

Stretch Exercises: Reducing the Musculoskeletal Pain and Discomfort in the Arms and Upper Body of Echocardiographers

WENDY D. CHRISTENSSSEN, BSc, RDMS, RDCS, RVT, ACR

Repetitive strain injuries and the signs and symptoms of a musculoskeletal injury are widely recognized as serious hazards for echocardiographers. The aim of this research project was to design, implement, and evaluate an appropriate exercise program and to reduce the reported levels of signs and symptoms that echocardiographers experience in their entire upper body during a working day. Ergonomic task assessments were performed on a group of echocardiographers. The specific muscles that were used were identified, and a stretch exercise program was designed to target those areas. A single blind research study was undertaken with two small groups of echocardiographers with similar work practices. The experimental group was trained in the stretch exercise program and was interviewed monthly while the 12-week study was taking place. The control group was given no information concerning the stretch exercises. Both groups completed pre and post questionnaires and signs and symptoms surveys. At the end of the study, the experimental group reported positive feedback on the stretch exercises and found them very beneficial. A longer, double blind study with more echocardiographers with similar workloads will have to be considered to properly test the designed stretch exercise program and to confirm that it will reduce the reported levels of signs and symptoms of musculoskeletal injury to which echocardiographers are susceptible.

Key words: stretch exercises, echocardiographers, musculoskeletal injuries, repetitive strain injuries

From the Ultrasound Department, Burnaby Hospital, Burnaby, British Columbia, Canada.

Reprint requests: Wendy D. Christenssen, Ultrasound Department, Burnaby Hospital, 3935 Kincaid Street, Burnaby, British Columbia V7C 2M1, Canada. E-mail: wendy_christenssen@sfr.hnet.bc.ca.

The author expresses her gratitude to Waqar Mughal, BSc, for his support and expertise as supervisor of the research project and as a member of the Bodyworks team. Thanks should also be given to Sue Hyatt, the other member of the Bodyworks team, who provided invaluable advice about performing an ergonomic risk assessment. The author would like to thank Marc Pelletier, Randy Harker, and Gwen Bertelsen for being so supportive and allowing the research project to take place. Finally, a big thank you to all the echocardiographers who took part in the study, particularly the experimental group.

As the population increases and average life expectancy rises, the demands on every area in a health service also increase. In cardiac ultrasound, the number of requests by family physicians and specialists for echocardiograms is increasing every year (see Table 1).

An echocardiogram is a cardiac ultrasound examination that has some major advantages over other forms of clinical tests to assess the patient's

TABLE 1
Number of Echocardiograms Performed at Burnaby Hospital From 1995 to 2000

Year	Number of Echocardiograms	Percentage Yearly Increase
April 1, 1995-March 31, 1996	2056	0
April 1, 1996-March 31, 1997	2251	9.5
April 1, 1997-March 31, 1998	2362	14.9
April 1, 1998-March 31, 1999	2505	21.8
April 1, 1999-March 31, 2000	2655	29.1

cardiac status: it is completely noninvasive and uses nonionizing radiation (a sound wave). The only discomfort sometimes felt by the patient during an echocardiogram is when the echocardiographer has to press the transducer head in between a rib space to optimize the ultrasound window.

The valuable information obtained from an echocardiogram of the heart's pathology, anatomy, and hemodynamics helps the ordering physician decide which cardiac path the patient should follow (e.g., will cardiac medication suffice, or will the patient need to be referred to a cardiac surgeon for further investigation?).

The average echocardiogram takes 45 to 50 minutes to perform and involves the echocardiographer remaining stationary, with his or her shoulder joint held in abduction for long periods while interrogating cardiac pathophysiology. Muscular forces are used to optimize the sonographic window and to maintain the echocardiographer's position. These factors induce muscular fatigue in the sonographer's shoulder, arm, and upper body, and thus the sonographer is highly susceptible to repeated microscopic injury and musculoskeletal symptoms that lead to repetitive strain injury. According to Vanderpool et al.,

In cardiac sonography, static or sustained isometric contraction of the neck, back, shoulder, and upper extremity are necessary to support and fix the arm in a position to hold the transducer against the patient. Conversely, dynamic or repetitive movements of the shoulder, forearm, wrist, hand, and fingers are needed to manipulate the transducer around the patient's left chest and adjust the monitor.¹

For the whole of British Columbia, the total number of practicing sonographers is only 232, and approximately 25% are echocardiographers. In a recent survey conducted by the British Columbia Ultrasonographers' Society et al.,

TABLE 2
Body Parts Sonographers Reported Using in Repetitive Motions

Repetitive Movements	Prevalence Reported by Sonographers
Wrist/hand motion	
Repetitive	92%
Awkward position or bending	100%
Twisting	62%
Arms/shoulders	
Repetitive	100%
General	
Sustained positions	92%
Repeated stretching/reaching	84%
Repeated pressing/twisting	77%

SOURCE: Bell et al.³

Respondents reported a high prevalence of musculoskeletal pain and discomfort during their scanning career [91%]. Pain and discomfort in the shoulder, neck and upper back constituted a large proportion of the problem areas.²

The types and frequency of repetitive or sustained motions required to perform cardiac sonography are shown in Table 2.

A musculoskeletal injury is usually the predecessor to a repetitive strain injury. When a muscle or joint is repeatedly being used to do a repetitive task, there is a strong possibility that permanent damage might occur. When a shoulder is held in abduction at more than 30 degrees, the muscles supporting the shoulder become tired quickly and leave the shoulder hanging by its tendons.⁴

Shoulder abduction while applying sustained pressure and upper-body repetitive twisting are common positions that echocardiographers find themselves in. Patients who have a suboptimal body habitus or critical care patients who are unable to be transferred onto the ergonomically designed ultrasound stretcher compound these ergonomic problems for the echocardiographer.

For a muscle to perform correctly, it must have a fine-capillary blood supply to exchange the carbon dioxide and waste products produced on exertion with oxygen and fuels needed to keep it healthy. If the waste products are not removed, the muscle can become sore and stiff.

A muscle held in a static position with sustained force will fatigue quickly, and if it is not allowed to

recover before repeating the same maneuver, it can become microscopically injured. If this is repeated over and over again, the echocardiographer could develop a repetitive strain injury.

The signs and symptoms of a musculoskeletal injury can happen at any stage of the repetitive injury process. The echocardiographer may experience symptoms long after carrying out an echocardiogram or have symptoms that he or she assumes are normal, everyday aches and pains. Bueckert and Weninger⁵ formulated the following list of general symptoms that are reported and attributed to a repetitive strain injury:

- Pain, dull ache
- Loss of sensation (numbness), especially at night
- Tingling and burning sensations
- Tenderness
- Swelling around the wrist/hand
- Dry shiny palm
- “Pins and needles” discomfort
- Clumsiness (loss of the ability to grasp items, impaired thumb and finger dexterity)
- A “crackling” feeling when swollen tendons are pressed tightly (known as crepitus)
- A cystlike swelling or node near a tendon or joint (known as ganglion)
- Muscle weakness and fatigue
- Muscle spasms
- Joint restriction/loss of movement
- Aches/pains, which may be worse at night

Warm-up and stretch exercise programs have been used by athletes for many years to prevent musculoskeletal injury. There have been numerous studies on the benefits of warming up and stretching. Shellock and Prentice⁶ postulated that a warm-up of the specific muscles that are to be used and improved flexibility by stretching appear to reduce the incidence and likelihood of musculoskeletal injury.

In Australia, an ergonomic study on echocardiographers suggested various ways of restricting injuries. One suggestion had sonographers doing a warm-up before starting a full day of echocardiograms.⁴

The static stretch, which has been chosen for this study as the mode of exercise performed by the echocardiographers, was described by Schultz as “the slow, gradual pulling, holding, and releasing of

specific muscle groups.”⁷ The static stretch improves the flexibility of a muscle and helps protect against muscle soreness and injury.⁷

The aim of this research project is to ascertain whether doing a stretch exercise program designed for echocardiographers during a working day will help improve their comfort level and reduce the musculoskeletal pain and discomfort in their arms and upper body. In their study of echocardiographers, Bell et al.³ found that overall fitness should be encouraged, that exercises should target the specific muscle groups at risk for repetitive strain injury, that personnel should stretch frequently during the day to restore blood flow (hourly is optimal), and that both workers and their managers should be aggressively educated about the benefits of exercise. Milner⁸ stated that stretching of the antagonist muscles and contraction/relaxation cycles between echocardiograms increase the comfort level for echocardiographers.

For this research project, two groups of echocardiographers from different hospitals were used. The control group comprised two similar groups from different hospitals who did not do the stretch exercise program but completed pre and post questionnaires and signs and symptoms surveys.

The experimental group completed the same forms at the beginning and end of the project and participated in the stretch exercise program. All of the experimental group members were interviewed every 4 weeks to monitor how they were coping physically and mentally while performing these exercises in a real working environment.

It is hoped that at the end of the research project, one of the following conclusions will be reached:

- There will be some indication that there is a reduction in the reported levels of signs and symptoms in the experimental group through participating in the stretch exercise program when compared with the control group.
- There will be no difference between the experimental group and the control group, and no reduction in the reported levels of signs and symptoms through participating in the stretch exercise program will be seen.
- Further study will be needed to affirm or deny that the stretch exercise program will reduce the reported levels of signs and symptoms in echocardiographers (e.g., a much longer study,

maybe 1 or 2 years, or a larger study involving more echocardiographers).

Designing a Stretch Exercise Program for Echocardiographers: Ergonomic Risk Assessment

The initial step for the ergonomic risk assessment was to fill in a task form.⁹ The task form was completed by a member of the experimental group and then discussed with the other echocardiographers in the group to affirm that everything had been documented correctly and that no steps had been missed.

The task form breaks down into finite detail every step that is taken by the echocardiographer when carrying out an echocardiogram on an outpatient, including what equipment/material is used and any other considerations that should be taken into account. The form documents the moment the echocardiographer starts the procedure to the point at which the examination is finished.⁹ The reason the task form was completed only for outpatients is that for this research project, with its limited time scale of 15 weeks from beginning to completion, it was not feasible to examine the multitude of factors that can affect the optimization of ergonomics for the echocardiographer (equipment, working environment, immobile inpatients, etc.).

The researcher and Bodyworks coordinator met and discussed the completed task form. From the original 30 steps, 9 steps were removed by merging into other steps, and a refined 21-step form was inputted into the computer (Appendix A). Members of the experimental group then verified the correctness of this form.

Once the task form was finished, the researcher and Bodyworks coordinator met again and constructed a spreadsheet of the 21-step form⁹ and designed an observation sheet.⁹ In addition to the task form information was ergonomic positional information (e.g., awkward posture, high force, static position, repetition, contact stress, duration).

Previous to this meeting, a verbal and written request for the research project to proceed was made to the manager of the experimental group's department, the regional director of medical imaging, and the vice president of community and strategic services. The request was approved provided that written consent from the echocardiographers in the experimental group be obtained, with a written disclaimer that none of the information gathered during the project would be used

outside the research project or the health region. At this meeting, a consent form was consequently drawn up.⁹ The consent form was then sent out for approval, which it received.

All of the echocardiographers in the experimental group signed the consent form and agreed to take an active role in the research project. The researcher and the Bodyworks team met to discuss the observation form and how they were going to fill out the form each time, so that there was uniformity.

Each member of the experimental group would be observed while he or she performed an echocardiogram by all three members of the observation group, and if at all possible more than one echocardiogram would be observed by each observer for each echocardiographer.

Over a period of 2 weeks, the researcher and Bodyworks team observed each of the experimental group members performing an echocardiogram. The observations were semiparticipant observations, where observers would rely on the echocardiographer to keep them informed of whether he or she was experiencing discomfort in any particular area while scanning. The echocardiographer would describe to the observer what he or she was experiencing, as this is a very subjective finding, which an observer would not know unless told by the sonographer. Hara described qualitative research as "being able to explain the psychological dimensions of a human being, which cannot be recorded numerically, when a quantitative research method is used."¹⁰

One observation form was used by each observer to record all members of the experimental group. All the observers used a pencil when recording, as it allowed them to make any necessary alterations. This method of observation was decided upon for the following reasons:

- Any idiosyncrasies that an individual echocardiographer performed would be documented.
- The common ergonomic maneuvers and problems encountered by an echocardiographer would be highlighted.

The ergonomic group met and discussed the three observation sheets, the main muscle groups involved were determined, and the key ergonomic problem areas were identified (Appendix B). The final observation results were agreed upon by everyone in

the observer group to be a representative ergonomic assessment of an echocardiogram.

At the end of this meeting, another form was drafted⁹ to document and record which muscle groups and movements are used in the various 21 steps performed during an echocardiogram. This form was then completed by the researcher.

A few days later, the researcher discussed the completed form (Appendix C) with the Bodyworks coordinator. The two then drew up a stretch exercise chart (Fig. 1) and a program (Fig. 2) and formulated a checklist⁹ for the echocardiographers to keep while part of the research project.

At this meeting, the questions to be included on the pre and post questionnaires for the research project were discussed⁹:

- In Section 1 of the questionnaire, there are demographic questions about each echocardiographer, typical number of hours worked per week including overtime, number of years in the profession and in their department, which scanning arm they preferred, how long the average echocardiogram takes, how many echocardiograms are performed daily, how many breaks they receive each day, and how long these breaks last.
- In Section 2, Part 1 of the Signs and Symptoms Survey, there are seven questions assessing perceived fitness level, ability to perform the daily work schedule, and level of exertion required to perform the most difficult aspects of an echocardiogram. The echocardiographers were asked to indicate their degree of agreement (1 = strongly disagree, 5 = strongly agree).
- Part 2 of the Signs and Symptoms Survey asked the echocardiographer to assess how each body part felt in the past week. How often the echocardiographer experienced an ache or discomfort was scored as never (1), 1 to 2 times during the past week (2), 3 to 4 times during the past week (3), once every day (4), or several times per day (5). If the echocardiographer did experience anything, it was scored as slightly uncomfortable (1), moderately uncomfortable (2), or very uncomfortable (3). The survey also asked whether and how the discomfort interfered with the echocardiographer's ability

to work (0 = not at all, 1 = slightly interfered, 3 = substantially interfered).

The questions have been used by the Bodyworks coordinator and are regarded as being reliable, but they have not been tested for their validity.

Literature Review

Ultrasound is still a comparatively new field in a modern medical imaging department, and it has only been in recent years that musculoskeletal injuries and repetitive strain injuries among sonographers have been recognized as a serious negative side effect to this safe sound wave test. The use of ultrasound has risen steadily, and the information attained from each test has multiplied. This has led to an increase in the demands for all types of ultrasound examinations, and one of the main fields to dramatically increase in demand is echocardiography.

Echocardiography is a small yet important ultrasound section, and because of the small numbers of echocardiographers involved, it has not been given its rightful importance in the number of research studies or articles that have examined this particular field with respect to musculoskeletal injuries.

It has only been in the past few years that the Workers Compensation Board in British Columbia has recognized repetitive strain injuries for sonographers and sonographers have gone onto long-term disability following an injury. Sonographers are now aware of the importance of documenting the very first sign or symptom that they have an injury and to make certain that all official channels are aware that they have a musculoskeletal problem.

Any literature review is limited in the number of studies that have been done specifically on echocardiographers and their signs and symptoms of musculoskeletal injuries. Even when examining the ultrasound community as a whole, there are few articles on this topic. The articles and studies addressing musculoskeletal problems for sonographers appear around 1985, are few in number, and are mainly in English. The limited numbers cause a problem when attempting to form an unbiased opinion from the sonographers involved in the studies. To get around this problem, the project has a control group that has no information about the stretch exercise program the



Bodyworks Program



Stretch Sheet For Echocardiographers

The following activities are STRETCHES (with one exception*) that are to be performed at various times in your workday. They are arranged into groups so you can do all the stretches together.

- Perform, **do both sides** (l and r), hold for **at least 20 seconds**
- and above all else, **GO SLOWLY AND LISTEN TO YOUR BODY!**

Hands and Forearms

Thenar Stretch	Supinator Stretch	Pronator Stretch
Make your hand as flat as possible. Move your thumb away from your fingers as far as possible.	Use one hand to turn the other as far into pronation as possible	Use one hand to turn the other as far into supination as possible.
Forearm Extensor Stretch	Forearm Flexor Stretch	
With the elbow straight, pull the hand up until a stretch is felt on the anterior forearm.	With the elbow straight, pull the hand down until a stretch is felt on the posterior forearm.	

Cervical and Lumbar Spine

Cervical Spine Extensors Stretch	Cervical Spine Rotation Stretch	Cervical Spine Lateral Flexors Stretch
Slide chin back, then drop chin toward sternum to feel stretch in back of neck – from the bottom of the skull to between the shoulder blades.	Slowly turn your chin to your shoulder to feel a gentle stretch.	Put one arm behind you, the other on your head. Gently pull head away from other shoulder until a stretch is felt on side of neck.
Neck/Shoulder Stretch	Lumbar Extension Stretch	
Hold arm and pull gently down and away from shoulder, while leaning head away from shoulder.	Place hands on buttocks, next to hips. Gently push hips forward (don't lean back!) until you feel stretch in your lower trunk.	

Upper Trunk and Shoulder Girdle

Upper Back Stretch	Chest Stretch	Posterior Shoulder Capsule Stretch
Place hands together, bring to shoulder level, and push hands forward (keep head up) until stretch is felt between shoulder blades	Place hands behind your back, slowly raise them until stretch is felt in upper chest. (Or, while seated, place hands behind chair back and lean forward)	Bring arm up to shoulder level, push elbow in with other arm until stretch is felt in the back of the shoulder
Anterior Shoulder Stretch	Inferior Shoulder Stretch	Shoulder Rolls*
Hold door or door frame, keep elbow at 90 degrees. Turn body away from hand until stretch is felt in front of shoulder	Grasp towel, drop it behind your back, and grasp with other hand. Pull up until stretch is felt in lower shoulder.	Make small circles with your shoulders, in both directions (This is to relax the joint and associated muscles). NOT A STRETCH.

FIG 1. Sheet of stretch exercises.

Echocardiographer Stretching Schedule

- For standing activities, ensure that the knees are "soft" (slightly bent)
- For those activities performed one arm/leg at a time, ensure that both sides are stretched
- Stretching activities are marked with * - 2-3 repetitions, holding for at least 20 seconds
- and above all else, **GO SLOWLY AND LISTEN TO YOUR BODY!**

On your Stretching Tracking Sheet, mark one (1) tick in that day's box next to the stretch for every **set** of stretches you do (i.e., at least two repetitions).

In your day, you should have at least two ticks for each stretch (i.e., you've done each *set of two stretches* at two different times in the day)

Stretch	January						
	17	18	19	20	21	22	23
Hands and Forearms							
• Digital stretch							
• Wrist/Forearm stretch							
• Forearm stretch							
• Forearm Extensor stretch							
• Forearm Flexor stretch							
Cervical and Lumbar Spine							
• Cervical spine Extension stretch							
• Cervical spine Rotation stretch							
• Cervical spine Lateral Flexion stretch							
• Neck/Shoulder stretch							

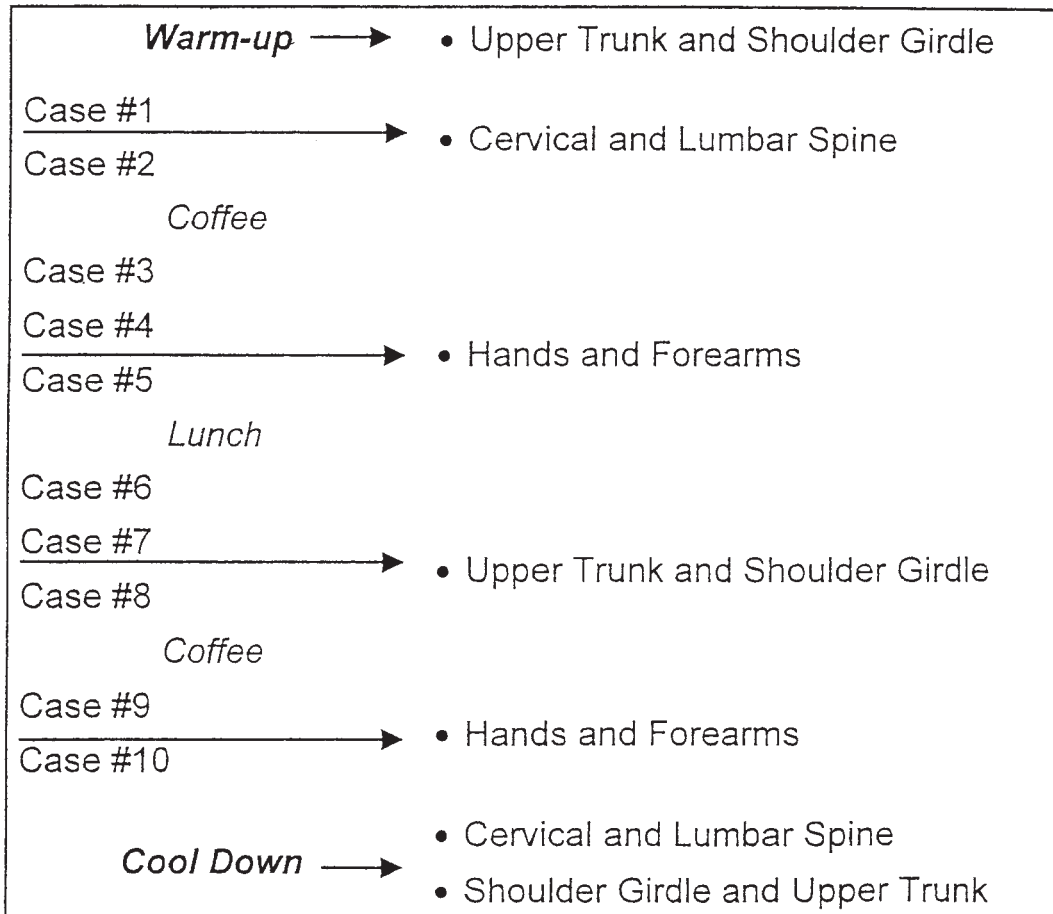


FIG. 2. Stretching schedule.

experimental group is performing (i.e., single blind research study).

Necas performed a survey of 413 sonographers on musculoskeletal symptomatology and repetitive strain injuries and confirmed that "musculoskeletal symptomatology and RSI [repetitive strain injury] pose a serious threat to the working sonographers . . . it is important for every sonographer to become familiar with the principles of ergonomics, and attempt to minimize musculoskeletal health hazards."¹¹ Necas's survey had only a very small percentage of echocardiographers. The response rate was 36% ($n = 149$). The survey was designed to determine the prevalence of musculoskeletal symptoms in the ultrasound technical community as a whole in Washington and Oregon.

The 413 sonographers were a demographic group from the Society of Diagnostic Medical Sonography. The group was biased in favor of general sonographers and had few cardiac or vascular technologists among its numbers. Unlike this research project, no recommendations on how to reduce musculoskeletal injuries or repetitive strain injuries were ascertained. In fact, Necas¹¹ described his study as a pilot study, and his data were attained from only one survey. The research surrounding the stretch exercise program is the next step subsequent to the Necas study, which demonstrated that sonographers were susceptible to musculoskeletal injuries and needed to become more proactive in protecting their physical well-being.

Echocardiography has expanded and grown quickly in recent years (see Table 1), and only a few studies have been carried out that attempt to assess how the echocardiographers can be helped to prevent injuring themselves. Vanderpool et al. suggested that "preventive education is a key factor in helping workers maintain and learn how to maintain their health."¹¹ No suggestions were made on how this was to be done, but the report did confirm that "some specific techniques and postures . . . show a strong relation to the number of symptoms experienced by cardiac sonographers." The participants in this study were randomly selected from the American Registry of Diagnostic Medical Sonographers. The total number of questionnaires distributed was 225, and the response rate was a moderate 47%. This report mainly examined carpal tunnel syndrome and revealed that the high-pressure handgrip used by echocardiographers significantly increased the risk of developing this condition. No particular exercises or preventative plan was

recommended, but the study did suggest that "emphasis should be placed on equipment and work environments . . . and allow frequent breaks to give soft tissues a chance to recuperate from awkward positions and repetitive movement."¹¹

Ergonomics has become the catch phrase of the late 1990s, but restrictions in funding for new equipment and for undertaking major renovations limit what can be done to improve poor work environments. Realistically, what can be done is to educate the echocardiographers to be in control of their own destiny by looking after their physical well-being.

The earliest study that examined ergonomic interventions in echocardiography was originally written in French by Daignault,¹² who argued that the two ergonomic factors of interest are the worker and the work tasks. According to Daignault, "In the traditional work environment, the worker adapts to the task required. It is now necessary to reverse our thinking on this matter. We must adapt the task, the furniture, tools to the human beings who perform/use them."¹² Daignault looked intensively at the equipment used but also commented on the sonographers' posture and recommended the following:

- Always working in the same position, on the same side, uses the same muscle group. We encourage the development of skills for both the left and right sides. This alternation of muscle groups used, permits the muscles to recuperate, and can avoid initiating chronic musculoskeletal problems.
- A hospital physiotherapist will design and teach a program of limbering and muscle stretching exercises. Every so often, the physiotherapist will offer refresher courses to insure that the exercises are being done properly.
- A written summary of the program will be given to each Technologist, as a reminder.
- The exercises will be simple to do, and can be performed in a seated or standing position.¹²

There was no indication in this report that the stretch exercises helped the three echocardiographers, and no control groups were used to determine how beneficial the stretch exercises would be. This program was set up to evaluate the benefits of performing regular stretch exercises, and the program was monitored throughout the project so that the possibility of any injuries occurring due to the stretch

exercises would be reduced. The echocardiographers in the Daignault¹² study performed only echocardiography, and this is why an attempt to scan ambidextrously was recommended, whereas the research project echocardiographers perform all types of ultrasound examinations and scan left-handed and right-handed. An interesting fact was included in the Daignault recommendations: “When changing a work technique, plan for a well supervised four to six month learning curve . . . adaptation skills vary dramatically by individual, and that some workers will take longer to assimilate the new information.”¹²

The time scale for the research project does not allow for this recommendation, but it is something that will have to be taken into consideration at the end of the project if it is shown that the stretch exercises are beneficial but the designed stretch exercise program is not adhered to.

Bell et al.³ performed a survey of echocardiographers in the Calgary area, and one of their recommendations was to introduce an exercise program: “Preventative Stretching Exercises: . . . cardiac sonography requires prolonged static positions. If these positions are interrupted frequently RSI [repetitive strain injury] can be reduced or even prevented. Stretching exercises are particularly important for risk reduction in jobs where ergonomically correct movements are not possible.”

Hebert (cited in Bell) postulated that “preventative stretching exercises on jobs with RSI [repetitive strain injury] risks should affect injury reduction the way preventative stretching for athletes reduces risks.”³ The Bell et al. report was based on a survey of 13 echocardiographers and interviews with ergonomic experts, which all could have been subject to a biased subjective interpretation. The subject of why echocardiographers are prone to musculoskeletal injuries and how these signs and symptoms and injuries can be reduced is a huge topic involving employers and employees equally. This project is looking into designing, implementing, and evaluating a stretch exercise program for echocardiographers to determine whether it will reduce the reported levels of signs and symptoms of musculoskeletal injury:

- Employers must ensure that work areas are ergonomically correct and that adequate time is

allowed for employees to take preventative measures throughout the working day.

- Employees must be diligent in taking regular breaks and doing stretch exercises whenever possible and to take control of their own safety program.

As Van Eerd (cited in Kome¹³) humorously suggested, the top three rules for avoiding musculoskeletal injuries are (1) take frequent breaks, (2) take frequent breaks, and (3) take frequent breaks.

One of the criteria behind the stretch exercise program designed for this project is that the echocardiographers perform stretch exercises throughout the scanning day and take frequent breaks between scans and exercise. Pike et al. acknowledged that “duration of work without rest is a contributing factor in the development of musculoskeletal disorders.”¹⁴ Pike and colleagues surveyed 3000 sonographers in the United States. The response rate of approximately 1000 allowed the researchers to make generalizations about the whole ultrasound community. The most frequently reported type of scan undertaken was an echocardiogram, “and the key activities that aggravate the pain and discomfort that indicates a musculoskeletal disorder were the specific activities of manipulating the transducer while applying sustained pressure, with shoulder abduction, and twisting of the neck and trunk.”¹⁴

Echocardiographers should be given advice and training on how to be more proactive in protecting their arms and upper body from injury. Daignault advised that a

program of limbering and muscle stretching exercises be designed, and taught to cardiac sonographers, which would involve 15 minutes of warm up exercises every morning, one or two exercises between examinations. Refresher training sessions should also be implemented to insure that the exercises were being done properly, and everything should be well supervised for four to six months as some workers will take longer to assimilate the new information.¹²

Daignault’s¹² study did not examine which exercises would be appropriate, or whether his academic ideas would be able to translate to clinical practice, but it did highlight some important points, especially those just

TABLE 3
Demographics of Echocardiographers in Experimental and Control Groups in Research Project

	Experimental Group				Control Group							Group Average		
	Tech A	Tech B	Tech C	Tech D	Tech A	Tech B	Tech C	Tech D	Tech E	Tech F	Tech G	Experimental	Control	Experimental and Control
Hours per week	22.5	42	39	38	36.5	37	25	8.2	42	30	36	35.4	30.7	32.4
Years in profession	9	16	6	2.5	10	11	6	13	3	16	8	8.4	9.6	9.1
Years in department	9	16	6	2.5	7	10	6	13	2	10	8	8.4	8.0	8.1
Preferred scanning arm	L	A	L	R	L	L	L	A	L	L	L			
Duration of scan (in minutes)	45	45	45	30	45	40	40	40	45	50	45	41.3	43.6	42.7
Number of echocardiograms per day	10	10	10	10	2	3	5	4	8	8	5	10.0	5.0	6.8
Number of breaks per day	3	3	3	3	3	3	3	3	3	3	3	3.0	3.0	3.0
Duration of lunch (in minutes)	30	30	30	37.5	30	30	30	30	30	35	30	31.9	30.7	31.1
Duration of breaks (in minutes)	17.5	20	20	15	15	15	15	15	15	10	15	18.1	14.3	15.7

NOTE: L = left; R = right; A = ambidextrous.

mentioned, that should be taken into account when designing an exercise program for echocardiographers.

In the current study, a warm-up, a cool-down, and regular stretch exercises throughout the day are recommended, but the ideal program may not be practical to follow in a real clinical setting. With the routine scheduling problems of patients not being on time, cases taking longer than expected due to technical difficulties, and the patient's physical condition, exercises tend to take second place in everyone's priorities at that moment, but with education this may change. Parker and Imbus advised that "stretching exercises are designed to maintain muscular mobility and circulation. . . . Employees should be encouraged to stretch muscles intermittently throughout the day when feeling fatigued or cramped, rather than allowing these sensations to worsen."¹⁵

The British Columbia Ultrasonographers' Society et al.² initiated the latest report on work-related musculoskeletal disorders among sonographers. A survey with 125 questions was sent to 232 sonographers (all of the known diagnostic medical sonographers in British Columbia). Two hundred eleven (92%) sonographers returned their questionnaires. Of the respondents, 91% had musculoskeletal pain and discomfort. Sustained shoulder abduction, applying pressure, twisting of the neck/trunk, and repetitive twisting were the work tasks most aggravating to musculoskeletal symptoms. The

report did not discuss how these symptoms could be alleviated.

Results

Eleven echocardiographers took part in the project. The echocardiographers were divided into an experimental group and a control group. The experimental group was composed of four echocardiographers, and the control group consisted of seven echocardiographers.

From Section 1 of the questionnaire, which all 11 echocardiographers completed before and after the study, the demographics for the experimental and control groups were determined as demonstrated in Table 3.⁹

Table 4 provides descriptive information with regard to average normal working week hours, number of years in the profession, length of time working in the department, number of echocardiograms performed each day, and the time it takes to perform an echocardiogram, including the number of scheduled breaks and times taken during a working day.

The echocardiographer in the experimental group and the control group works an average of 35.4 and 30.7 hours per week, respectively. In the experimental group, the echocardiographer has

TABLE 4
Demographics of Echocardiographers in Experimental and Control Groups (average)

	Experimental Group (<i>n</i> = 4)	Control Group (<i>n</i> = 7)	Experimental and Control Groups
Hours per week	35.4	30.7	32.4
Years in profession	8.4	9.6	9.1
Years in department	8.4	8.0	8.1
Length of scan (minutes)	41.3	43.6	42.7
Number of echocardiograms per day	10.0	5.0	6.8
Number of breaks	3	3	3
Length of lunch break (minutes)	31.9	30.7	31.1
Length of coffee break (minutes)	18.1	14.3	15.7

worked an average of 8.4 years in the profession and 8.4 years in the department. The echocardiographers in the control group have worked an average of 9.6 years in the profession and 8.0 years in the department.

Each member of the experimental group takes approximately 41.3 minutes to perform an echocardiogram and averages 10 echocardiograms per day. In the control group, the echocardiographers average 5 echocardiograms per day and take 43.6 minutes to perform the study. Both groups take three regular breaks in a working day. Experimental group members take two 18.1-minute coffee breaks and a 31.9-minute lunch break. Control group members take two 14.3-minute coffee breaks and one 30.7-minute lunch break.

Figure 3 demonstrates the preferred scanning arm for all the echocardiographers taking part in the research project. In the experimental group, two of the echocardiographers preferred to scan left-handed

when performing an echocardiogram, one preferred to scan right-handed, and one was ambidextrous. In the control group, six of the echocardiographers preferred to scan left-handed and one was ambidextrous.

Table 5 demonstrates the results from Section 2 on the questionnaire describing echocardiographers' abilities while at work, their perception of fitness at the beginning and end of the 12-week study, and any changes that occurred. One echocardiographer from the experimental group and two from the control group stated that the worst activity involved with an echocardiogram was the pressure and high force that had to be applied to obtain a window on large patients. Three echocardiographers from the experimental group and five from the control group considered moving equipment one of the most difficult aspects of an echocardiogram. One echocardiographer from the control group stated that doing a portable echocardiogram when one could not set up one's optimal ergonomic scanning parameters was the least desired activity when performing an echocardiogram.

Table 5 demonstrates the changes noticed by the echocardiographers in both groups in how they answered before and after the research project:

- One echocardiographer in the experimental group noticed a decrease in the ability to take scheduled breaks during the study, and two of the control group members noticed an increase in their ability to take their breaks.
- At the end of the shift, one of the experimental group members felt more exhausted and one felt less exhausted. In the control group, two felt more exhausted when they finished their working day.
- One echocardiographer in the experimental group felt less able to complete his or her work in the time given, and no change was felt by any of the

Preferred Scanning Arm	Experimental Group (<i>n</i> = 4)				Control Group (<i>n</i> = 7)						
Ambidextrous		•		•				•			
Right	•		•		•	•	•		•	•	•
Left	Tech A	Tech B	Tech C	Tech D	Tech A	Tech B	Tech C	Tech D	Tech E	Tech F	Tech G

FIG. 3. Preferred scanning arm.

TABLE 5
Echocardiographers on the Research Project's Abilities and Perception of Work When Performing an Echocardiogram

Question	Experimental Group (n = 4)			Control Group (n = 7)		
	Prestudy	Poststudy	Change	Prestudy	Poststudy	Change
Able to take scheduled breaks	Strongly agree n = 3 Agree n = 1	Strongly agree n = 2 Agree n = 2	<1	Agree n = 3 Neutral n = 3 Disagree n = 1	Agree n = 5 Neutral n = 1 Disagree n = 1	>2
Exhausted at end of shift	Strongly agree n = 2 Agree n = 1 Neutral n = 1	Strongly agree n = 1 Agree n = 3	<1 >1	Strongly agree n = 1 Agree n = 1 Neutral n = 3 Disagree n = 2	Strongly agree n = 1 Agree n = 3 Neutral n = 2 Disagree n = 1	>2
Able to complete work in time given	Agree n = 4	Agree n = 3 Neutral n = 1	<1	Strongly agree n = 1 Agree n = 4 Neutral n = 1 Disagree n = 1	Agree n = 6 Neutral n = 1	>1 <1
Feel pressured to finish on time	Strongly agree n = 1 Agree n = 2 Neutral n = 1	Strongly agree n = 1 Agree n = 2 Neutral n = 1	No change	Strongly agree n = 1 Agree n = 3 Neutral n = 1 Disagree n = 2	Strongly agree n = 1 Agree n = 2 Neutral n = 3 Disagree n = 1	>1 <1
Indicate your level of fitness ^a	High n = 2 Average n = 2	High n = 3 Average n = 1	>1	High n = 1 Average n = 6	High n = 1 Average n = 6	No change
Exercise at least 2-3 times per week	Strongly agree n = 2 Agree n = 2	Agree n = 4	<2	Agree n = 1 Disagree n = 5 Strongly disagree n = 1	Agree n = 1 Disagree n = 6	>1
Level of exertion required for difficult aspects of job ^b	Strongly agree n = 1 Neutral n = 3	Strongly agree n = 3 Neutral n = 1	>2	Strongly agree n = 2 Agree n = 2 Neutral n = 3	Strongly agree n = 1 Agree n = 3 Neutral n = 3	<1

NOTE: Based on a 5-point scale from strongly disagree to strongly agree unless indicated otherwise.

a. Based on a 5-point scale from poor to good.

b. Based on a 5-point scale from very light to very heavy.

experimental group members in the pressure to finish on time. The control group had one echocardiographer who felt an increase and one who felt a decrease in the pressure to finish on time and their ability to complete their work in the time given.

- One of the experimental group members self-rated as having a higher level of fitness at the end of the study, and two members of this group decreased their level of exercise each week. The control group members showed no change in their level of fitness, and one increased his or her level of exercise during the project.
- Two echocardiographers in the experimental group felt that the level of exertion required to do the most difficult aspects of an echocardiogram

had increased. In the control group, one echocardiographer felt that the most difficult aspects of an echocardiogram had decreased.

At the end of the project, 12 body parts on the signs and symptoms survey had been indicated by the echocardiographers as being a problem area.

At the end of the project, the experimental group had 5 body parts and the control group had 7 body parts with a higher frequency of the signs and symptoms of a musculoskeletal injury. Eight body parts in the experimental group and 12 in the control group showed improvement and a decrease in the frequency of signs and symptoms.

Three body parts in the experimental group and 9 in the control group showed a deterioration in

comfort level. Five body parts in the experimental group and 9 in the control group showed an improvement in comfort level.

Three body parts in the experimental group and 5 in the control group were increasing in interference with the echocardiographer's ability to work. Five body parts in the experimental group and 9 in the control group had become less of an interference to echocardiographers in their working day. The experimental group during the 12 weeks of the study was interviewed by the researcher and Bodyworks coordinator in a group interview, approximately once every 4 weeks, to monitor whether group members were experiencing any problems with the exercise program or with any of the stretch exercises. The interviews also clarified any stretch exercises to the four echocardiographers who were having problems with them and allowed the researcher and Bodyworks coordinator to assess how the project was progressing and to determine whether there were any improvements that could be implemented to make the stretch exercise program more acceptable and easier for the sonographers to follow.

The interviews were tape-recorded and transcribed later by the researcher. Fourteen standard questions were asked at each interview session.⁹

All the answers from the echocardiographers were subjective opinions and could not be scientifically proven, but what was valid was that each echocardiographer at all three interviews confirmed that he or she was finding the stretch exercises very beneficial and easy to do and would continue doing the stretch exercises when the study ended.

All four echocardiographers found that the schedule for the stretch exercise program (Fig. 2) was taking too much time and was unrealistic when they were scanning 10 echocardiograms a day. Each echocardiographer by the end of the study had developed his or her own schedule and did the stretch exercises that he or she found most beneficial. Table 6 demonstrates which stretch exercises the group favored.

One echocardiographer asked for a stretch exercise for the medial scapular area, as this echocardiographer had been injured 3 weeks into the study at another ultrasound facility. The echocardiographers were repeating the stretches at least twice when they did them. One experimental group member was doing stretch exercises between each echocardiogram. Three were also taking micro breaks during a scan if they were feeling discomfort. All of the experimental

TABLE 6
Stretch Exercises Favored by the Experimental Group

Stretch Exercise	Number of Echocardiographers Preferring Stretch Exercise (n = 4)
Thenar stretch	3
Upper back stretch	2
Chest stretch	2
Cervical spine extensor stretch	2
Inferior shoulder stretch	1
Shoulder rolls	1
Cervical spine lateral flexor stretch	1
Neck/shoulder stretch	1
Forearm extensor stretch	1
Forearm flexor stretch	1

group members said that the study had made them more aware of being in control of their own ergonomic situation. Two echocardiographers were no longer persisting with suboptimal examinations that were causing signs and symptoms in their arms and upper body. They would record 2 to 3 cardiac cycles and then change to a more comfortable position. One right-handed echocardiographer was starting to scan ultrasound procedures with the left hand. All four echocardiographers said that they were doing the stretch exercises when doing other types of ultrasound examinations and found the exercises very beneficial. Three members of the experimental group had noticed improvements during the study of the signs and symptoms that old musculoskeletal injuries had been giving them. Everyone in the experimental group stated that the stretch exercise chart was excellent and easy to follow; however, they found that the stretching tracking sheet was not very helpful.

Suggestions were made to improve the study:

- A computer prompt to remind the echocardiographer to stretch when he or she enters into the computer order/entry system
- More training sessions in the first few weeks of the program until the echocardiographers are comfortable with the stretch exercises.

Conclusions

The study showed that there were strong indications that benefits were being felt by the echocardiographers in the experimental group because they were

performing stretch exercises during their working day, but the stretch exercise program itself had not been successful.

Limited time and the inability to develop a work habit that included the stretch exercise program were the two main reasons that echocardiographers had not kept to the appropriate designed program. Therefore, no real evaluation could be made on the appropriateness of the research project's designed stretch exercise program.

Unfortunately, a reduction in the reported levels of signs and symptoms of a musculoskeletal injury in the experimental group could not be verified. A comparison was made with a control group, which had no prior knowledge of the stretch exercises, which showed no real linear relationship with respect to reducing these reported levels.

One fault that was not found until the study had started was that both groups did not perform the same number of echocardiograms per day. The fact that the experimental group scanned twice the number of echocardiograms per day compared with the control group could have been a contributing reason for not seeing any reduction in the signs and symptoms levels in the echocardiographers in the experimental group.

The researcher, being one of the experimental group, could also have brought in an element of bias to the study, although the impartial Bodyworks coordinator did also attend the interviews, which should have helped limit the amount of bias introduced.

However, there is enough positive feedback from the echocardiographers in the experimental group that stretch exercises are beneficial to suggest that further study should be done to prove the hypothesis that an appropriate stretch exercise program will help reduce the levels of signs and symptoms that echocardiographers experience in their entire upper body during a working day.

- A longer study would be more reliable and valid, possibly one that would run for 4 to 5 years.
- There should be more supervision in the first 6 months, or until everyone has reached a suitable comfort level with the stretch exercise program.
- A much larger number of echocardiographers should be involved in the study so that scientific statistics can be used.
- All groups in the study should perform the same number of echocardiograms each day.

- A double blind study may be more valid, where both the researcher and control group have no knowledge of who is doing the stretch exercise program or how it is designed.
- The ergonomic factors such as the ultrasound equipment, work environment, and work practice should also be looked at in conjunction with the stretch exercise program. Any ergonomic factor can influence whether an echocardiographer sustains a musculoskeletal injury, and performing a stretch exercise program should not be evaluated in isolation from all of the other ergonomic issues.

Because of time limitations, this research project was unable to examine all the ergonomic factors that could induce injury to the working echocardiographer.

Summary

This research project set out to design, evaluate, implement, and prove that a stretch exercise program appropriate for working echocardiographers would reduce their reported levels of signs and symptoms of a musculoskeletal injury in their entire upper body during a working day.

To confirm this hypothesis, a single blind study was set up with two groups of echocardiographers with similar work practices. The experimental group was to perform a stretch exercise program throughout their working day for 12 weeks and have regular monthly group interviews with the researcher and Bodyworks coordinator. The control group had no knowledge of the stretch exercises and performed their normal work practices during the 12-week period. Both groups completed pre and post questionnaires and signs and symptoms surveys so that the demographics of the average member in each group could be ascertained. The fitness level and the abilities of the echocardiographer to perform their work and any signs or symptoms that they were experiencing were also recorded, and the differences between the pre and post answers were compared between the groups at the end of the research project.

At the end of the study, all of the experimental group had found the stretch exercises to be very beneficial and had indicated that they would continue doing them when the research project ended.

The stretch exercise program that had been specifically designed for the echocardiographers as a result of an ergonomic risk assessment done by the researcher and Bodyworks team was not being adhered to, and limited time and not having an adequate learning curve to assimilate the stretch exercise program were reasons given for this.

Each member of the experimental group had selected the stretch exercises that they perceived were the most beneficial to them individually and were performing the stretches whenever they could. Everyone in the experimental group reported that

they had become far more conscious of their own physical well-being when scanning an echocardiogram, were limiting studies that were causing them to have any discomfort, and were taking micro breaks and stretching between echocardiograms.

The two groups in the study were found to have very different workloads, and the research project's limited time scale and the small number of echocardiographers in the study were all reasons that a firm conclusion could not be made that the stretch exercise program would reduce the reported levels of signs and symptoms of a musculoskeletal injury.

Appendix A: Twenty-One Tasks for an Echocardiogram

Date: _____ Evaluator: _____ Site: _____

Position: _____ Department: _____ Shift: _____

Steps	Equipment/Material Used	Other Considerations
1. The technologist reviews the patient's medical history and previous echocardiogram reports.	The technologist sits in the ultrasound QC office to read documentation.	If the previous echocardiogram is not available, the technologist will use a PC to review any relevant reports.
2. The technologist prepares his or her paperwork and locates the starting point for recording on his or her videotape.	Ultrasound machine, video tape, video cassette recorder, record sheet	Depending on where the doctor reviewing the tape stopped, he or she can make this a 2-minute or 2-second task.
3. The technologist inputs the patient's details into the ultrasound machine and records these details on the videotape.	Ultrasound machine, keyboard, video cassette recorder	
4. The technologist connects the right transducer to the ultrasound machine and selects all the computer software prerequisites for an echocardiogram.	Controls on ultrasound machine, keyboard, transducer	
5. The technologist starts to fill in his or her paperwork and goes to collect the patient.	Mobile writing table, Patient identification computer label, ultrasound technologist's echocardiogram impression sheet	
6. The technologist identifies the patient and escorts him or her to the ultrasound exam room.	Ultrasound in-tray at front desk, physician requisition, patient gowns	If clerk is too busy at front desk, time may be spent with the patient changing into gown.
7. The technologist assists the patient onto the ultrasound stretcher and explains the procedure to the patient.	Ultrasound stretcher	
8. ECG leads are located in the patient's chest, and his or her medical history is discussed.	ECG leads, alcohol swabs, ultrasound machine, control panel	ECG leads may need to be readjusted to obtain optimal signal, and time may be taken to settle ECG (2 to 3 minutes)

(continued)

Appendix A Continued

Steps	Equipment/Material Used	Other Considerations
9. Patient is positioned on ultrasound stretcher, and a relevant medical history is obtained from the patient.	Automatic ultrasound stretcher, chest support sponge, towel	The patient may have to change his or her location on the stretcher.
10. The automatic stretcher is raised and correctly positioned. The technologist adjusts the scanning chair for height and comfort.	Automatic ultrasound stretcher (with push buttons), adjustable scanning chair (with control levers)	Depending on height and weight of patient, how much adjustment is necessary needs to be determined.
11. The technologist assesses the ECH trace and documents the medical history data obtained from the patient.	Ultrasound machine, echocardiogram, impression sheet, pen, mobile writing table	Further adjustment to ECG leads may be necessary to obtain an optimal trace.
12. The technologist prepares the transducer and puts it on the patient's chest wall in the approximate position for the parasternal long window.	3- to 5-mHz sector transducer, aquasonic gel, ultrasound machine	Depending on the situation of the patient's heart in the chest, this can take 30 seconds or 2 to 3 minutes to do.
13. The technologist now fine-tunes the scanning arm's ergonomic position and optimizes the image parameters on the ultrasound machine.	Small pad or rolled towel, transducer, ultrasound machine, keyboard controls	The patient's size determines how much force is applied to obtain a window.
14. The technologist stays in the parasternal long window for 5 to 8 minutes, interrogating the heart. The technologist is static for 1- to 2-minute sessions during this time.	Ultrasound machine, 3- to 5-mHz transducer, impression sheet, video cassette recorder	What pathology and window can determine the time held in this position.
15. Using the same window, the technologist rotates the transducer counterclockwise in his or her hand to obtain the parasternal short window.	Ultrasound machine, 3- to 5-mHz transducer	The location of the heart in the patient's chest determines how long this will take, usually 30 seconds.
16. The technologist interrogates this window for 3 to 5 minutes, recording representative images.	3- to 5-mHz transducer, keyboard, and control for ultrasound machine	
17. The technologist now relocates the transducer. Fine rotational movements of the transducer in the technologist's hand locates various apical windows. Static positions are held for 1 to 2 minutes.	Ultrasound machine, keyboard, 3- to 5-mHz transducer, support pad, impression sheet	
18. The patient is laid flat, and the technologist stands up. The transducer is now located under the xiphisternum, and the subcostal window is located. This window is interrogated and recorded for 3 to 4 minutes.	Ultrasound machine, keyboard, 3- to 5-mHz transducer	Depending on the size of the patient and the visibility of the window, a lot of force can be used to optimize this window.
19. The technologist now scans the patient's right and left sides, takes off the ECG leads from the patient's chest, and lowers the stretcher.	3- to 5-mHz transducer, ultrasound machine, keyboard, ultrasound stretcher	
20. The technologist discharges the patient, rewinds the videotape, and cleans the equipment for the next patient.	Ultrasound machine, keyboard, video cassette recorder	If the patient gets dizzy when he or she stands up, he or she may require 2 to 3 minutes to recuperate.
21. The technologist finishes his or her paperwork and completes the computer documentation.	Meditech Dummy Terminal PC plus keyboard	Time may be lost waiting for a terminal to complete a case documentation.

Appendix B: Step 13 From the Completed Ergonomic Assessment Sheet

Step	Equipment Used	Awkward Posture				High Force	Static Position	Repetition	Contact Stress	Duration	
		Hand	Lower arm	Upper arm	Shldr						
13. The technologist now fine-tunes his or her position and optimizes the image parameters to obtain an image.	Small pad or rolled towel	√√	√√	√√	√√	√	√ √	√	√ √	Varied from 2 mins. to 6 mins.	
	Transducer	√√	√√	√√	√√	√	√	√	√ √		
	Ultrasound machine	√√	√√	√√		√	√	√	√ √		
	Pen	√√	√√	√√		√	√	√	√ √		
			√√	√√	√√		√	√	√		√ √
			√√	√√	√√		√	√	√		√ √
		Csp	Tsp	Lsp		Scanning Shoulder, Arm, Hand LSpine 2-6 mins.	Scanning Shoulder, Arm, Hand. 2-6 mins. CSp/LSp/TSp rotation 2-6 mins Key-board Shoulder/ Arm 2 min sess.	Keyboard Hand Lower Arm. 4 minutes Scanning	Keyboard Wrist 1-3 minutes. 3 Techs-forearm 2-6 mins.		

Appendix C: Step 13 From the Spreadsheet Used to Determine Stretch Exercises Sheet

Step	Equipment Used	Movements (action, joint)	Muscle Groups	Exercises
13. The technologist now fine-tunes his or her position and optimizes the image parameters to obtain an image.	Small pad or rolled towel Transducer Ultrasound machine	Scanning arm—sustained contraction (approx. 5 minutes) 1. Shoulder abduction, horizontal flexion 2. Elbow extension 3. Hand pinch movement 4. Contact stress forearm Writing arm 1. Shoulder abduction (sustained approx. 5 minutes), horizontal flexion, internal/external rotation 2. Elbow extension 3. Wrist radial/ulnar deviation, extension (sustained when trackball used) 4. Hand, fingers, abduction, adduction, flexion/extension (numerous repetitive movements), pinch hand 5. Finger tips pushing keys on keyboard 6. Contact stress writing forearm Cervical rotation to scanning and writing arms, flexion, protrusion Thoracic/lumbar sustained rotation to scanning arm (approx. 5 minutes)	Sternocleidomastoid, Deltoid, Pectoralis Major, Latissimus Dorsi, Teres Major, Coracobrachialis, Supraspinatus, Infraspinatus, Teres Minor, Subscapularis, Biceps Brachii, Triceps Brachii Thenar Eminence, Hypothenar Eminence, deep muscles of hand, extensors, flexors, supinators, pronators of forearm Trapezius, Splenius, Erector Spinae, Transversospinalis, Intertransversarii, Interspinalis	

References

1. Vanderpool H, Friis E, Smith B, Harms KL: Prevalence of carpal tunnel syndrome and other work related musculoskeletal problems in cardiac sonographers. *J Occup Med* 1993;35: 604–610.
2. British Columbia Ultrasonographers Society, Healthcare Benefit Trust, Health Sciences Association of British Columbia: *Report on Sonographer's Work, Health & Disability Survey 1999*. British Columbia Ultrasonographer's Society; 1999.
3. Bell M, Atkins J, Contreras J, Stevens D: *Repetitive Strain Injuries in the Workplace 1994*. Calgary, Alberta: Workers Compensation Board; 1994.
4. Steiler G: Ergonomics in ultrasound. *Australian Society of Ultrasonographers in Medicine Bulletin* 1998;1:4.
5. Bueckert L, Weninger L: *Repetitive Strain Injuries in the Workplace*. Women and Work Research and Education Society; 1991.
6. Shellock FG, Prentice WE: Warming-up and stretching for improved physical performance and prevention of sports-related injuries. *Sports Med* 1985;2:267–278.
7. Schultz P: Flexibility: day of the static stretch. *The Physician and Sportsmedicine* 1979;7(11):109–117.
8. Milner T: *Intervention for MSI in Sonography*. Lecture given at British Columbia's Ultrasonographers Society SonoSunday, October 3, 1999.
9. Christenssen WD: *Stretch Exercises: A Study Into Reducing the Musculoskeletal Pain and Discomfort in the Arms and Upper Body of Echocardiographers* [thesis]. 2000.
10. Hara K: Quantitative and qualitative research approaches in education. *Education* 1995;115:351.
11. Necas M: *Musculoskeletal Symptomatology and Repetitive Strain Injuries in Diagnostic Medical Sonographers (a Pilot Study in Washington and Oregon)*. Bellevue Community College; 1996.
12. Daignault R: *Ergonomic Intervention in Echocardiography*. Association of Cardiologists and the Society of Echocardiographers of Quebec; 1992.
13. Kome P: *Wounded workers*. Toronto: University of Toronto Press; 1998.
14. Pike I, Russo A, Berkowitz J, Lessoway V: The prevalence of musculoskeletal disorders among diagnostic medical sonographers. *JDMS* 1997;13:219–227.
15. Parker KG, Imbus HR: *Cumulative trauma disorders*. Chelsea, MA: Lewis; 1992.