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Fields of Study

Major Field: Allied Medicine
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Chapter 1: Introduction

1.1 Evidence of WRMSD Among Sonographers

It is the responsibility of healthcare professionals to meet the unique needs of their patients in order to deliver high quality, individualized care. The specific work which is necessary to provide excellent care and improve the lives of patients is typically very “hands on” in nature. In order to complete these tasks, healthcare workers are often required to put themselves in very physically demanding and highly repetitive situations. The activities that are required to provide patient care have long been acknowledged as a major contributor to the high incidence of work-related musculoskeletal disorders (WRMSD) in health care staff.\textsuperscript{1,2}

One population of healthcare workers for which the link between job specific activities and WRMSD has been extensively reported are sonographers. Advancements in technology in recent decades have made the use of ultrasound a particularly valuable tool for various medical fields. The increase in use of sonographic exams for screening, diagnostic, and therapeutic purposes has led to an increased demand in highly trained and skilled sonographers. While continued growth in the field shows promise for vast opportunities and future development of those in the field, it also brings increased physical expectations of sonographers. This includes an increase in the number of exams
performed by individual sonographers as well as the duration of each individual scanning session.³

The demand for sonographic examinations influence the micro-ergonomic interface between sonographer and the equipment in order to quickly and efficiently supply diagnoses (see Key Terms, page 5). On the micro-ergonomic level, a typical exam requires the sonographer to move in different physical positions while applying a variable amount of pressure to the ultrasound transducer. In order to obtain a technically satisfactory image, the sonographer may often manipulate his or her body in ways that result in statically held or repeated dynamic loading of the muscles of the neck, shoulder, arm and back. Additionally, they may exhibit repeated fine motor movements of the shoulder, forearm, wrist, hand and fingers throughout an exam.³

The effects of the continued physical strain that occurs in sonographers have been linked to an increased risk of WRMSD. Concern for the issue gained much attention in 1985, as Craig published a series of case reports relating WRMSD to working with patients and equipment specific to the practice of ultrasonography.⁴ Since that time, numerous studies have sampled populations of sonographers to determine the prevalence of WRMSD symptoms and attempted to identify risk factors for injury. Further descriptive data have been gathered regarding potential macro-ergonomic contributing factors, such as age, gender, workplace culture, mental health status, and workload.

The existing literature on WRMSD prevalence and ergonomic issues among sonographers varies greatly in sample size, geographic location, and population demographics. However, overall results of previous studies demonstrate consistently that
the majority of sonographers are performing their jobs in pain. In fact, a recent cross-sectional survey performed by Evans et al. of 2963 registered Diagnostic Medical Sonographers (DMS) found that 90.4% were scanning in pain.\textsuperscript{5} Additionally, there were several macro-ergonomic factors such as increased patient workload, inability to take breaks, and low job satisfaction woven throughout the presented data as positively correlated with symptoms of WRMSD.

1.2 Raising the Evidence

While the statistics continually exhibit the need for ergonomic improvement of sonographic practice for the prevention of work-induced pain in sonography, most of the previous research has been focused on documenting the problems and doing so through cross-sectional surveys. Generally, the data on outcomes and exposure were self-reports from working sonographers about their work-related pain and the mental, physical, and social factors that they think may contribute to risk of WRMSD. Objective data describing both micro- and macro-ergonomic demands on sonographers has been limited and very few prospective or intervention studies have been executed to address this occupational risk.

In order to gain a higher level of evidence for the prevention of WRMSD in sonography, it is important to move beyond survey research, self-reported information and cross-sectional data collection. The current study was designed as a prospective teaching pilot of a series of mind-body techniques, introduced as part of the educational
curriculum, for a group of student sonographers. As educators, our goal is to properly prepare sonography graduates to deal with the physical and psychosocial pressures of the hospital department. This pilot was composed to explore the possibility of implementing these mind-body techniques to address the anticipated micro and macro-ergonomic influences that graduates’ encounter as they enter the workforce. Specifically, observing a student cohort that are provided these educational interventions provides descriptive information on how these could be successfully implemented in professional curriculum and positively influence their behavior and attitudes as they enter the workforce. The overall arching objective is to produce sonographer graduates who are not only academically prepared but also able to avoid career ending injuries, due to the inability to cope with the pressures at the micro and macro-ergonomic level of the workplace.

1.3 Ergonomics Education and Mind-Body Techniques

**Ergonomics education** is currently a required curricular activity in academic sonography programs. In order to enhance the successful translation of this curriculum to the clinical practice of first year sonography students, varying levels of mind-body techniques were introduced to entering students, specifically to address micro- and macro-ergonomic influences that they will clinically encounter. The first of these interventions is the use of **biofeedback** data acquired using surface electromyography (EMG) while the participants are scanning and receiving audio feedback. The hypothesis is that the biofeedback will assist the subject to become aware of excessive levels of muscle activity while scanning, by providing audible cues related to amount of muscle
activation/tension. The second intervention would be instruction of **mindful sonography yoga** to increase strength, flexibility, balance, coordination, and psychological awareness of the body during scanning. An added component to the mindful yoga stretching is use of **cuing** which help to remind the participant to be mentally and physically prepared for each patient examination. By obtaining pre-and post-intervention survey data on perceived pain, stress, and physical and mental health, and evaluating posture during biofeedback treatments, it is hypothesized that progressive changes may be detected as the student sonographers advance through their academic and clinical curriculum. Results from piloting these educational interventions could demonstrate their potential as curricular methods to address both micro- and macro- ergonomic factors in the risk of WRMSD for this occupation.

### 1.4 Key Terms

**Micro-ergonomics**

*theoretical definition*- Evaluates both the human and the human environment interface with technology.⁶

*operational definition*- In this study, the micro-ergonomic focus will be on the interface between the sonographer and their ultrasound equipment, the software, and the scanning performance space.
Macro-ergonomics

*theoretical definition*- Evaluates the human organizational interface with technology.\(^6\)

*operational definition*- In this study, the macro-ergonomic focus will address the sonographer’s clinical work system and evaluate challenges and potential barriers that exist at each sub-level for performing their work.

Mind-body techniques

*theoretical definition*- Mind and body practices include a large and diverse group of procedures or techniques administered or taught by a trained practitioner or teacher, which focus on the interactions among the brain, mind, body and behavior. The 2012 NHIS showed that yoga, chiropractic and osteopathic manipulation, meditation, and massage therapy are among the most popular mind and body practices used by adults.\(^7\)

*operational definition*- In this study, the mind-body techniques that are utilized are biofeedback (audio), yoga stretching, and mindful cueing.

Biofeedback

*theoretical definition*- A mind-body technique in which individuals learn how to modify their physiology for the purpose of improving physical, mental, emotional, and spiritual health. Its intervention requires the use of specialized equipment to convert physiologic data into visual or audible cues which allow the individual to voluntary control body processes.\(^8\)
**operational definition**- Muscle activation of the deltoid that is captured as an electrical impulse and projected as an audible tone for reminding the participant.

**Mindful Sonography Yoga**

**theoretical definition**- Mindfulness is described as a state of active, focused attention to what one is experiencing in the mind and body at the present moment. Yoga in its full form combines physical postures, breathing exercises, meditation, and a distinct philosophy. There are numerous styles of yoga. Hatha yoga, commonly practiced in the United States and Europe, emphasizes postures, breathing exercises, and meditation.

**operational definition**- In this study, mindful sonography yoga is a modified form of yoga that employs postures, exercises, and breathing to stretch specific upper extremity muscles to prepare for the micro- and macro- ergonomic demands of working as a sonographer.

**Cueing**

**theoretical definition**- Cues are verbal or nonverbal suggestions which may be employed during meditation and yoga practices in order to produce the body’s natural relaxation response.

**operational definition**- In this study, we combined meditation and the practice of yoga to customize a set of verbal and nonverbal cues to remind and improve psychological balance, coping, and overall health and well-being, specifically customized to the sonography work environment to enhance job satisfaction and patient centered care.
Chapter 2:
Literature Review

2.1 Introduction

In order to properly determine potential gaps in the research relative to work-related musculoskeletal disorders (WRMSD) in health care workers, specifically sonographers, a review of the literature was needed. This chapter is devoted to the most current review of the published literature on this topic and will focus on the micro- and macro- ergonomic influences most commonly impacting sonographers and other health care workers. This review will be divided into a synthesis of the published works relative to the occupation of diagnostic medical sonography and then also a review of research that is applicable from related health care professions. Finally, a review of relevant research in the use of mind-body techniques to prevent work-related musculoskeletal disorders (WRMSD) will be included. The objective is to build on seminal work in this area and also to replicate any techniques or methods that will help us to answer our research question.
2.2 Evidence of WRMSD Among Sonographers

The concern for work-related musculoskeletal disorders (WRMSD) in the profession of sonography gained much attention in 1985, as Craig published a series of case reports relating MSK injury to working with patients and equipment specific to the practice of ultrasonography.¹ This is the first published report of the risk of injury at the micro-ergonomic level in this profession. Since that time, a number of research studies have profiled the existence of WRMSD among diagnostic medical sonographers (DMS). While these studies have variations in sample size, demographics, and methods, they were conducted with similar primary objectives. These goals include determining the prevalence of WRMSD among sonographers as well as assessment of current sonographic methods to identify risk factors and behaviors positively linked to WRMSD symptoms. Additionally, certain case series and cross-sectional studies have introduced ergonomic interventions in populations of sonographers to evaluate their effect on posture, kinematics, and incidence of WRMSD (see table 2.1).
Table 2.1 Studies on the topic of WRMSD among sonographers arranged according to evidence based pyramid

<table>
<thead>
<tr>
<th>Case Reports I (n&lt;150)</th>
<th>Author</th>
<th>Sample (n)</th>
<th>Method</th>
</tr>
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<tbody>
<tr>
<td>David (2005)</td>
<td>70</td>
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<td></td>
</tr>
<tr>
<td>Necas (1996)</td>
<td>149</td>
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<td></td>
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<td>Wihlidal and Kumar (1995)</td>
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<td>self-reported survey</td>
<td></td>
</tr>
<tr>
<td>Muir (2004)</td>
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<td>self-reported survey</td>
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</tr>
<tr>
<td>Murphy and Milkowski (2006)</td>
<td>22</td>
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<td></td>
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<tr>
<td>Village and Trask (2007)</td>
<td>11</td>
<td>sonographer assessment</td>
<td></td>
</tr>
<tr>
<td>Vetter (2013)</td>
<td>3</td>
<td>self-reported survey and sonographer assessment</td>
<td></td>
</tr>
<tr>
<td>Evans et al (2010)</td>
<td>5</td>
<td>self-reported survey and sonographer assessment</td>
<td></td>
</tr>
<tr>
<td>Burnett (2009)</td>
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<td>sonographer assessment</td>
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<td>Suzuki et al (2012)</td>
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<td></td>
</tr>
<tr>
<td>Radin et al (2011)</td>
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<td>sonographer assessment</td>
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<td>Smith et al (1997)</td>
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<td></td>
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<tr>
<td>McColloch (2002)</td>
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<td>Russo (2001)</td>
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<tr>
<td>Pike et al (1997)</td>
<td>983</td>
<td>self-reported survey</td>
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<tr>
<td>Evans et al (2009)</td>
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<td>self-reported survey</td>
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</thead>
<tbody>
<tr>
<td></td>
<td>Murphy and Russo (2000)</td>
<td>1621</td>
<td>self-reported survey and sonographer assessment</td>
</tr>
</tbody>
</table>

Several of the reviewed publications were completed by obtaining cross-sectional data related to WRMSD on a small, convenience sample of sonographers at a specific medical site or geographical area. Of these case reports, many used descriptive surveys as the source for statistical data, including a study performed by David in 2005. In this study, 70 surveys were completed by sonographers who were employed at clinical affiliates of the University of Oklahoma, College of Allied Health. The aim of the study...
was to determine how often DMS are reporting pain to administration and the barriers that are preventing them from reporting their WRMSD. The results indicated that many sonographers were scanning in pain, but were not reporting it to their supervisors, due to the belief that it was “part of the job”.\textsuperscript{12} While this data underscores the importance of workplace support for the prevention of WRMSD, the evidence was strictly qualitative and could not be generalized. No data were provided on the demographics of this small population or statistical correlations for specific survey responses.

Several case reports did provide quantitative evidence on the incidence of WRMSD by the use of descriptive surveys. Studies by Necas, Wihlidal, and Muir each implemented a cross-sectional survey regarding the prevalence of WRMSD symptoms and various characteristics relating to WRMSD risk factors among a small sample of sonographers.\textsuperscript{13-15} The key value examined in the Necas\textsuperscript{13} survey was a “work habit score.” This score was derived from the number of times respondents answered “yes” to indications of workplace behavior that would increase chances of WRMSD developing. Of this group of 149 sonographers in Washington State and Oregon, 66% reported symptoms of WRMSD and showed positive correlations with stress levels, numbers of hours worked, and number of exams performed per day. The surveys distributed by Wihlidal and Muir showed even higher prevalence for WRMSD symptoms, with 88.5% and 91% of respondents scanning in pain, respectively.\textsuperscript{14,15} Interestingly, Wihlidal found that younger sonographers had a higher percentage of work-related injury and that lower job satisfaction was linked with increased WRMSD symptoms/injuries.\textsuperscript{14} However,
Muir’s results showed that although symptoms affected 77% of respondents in their activities of daily living, most of them reported excellent health and active lifestyle.\textsuperscript{15}

Each of the above quantitative studies demonstrated that differing cohorts of sonographers from different geographical areas were reporting high prevalence of symptoms of WRMSDs. Additionally, they each provided information on various physical, environmental, behavioral, and psychosocial factors that exist in the field of sonography and may contribute to the occurrence of MSK symptoms and injuries. However, the sonographers selected were from limited geographical areas with very small numbers of participants. As all data were gleaned from a survey format, results were all of a self-reported nature, and relatively low response rates may mean that only symptomatic sonographers chose to respond, thus potentially hampering the validity of the data.

\textit{Assessment of Current Methods}

Certain case reports and cohort studies quantitatively evaluated WRMSD risk by assessing postural and muscular loads involved in performing sonographic exams. In 2006, Murphy and Milkowski\textsuperscript{16} used surface electromyography (EMG) in 22 sonographers recruited from an education class. Subjects were evaluated while doing left (control panel and keyboard) and right-sided (abduction of shoulder) tasks which were typical of daily work in a sonography department. Muscle activity was measured for both “standard” and ergonomically “improved” postures on each side. Results demonstrated
that left upper trapezius muscle activity decreased 65% when rotated from an extended-reach posture to neutral, and right rotator cuff activity decreased 46% when abduction decreased, then further decreased 78% when the forearm was supported.\(^\text{16}\) While these results could have led to the cause and effect relationship for improved posture and decreased muscle load, scanning for this experiment was done in a very controlled environment, and differences among subjects regarding experience, physical characteristics, and prior presence of WRMSD symptoms was not provided.

In 2007, Village and Trask\(^\text{17}\) combined EMG of neck and shoulder muscles with subjective video analysis of shoulder abduction and neck bending/twisting in a group of 11 sonographers for 24 total sonographic exams (2-3 exams for each subject.) During 62.6% of the total scan time the scanning arm was abducted >30 degrees, and 42.6% of the time it was abducted >45 degree, with the neck bent or twisted 30% of the time. While the EMG indicated overall “medium” risk for muscle load, there were high grip forces throughout the scans with no rest breaks provided.\(^\text{17}\) Although it can be seen from these results that the typical movements of a sonographer during a scan are ergonomically incorrect, there was not a specific sonography examination type or length for which the subjects were observed. Thus, there was great variability in the postures assumed between subjects and exams, making it difficult to draw conclusions about the risks of specific arm positions.

Vetter\(^\text{18}\) et al. used a mixed methods approach to obtain quantitative and qualitative assessment of ergonomic risk factors in relation to the chosen transducer size. A sample of 3 sonographers performed a renal sonogram using a large and a small sized
abdominal transducer. During this time, a pressure sensor was attached over the transducer to quantitatively measure pressure and force throughout the scan. A pre- and post-scan questionnaire was also obtained, providing qualitative data on level of pain, scanning experience, and probe preference. Results demonstrated that pressure increased with the smaller transducer, and maximum pressure was applied by the thumb for both transducers. Additionally, it was reported that the smaller transducer allowed for better scanning angles.\textsuperscript{18} This study does provide valuable numerical evidence for pinch and grip force and demonstrates how differences in equipment set up (i.e. probe size) can affect these factors. However, the sample of sonographer participants was very small and only one type of sonogram was performed.

By combining measures of the independent variables of demographics, work demands, psychosocial status, and behavioral and physiologic upper extremity symptoms, Evans et al\textsuperscript{19} performed a pre-test/post-test design intended to identify specific holistic risk factors that contribute to WRMSDs. Five sonographers who perform portable neurosonograms were observed performing four separate portable exams of the neonatal head and were scored for posture using the Rapid Upper Limp Assessment (RULA) tool.\textsuperscript{20} They also completed the Short Form 12 (SF-12v2\textsuperscript{®})\textsuperscript{21} giving a Physical Composite Score (PCS) and Mental Composite Score (MC), a Visual Analog Scale (VAS) giving a level of discomfort, and had a sonogram of their elbow and wrist to document the condition of their median nerve, before and after performing the portable exams. No statistically significant changes were noted between the pre- and post-test measures for physical and mental health, or pain scores. There was also no significant change in the median nerve
for any of the subjects.\textsuperscript{19} This study did not demonstrate the hypothesized results that specific risk factors contributing to musculoskeletal distress in the wrist and hand for those who perform portable neurosonology would be identified. It was performed with a small, convenience sample of participating sonographers with no specific time intervals during and between sonographic exams. However, this again indicates the need for further studies using a similar design of combining descriptive survey data with ergonomic evaluation of sonographer scanning techniques.

A study performed by Burnett\textsuperscript{22} et al in 2009 quantified ergonomic risk-factors in a small sample of sonographers by having participants perform five separate, specific, abdominal ultrasound protocols: thyroid (TH), right abdomen (RA), left abdomen (LA), right deep venous thrombosis (RDVT), and left deep venous thrombosis (LDVT). Data collection included video analysis of posture using the RULA tool, determination of joint angles using a goniometer, and measurement of push force with a strain gauge. RULA results revealed that posture for LA and LDVT scans needed immediate attention, and RA, RDVT, and TH postures needed additional investigation. While the angles of the participants’ joints were varied, excessive and repetitive force and awkward wrist angles occurred overall in four out of five of the scans.\textsuperscript{22} This study of a small sample of sonographers did not introduce any specific type of ergonomic intervention for the improvement of posture or scan force. However, it did indicate that specific risk-factors may vary between scan types, necessitating the introduction of scan-specific ergonomic interventions in future research.
**Intervention Studies**

In the studies outlined above, researchers have performed procedures which evaluated ergonomic variables of sonographic procedures. Gaining both qualitative and quantitative assessments of sonographic methods allow for descriptive risk assessment and indicate the need for ergonomic intervention studies of sonographers. In 2011, Sommerich\(^2^3\) et al. completed an early stage intervention study by involving a sample of 20 sonographers in the process of identifying workplace risk factors for MSK injury and developing ideas for practical, effective ergonomic interventions. With a multi-stage experience including workbook preparation, focus group discussion, and idea-generation sessions, participants gave feedback which allowed the researchers to produce a set of ten interventions for the next stage of use.\(^2^3\) This study demonstrated the feasibility and value of engaging sonographers in the development of interventions, in order to improve the likelihood that the interventions will be viewed as useful and desirable.

A limited number of researchers have investigated the effects of alterations in sonography equipment as a practical ergonomic intervention for reduction of WRMSD risk factors. In 2012, Suzuki et al studied the effects of differences in height of ultrasound machine panel, for sonographer keyboard and technical control, on MSK stress during scanning.\(^2^4\) A group of 8 Japanese students were asked to perform a sonographic exam on a test dummy, touching nine standardized points on the machine with their non-scanning hand. The procedure was repeated at four different panel heights and muscle stress, joint angle, pushing force, and subjective ease of use from the participants point of view were measured. It was found that the overall optimum panel height for muscle stress, joint
angle, and force was 700mm from the floor, which is at elbow level. However, there was no overall subjective change in ease of manipulation at the differing heights.\textsuperscript{24}

Another study by Radin Umar\textsuperscript{25} et al. also evaluated sonographic intervention with the introduction of an articulating arm for echocardiography. A functional prototype which could be locked into place during cardiac scanning was developed based on needs assessment and concept generation and evaluation. The goal of the articulating arm was to reduce probe grip, push force, sustained exertions and repetitive awkward body postures. Six cardiac sonographers were asked to perform a current protocol with and without the device. Scan sessions were recorded on audio and video, image quality was professionally assessed, and sonographer’s perceptions of the interventions were documented. Results demonstrated that overall image quality with the articulating arm was good, that it reduced exertion, and that it was subjectively useful.\textsuperscript{25} A follow-up pilot study was conducted that confirmed the viability of this intervention concept for use on larger patients.\textsuperscript{26}

Both Suzuki and Radin Umar et al. provide evidence of possible useful interventions for sonographers at the micro-ergonomic level, in which the interface between the operator and machine is changed. However, both studies were performed in controlled settings involving small numbers of sonographers, with no extension into clinical practice. While Suzuki did perform quantitative assessment of joint position at different console heights, the procedure was performed on a test dummy rather than a phantom dedicated for sonographic imaging.\textsuperscript{24} As no acceptable clinical image was required to be obtained, it is difficult to determine whether participant posture was similar
to an actual patient scan. Conversely, subjects in the study performed by Radin Umar et al. were required to obtain a set of images on the adult heart which are required in a typical echocardiographic protocol, thus giving the results stronger internal validity. No quantitative analysis of posture or joint position was performed by Radin Umar et al., but in the follow-up study shoulder posture and muscle activity data were measured and found improved when using the articulating arm probe support in comparison to normal scanning methods.

2.2.2 Case Reports II

Larger Scale

A similar set of case reports also evaluated the incidence of WRMSD among sonographers, but on a larger scale than the previously noted studies. Although subject selection was not randomized, either larger sample sizes were assessed or sonographers were selected from a wider geographic area, and a variety of different workplaces. One such report was written by Gregory in 1998. He used results of a pilot survey performed by the Workcover Authority New South Wales (NSW), in which 77% of the 197 Australian sonographers showed symptoms of WRMSD, as the foundation of his report. Included in his work is a description of various WRMSD, along with a breakdown of their causes and possible methods for prevention. He also included a case report of an ergonomics survey from his particular sonography department. This type of study can serve as a useful tool for sonographers and managers alike to gather insight and advice on
dealing with WRMSD in the workplace. However, most of the work is anecdotal evidence with very little statistical analysis of data.

Two other studies by Smith et al. and McColloch, performed more quantitative descriptive surveys on populations consisting of mostly cardiac sonographers.\textsuperscript{28,29} With a sample size of 113, Smith et al. had respondents representing 98 different cardiac scan labs across the U.S. Of those participants, 80% reported back, neck, or shoulder pain, with statistically significant associated factors including increased number of scans performed and greater scan time per patient.\textsuperscript{28} Similar results were found by McColloch, who recruited 295 subscribers to 3 different national cardiac ultrasound publications, 75% of whom were registered cardiac sonographers. 82% of the sample reported work related discomfort, which also increased with number of scans per day and scan time.\textsuperscript{29} These studies both had relatively large sample sizes and sonographer representation from many different geographic locations. However, because the samples were composed mostly of cardiac sonographers, results can only be applied to job tasks specific to professionals in this specialty. Nonetheless, the need to evaluate ergonomics for a specific application of sonography on a larger scale is again demonstrated.

In 2001, Russo\textsuperscript{3} performed a more rigorous survey with a target population of sonographers in British Columbia (BC). The sample size was 211, which represented 92% of the credentialed sonographers in BC at that time. Results of the survey not only showed the prevalence of WRMSD symptoms, with 91% of respondents reporting work-related pain, but also identified demographic, individual, physical, organizational, and psychosocial factors associated with WRMSD among sonographers. In this sample, 65%
of the sonographers who reported symptoms consulted a professional, and two thirds of those received a diagnosis. Regarding psychosocial factors, the group with highest level of pain demonstrated significantly lower mean scores for co-worker support, supervisor support, work tasks, work schedule, and work clarity. The inability to control workload or scheduled breaks were identified as challenges. The fact that this survey obtained responses from most of the credentialed sonographer population in BC, at the time, underscores the seriousness of WRMSD and the direct relationships they may have with many other work-life factors. However, it is only representative of this population at one point in time, and being cross-sectional in design cannot, therefore, provide any confirmation regarding causality. This indicates there is still a need for longitudinal studies on WRMSD risk and intervention in sonographer populations.

In 2012, Euler and Meadows conducted an in depth analysis of the impact that sonographer WRMSD had on their healthcare organization and the effects that a set of subsequent ergonomic interventions had on factors such as WRMSD and sonographer productivity. The study was performed over a period of 10 years, and sonographers in cardiac/vascular laboratories at the organization were introduced to variable combinations of eleven types of ergonomic interventions starting in the 4th year. These interventions included guest speakers, video in-service, height adjustable chairs, keyboards, and ultrasound equipment consoles. Results demonstrated that although productive hours remained nearly the same, procedure volumes gradually increased over the decade. Also notable was that one year contained four reported WRMSD, which cost $22,000 of treatment and 191 hours of lost time. However, the introduction of the
interventions in 2004 resulted in a decrease in cost of treatment, hours lost, and reported WRMSD, for the incidence rate dropped by 50% in the time period after the interventions were introduced.\textsuperscript{30} While this longitudinal study provided evidence of the long-term positive effects of ergonomic interventions, it provides no information on the demographics of the sample, and no qualitative information on sonographers’ level of pain or subjective response to the interventions. Thus, it is difficult to ascertain the social and psychological effects that the interventions had on the overall well-being of this cohort.

\textbf{2.2.3 Cross-Sectional Studies}

\textit{Larger Scale, Random Selection}

Certain notable publications on WRMSD in sonography have, in fact, used random selection when obtaining large samples of sonographers for quantitative cross-sectional surveys. Included in these is the 1993 study by Vanderpool et al., in which 101 respondents were randomly selected from the American Registry of Diagnostic Medical Sonographers (ARDMS) in order to determine the prevalence and characteristics of carpal tunnel syndrome (CTS) symptoms among cardiac sonographers.\textsuperscript{31} Results demonstrated that 63\% of respondents reported CTS symptoms. This study also pointed to the need for an emphasis specifically on the work place configuration of sonography equipment and the associated environments which allow cardiac sonographers to
maintain their upper arm joints in an optimum position, practice balanced posture, and allow frequent breaks to give muscles recuperation time.\textsuperscript{31}

In 2003, Horkey and King used the same procedure and randomly selected a sample of 81 credentialed cardiac sonographers from the ARDMS.\textsuperscript{32} In addition to prevalence of WRMSD symptoms and need for ergonomic interventions, respondents were also surveyed on their awareness, extent of use, and preference and feasibility of various recommended interventions. Results demonstrated that the majority of respondents were aware of most of the interventions and implemented about half of these, with adjustable beds and chairs, frequent breaks, and variable scan postures throughout the day identified as the most preferred, feasible interventions.\textsuperscript{32}

The discussion points in each of the studies which employed random selection of participants are useful for future research. The descriptive data regarding sonographer knowledge and preference of ergonomic practice in the workplace is a starting point for the type of interventions that may be most useful and practical in the prevention of future WRMSD. However, both of the samples were randomized from registered cardiac sonographers, and the results may not be representative of sonographers registered in other specialty areas.\textsuperscript{31,32} Still, these studies also point to the need for determining the effectiveness of identified interventions.

For many years, the largest randomized cross-sectional study that attempted to describe the prevalence of WRMSD and related work and personal factors among diagnostic medical sonographers was a study performed by Pike et al. in 1997.\textsuperscript{33} Surveys were distributed to randomly selected registrants of the ARDMS. Of the 983 respondents,
81% reported musculoskeletal pain or discomfort that they associated with the work tasks of scanning. The neck, shoulder, wrist, hand and back was where their pain was most often reported, as well as the specific activities of sustaining applied transducer pressure, shoulder abduction, and twisting of the neck/trunk were the key activities that aggravated the pain. Respondents indicated increased work periods without rest and inability to control work flow. However, they indicated overall satisfaction with their work and only a small minority were absent from work due to their pain or discomfort.  

In 2009, Evans et al. proposed to examine the prevalence of sonographers scanning in pain in the U.S. as demonstrated by Pike et al. years earlier. An online cross-sectional survey was made available to 3000 randomly selected ARDMS registrants as well as 2785 randomly selected customers of the Sound Ergonomics, LLC vendor list. With a final sample size of 2963, 90.4% of respondents indicated scanning patients while in pain. A number of findings were consistent with the Pike et al. study, including 38% of respondents reporting intermittent pain in the shoulders and neck, and 64% of younger sonographers and 72% of older sonographers reporting taking anti-inflammatory medications to help with the pain. Evans also found that pain was attributed to the same specific transducer and posture positions as the Pike study years earlier. The main variation in the studies pertained to age: Evans’ study results were skewed toward older, more experienced sonographers (indicative of an aging worker population) who were more likely to take time off than their younger counterparts. In a follow-up analysis of this data set in 2010, Evans et al. discovered that 60% of the respondents had pain in their distal upper extremities.
Both Pike and Evans obtained large, randomized samples of sonographers and exhibited the significance of WRMSD across the United States\(^5,^{33}\). Over ten years separated the two studies, during which time many ergonomic ultrasound innovations were introduced, more education was provided, and workstations were redesigned by many popular manufacturers. However, the professionals surveyed continued to report the same job demands causing pain as a whole, and actually reported an increase in the prevalence of pain. In order to decrease these alarming statistics, additional or alternative intervention and treatment methods for WRMSD prevention need to be developed and researched.

### 2.2.4 Meta-Analysis

The study with the highest available level of evidence regarding WRMSD in sonographers to date is a meta-analysis performed by Murphy and Russo in 2000\(^{35}\). Objectives of the project were to quantify physical and psychosocial stressors and symptoms related to ultrasound tasks, identify potential solutions related to changes in work practices, and determine the efficiency of the proposed solutions. In order to measure these objectives, the authors combined results from a cross-sectional survey of three separate sample populations: British Columbia, Canada, and the United States. The mixing of data from these surveys produced a complete sample size of 1621. The results indicated that a large portion of sonographers were scanning in pain. Sustained transducer pressure, abduction of shoulder, and sustained repetitive twisting of neck were the activities that aggravated this pain the most. Although there were overall positive
perceptions of co-worker support and work clarity, problems were identified with repetitive tasks and inability to plan overtime and extra work.\textsuperscript{35}

Also included in the report was a clinical study of 27 sonographers at four British Columbia hospitals, who were evaluated doing several different tasks associated with sonography examinations. Among the observations from these sessions was that scanning while standing resulted in less muscle activity in the neck and trunk muscles and that elbow support reduced muscle activity in the neck, shoulder, and trunk muscles.\textsuperscript{35}

Murphy and Russo provide a higher level of evidence for their update on ergonomic issues in sonography. However, applying an AMSTAR assessment, a reliable and valid measurement tool to assess the methodological quality of systematic reviews\textsuperscript{36} of the report indicates that there is a lack of statistical details for both the survey and the clinical study portions. There is no demographic breakdown or separation of the melded sample, nor a description of methods and procedures used to obtain survey results. Additionally, the clinical study involved a much smaller, convenience sample and there is no explanation of a protocol that was followed to draw the gathered conclusions about ergonomic improvements.

\textbf{2.3 Evidence of WRMSD Among Related Professions}

Nursing, Physical Therapy, and Occupational Therapy are health care professions whose patient care responsibilities that have similar micro-ergonomic influences and share macro-ergonomic concerns for WRMSD with Sonography. This section will
provide a selective review of those published studies, in these allied health professions, that are further evidence of a need for an interventional study. Common risks and exposures will need to be examined in order to allow any proposed educational interventions to be translated to other health care professionals.

2.3.1 Nursing

Nursing is a well-established high-risk occupation for WRMSD, in particular low back pain. Certain cohort studies have addressed the prevalence of low back pain in nurses by assessing the impact of patient handling activities and individual indicators on symptoms. In 1997, Smedley et al. administered a questionnaire regarding non-occupational and occupational risk factors for low back pain every three months over a two-year period to a cohort of 838 nurses. In order to be included in data analysis, survey respondents were required to be free from low back pain for a period of one month prior to completion of the baseline questionnaire. Results of the study revealed that 38% of the sample developed low back pain at some point over the follow up period. In analysis of risk factors, frequent low mood at baseline was associated with the greatest risk for absence from work due to back pain. Occupational risk factors most associated with reported back pain were frequent manual transfer of patients, manual repositioning of patients in bed, and hoisting patients in and out of bath. While this study is limited to nurses who did not feel pain at baseline survey administration, the longitudinal design allowed for participants to respond regarding their current symptoms and risk factors, rather than ascertain them from memory. Additionally, results target potential micro- and
macro-ergonomic influences of back pain in nurses that need addressed in future interventional studies.

In an attempt to summarize the findings regarding prevalence of low back pain in nurses and the role of ergonomics intervention for improved patient activities, Hignett performed a systematic review of over 80 published studies in 1996.39 Overall, the reviewed studies demonstrated variable reports of lifetime incidence of low back pain in nurses from 35-81%. Also of note was that more frequent patient handling activities appeared to correlate with increased incidence of low back pain. However, the traditional prevention approach of technique training in patient lifting in handling appeared to have little or no long term benefit on low back pain risk. Additionally, engineered ergonomic interventions such as lifts have only proved to be partially effective.39 Thus, this systematic review indicates the need for future studies which test the feasibility of non-traditional ergonomic interventions and participatory methods for the prevention of lower back pain in nurses.

2.3.2 Physical and Occupational Therapy

The macro-ergonomic interface for physical (PT) and occupational (OT) therapists often requires them to perform lifting and moving of their patients, causing high rates of pain in these healthcare professionals. In 2000, Cromie et al. administered a cross-sectional survey to a sample of 506 registered physical therapists in Australia.40 Results revealed that 91% experienced work-related musculoskeletal pain or discomfort at some time in their working life, with 80% experiencing this pain within a 12 month period preceding survey administration.40 In 2009, Darragh et al. conducted a similar
cross-sectional survey in order to gather new information about the prevalence, severity, and characteristics of work-related musculoskeletal symptoms among physical as well as occupational therapists.\textsuperscript{41} The sample, which consisted of 674 physical therapists and 476 occupational therapists randomly selected from a list of licensed therapists living in the state of Wisconsin, indicated a 2006 annual incidence rate of injuries of 16.5\% for occupational therapists and 16.9\% for physical therapists.\textsuperscript{41} These are injury rates similar to those of heavy manufacturing workers, which indicates the seriousness of the risk of WRMDS in occupational and physical therapists and points to the need for future research with more detailed observational exposure analysis.

An additional area of concern highlighted by the Darragh et al. survey is the underreporting of WRMSD by PT and OT professionals, with less than half of the survey reporting symptoms to their employers and less than 25\% reporting a diagnosed WRMSD.\textsuperscript{41} These therapists also reported self-treating their own symptoms as well as adapting their work environments in order to accommodate their injury. While this allows PT and OT professionals to use their unique skill sets to deal with their own WRMSD, it may decrease their level of presenteeism. Campo and Darragh refer to presenteeism as an employee who is not only present, but also performing productively.\textsuperscript{42} In order to further explore the idea of impaired presenteeism, these authors collected cross-sectional survey data on a sample of 712 randomly occupational and physical therapists using the Stanford Presenteeism Scale (SPS).\textsuperscript{43} Results revealed that both work output and work efficiency were affected by WRMSD, with work output reduced by 5\% for therapists with moderate WRMSD and by 7\% for therapists with minor WRMSD.\textsuperscript{42}
In an additional mixed-methods approach, Campo and Darragh obtained qualitative data from a cohort of nineteen PT and OT professionals who were experiencing work-related pain by conducting focus groups on the topics of work-related pain, presenteeism, and job satisfaction. An emergent theme from the discussions was the participant’s aspirations to demonstrate professional ideals of altruism and dedication. In the presence of work-related pain, these macro-ergonomic concerns were resolved by working in pain, performing self-treatment and altering work habits so that coworker and patient satisfaction would not be sacrificed. Combining anecdotal evidence from these focus groups along with survey data regarding impaired presenteeism demonstrates the need for further research to explore specific interventions that would decrease the occurrence of WRMSD in physical and occupational therapists and thus prevent them from entering this distressing cycle of pain.

2.4 Evidence of Mind-Body Techniques as Ergonomic Interventions

There is an extensive amount of evidence demonstrating that sonographers are among the various populations of healthcare professionals who are at-risk for WRMSD. Much of this evidence is revealed through the use of self-reported survey data. While certain case control and cohort studies have reinforced sonographer’s WRMSD risk by assessing current workplace methods and in some cases introduced ergonomic interventions to reduce this risk, their existence is limited. Particularly, a gap exists in the investigation of interventions that address both micro-ergonomic concerns between the sonographer and workplace equipment as well as macro-ergonomic concerns.
between the sonographer and the work system. A group of interventions that would address both micro- and macro- ergonomic concerns of sonographer behavior are mind-body techniques, which focus users on the interactions among the brain, mind body and behavior. In the present study, the specific mind-body techniques which are investigated are biofeedback and mindful sonography yoga and cueing. The following section is a brief review of published studies which provide evidence of these mind-body techniques for the reduction of WRMSD in at-risk employee populations.

2.4.1 Mindful Sonography Yoga and Cueing

Mindfulness is described as a state of active, focused attention to what one is experiencing in the mind and body at the present moment. One goal in the practice of mindfulness as part of daily living is for an individual to maintain an enhanced state of consciousness, which allows for a greater appreciation of the possible behavioral responses toward life events. In turn, this practice may create greater resiliency toward illness, disease, and self-induced stress. Common methods included in the practice of mindfulness include yoga stretching and meditation.

There is a growing body of research which focuses on the effects of teaching of mindfulness practices such as yoga and meditation in the reduction of physical, emotional, and mental stress among healthcare workers. In 2015, Hevezi conducted a pre-post intervention study to evaluate the effects of a four week meditation intervention on compassion fatigue in a convenience sample of 15 nurses.

Compassion fatigue
describes the state of physical, emotional, and spiritual depletion experienced by caregivers of seriously ill or traumatized patients. Level of compassion fatigue was quantitatively measured before and after implementation of the meditation course with the Professional Quality of Life Survey. Qualitative data were also collected with four supplemental questions following the survey. Results demonstrated that the sample showed a statistically significant reduction in compassion fatigue and burnout over the study period, and that all participants reported increased feelings of relaxation and well-being on supplemental question responses.

In a similarly designed study, Martin-Asuero and Garcia-Banda tested the effects of the Mindfulness Based Stress Reduction (MBSR) intervention, a mindfulness intervention which includes activities such as yoga and meditation instruction, over a period of eight weeks. There is substantial research-based evidence of the success of practicing MBSR to retrain the mind to change its usual response to stressful situations. The 29 healthcare professionals included in the study completed a set of surveys which quantitatively measure level of stress before and after the implementation of an eight week MBSR intervention, and then again at three months post-intervention. Results demonstrated that the sample had a 35% decrease in level of distress, a 30% decrease in focus on distress, and a 20% decrease in negative affect. These variables were also shown to be highly correlated, and the improvements in distress levels lasted for the 3 month follow up period. Although each of the above studies evaluated a small, convenience sample, they demonstrate the efficacy of mindfulness interventions to address the macro- and micro- ergonomic influence that stress and burnout have on healthcare workers.
Certain studies have conducted randomized-controlled trials to investigate the effects of mindfulness interventions for the improvement of healthcare worker’s job satisfaction and level of psychological distress. In 2005, Shapiro et al. tested the effects of the MBSR intervention by dividing a sample of 38 healthcare workers into an experimental and wait-listed control group. All participants completed a set of surveys which provided quantitative measures on psychological factors such as level of stress, depression, burnout, and satisfaction with life. The surveys were administered both pre- and post-MBSR intervention for the experimental group, and the control group took them at the same point in time. The control group then began the MBSR intervention after post-treatment surveys were complete. Results demonstrated that when compared with the control group, the MBSR experimental group had significant reductions in perceived stress and a significant increase in level of self-compassion over the course of the study. They also reported greater satisfaction with life and less burnout from pre- to post-intervention. While this study was performed on a small sample, its design provides a high level of evidence for the benefits of mindfulness interventions in the health and wellness of healthcare workers.

2.4.2 Biofeedback

Biofeedback is a mind-body technique which proposes that an individual’s behaviors can be altered, sometimes permanently, if they are given timely information on their bodies’ physiological activities. One of the most common ways that this information is obtained is through the use of electromyography, which measures
electrical activity in the muscles. Individuals can learn to interpret the audible biofeedback signals that register EMG activity and improve their postures by avoiding or correcting stressful positions. Certain studies have evaluated the use of biofeedback on the micro-ergonomic improvement of workplace postures which put employees at risk of WRMSD. With the rapid development of technology, more recent literature has focused the effect of EMG biofeedback to improve posture during computer work.⁴⁹-⁵¹

In 2006, Pascal et al. investigated the effects of EMG biofeedback on upper trapezius muscle activity in a cohort of 11 females who were experienced computer users with known neuromuscular disorders.⁴⁹ Participants performed 3 minutes of computer work with audible EMG biofeedback and 3 minutes of computer work without biofeedback. Statistical analysis revealed a significant reduction in right upper trapezius muscle activity when using EMG biofeedback.⁵⁰ A similar study by Breen et al. assessed neck posture on six subjects while performing five hours of computer work with audible biofeedback and five hours of computer work without audible biofeedback.⁵¹ Results demonstrated that that on average, when using EMG biofeedback, the participants spent a significantly reduced portion of the five hour session in poor posture, from 35.7% without biofeedback to 6.5% with biofeedback.⁵¹ While each of these studies contained small sample sizes and did not follow participants prospectively, they demonstrate the need for larger studies to assess the effects of biofeedback to reduce WRMSD.

In order to compare the effects of biofeedback training with traditional ergonomics education, Faucet et al. conducted a randomized controlled trial with a sample of 108 workers who had occupations with physically intense work environment,
but had not been previously diagnosed with a WRMSD.\textsuperscript{52} Training of these two interventions for the experimental groups took place once weekly for six weeks, with a single reinforcement training at 18 and 32 weeks. Outcomes measures included pre- and post- intervention survey data regarding WRMSD symptoms and pre- and post-intervention EMG measurements of muscle tension. Results demonstrated that although the group who received biofeedback training did not show significant reductions in MSK pain over the course of the study, they were able to significantly reduce muscle tension in the trapezius muscle, a result which was not appreciated in the education treatment or control groups. Additionally, the control group reported a significant increase in their WRMSD symptoms over the course of the study.\textsuperscript{53} Although the participants in this study did not report improvement in self-reported symptoms of WRMSD after being exposed to biofeedback training, they were able to improve their muscle tension over the course of the study. This is a promising finding in the viability of biofeedback as a mind-body technique to decrease the incidence of WRMSD at the micro-ergonomic level.

\textbf{2.5 Summary}

Regardless of the level of evidence, the majority of cross-sectional surveys regarding ergonomic issues and the incidence of WRMSDs among sonographers, found similar statistics for those who were scanning in pain.\textsuperscript{3-5, 13-15, 27-29, 33-35} In many instances, a rigorous attempt was made to pinpoint the risk factors that contributed to WRMSD and a better understanding of the physical and psychosocial aspects which may increase these risk factors. Within the individual studies, several potential patterns may point to possible
micro- and macro-ergonomic causes for increased self-reports of pain while scanning with an ultrasound transducer. These descriptive patterns come from multiple reports of repeated poor posture and excessive force while scanning with a transducer, inability to manipulate sonography equipment and the associated workspace, and an increased patient load, which provides little time for physical rest.

Several studies evaluated these sonographic behaviors quantitatively by assessing clinical methods. A number of instruments were used to quantify ergonomic variables, such as muscle activity, upper extremity joint angles, push force and posture during scanning. The reported data provide affirmation to survey data about WRMSD risk factors for sonographers, such as excessive force and repetitive awkward wrist and hand angles while performing certain sonographic exams. However, when reviewing the overall literature on this topic, the respondent sample sizes were rather small and most sonographic procedures were performed at one point in time.

A number of studies have introduced a single or set of ergonomic interventions for WRMSD prevention to a cohort of sonographers. While many of these studies are also cross-sectional in nature, Euler and Meadows did conduct an analysis of ergonomic interventions at one medical facility over time, finding that procedure volume increased while incidence of WRMSD decreased. However, the study did not report any sample demographics, such as number of sonographers employed, and did not document any psychosocial or environmental data that was reported by the sonographers involved in the study. This makes it impossible to determine the significance of the decrease in reported
WRMSD or if the interventions effected sonographer level of pain, stress, or perception of workplace changes.

The key limitations that are present throughout the literature are the repeated use of self-reported survey data and the cross-sectional analysis of current sonographic methods. As with any self-reported data, perceived health, pain and stress may be over or under reported by the respondents. Additionally, the cross-sectional nature of most of the cohort studies does limit the assessment of changes in sonographer’s scanning behaviors that could have a quantitative or qualitative influence on a specific ergonomic intervention.

Reviewing related health care professionals risk for WRMSD, it appears that much of the exposure is task related. However, lifting patients, low back injuries, and other micro-ergonomic stressors make health-care a physically demanding and often risky career. It would appear from the limited review of the allied health professionals WRMSD evidence, that specific body areas can be targeted for interventions and further education is needed about profession-specific physical and mental stressors.

Specifically, a gap exists in the current understanding of the development of WRMSDs among sonographers. In order to gain higher level information on ergonomic solutions that have the potential to positively influence the prevention of future WRMSDs among sonographers, the present study piloted a series of non-traditional mind-body techniques to determine their utility in addressing both micro- and macro-ergonomic concerns. The particular mind-body techniques which were explored are biofeedback and mindful sonography yoga and cueing. A review of the recent
literature has demonstrated the efficacy of mindfulness interventions to decrease stress and burnout and improving job satisfaction in populations of healthcare workers.\textsuperscript{45-48} Additionally, many studies have shown the success of biofeedback training in improving workplace posture in frequent computer users.\textsuperscript{50-52}

Following a designated cohort could be accomplished through an educational program such that students could be directly assessed from the beginning of their sonography training and followed over a period of time. The interventions of interest include ergonomics education, audible biofeedback, and mindful sonography yoga and cueing; assessment would include the biofeedback data and multiple surveys to monitor sonography students over specific time intervals. This type of educational pilot study would allow researchers to determine whether it was possible to provide these interventions and what the impact would be on a group of novice sonographers. This study is a first step in trialing a series of mind-body techniques that may have some impact on the long-term micro- and macro-ergonomic concerns of this type of allied health care worker. Our research question is: What combination of mind-body techniques, taught to a cohort of novice sonography students, would provide exploratory reduction of the risk of WRMSDs?
Chapter 3:

Methods

The current study investigated the exploratory impact of providing a series of mind-body techniques to a cohort of sonography students throughout their first semester of coursework. Because they have virtually no experience in the use of clinical sonography, it is assumed that students lack a bias toward ergonomic solutions, habitual sonographic scanning positions, and work-related musculoskeletal disorders (WRMSD). Also, they have not had exposure to scanning postures that would trigger acute or chronic injuries to the neck, shoulder, and upper extremity. By teaching a series of mind-body techniques to a sample of sonography students from the onset of their sonographic training and following them over a period of time as their skills progress, it is hypothesized that this may influence their risk of injury and long-term work engagement. This will provide a unique set of data which will allow researchers to pinpoint which of the mind-body techniques is best suited for inclusion in the curriculum and could be helpful in reducing WRMSD and improving quality of life for future sonographers.
3.1 Design

Longitudinal data were collected from a cohort of first year sonography students at The Ohio State University, which employed a pre-post experimental design. In order to quantitatively measure perceived pain, stress and physical and mental health, three survey instruments were administered to participants both pre- and post-intervention; the Short Form health survey (SF-12v2®),21 Perceived Stress Scale (PSS),53 and a Visual Analog Scale (VAS) for upper extremity pain. All students who volunteered to participate in the study were exposed to two types of interventions: ergonomics education and mind-body techniques. The two mind-body techniques used were biofeedback, and mindful sonography yoga and cueing. Participants were randomly assigned to one of three levels of experimental treatment: 1) ergonomics education + biofeedback (BF), 2) ergonomics education + biofeedback + mindful sonography yoga and cueing (BFYM) or 3) ergonomics education + mindful sonography yoga and cueing (YM). Pre-testing survey data was collected at the beginning of the first semester of the sonography program and interventions were given at six intervals throughout the first semester of the sonography curriculum. Post-testing survey data were collected upon completion of the first semester of the sonography program (See Table 3.1). The study was peer-reviewed and approved by the OSU Biomedical IRB-Protocol number 2013H0105.
Table 3.1 Experimental treatment level by study group

<table>
<thead>
<tr>
<th>Group</th>
<th>Ergonomics Education</th>
<th>Biofeedback</th>
<th>Mindful Sonography Yoga and Cueing</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF</td>
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</tr>
<tr>
<td>YM</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

3.2 Limitations

The use of a group of sonography students as the sample population did create some inherent limitations. It is the responsibility of the sonography program to maintain accreditation, limiting the extensiveness of treatments which can be given to a group of students. An example of this limitation was that all students are mandated by the Joint Review Commission on Education in Diagnostic Medical Sonography (JRC-DMS) to receive ergonomics education (unspecified). This mandate made it impossible to form a control group of students who received no interventions. The university also stipulates that all students receive a similar education so this made it difficult to prevent contamination across groups.

Threats to internal validity may have occurred due to history and maturation effects. While the students had no clinical experience hours prior to the study, they were learning and practicing during scan labs throughout the treatment period. Thus, events that occurred during the labs may have affected outcomes of surveys and mind-body techniques as well as students may have improved their posture score over time.
regardless of the treatment they received. Additionally, the instrumentation used for the RULA scoring was a standardized yet subjective scoring tool, and although the scorers were blinded to group status of participants and timing of image collection, differences in their observations may have affected the validity of the posture scoring results.

External validity may have been jeopardized by the fact that multiple treatments were given to the same subjects, making it difficult to control for the effects of prior treatments. Because pre-experimental research is a descriptive level of research, no generalization can be made beyond the participants in this study themselves. Finally, the current study included sonography students from only one program, thus limiting the data to a small sample size that was further divided into smaller treatment groups.

3.3 Recruitment

The sample consisted of first year sonography students enrolled in the School of Health and Rehabilitation Sciences at The Ohio State University. As part of their orientation, all students accepted to the Sonography program must review and sign a set of professionally specific technical standards which indicate that they meet physical requirements of the clinical work-load. They were also required to visit their health care provider for a health screening and provide documentation of updated vaccinations before they could begin clinical experience.

The students were randomly assigned to a level of experimental research within this study, which eliminated bias due to age, gender, or ethnicity. All students in the first
year sonography class volunteered to participate in the study, yielding a total sample size of \( n=12 \). As ergonomics education for sonography students is a curriculum requirement for accredited programs, each of the treatment groups received our program’s didactic instruction, as well as exposure to one or more mind-body techniques. Group sizes were \( n=4 \) for students who received ergonomics education + biofeedback (BF), \( n=4 \) for students who received ergonomics education + biofeedback + mindful sonography yoga and cueing (BFYM), and \( n=4 \) for students who received ergonomics education + mindful sonography yoga and cueing (YM).

3.4 Independent Variables

The treatment level that each participant received was the independent variable in this study. Each student was randomly assigned to a group which received a different combination of ergonomic interventions. Each of the three levels consisted of one or more mind-body techniques plus didactic ergonomics education: 1) ergonomics education + biofeedback (BF), 2) ergonomics education + biofeedback + mindful sonography yoga and cueing (BFYM) or 3) ergonomics education + mindful sonography yoga and cueing (YM).

3.4.1 Ergonomics Education

As mentioned earlier, the delivery of didactic ergonomics education to first year sonography students is mandated for accredited educational programs by the Joint
Review Committee on Education in Diagnostic Medical Sonography (JRC-DMS.) At Ohio State, this education was delivered in the form of two didactic lectures. These lectures were provided by instructors Kate Zale, MS, RDMS, VT and Kevin Volz, MS, RVT at the beginning and middle of the first semester of the Sonography program to all three treatment groups (BF, BFYM, YM). Both of the didactic instructors have had graduate level preparation in the study of ergonomic solutions for the workplace. These twin lectures were co-created and also edited by Shawn Roll, PhD, OTR/L, RMSK who is an Occupational Therapist, Sonographer, and a researcher in musculoskeletal disorders. An overview of lecture objectives for the ergonomics education intervention are provided in Appendices A and B.

3.4.2 Biofeedback

One of the mind-body techniques was biofeedback. Biofeedback is described as a mind-body technique in which individuals learn how to modify their physiology for the purpose of improving physical, mental, emotional, and spiritual health.\(^8\) Its intervention requires the use of specialized equipment to convert physiologic data into visual or audible cues which allow the individual to voluntarily control body processes. One of the most common forms of biofeedback is surface electromyography, in which surface electrodes are attached to the participant’s skin over the muscles of interest to evaluate the electrical activity produced by those muscles. The goal of the treatment over time is for the patient to learn to control the amount of muscle tension during an activity or posture. In fact, a systematic review of six randomized controlled trials studying the
effectiveness of electromyographic biofeedback on musculoskeletal pain found that the treatment, often used in conjunction with other interventions, provided significant pain relief.\textsuperscript{54}

Those students attending the sonography simulation labs were separated into specific groups to participate in the biofeedback intervention. Those students who received this intervention were asked, during the simulation lab, to scan with the ultrasound transducer and capture a longitudinal image of the left kidney on a teaching phantom. This intervention was repeated over six separate sonography scanning sessions. While scanning with the transducer, muscle activity was recorded from the student participant’s right lateral deltoid muscle using the Ergometer\textsuperscript{TM} by Sound Ergonomics, LLC. The Ergometer\textsuperscript{TM} is a specialized portable system that uses a set of surface electromyographic sensors and provides audible tones as biofeedback to the individual who is hooked up to the unit. Recordings were also done of the scanning sessions using iPads\textsuperscript{TM} (Apple, Inc.). Two of the student groups received this intervention, one with ergonomics education (BF) and one with ergonomics education as well as the mindful sonography yoga and cueing (BFYM).

3.4.3 Mindful Sonography Yoga and Cueing

Mindfulness is characterized by non-judgmental, moment-to-moment awareness of physical sensations, perceptions, affective states, thoughts and imagery.\textsuperscript{55} One goal in the practice of mindfulness as part of daily living is for an individual to maintain an
enhanced state of consciousness, which allows for a greater appreciation of the possible behavioral responses toward life events. In turn, this practice may create greater resiliency toward illness, disease, and self-induced stress. Mindfulness-based stress reduction (MBSR) is a structured, participatory educational program which utilizes mindfulness meditation to help manage a variety of adverse health issues.\(^5^5\) It has substantial research-based evidence for its efficacy in a variety of medical, educational, and work-site settings.\(^5^6\)

Participation in a formal MBSR program includes an individual commitment to meditation and yoga stretching. Unfortunately, this commitment may negatively affect its applicability for personnel working in environments with a high level of job demands. In fact, a study by using MBSR indicated that high attrition rates were cause by the required time commitment.\(^5^7\) Mindfulness in Motion (MIM) is a Mindfulness Based Intervention (MBI) which was developed to serve as a modified, less time intensive version of MBSR. It was designed to be delivered onsite to busy, working adults in a group format, and many of the studies which investigate its interventional feasibility were done in the healthcare setting.\(^5^8\)

Students who received the mindful sonography yoga and cueing intervention were exposed to a version of MIM, specifically designed for the first year sonography students, which was adapted by Dr. Maryanna Klatt. Dr. Klatt has authored numerous publications demonstrating the positive effects of low-dose, low-cost mindfulness interventions on populations of OSU faculty and staff, Intensive Care personnel, and inner-city school children.\(^5^6, 5^8-6^2\) These interventions have demonstrated numerous improvements in health
outcomes, including increased mindfulness, decreased inflammation, and significant biological changes in stress reduction. Additionally, Dr. Klatt has been using MBI’s at The Ohio State University since 1995. In regard to the present study, Dr. Klatt customized her presentation and exercise series based on her observation of sonography workplace challenges. She and Sonography instructor Kate Zale, MS, RDMS, RVT, discussed the physical and mental challenges associated with working in the sonography workplace, and a mindful yoga stretching routine for the sonography student was designed by Dr. Klatt to address these specific challenges.

These mindful yoga stretching sessions provided instruction to the student participants on both cognitive habits as well as yoga to encourage heightened awareness of the sonographer to their work routine body mechanics. The foundation of the mindful yoga stretching intervention is stretching exercises meant to improve core strength, flexibility, balance, and coordination. Secondly, training on progressive muscle relaxation is included to reduce tension and relieve stress to enhance stretching. These techniques have been shown to promote psychological benefits such as relaxation, improved concentration, and elevated mood in other populations of healthcare professionals.58

Finally, cueing is a mind-body technique which provided participants with mental exercises meant to develop automatic responses associated with sonographer work tasks. These exercises encourage both work satisfaction for the sonography as well as patient-centered care. For example, sonographers can think about how they will individually connect with the patient as they physically reach for the exam door or curtain. Other
examples include mental cues to check physical posture when touching a patient’s identification band and developing a habit to actively relax muscles by taking in a deep breath and exhaling when first touching the sonography equipment or computer workstation.

Delivery of mindful sonography yoga and cueing instruction was done together in six sessions. These sessions were manualized as well as captured on video for further review. The exercises were reviewed and practiced each week by Kate Zale, MS, RDMS, RVT. Ms. Zale has extensive training in martial arts and was the instructor who taught these mindful yoga sonography sessions. Ms. Zale delivered instruction of these exercises throughout the first semester, prior to beginning each of the interventional scan lab sessions. Two of the student groups received the mindful sonography yoga and cueing intervention, one with ergonomics education (YM) and one with ergonomics education and biofeedback (BFYM).

3.5 Dependent Variables

3.5.1 Self-Reported Survey Data

Self-reported health and pain are considered highly reliable measures of overall health and can be taken at various times and compared within and across subjects. The SF-12v2® survey was used to assess the change in perceived mental and physical health and the Perceived Stress Scale measured the change in perception of stress throughout the
time of the study. Additionally, the students were asked to rate their pain in each upper extremity pre-and-post intervention using a Visual Analog Scale (VAS). Each of the three treatment groups completed this set of surveys pre- and post-intervention. Detailed instrument descriptions are provided in the following section, and a sample of the survey instrument given to participants in this study pre- and post-intervention is provided in Appendix B.

3.5.2 RULA Postural Scoring

The posture of students who received the biofeedback treatment, was evaluated while they were scanning, using the Rapid Upper Limb Assessment (RULA) tool. RULA is a postural targeting method developed to evaluate the exposure of employees to work-related risk factors associated with upper extremity MSK disorders. A single worksheet is used to enter a set of scores for the arm and wrist as well as a set of scores for the neck and trunk. Overall scores for each body area are used to generate a single, overall RULA score that represents the level of musculoskeletal risk for a particular posture. This score is a numerical value 1-7, with one indicating acceptable posture and 7 indicating the need to investigate and implement change of the assessed posture. An image of a RULA scoring sheet is provided in Appendix C.

Participants in the BF and BFYM groups were knowingly captured on video for each simulation lab that included the phantom scanning session with biofeedback. This was done by using two iPads™, which provided bi-plane (frontal and lateral) video files
and allowed for subjective identification of the exact time that the student’s posture and position elicited the loudest tone while wearing the Ergometer™ electrodes.

Corresponding grading of the video of the student’s posture was completed retrospectively with the RULA grading sheet, by the graduate researcher, who was blinded to biofeedback group assignment and intervention session date. The graduate researcher was closely supervised by faculty to insure consistency with grading the video clips with the RULA tool. The Principal Investigator (PI), who has experience using the RULA, graded video clips independently and the then the same clips were graded by the graduate researcher. Any discrepancies in grading were identified by an undergraduate student researcher, and those videos were re-graded by both the PI and the graduate researcher. These steps helped to provide consistency and reproducibility for the RULA scoring.

3.5.3 Muscle Activity Measures

The sounds from the Ergometer™ were also recorded on the video files from each biofeedback session and loaded into Audacity 2.0® software. This is a free, open source, cross-platform audio editor software program which was used to display the sounds from the Ergometer™ as a waveform on a graph (X, time-s and Y, sound pressure -1 to +1). The waveforms for each participant at each session were evaluated by the graduate researcher and the PI. “Plot Spectrum” is a feature of the Audacity 2.0® software which allows the user to convert the original sound waveform to a graph of frequencies.
This feature was used to measure the amplitude (dB) as well as frequency (Hz) of the sound from the Ergometer™. “Split Clip” is a feature of the Audacity 2.0® software which allows the user to separate a portion of the original waveform and manipulate it independently. This feature was used to quantify the frequency of beeps at the time that the RULA score was generated for each participant at each biofeedback session. Repeated measures assessment of these scores over this longitudinal study allow for analysis of changes in the student’s attention to biofeedback and adoption of ergonomic scanning. As previously mentioned, the graduate researcher was closely supervised by faculty to insure consistency with grading the audio clips with the Audacity® software. The PI, who has experience using Audacity® software, recorded data from the audio clips independently and then the same process was completed by the graduate researcher. Any discrepancies in data were identified by an undergraduate student researcher and those clips were re-evaluated by both the PI and the graduate researcher. These steps helped to provide consistency and reproducibility for the analysis of the audible tones emitted by the Ergometer™.

3.6 Instrumentation

- SF-12v2®: The Short Form Health Survey is licensed by OPTUM™, a health services and innovation company which is dedicated to improving healthcare through the use of technology and data analytics.²¹ The use of the SF-12v2® was purchased from OPTUM and they provided the most recent version of the survey and corresponding grading algorithm. The survey contains 12 multiple choice
questions which are used to measure functional health and well-being from the participant’s point of view. The participant is asked to place a check mark in front of the most appropriate response from a provided ordinal scale. Scoring was closely checked by an undergraduate research student to insure that all surveys were completed and that no missing data occurred.

- **PSS**: The Perceived Stress Scale is the most widely used psychological instrument for measuring the perception of stress. The survey contains an ordinal, 5 item Likert scale which is used to answer each of the ten questions regarding the respondent’s feelings over the past month. Scores are computed by reversing responses on the four positively stated questions and adding for a total score out of 0 through 40, with a higher numerical value indicating a higher level of perceived stress. The participant’s scoring was closely checked by the undergraduate research student to insure that all surveys were completed and that no missing data occurred.

- **VAS**: The Visual Analog Scale is a widely used instrument which quantifies a characteristic or attitude that is believed to range across a continuum of values and cannot easily be directly measured. Participants were asked to use the VAS to separately rate their left and right upper extremity pain by marking the appropriate point on a continuous rating scale label 0 (no pain) through 10 (agonizing pain.) The participant’s scoring was closely checked by the undergraduate research student to insure that all surveys were completed and that no missing data occurred.
• **Ergometer™**: is a surface electromyographic system that provides audible biofeedback to the user via a set of electrodes that are attached to the skin to evaluate the electrical activity produced by skeletal muscles. The goal of this treatment over time is for the patient to learn to control the amount of muscle tension during an activity or posture. Prior to beginning the biofeedback intervention sessions, the graduate researcher attached a set of three electrodes, which were connected to the Ergometer™ via electronic cables, over the student’s right lateral deltoid. In order for the researcher to correctly identify the location of the deltoid, each individual participant was asked to abduct their upper arm in order for the muscle borders to be more easily visualized and palpated. After the first biofeedback session, video files from each participant’s preceding session was viewed on the frontally placed iPad™ in order to subjectively verify accuracy of electrode placement.

• **iPad™ (Apple, Inc.)**: is an iOS-based tablet computer that can record video, take photos, play music, and perform Internet functions. Biofeedback intervention sessions were recorded using two iPad™ tablets. One tablet was placed to record a frontal projection of the student, and one tablet was placed to record a lateral projection of the participant. During the biofeedback scanning sessions, the graduate researcher operated the recording and viewing of any previous videos without moving the tablets from their designated positions. In order to ensure consistency of iPad™ placement from one session to the next, each tablet was assigned a designated position in the student laboratory. Photographs of the
placements were taken prior to beginning treatment, and the graduate researcher used these photographs for proper placement of the iPads™ for subsequent biofeedback sessions. The audiovisual files from the iPads™ were used to subjectively identify the exact time that the student was producing the loudest Ergometer™ activity in order to obtain RULA scores and quantify biofeedback cues with Audacity 2.0®.

- **Ultrasound Machine**: All sonography students completed their simulated sonographic scanning on a GE Logiq i-laptop unit using a 3 MHz curvilinear transducer that was preset for completing a series of images on the tissue mimicking phantom. Students were required to make all necessary instrumentation changes on the GE logiq laptop during the time that they had to freeze a longitudinal image of a left kidney. The lab instructors provided no assistance to students during this portion of the video and audio capture of their simulated sonographic scanning.

- **Phantom**: All sonography students completed their simulated sonographic scanning on the tissue mimicking phantom that was purchased from Kyoto Kagkau Co., LTD. The phantom was placed supine on an examination table and the students were seated to make their images on the phantom.

- **RULA**: The Rapid Upper Limb Assessment (RULA) tool is a postural targeting method which is used to assess an employee’s level of ergonomic risk associated with MSK disorders associated with exposure to forceful or repetitive work tasks and awkward work postures.
- **Audacity 2.0®**: is a free, open source, cross-platform audio editor software program. The use of this software program, in conjunction with recording RULA scores, allowed for retrospective quantification of the student’s responses to the biofeedback, mind-body technique.

### 3.7 Procedures

All of the study participants completed the SF-12v2® survey, PSS, and VAS for upper extremity pain as pre-test measures at the beginning of their first semester of the sonography program before their clinical training experience began. These instruments were administered again at the end of the first semester of the curriculum and their sonographic training. See Table 3.2 for timeline of all study treatments.

<table>
<thead>
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<th>Pre-Survey</th>
<th>Study Treatment Period</th>
<th>Post-Survey</th>
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<td></td>
</tr>
</tbody>
</table>

EE = Ergonomic Education, BF = Biofeedback, YM=Mindful Sonography Yoga and Cueing

Table 3.2 Timeline of study period

All three treatment groups (**BF, BFYM, YM**) received the ergonomics education intervention. This was delivered in the form of two lectures at the beginning and middle of the first semester of the sonography program by the school’s clinical instructors. The
lectures were presented during the student’s normally scheduled General Sonography course.

Two of the treatment groups received the biofeedback intervention, a mind-body technique (BF, BFYM). At the beginning of six of their routine scan labs, they were asked to obtain a subjectively clinically acceptable image of the left kidney on an abdominal phantom. At the time of the first intervention session, the graduate researcher had a script that was read to each student explaining the purpose of the study and the instructions for the procedure. This script was read at each subsequent session and was also available to participants on paper at each of the sessions.

Prior to beginning the scan and the video recording, the graduate researcher attached a set of three electrodes, which were connected to the Ergometer™ via electronic cables, over the student’s right lateral deltoid. The deltoid was chosen as the site for data collection for this study, based on the Evans et al.⁵ article that indicated that the shoulder was the most reported area of acute pain and discomfort (See Figure 3.1).
The ergometer was turned on and two iPads™, one positioned to provide a frontal projection as well as lateral projection of the participant, were set to “record”. Once the student obtained a longitudinal image of the kidney which met their perception of clinically acceptable, they froze the image on the GE Logiq laptop and signaled the graduate researcher that they had completed the task (see Figure 3.2). It was at this point that the recording devices as well as the Ergometer™ were stopped.
Figure 3.2 Sonography student hooked to the Ergometer™ and completing a simulated clinical exam: A lateral projection, B AP projection

Two of the treatment groups received mindful sonography yoga and cueing, as a mind-body technique (BFYM, YM). These interactive lessons were provided by Dr. Maryanna Klatt and reinforced by Kate Zale, MS, RDMS, VT, Instructor and Clinical
Coordinator, at the beginning of six separate lab sessions. Ms. Zale repeated all of the yoga stretching prior to each of the sonography simulation lab sessions during the first semester of the sonography program. For the BFYM group, the mindful sonography yoga and cueing lessons were given at the beginning of the same six lab sessions in which the biofeedback intervention was performed (see Figure 3.3). Dr. Klatt’s standardized video training on mindfulness and yoga stretching was available to students if requested.

![Figure 3.3 Student participants during instruction of mindful sonography yoga and cueing](image)

**3.8 Data Analysis**

Mean scores for the Perceived Stress Scale (PSS) and Visual Analog Scale (VAS) for pain were determined for each group pre- and post- intervention. Change scores over the course of the study were also determined for the VAS and PSS by individual
participant, and the mean change scores for each group were calculated. Additionally, the mean Physical Composite Score (PCS), Mental Composite Score (MCS) and Bodily Pain domain scores for the SF-12v2® were determined for each group pre- and post-intervention, as well as change scores for each individual and across the groups for these three scores.

3.8.1 SF12v2®

Responses from each of the three surveys for all three treatment groups were recorded pre-and post-intervention. The twelve multiple choice questions on the SF-12v2® were scored with software from OPTUM™. Results contain norm-based scores for 8 separate health domains, as well two overall sub-scores; Physical Composite Score (PCS) and Mental Composite Score (MCS). The numerical value which is assigned to each score is a percentile value from 0-100 for comparison with a calibrated average of 50 (SD 10.) Higher numerical scores indicate a higher level of self-reported health.

3.8.2 PSS

The ten questions in the Perceived Stress Scale were added by assigning each response to the 5 item Likert-type scale a value one through four, with reversal of these values on the four positively stated questions. The total score is out of 40 possible points,
with a higher score more perceived stress by the participant. These scores were computed by the undergraduate researcher and subsequently checked by the graduate researcher.

3.8.3 VAS

The Visual Analog Scale for pain was answered by participants with separate scores for the right and left upper extremity. Participants were asked to mark their current level of pain at the appropriate point of a continuous rating scale labeled with whole integers 0 through 10, each spaced 1 cm apart. Anchors were provided on the scale at 2 cm intervals to assist the participants in quantification of pain level, with written descriptions as follows: 0 meaning “none,” 2 meaning “annoying,” 4 meaning “uncomfortable,” 6 meaning “dreadful,” 8 meaning “horrible,” and 10 meaning “agonizing.” These scores were checked for accuracy and completeness and recorded by the undergraduate researcher.

3.8.4 Biofeedback Data

Analysis of the audio and video recordings during the biofeedback sessions was retrospectively completed by the researchers by using the RULA tool and Audacity 2.0® software program. It is standard clinical procedure for abdominal sonographic
examinations to be performed with the ultrasound equipment on the patient’s right side, with the sonographer holding the transducer in their right hand. Thus, this was the set-up with the laboratory equipment and abdominal phantom. If a student had preferred to scan left-handed, the set-up of equipment would have been adjusted, however none of the student participants made this request of the graduate researcher. In order to obtain the best visual of the participant’s arm and wrist position for RULA analysis, the frontal projection video was used. In order to obtain the best visual of the participant’s neck, trunk and leg position for RULA analysis, the lateral projection video was also captured and reviewed as part of recording the RULA score.

In order to evaluate posture at the time during each session when the participant’s muscle activity was highest, the graduate researcher watched each frontal video in its entirety and subjectively chose when the Ergometer™ had the highest beep frequency. This time was recorded, and was the time in both the frontal and lateral projections that all RULA scores were assigned. The RULA consists of a set of 15 sub-scores which were completed by the graduate researcher through the comparison of the subject’s posture to diagrams, criteria, and charts provided on the worksheet. After the total arm and wrist score and total neck, trunk, and leg score were acquired, the final score was assigned by using a comparison table which is also provided on the worksheet. Each RULA sub-score and final score was recorded for each participant who received the biofeedback intervention (BF, BFYM) for each of the six intervention sessions. An average final RULA score for each intervention session by group was calculated. A RULA change score over the time of the study was also determined for each participant in groups BF
and BFYM as well as an average change score for group BF and an average change score for group BFYM.

The video time stamping procedure also allowed researchers to use Audacity 2.0® to quantitatively assess the data of the sound from the Ergometer™ that corresponded in time with the RULA score. The Ergometer™ sounds for each participant in group BF and BFYM was represented as a waveform, with the time (seconds) on the X-axis and the sound pressure (-1 to +1) on the Y-axis. Sound analysis was performed on the waveform using a Plot Spectrum, which converts the waveform to a graph of frequencies (Hz) on the X-axis against amplitudes (dB) on the Y-axis, with 0dB being maximum amplitude reference value (see Figure 3.4). The frequency (Hz) and amplitude (dB) value at the time that the RULA score was assigned was recorded. The sound clip was then split from one second (s) before until one second (s) after the time-stamped RULA score was assigned and the beep frequency (number of beeps during the period) was calculated and recorded. This process was completed for each participant in group BF and BFYM at the six scan sessions. The average of these values for each biofeedback session for group BF and BFYM, as well as an average change score for each group was calculated.
3.8.5 Data Analysis/Statistics

The statistical significance of the data was set at p level <0.05. In order to determine the cohesive strength of the interventional measurement tools, Spearman correlation coefficients were determined for the individual RULA scores vs. the beep frequency, pitch frequency (Hz) and amplitude (dB) of the biofeedback sounds on Audacity 2.0. In order to determine whether there was a significant difference in pre-treatment perception of stress and health between groups, an independent samples Kruskal-Wallis test was performed using the initial survey scores. In order to determine whether significant changes existed between the three groups over the study period, an independent samples Kruskal-Wallis test was performed using the change scores from the
SF-12v2® PCS, MCS, bodily pain score, PSS, and VAS for right and left upper extremity pain.
Chapter 4: 
Results

The present cohort of sonography students participated in ergonomics education and one of three levels of mind-body techniques during their first semester of professional coursework. The ergonomics education intervention was given in the form of two organized lectures during the student’s regularly scheduled General Sonography course. The two mind-body techniques, biofeedback (BF) and mindful sonography yoga and cueing (YM), were delivered on six separate occasions prior to commencement of the student’s clinical experience. Each study group was comprised of four students receiving one of three combinations of treatments: 1) ergonomics education + biofeedback (BF), 2) ergonomics education + biofeedback + mindful sonography yoga and cueing (BFYM), or 3) ergonomics education + mindful sonography yoga and cueing (YM).

In order to quantitatively assess the effects of the ergonomics interventions on the participant’s risk of WRMSD related to performing sonographic exams over the course of the study, a pre-post experimental design was implemented. By administering a set of survey tools before and after the treatment, various factors of self-reported health were measured: The SF-12v2® for functional health and well-being from the participant’s
point of view, the Perceived Stress Scale (PSS) for the participant’s perception of personal stress, and a Visual Analog Scale (VAS) for the participant’s estimation of their upper extremity pain. Individual participant and mean group scores pre-and post-intervention, as well as individual change scores and group average change scores were reported for each of the three survey tools. A table with results of each participant’s pre-treatment, post-treatment, and change scores for each survey tool is included in Appendix D.

In addition to quantitative survey data, videos of each biofeedback scanning session were recorded on two iPads™, and postural analysis of the two study groups who received the biofeedback treatment was performed retrospectively by the graduate researcher. The RULA postural analysis tool was used to assign a quantitative score to the student’s posture at the time of highest muscle activity at each intervention session. Audio files from the Ergometer™ were translated into waveforms via the Audacity 2.0® software, and peak amplitude (dB), pitch frequency (Hz), and beep frequency (number of beeps during period) were measured using the plot spectrum and split clip features of the program. This was completed for each participant at each biofeedback intervention session.

4.1 Sample Demographics

The sample consisted of $n=12$ sonography students enrolled in the Sonography program of the Radiologic Sciences and Therapy Division at The Ohio State University.
The mean age of the sample at the time of the administration of the first set of survey instruments was 25.9 (median 21, mode 21, SD 12.8). The age range for 10 of the 12 participants was 20-23 years. The sample was 84% (10 out of 12) female, with the two male participants being placed in the BF and BFYM treatment groups. The reported sample race was 92% (11 out of 12) Caucasian.

4.2 Self-Reported Survey Data

4.2.1 SF-12v2® Survey

The SF-12v2® is a multiple choice survey containing 12 questions used to measure functional health and well-being from the participant’s point of view. Using scoring software purchased from OPTUM™, scores are reported numerically as a percentile value from 0-100, with 0 being the lowest level of reported health, and 100 being the highest level of reported health. These values allow researchers to base interpretations on norm-based scores of the general US population, calibrated to a mean score of 50 (SD 10). The software algorithm analyzes survey responses to yield scores for eight separate health domains, which are used to compute two composite scores: Physical Composite Score (PCS) and Mental Composite Score (MCS).

In a 2006 report of nationally representative values for the non-institutionalized US adult population for health-related quality of life scores, over 20,000 respondents were surveyed with the SF12v2®. The age- and sex- stratified results demonstrated that females tended to score slightly lower on both the MCS and PCS across all age groups.
Additionally, it was noted that mean MCS tended to increase with increasing age from 20-79, with a slight decline after age 80 in both males and females. Conversely, the mean PCS tended to decrease with increasing age from 20-89 in both males and females.

The mean pre-treatment PCS for our sample were 57.7 for the BF group, 56.9 for the BFYM group, and 57.9 for the YM group, and the mean post-treatment PCS were 57.1, 55.4 and 50.7, respectively. The reported mean U.S. population norm on the PCS for females age 20-29 was 53.0 (males 53.8) with a 95% confidence interval of +/- 0.3. The only study group that did not maintain a slightly higher than average age- and gender-matched PCS score both pre- and post-treatment was the YM group. This group reported a mean decreased PCS of 7.2 over the treatment period, from 57.9 to 50.7. The participants in the YM group were all female, with a mean age of 21. One participant (12) in this group reported a pre and post-treatment PCS of 60.38 and 42.35, respectively, which is a decline in reported physical health of 18.03 and was the most changed PCS across the sample. In the absence of this participant’s (12) PCS scores, the YM group would have had a mean decreased PCS score of 3.6 from, with a mean pre-treatment PCS of 57.11 and post-treatment PCS of 53.55 (See Figure 4.1).
The group with the lowest level of reported mental health pre-treatment was the YM group, with a mean MCS of 40.1. However, they did demonstrate an average increased MCS of 8.2 over the treatment period, (post-48.7) which is slightly lower than the reported U.S. population norm of 49.5 for females aged 20-29. One participant (11) from this group did have a pre-treatment MCS of 25.55, which is more than two SD (10) below the calibrated mean of 50 and was the lowest MCS score for any participant both pre-and-post treatment. The same participant demonstrated an increase in reported mental health of 21.32 over the treatment period. In the absence of this participant’s (11) scores, the YM group would have a mean increased MCS score of 4.2, with a pre-treatment mean MCS of 45.2 and a post-treatment mean MCS of 49.6 (See Figure 4.2).
The BF and BFYM groups also showed an increase on the MCS over the treatment period, with BF going from a mean of 52.8 to 53.3 and BFYM from 46.9 to 50.4. The BF group had the highest mean MCS across the study both pre-and post-treatment. This group did have one participant (1) who is a 65-year-old male, and demonstrated an MCS of 53.8 pre-treatment and 59.2 post-treatment, compared to an age- and gender- matched mean MCS of 52.7 (males age 60-69).69

Figure 4.2 Group mean MCS vs. reported U.S. norm for females aged 20-29.69

Although the two overall reported scores for the SF-12v2® Survey are the Physical and Mental Composite Scores, there are eight health domains with corresponding sub-scores which are used to obtain the composite scores. One of the
domains which is computed into the Physical Composite Score is Bodily Pain, of which a higher numerical value equates to a higher reported level of pain. Bodily Pain scores for each group both pre- and post- intervention were within one standard deviation (10) of the general US population mean of 50. The BF group showed no change in bodily pain over the course of the study, with mean pre- and post- scores of 55.5. The BFYM and YM groups both showed a slight increase in bodily pain of 2.25 over the course of the study, with pre-treatment scores of 55.5 for Group 2 and 51 for Group 3, and post-treatment scores of 57.7 and 53.2, respectively.

4.2.2 PSS

The possible range of scores for the PSS is 0 (no stress) to 40 (most stress). The lowest reported level of perceived stress both pre- and post- treatment was reported by the BF group, with average scores of 10.7 and 10.3, respectively. These scores are lower than reported U.S. population norms for ages 25-34 (mean 17.46, SD 7.31) matched to our sample’s mean age of 25.9. The BF group contained one participant (1) who was a 65-year-old male. This participant demonstrated a PSS score of 5 pre-treatment and 4 post-treatment, which were both lower than any other participant in all three groups. The mean reported U.S. norm values on the PSS for age 65 and older is 11.09 (SD 6.77). In the absence of this participant’s (1) scores, the BF group’s mean PSS scores would be 12.67 pre-treatment and 12.3 post-treatment, with a mean decrease in stress of 0.33 over the treatment period.
The BFYM and YM groups both showed a slight decrease in level of perceived stress over the study period. The BFYM scored lower than the age-matched U.S. population norm (17.46, SD 7.31 for age 25-34)\textsuperscript{70} with a pre-treatment mean PSS score of 16, and a post-treatment mean PSS score of 15.5. However, only one participant (8) in the BFYM reported a decrease in stress over the treatment period, with a pre-treatment PSS score of 17 and a post-treatment score of 10. This participant was a 33-year-old male. Thus, his PSS changed from above the reported sex-matched U.S. population norm (mean 15.52, SD 7.44)\textsuperscript{70} to below the reported sex-matched U.S. population norm. In the absence of this participant’s (8) scores, the BFYM group’s mean PSS scores would be 15.7 pre-treatment and 17.3 post-treatment, with a mean increase in stress of 1.67 over the treatment period (See Figure 4.3).

The group with the highest level of psychological stress pre-treatment was the YM group, with a mean score of 18.5, which is slightly higher than the reported U.S. norm for age 25-34 of 17.46\textsuperscript{70} The YM group also demonstrated the most change in psychological stress over the treatment period, with a mean decrease of 4 to 14.5 post-treatment. In fact, three of the four participants in this group (9, 10, 11) demonstrated a mean pre-treatment score above the reported U.S. age-matched norm, with PSS scores of 24, 17, and 26, respectively. Of these three participants, only one (9) had an average score above the U.S. population after the study period, with a post-treatment score of 21. Additionally, all of the participants in the YM showed a decrease in level of psychological stress over the treatment period.
Figure 4.3. Group mean PSS vs. reported U.S. norm for ages 25-34.70

4.2.3 VAS

The Visual Analog Scale (VAS) is an instrument which is used to quantify a characteristic or attitude.64 In the present cohort, it was used to measure the participant’s perceived level of upper extremity pain pre-and-post ergonomics education and mind-body technique intervention. Participants were asked to mark their level of pain at the appropriate point of a continuous rating scale labeled with whole integers 0 through 10, each spaced 1 cm apart. Anchors were provided on the scale at 2 cm intervals to assist the participants in quantification of pain level, with written descriptions above the anchors as follows: 0 meaning “none,” 2 meaning “annoying,” 4 meaning “uncomfortable,” 6 meaning “dreadful,” 8 meaning “horrible,” and 10 meaning “agonizing.” Two responses
were requested, one for the right upper extremity and one for the left upper extremity. While each whole numeric integer on the scale was labeled, instructions on the survey indicated the mark could be placed in the space in between whole numbers.

The BF group was the only group to report an average increased level of pain over the course of the treatment period (See Table 4.1). Their mean pre-treatment VAS scores were 0 for the right side and 0 for the left side and their mean post-treatment VAS scores were 0.5 for the right side and 0.5 for the left side. The BFYM group showed a mean decrease in level of pain in both extremities, with a pre-treatment mean of 1 on the right and 0.25 on the left, and a post-treatment mean of 0.5 on the right and 0.25 on the left. The BFYM did have one participant (6) who indicated a pain level of 3 in the right upper extremity pre-treatment, which was reduced to 0 over the course of the study.

The YM demonstrated the highest mean pain scores overall, with pre-treatment averages of right 3, and left 1.5 and post-treatment averages of right 2 and left 1.5. There was one participant (9) in the YM group who indicated a pain level of 4 in both extremities pre-treatment. However, this participant’s right upper extremity pain decreased to 1 post-treatment, while her left upper extremity remained the same. The YM group also included a participant (11) who indicated a pain level of 5 in her right upper extremity pre-treatment, which was the highest pain score reported by participants in all groups both pre-and-post treatment. Her post-treatment score for the right side was reported as 3.
Table 4.1. Group mean VAS across the treatment period

<table>
<thead>
<tr>
<th></th>
<th>RUE-Pre</th>
<th>RUE-Post</th>
<th>RUE-Change</th>
<th>LUE-Pre</th>
<th>LUE-Post</th>
<th>LUE-Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>BFYM</td>
<td>1</td>
<td>0.5</td>
<td>-0.5</td>
<td>0.25</td>
<td>0.25</td>
<td>0</td>
</tr>
<tr>
<td>YM</td>
<td>3</td>
<td>2</td>
<td>-1</td>
<td>1.5</td>
<td>1.5</td>
<td>0</td>
</tr>
</tbody>
</table>

RUE = Right Upper Extremity, LUE = Left Upper Extremity

4.3 RULA Evaluation

The mean RULA scores (out of 7) for the BF group across the six biofeedback treatment sessions were 5.3, 5.5, 5.3, 6.3, 4.8, 4.8. The mean RULA scores for the BFYM group across the six biofeedback treatment sessions were 6.5, 5.3, 4.5, 5.8, 4.8, 5.3 (See Figure 4.4). Both groups demonstrated a decrease in average RULA score over the course of the study, indicating an improvement in posture during the scanning sessions. The BFYM demonstrated the higher of these decreased mean scores, with an average RULA total of 6.5 at session 1 and 5.25 at session 6, an overall 1.25 improvement.
4.4 Muscle Activity Measures

The sounds from the Ergometer™ were recorded on the iPads™ and these audio files were uploaded into the Audacity 2.0® software. Waveforms were analyzed and the peak amplitude (dB), pitch frequency (Hz), and beep frequency (number of beeps) was recorded for each participant in the BF and BFYM groups at each biofeedback treatment session using the plot spectrum and split clip features of the program.

The mean values for muscle activity for the BF group all demonstrated slight changes from biofeedback session 1 to session 6. The average amplitude increased from -32.0dB to -31.6dB (maximum value 0dB) from biofeedback session 1 to biofeedback
session 6. The mean pitch frequency for the BF group decreased from 4320 Hz to 4314 Hz, and the mean beep frequency decreased from 17 to 16.25 beeps over the course of the study.

The mean values for muscle activity for the BFYM group all slightly increased. The average amplitude for the BFYM group increased from -50.8 to -32.9 (maximum value 0dB) from session 1 to session 6. The mean pitch frequency for the BFYM group increased from 2813 Hz to 4543 Hz from session 1 to session 6. The mean beep frequency for the BFYM group increased from 5.75 to 16 (10.25 beeps) from session 1 to session 6.

4.5 Spearman’s Correlation

In order to determine the strength of association between the RULA scoring and the Ergometer™, Spearman’s correlation was completed for the RULA total score and the corresponding measures of muscle activity (see Table 4.2). None of these measures were found to be highly correlated, with an $r$ value of 0.06 for the RULA vs. beep frequency ($p=0.70$), -0.08 for the RULA vs. amplitude ($p=0.61$), and 0.07 for the RULA vs. pitch frequency ($p=0.68$).

Additional Spearman correlation coefficients were determined for the strength of association between the individual measures of the Ergometer themselves. Amplitude vs. frequency as well as frequency vs. beep frequency were shown to be moderately correlated, with $r$ values of 0.46 ($p=0.001$) and 0.43 ($p=0.002$), respectively. The most
highly correlated of these relationships was between amplitude and beep frequency, with 
r = 0.9 (p=0.000).

<table>
<thead>
<tr>
<th>Dependent Outcomes Measure</th>
<th>RULA vs. Amp (dB)</th>
<th>RULA vs. Freq (Hz)</th>
<th>RULA vs. beep frequency</th>
<th>Amp (dB) vs. Freq (Hz)</th>
<th>Amp (dB) vs. beep frequency</th>
<th>Freq (Hz) vs. beep frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spearman’s Coefficient (r)</td>
<td>-0.08</td>
<td>0.07</td>
<td>0.06</td>
<td>0.46</td>
<td>0.90</td>
<td>0.43</td>
</tr>
<tr>
<td>p</td>
<td>0.61</td>
<td>0.68</td>
<td>0.70</td>
<td>0.001</td>
<td>0.000</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Table 4.2. Spearman’s correlation of muscle activity measures

4.6 Study Group Comparisons

In order to determine whether changes in survey scores between the three treatment groups over the study period were meaningful, non-parametric tests of statistical significance were performed on change scores of the SF-12v2® Physical Composite Score (PCS), Mental Composite Score (MCS), and Bodily Pain (BP) domain, PSS, and the VAS for right and left upper extremity pain. Additionally, it was desired to investigate whether the three groups began the study with similar scores, thus pre-treatment data were also interrogated. An independent samples Kruskal-Wallis test with a significance level of p<0.05 was performed using the pre-treatment and change scores for each of the 12 study participants. Results revealed that pre-treatment scores were
distributed the same across all three groups on each of the survey tools except for the VAS for right upper extremity pain. Mean change scores from pre- to post-treatment across the three groups did not show statistical significance for any of the survey tools (See Table 4.3).

<table>
<thead>
<tr>
<th>Survey</th>
<th>SFP</th>
<th>SFM</th>
<th>SFBP</th>
<th>PSS</th>
<th>VAS-RUE</th>
<th>VAS-LUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment (p)</td>
<td>0.981</td>
<td>0.059</td>
<td>0.594</td>
<td>0.241</td>
<td>0.027*</td>
<td>0.082</td>
</tr>
<tr>
<td>Change Scores (p)</td>
<td>0.155</td>
<td>0.551</td>
<td>0.918</td>
<td>0.159</td>
<td>0.431</td>
<td>0.358</td>
</tr>
</tbody>
</table>

* *significance level p<0.05

SFP=SF-12 Physical Composite Score, SFM=SF-12 Mental Composite Score, SFBP= SF-12 Bodily Pain score, PSS=Perceived Stress Scale, VAS-RUE= Visual Analog Scale-Right Upper Extremity, VAS-LUE= Visual Analog Scale-Left Upper Extremity

Table 4.3 Comparisons between treatment groups: Statistical significance of differences between groups on pre-treatment and on survey change scores
Chapter 5:
Discussion

In recent years, an extensive amount of evidence has been published identifying sonographers as a population of health care workers who are at an increased risk for work-related musculoskeletal disorders (WRMSD).\textsuperscript{3-5, 12-19, 22-35} Previous literature on the topic has focused on the incidence of work-related pain, as well as the identification of micro- and macro- ergonomic influences which increase sonographers risk of WRMSD. Many of these studies have been conducted with the use of self-reported survey data or cross-sectional assessment of workplace behaviors in a small cohort, and their results have reproducibly demonstrated that the majority of sonographers are scanning in pain and performing risky physical tasks while scanning. These results point to the need for longitudinal studies to assess the effects of interventions which address micro- and macro ergonomic influences specific to sonographer risk of WRMSD. Mind-body techniques, which focus on the interaction between the brain, mind, body, and behavior, are a group of practices which have demonstrated promise in the improvement of both micro-and macro- ergonomic risk factors among groups of workers at risk for WRMSD.\textsuperscript{45-52}

The present study was designed as a prospective teaching pilot of a series of mind-body techniques, introduced as part of the educational curriculum, for a group of
student sonographers. As educators, we strive to provide sonography students with adequate preparation for the physical and psychosocial demands of professional work. This pilot was composed to explore the possibility of implementing interventions which may reduce the effects of these demands on WRMSD risk for sonographers at both the micro- and macro- ergonomic level. Currently, the Joint Review Committee on Education in Diagnostic Medical Sonography (JRCDMS) requires that educational programs provide sonography programs with didactic ergonomics education. Thus, students in the cohort participated in ergonomics education as well as random assignment to one of three levels of mind-body techniques: 1) ergonomics education + biofeedback (BF), 2) ergonomics education + biofeedback + mindful sonography yoga and cueing (BFYM), or 3) ergonomics education + mindful sonography yoga and cueing (YM).

In order to gauge the effects of the interventions, a pre-post experimental design was implemented by administering a set of survey tools once at the study baseline, and once upon each group’s completion of exposure to six mind-body technique intervention sessions. The surveys employed intend to quantify various aspects of self-reported health. The combination of data from this set of scales provide measures that demonstrate both micro- as well as macro-ergonomic issues from the participant’s point of view. The SF12v2® for functional health and well-being yields a Physical Composite Score (PCS) and Mental Composite Score (MCS) from a set of questions which probe the participant on health topics that would be influenced by micro- as well as macro-ergonomic factors. The Perceived Stress Scale (PSS) contains ten items which relate to perception of personal stress, which would encompass macro-ergonomic influences of the sonography
environment. Finally, the Visual Analog Scale (VAS) requests participant estimation of upper extremity pain with a numerical value to demonstrate effect the micro-ergonomic interface between the sonographer and their ultrasound equipment. Individual as well as group mean scores both pre-and post-intervention, as well as individual and group mean change scores over the study period for each survey instrument were calculated.

Additionally, a postural analysis was performed using the RULA tool and muscle activity measures using the Audacity 2.0® software for the two study groups who received the biofeedback treatment at each intervention session. This analysis allowed for quantitative data collection from the micro-ergonomic interface between the student sonographer and the ultrasound equipment at the time of the biofeedback interventions. Mean group change scores for the RULA and muscle activity measures from the first to last intervention session were also reported.

5.1 Sample Demographics

Demographic information describes a student cohort \( n=12 \) who were predominately female and Caucasian, with a mean age of 25.9 at the time of baseline survey administration. The two male participants (1 and 8), were also the oldest participants, with ages 65 and 33, respectively. Additionally, the 33-year old male participant was the only member of the sample who did not have a reported race of Caucasian. The 12 study participants were randomly assigned to one of the three
treatment groups, each with a size of \( n=4 \). The study concluded with an attrition rate of 0\%, and attendance at each of the intervention sessions for each group was 100\%.

As The Ohio State University mandates that all students receive a similar education, all of the members of the first-year sonography class were asked for consent to participate in the instruction of mind-body techniques, and no exclusion criteria or screening processes were implemented prior to commencement of the study procedure. Influential factors such as prior musculoskeletal injury and previous training of mind-body techniques was not accounted for, which threatens the internal validity of the cause and effect relationship between level of treatment and observed results. Additionally, the small sample size, which was further divided into small group sizes, limits the statistical power to adequately demonstrate relationships between pre-and post-measures. An independent sample Kruskal-Wallis test of statistical significance (p<0.5) did not show statistical significance for mean change scores from pre- to post-treatment across any of the three groups for any of the survey tools. Therefore, in order for this pilot data to offer more insight for the direction of future research on the implementation of mind-body techniques in educational sonography programs, a separate discussion of each dependent variable is provided.
5.2 Self-Reported Surveys

5.2.1 SF-12v2®: Micro-and Macro-Ergonomic Assessment

In a 2006 report of nationally representative values for the non-institutionalized U.S. adult population for health-related quality of life scores, the age- and sex-stratified results demonstrated that females tended to score slightly lower than males on both the Mental Composite Score and the Physical Composite Score across all age groups on the SF-12v2. Additionally, it was noted that mean MCS tended to increase with increase age from 20-79, and the mean PCS tended to decrease with increasing age from 20-89 in both males and females. Descriptive data for the present sample was compared to an age-gender matched U.S. population norm for females age 20-29.

Each of the three treatment groups did show a mean decrease in PCS over the course of the study. However, none of these changes were statistically significant (see table 4.1,) and the only group that did not maintain a slightly higher than average age-gender matched PCS score of 53.0 both pre- and post-treatment was the YM group. One participant in this group (12), who was a 21-year-old female, demonstrated a pre-treatment PCS of 60.38 and a post-treatment PCS of 42.35, which is the most changed across the sample. Interestingly, this participant demonstrated a decrease in Bodily Pain (BP) on the SF-12v2®, no change in right upper extremity pain on the VAS, and decreased left upper extremity pain on the VAS. It is possible that this student’s responses on the SF-12v2® which influenced her PCS scores were due to variables of
physical health unrelated to the study. In the absence of this participant’s scores, the YM group would have also had pre- and post-treatment mean scores above the age- and gender-matched reported U.S. norm.

Conversely, each of the three treatment groups did show an increase in mental health over the course of the study. Mean group MCS scores both pre-and post-treatment were comparable to the age- and gender-matched reported U.S. norm of 49.5. The YM group demonstrated the greatest increase in level of mental health, and they did have once participant (11) whose baseline MCS was 25.55. Although this participant may have had external influences at the time of baseline survey administration which would cause a decreased mental health score, her MCS was raised from more than two standard deviations lower (10) than the calibrated norm of 50 to 46.87 after participation in the mindful sonography yoga and cueing intervention.

One health domain for which the SF-12v2® computes a sub-score is bodily pain. While the BF group demonstrated no change in Bodily Pain scores over the course of the study, the BFYM and YM groups both showed a slight increase in bodily pain. Interestingly, the BFYM and YM groups both showed a slight decrease in right upper extremity pain on the VAS and no change in left upper extremity pain on the VAS over the course of the study, while the BF group showed a slight increase in both upper extremities from pre- to post-treatment.
5.2.2 PSS: Macro-Ergonomic Assessment

In 2009, Cohen and Janicki-Deverts surveyed a probability sample of 2000 U.S. adults using the PSS as an indicator of psychological stress. The sample consisted of 968 men and 1032 women ages 18 and older, and results were reported as unadjusted mean PSS scores by sex, age, race, education level, employment status, and annual income. The age group who reported the highest level of perceived stress was 25-44 years at 17.46 (SD 7.07). Men reported a slightly lower level of stress than women, with mean scores of 15.52 and 16.14, respectively. Additionally, respondents with less than a high school degree reported the highest level of stress with a mean PSS score of 19.11, and level of stress decreased as level of education increased across the sample.

All three of the treatment groups demonstrated a mean decrease in level of perceived stress over the treatment period. The group with the lowest level of stress both pre-and post-treatment was the BF group. This group had a participant (1) who was a 65-year-old male, and reported PSS scores of 5 pre-treatment and 4 post-treatment. These scores were both lower than any other participant as well as the age-matched reported U.S. norm value of 11.09. However, this group’s pre- and post- scores would be 12.67 and 12.3, respectively, in the absence of this participant, still making them lower than any other group.

While the BF group reported the lowest levels of stress both pre-and post-intervention, only one member of this group (4) actually showed a slight decrease in their PSS score over the treatment period. The YM group was the only group in which all four of the participants demonstrated a decrease in stress over the treatment period. In fact,
only one participant (9) had a stress level greater than the age-matched reported U.S. norm of 17.46 post-treatment. Two of the participants (10 and 11) had pre-treatment scores greater than the U.S. norm and post-treatment scores lower than the U.S. norm. Also interesting is that the participant (11) who reported the highest level of perceived stress across the sample pre-treatment is the same participant who reported the lowest level of mental health across the sample pre-treatment, but improved more than anyone in both of these measures after participation in mindful sonography yoga and cueing.

5.2.3 VAS: Micro-Ergonomic Assessment

Notably, the VAS pre-treatment scores for the right upper extremity were the only survey scores for which the groups were significantly different at baseline survey administration (p=0.027). This was likely due to the differences between the BF and YM groups. Each member of the BF group reported a pre-treatment pain level of 0 in their right upper extremity, while pre-treatment pain levels of the YM group were, 4, 2, 5 and 1, respectively. However, the BF group did report a slight increase in upper extremity pain over the study period, with an average pain score of 0.5 in each arm post-treatment. Also interesting was that the BFYM and YM both reported a slight decrease in right upper extremity pain, and no change in their left upper extremity.

In a convenience sample of 77 patients with isolated extremity trauma, Bird and Dickson sought to test the amount of change in pain along the Visual Analog Scale that was clinically significant. Results demonstrated that a lower VAS pain score required less
of a change than a higher VAS score in order to be clinically significant. For respondents of the survey who indicated an initial pain score of 3.4 or less, an absolute value of change in VAS of 1.3 (SD 1.4) was required to be clinically significant, and an initial score of 3.4-6.7 required a change of 1.7 (SD 1.0). However, respondents who indicated an initial pain score of 6.7 or higher required an absolute value of change of 2.8 (SD 2.1) in order to be clinically significant.71

In comparison with the study performed by Bird and Dickson, three participants in the current study indicated changes in VAS scores over the treatment period which would be clinically significant. One of these participants (6) was in the BFYM group, and two (9 and 11) were in the YM group. All of these changes were in the negative direction, meaning that the participants felt less pain from pre- to post –treatment over the study period. They were also all observed in the participant’s right upper extremity, which is the arm that was used by all participants in the BF and BFYM group during the biofeedback treatment sessions. There were no other change scores greater than 1 in the positive or negative direction for any other participants on either extremity.

5.3 RULA: Micro-Ergonomic Assessment

Both of the groups who received the biofeedback treatment (BF, BFYM) demonstrated a decrease in their mean RULA scores from the first to last intervention session. The BFYM group experienced the greatest of these changes, with a group mean of 6.5 at session 1 and 5.3 at session 6, compared with the BF group, who’s mean RULA
went from 5.3 to 4.8 over the study period. Group mean scores for the BF and BFYM group across all six of the biofeedback intervention sessions were between 4.5 and 6.4, indicating that the posture of the participants in both groups needed either “investigated further” or “investigated further and changed soon” according to the guidelines on the RULA tool itself.

In a comparable study of scan specific ergonomic risk factors for sonographers in 2009, Burnett used the RULA tool to evaluate a cohort of seven sonographers while performing several types of scans.22 Included in these exams was the Left Abdomen, which is an ultrasound exam of the patient’s left abdomen. This would include the left kidney for analysis, which is the anatomic region which was scanned by the student sonography cohort in the current study. The sonography cohort in Burnett’s study demonstrated a mean RULA score of 7.0 on the Left Abdomen scan, indicating the need to investigate and change immediately. This was the highest RULA score across the exams in the study, with Thyroid exams being the lowest (mean 4.0)22 Thus, our student cohort, while their posture indicated the need for further evaluation, was more ergonomically correct than the sonographers in the Burnett study. This points to the need for future prospective studies which evaluate student posture while scanning at intervals after they begin practice as a professional sonographer.
5.4 Muscle Activity: Micro-Ergonomic Assessment

The muscle activity measures which were recorded for analysis were amplitude (dB), pitch frequency (Hz), and beep frequency of each participant in the BF and BFYM groups at each biofeedback intervention session. It was anticipated that muscle activity would decrease for these groups from the first to last session. While the BF group did demonstrate a decrease in pitch frequency (Hz) and beep frequency, the BFYM group demonstrated an increase in muscle activity measures. Additionally, Spearman’s correlation between the individual muscle activity measures and the RULA scores did not show any two variables to be highly correlated.

In future studies of this nature, it may be beneficial to perform a controlled pre-treatment validity study on the muscle activity measures from the Ergometer™ in order to ensure successful demonstration of the change in sound amplitude and pitch. An additional component of consideration for this study is that the analysis of sounds from the Ergometer™ was only done at one point in time during the biofeedback scanning. This was the time which the researcher subjectively chose as the time of highest muscle activity when retrospectively viewing the iPad™ audio and video files, and was also the time for which the RULA analysis was performed. Although the graduate researcher was closely monitored by the faculty PI, who has training in performing RULA analysis, a pre-treatment reliability study on RULA scoring of sonographers may be beneficial for future studies. Furthermore, the use of the Audacity 2.0® program to further explore the change in muscle activity measures at different points in the scanning sessions themselves may be useful.
5.5 Summary

In this cohort of student sonographers, no significant changes in outcomes measures of self-reported health, at the micro- or macro-ergonomic level, were noted for any of the treatment groups, who each received instruction of one of three combinations of mind-body techniques. However, statistical power and generalizability of results are limited by the small sample size of $n=12$, which yielded three treatment group sizes of $n=4$. In order to provide the entire class of first year sonography students with similar education opportunities, a mandate of The Ohio State University, no inclusion or exclusion criteria were defined for the present study beyond acceptance to the OSU Sonography program. Thus, no conditions were set for participants regarding previous upper extremity injury, previous diagnosis of mental health disorders, or previous exposure to mind-body technique instruction, all of which are influences that would threaten the internal validity of the study. In future studies of this nature, it may be beneficial to include more in-depth demographic data regarding physical and mental health history of the participants in order to analyze results according to these variables.

5.5.1 Study Limitations

Additionally, it is important to note the limitations in the use of self-reported survey data. Responses to the survey tools used in the present study provided subjective information from the participant regarding self-reported physical and mental health,
stress level, and level of pain in the upper extremities, which was then scored and analyzed as quantitative data. While the results do provide a unique set of prospective data regarding WRMSD risk for student sonographers, it is difficult to control for over- and under-reporting of pain and stress and the influence of outside life factors on the student’s view of their own health. Pre- and post-intervention measurements of specific biological markers of physical and mental health may have provided supplemental, objective data regarding change in participant health after the introduction of mind-body technique instruction. One feasible example would be the collection of saliva samples to evaluate change in cortisol, a biological marker which has been shown to reduce with reduction in perceived stress,\textsuperscript{72} over the course of the study.

The present cohort of sonography students participated in the instruction of variable levels of mind-body techniques throughout their first semester of professional coursework in the Sonography program at The Ohio State University. Results of self-reported physical and mental health using the SF-12v2\textsuperscript{®} and Perceived Stress Scale were shown to be comparable to age- and gender- matched means from previous reports of U.S. norms, demonstrating some generalizability of these outcomes measures.\textsuperscript{69} However, the intervention sessions in this study were performed during the students normally scheduled lab time, which could have affected their response to the mind-body techniques. Previous literature regarding stress in college has shown that students report experiencing the most academic stress at predictable times during a semester, namely when studying for exams, during times of grade competition, and at times when they have a large amount of content to master.\textsuperscript{73} While the student cohort was given distinct
instruction that the all activities during mind-body technique instruction did not count
toward a formal grade, it is possible that they felt a sense of pressure to perform or
compete at a certain level, as fellow classmates and instructors were on site during the
intervention sessions. This may have affected not only effectiveness of the mind-body
techniques, but also survey responses of individual students. An adaptation of these
methods using a lab environment which requires student participants to attend mind-body
technique instruction outside of class time may assist in controlling for these variables.

5.5.2 Study Strengths

This pilot study in the instruction of mind-body techniques to address WRMSD
risk did not demonstrate statistically significant changes on any outcomes measures.
However, certain participants showed development in micro- and macro-ergonomic
behaviors through the improvement in stress, mental health, upper extremity pain, and
sonography posture over the study period. These results exhibit feasibility of mind-body
techniques such as biofeedback and mindful sonography yoga and cueing as successful
interventions for WRMSD prevention in student sonographers. They also point to the
need for future, larger scale studies of this nature using multiple educational sites in the
recruitment of student cohorts. In order to provide more evidence on the success of mind-
body techniques to prevent WRMSD, other imaging sciences majors, in addition to
sonography, should also be explored as potential participants.
5.5.3 Implications for Future Research

While previous literature regarding WRMSD risk of Radiographers is not as extensive as Sonographer risk, certain studies have attempted to capture the seriousness of micro- and macro-ergonomic influences in the field of Radiography. In 2003, Kumar et al. conducted a survey regarding morbidity among Radiographers, and found that 83% of the 20 randomly selected participants were experiencing back pain. That same year, these authors also performed, an evaluation of biomechanical loads on radiographers during work, finding that a convenience sample of seven radiographers performed patient-related tasks which exceeded the maximum permissible load limit set by the National Institute for Occupation Safety and Health (NIOSH). Finally, literature review performed by Raj in 2006 revealed significant stress-related consequences on the physical and mental health of radiographers.

The addition of Radiography students as participants in future studies would allow for further analysis of the feasibility of mind-body techniques to address profession specific micro-and macro-ergonomic risk factors of WRMSD in the imaging sciences by comparing results among and between student groups. Additionally, the use of a qualitative component of data collection, such as focus groups, would provide supplemental evidence of the efficacy of mind-body techniques for WRMSD prevention. By allowing participant’s the opportunity to interact and contribute in a group atmosphere, the identification of important topics and emergent themes from the study could be developed. Furthermore, designing a prospective study with pre- and post-treatment measures as well as follow up analysis at intervals as the student participants
progress in their career would provide information on the long term benefits of mind-body techniques for WRMSD prevention.

5.6 Conclusion

Results from this pilot study to address WRMSD risk in a cohort of student sonographers did not demonstrate any statistically significant reduction in micro- and macro- ergonomic outcomes measures of physical and mental health, perceived stress and upper extremity pain. However, statistical power was limited by a small sample and treatment group size. Furthermore, internal validity of the results was threatened by inability to comprise inclusion and exclusion criteria to students in the program, lack of health history data, and implementation of treatment during formal lab time.

Nevertheless, improvements in measures of mental health, perceived stress, pain, and scanning posture were observed for specific treatment groups. Most notably, the YM group, who received ergonomics education + mindful sonography yoga and cueing, demonstrated a group mean improvement in mental health, perceived stress level, and right upper extremity pain over the study period. Three of the study participants experienced a possibly clinically significant reduction in right upper extremity pain over the study period, one of which was in the BFYM group and two who were in the YM group. Also, biofeedback training was shown to improve posture in both groups who received this treatment over the study period, and to a greater extent when it was combined with mindful sonography yoga and cueing for the BFYM group.
The findings of the prospective pilot study indicate the need for future, larger scale studies which investigate the use of mind-body techniques which address micro- and macro- ergonomic risk factors in WRMSD reduction. The combination of quantitative data from health surveys, postural and muscle activity analysis, health biomarkers, and qualitative data from focus groups in larger samples of student sonographers would allow for greater generalizability of results. Furthermore, the investigation of comparison groups of Radiography students as well as the addition of longitudinal follow up intervals in the study design would provide further evidence of the efficacy of mind-body techniques to address WRMSD risk in future imaging professionals.
References


Appendix A: Ergonomics Education Lecture Objectives
Goals for the Discussion

- Define ergonomics
  - Micro- vs. macro-influences for sonographers

- Define Work-Related Musculoskeletal Disorders (WRMSD)

- Review results from current research on incidence of WRMSD in sonographers

- Identify ergonomic interventions for the prevention of WRMSD in sonographers

Figure A.1 Goals for ergonomics education lecture 1
Figure A.2 Goals for ergonomics education lecture 2
Appendix B: Survey Tool
As a participant in this study, your answers to this questionnaire are important. All answers will be kept confidential and secure.

This questionnaire is divided into three sections. We ask you complete each section fully and answer every question. Please do not skip any questions. The questions pertain only to your current status, and pain levels. Furthermore, we ask for your honesty and first intuitive response. Do not spend time deliberating over these questions.
Section 1: This survey asks for you views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. Answer the following questions by placing a check mark on the line in front of the appropriate answer.

1. In general, would you say your health is:
   _____ Excellent (1)
   _____ Very Good (2)
   _____ Good (3)
   _____ Fair (4)
   _____ Poor (5)

The following two questions are about activities you might do during a typical day. Does YOUR HEALTH NOW LIMIT YOU in these activities? If so, how much?

2. MODERATE ACTIVITIES, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf:
   _____ Yes, Limited A Lot (1)
   _____ Yes, Limited A Little (2)
   _____ No, Not Limited At All (3)

3. Climbing SEVERAL flights of stairs:
   _____ Yes, Limited A Lot (1)
   _____ Yes, Limited A Little (2)
   _____ No, Not Limited At All (3)

During the PAST 4 WEEKS, how much of the time have you had any of the following problems with your work or other regular daily activities AS A RESULT OF YOUR PHYSICAL HEALTH?
4. ACCOMPLISHED LESS than you would like:
   _____ All Of The Time (1)
   _____ Most Of The Time (2)
   _____ Some Of The Time (3)
   _____ A Little Of The Time (4)
   _____ None Of The Time (5)

5. Were limited in the KIND of work or other activities:
   _____ All Of The Time (1)
   _____ Most Of The Time (2)
   _____ Some Of The Time (3)
   _____ A Little Of The Time (4)
   _____ None Of The Time (5)

During the PAST 4 WEEKS, how much of the time have you had any of the following problems with your work or other regular daily activities AS A RESULT OF ANY EMOTIONAL PROBLEMS (such as feeling depressed or anxious)?

6. ACCOMPLISHED LESS than you would like:
   _____ All Of The Time (1)
   _____ Most Of The Time (2)
   _____ Some Of The Time (3)
   _____ A Little Of The Time (4)
   _____ None Of The Time (5)

7. Did work or other activities LESS CAREFULLY THAN USUAL:
   _____ All Of The Time (1)
8. During the PAST 4 WEEKS, how much did PAIN interfere with your normal work (including both work outside the home and housework)?
   _____ Not At All (1)
   _____ A Little Bit (2)
   _____ Moderately (3)
   _____ Quite A Bit (4)
   _____ Extremely (5)

The next three questions are about how you feel and how things have been with you DURING THE PAST 4 WEEKS. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the PAST 4 WEEKS . . .

9. Have you felt calm and peaceful?
   _____ All of the Time (1)
   _____ Most of the Time (2)
   _____ Some of the Time (3)
   _____ A Little of the Time (4)
   _____ None of the Time (5)

10. Did you have a lot of energy?
    _____ All of the Time (1)
    _____ Most of the Time (2)
    _____ Some of the Time (3)
11. Have you felt downhearted and depressed?
   _____ All of the Time (1)
   _____ Most of the Time (2)
   _____ Some of the Time (3)
   _____ A Little of the Time (4)
   _____ None of the Time (5)

12. During the PAST 4 WEEKS, how much of the time has your PHYSICAL HEALTH OR EMOTIONAL PROBLEMS interfered with your social activities (like visiting friends, relatives, etc.)?
   _____ All of the Time (1)
   _____ Most of the Time (2)
   _____ Some of the Time (4)
   _____ A Little of the Time (5)
   _____ None of the Time (6)
Section 2: Please answer the following questions. The questions in this scale ask about your feelings and thoughts DURING THE LAST MONTH. In each case, please indicate how often you felt or thought a certain way by filling in the appropriate circle.

<table>
<thead>
<tr>
<th>Question</th>
<th>Never</th>
<th>Almost Never</th>
<th>Sometimes</th>
<th>Fairly Often</th>
<th>Very Often</th>
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<tbody>
<tr>
<td>1) In the last month, how often have you been upset because of something that happened unexpectedly?</td>
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<td>2) In the last month, how often have you felt that you were unable to control the important things in your life?</td>
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<td>3) In the last month, how often have you felt nervous and “stressed”?</td>
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<td>4) In the last month, how often have you felt confident about your ability to handle your personal problems?</td>
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<td>5) In the last month, how often have you felt that things were going your way?</td>
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<td>6) In the last month, how often have you found that you could not cope with all the things that you had to do?</td>
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<td>7) In the last month, how often have you been able to control irritations in your life?</td>
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<td>8) In the last month, how often have you felt that you were on top of things?</td>
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<td>9) In the last month, how often have you been angered because of things that were outside of your control?</td>
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<td>10) In the last month, how often have you felt that difficulties were piling up so high that you could not overcome them?</td>
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Section 3: Please answer the following questions.

13. Overall, how would you rate your RIGHT upper extremity pain? Please mark the corresponding level on the scale below (your pain level does not have to be an integer/whole number).
14. Overall, how would you rate your LEFT upper extremity pain? Please mark the corresponding level on the scale below (your pain level does not have to be an integer/whole number).
Appendix C: RULA Score Sheet
Figure C.1 RULA analysis worksheet
Appendix D: Individual Participant Data
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<th>SFP-post</th>
<th>SFP-C</th>
<th>SFP-m</th>
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Figure D.1 Individual participant survey data