Case Study #8

Ultrasound Transducer Design

IE 327 Lab Report

Executive Summary:

Given multiple scenarios of work place environments for sonographers, we needed to analyze and calculate data to determine that there was a need for a redesign of ultrasound sonography processes. CTD risk indexes, a workstation evaluation checklist and a tool evaluation checklist were all completed to lead us to the necessary components of the redesign. In our redesign, we focused on reducing the force factor in the CTD risk analysis to therefore reduce the risk index as a whole from 1.247 to 0.8481, in order to make the work place acceptable. The evaluation checklists lead us to alter the physical design of both the work area and the transducer tool. The work space includes a bed, chair, and monitor system that are all adjustable in order for the sonographer to position the equipment at the optimal height for an ergonomically correct work environment. This greatly reduces the aggravating musculoskeletal symptoms that have been previously linked to this job. Our redesigned transducer incorporates a rubber griped handle that is 1.5 inches in diameter to reduce the force needed to apply pressure with the transducer, which has been the most aggravated symptom sonographers currently suffer from. With the new design, a better integrated design of ultrasound sonography was produced.

Introduction:

Diagnostic medical sonographers use ultrasound, which is sound waves, to create images of structures in the body and these images are then used to help diagnose patients concerns which can be associated with many internal structures, including organs, tissues and blood flow. The main instrument these sonographers use is called a transducer. The transducer sends high frequency sound waves into the body and then detects them as they bounce off internal structures in the body. These sounds than generate an image of the structure.

The transducer, along with other aspects of the workplace, presents the sonographer with many ergonomic issues. Due to the continual, repeated pressure that sonographers enforce, the poor design of equipment, and the schedules sonographers adhere to, they have an increased risk of developing musculoskeletal disorders (MSDs).

Through analysis of the factors contributing to the MSDs, including posture during exertion, type of grip, force of exertion, and repetition of exertion, we will be able to redesign both the workplace and technology to create an environment that is more ergonomically efficient to both the technician and the patient. The focus of this redesign is to be able to reduce the presence of MSDs in sonographers, while also improving the workspace of a sonographer as a whole. In doing this, we are to take into account the physical and musculoskeletal issues of the transducer as well as the work place set up for both the sonographer and the patient.

Objective:

The objective of this study is to produce a better integrated design of ultrasound sonography. The redesign should reduce musculoskeletal issues present in the technicians as well as reducing the number of medical errors as much as possible to prevent cases of misdiagnoses in patients. Analysis of CTD risk indexes and use of Signal Detection Theory will lead us to the final redesign of ultrasound sonography.

Methods:

First, we calculated CTD risk indexes for each of the figures which constitute the different positions of a sonographer, and for each of the possible grips that can be used on the transducer. There were a few assumptions that were made when calculating these indexes. We assumed that the amount of time allocated for breaks and lunch would result in 50 minutes, that the time for the sonographer to complete one cycle was 15 seconds, and that each cycle had 3 hand motions. In regards to force for the power grip, we assumed the regular grip force to be 5lbs and the maximum grip force to be 10lbs. For the pulp pinch, we assumed the regular grip force to be 10lbs and the maximum to be 15lbs and for the lateral pinch, we assumed the regular grip force to be 15lbs and the maximum to be 25lbs. The scenario and grip that produced the lowest CTD indexes will be what we will base our redesign off of.

Once the particular position and grip is determined, a workstation evaluation checklist is completed to determine any improvements or changes that need to be applied to the work station of the sonographer to obtain an optimal ergonomic environment. A tool evaluation checklist is also completed for the transducer to emphasize on any disadvantages that need to be redesigned for favorable usage.

Lastly, we examined the ultrasound transducer technically and applied knowledge of the Signal Detection Theory to depict the current advantages and disadvantages of the transducer being used in the original design to see if we can improve the actual image being sent to the monitor.

A breakdown of all of these aspects leads us to create a redesign of ultrasound technology. We then calculated a CTD risk index for the redesign to show improvements from the original design.

Results:

Table 1 below shows the calculated values of the CTD risk indexes for the positions that are associated with a sonographer when performing an ultrasound as well as the values of the factors incorporated into the CTD risk analysis, including the frequency factor, posture factor, force factor and miscellaneous factor. All of the risk index values of the original positions resulted in numbers greater than 1, which is considered an unacceptable working environment. As mentioned in the methods, we used the position that resulted in the lowest CTD risk index, which was a sitting position with an adjustable bed and adjustable chair, as shown in Figure 2, as a basis of the redesign since an improved design to the lowest risk scenario would automatically be an improved design to all the other possible postures. The overall index for this particular position is 1.247, with the most influential factor being the force factor, having a value of 3.33. Through the redesign, we were able to reduce the force factor from 3.33 to 2 which consequently reduced the CTD risk index from 1.247 to 0.8481, deeming the redesign as acceptable work and therefore decreasing the likelihood of developing MSDs.

Table 1: CTD Risk Indexes for Positions of Sonographers

	Figure 1	Figure 2	Figure 3	Figure 4	**Redesign**
Frequency Factor	0.516	0.516	0.516	0.516	**0.516**
Posture Factor	0.4	0.2	0.3	0.5	**0.2**
Force Factor	3.33	3.33	3.33	3.33	**2**
Miscellaneous Factor	0.333	0.333	0.333	0.333	**0.333**
CTD Risk Index	**1.3071**	**1.247**	**1.277**	**1.34**	**0.8481**

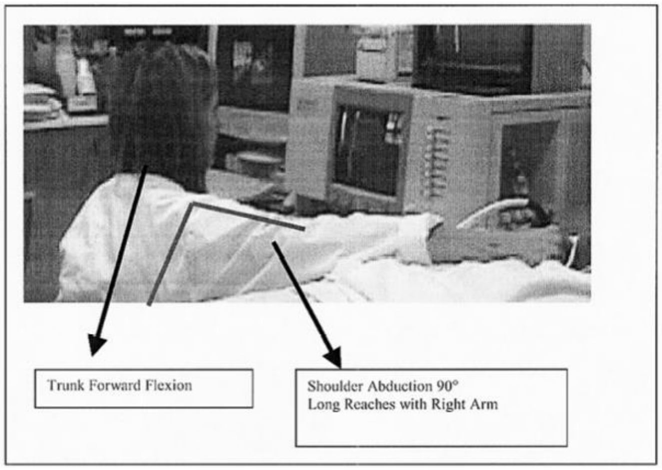

Figure 1: Sitting with bed non-adjustable and chair adjustable

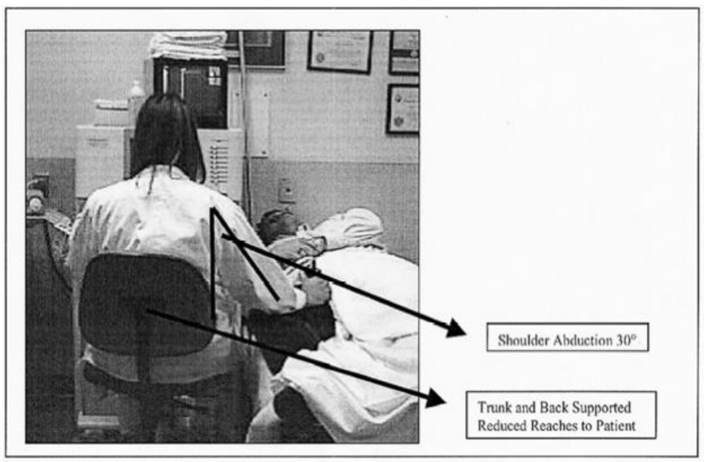

Figure 2: Sitting with chair and bed adjustable

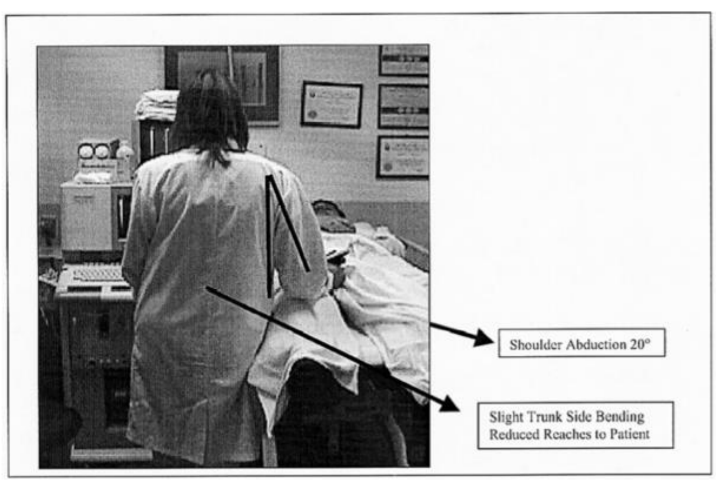

Figure 3: Standing with bed non-adjustable

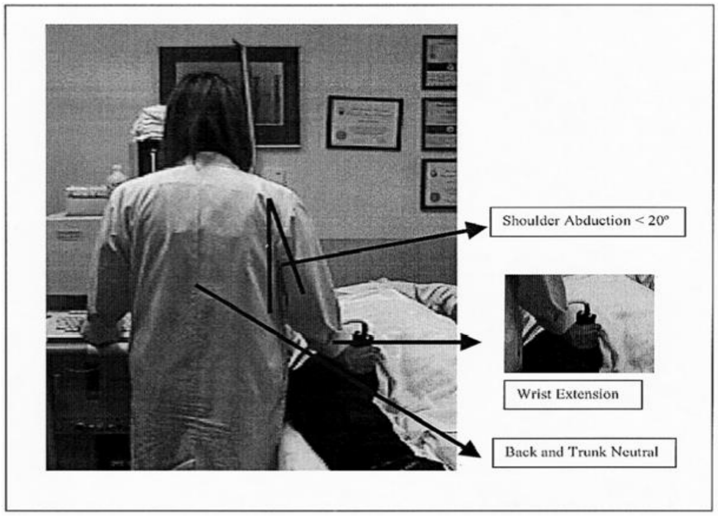

Figure 4: Standing with bed adjustable

Table 2 displays the CTD risk index values and factor values for the two different ways to grip a transducer; pinch grip and power/pinch hybrid grip. The same procedures that were utilized in choosing a basis for redesign in Table 1 are applied through Table 2. This data shows that the pinch/power hybrid grip, Figure 6, resulted in a lower CTD risk index than the pinch grip, Figure 5. The index for the hybrid grip calculated to be 1.3551 which, even though it is lower than that of the pinch grip index of 1.6101, depicts unacceptable work and is therefore not ergonomically acceptable. The main factor in the grip CTD analysis was the force factor, just like in the position CTD table, having a value of 3.587. The redesign resulted in a significantly lower force factor of 2, compared to 3.587 and accordingly, reduced the CTD risk index value from 1.3551 to 0.8481 with the redesign. This value constitutes the redesign as acceptable work on terms of safety and ergonomics.

Table 2: CTD Risk Indexes for Grips Sonographers use on Transducers

	Figure 5	Figure 6	**Redesign**
Frequency Factor	0.516	0.516	**0.516**
Posture Factor	0.3	0.3	**0.2**
Force Factor	4.44	3.587	**2**
Miscellaneous Factor	0.333	0.333	**0.333**
CTD Risk Index	**1.6101**	**1.3551**	**0.8481**

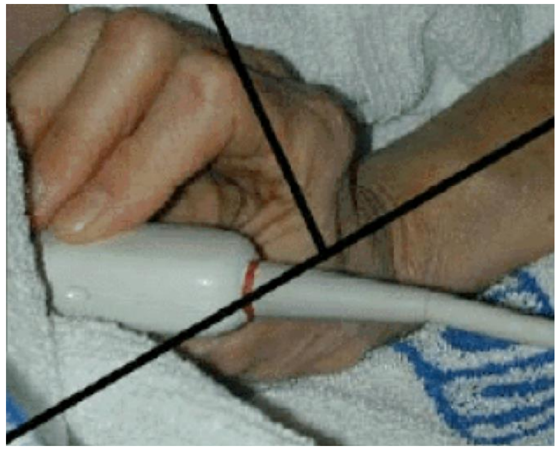

Figure 5: Pinch Grip

Figure 6: Pinch/Power Hybrid Grip

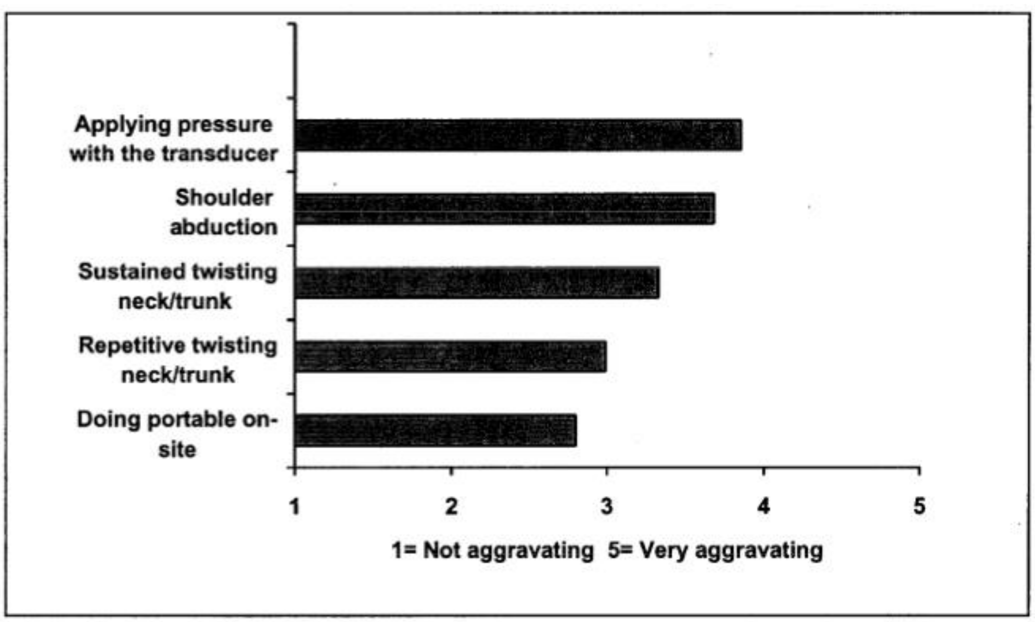

Figure 7: Tasks that Aggravate Musculoskeletal Symptoms (Mean Scores on a 5 Point Scale)

Continuing with analysis of the work place, figure 8 shows a workstation evaluation checklist for the sitting workstation displayed in figure 2. The evaluation depicts the work place to be a fairly suitable working environment, only showing four 'no's' in the evaluation. The redesign alters the work station to be able to improve the checklist even further by designing a chair that has lumbar support.

Figure 9 shows an evaluation of the ultrasound sonography tool, the transducer, itself, through a tool evaluation checklist. The results show that the transducer causes fatigue with continued use and that it is not ergonomically designed, in terms of the handle and grip of the tool. The redesign focused on the handles and grips section of the checklist to create a tool that is both efficient and ergonomically optimal, consequently causing less fatigue with use.

Discussion:

The focus of the redesign of ultrasound sonography was based around the physical and structural design of the work station, the design of the transducer tool, and the quality of the image sent to the monitor in result of the ultrasound. After analysis of those factors pertaining to the determined position and grip, figures 2 and 6, to be compared to, we were able to determine what needed to be altered or added in order to improve the overall process of sonography.

The CTD risk analysis' of figure 2, which is the sitting position of the sonographer with both an adjustable bed and chair, and figure 6, which is the pinch/power hybrid grip, resulted in a risk indexes greater than 1 which means that there is potential of injuries, such as musculoskeletal disorders, resulting from the designs. In order to make an improvement through the redesign, we had to reduce the value of the CTD to less than 1 to be viewed as acceptable work. Both table 1 and 2 displayed the values of the individual factors of the CTD analysis' to help pin point which aspect of the design needs the most improvement. Also, figure 7 shows sonographer tasks that aggravate musculoskeletal symptoms and displays the most aggravating task to be applying pressure with the transducer. Examining the individual factors and figure 7, we focused on decreasing the value of the force factor in order to decrease the CTD index as a whole and improve the ergonomics of the design. The redesign resulted in a force factor value of 2 and a CTD value of 0.8481. The final value of the CTD proves that the redesign was beneficial since it moved the sonography process from the category of unacceptable work to acceptable work by decreasing the CTD risk index to less than 1.

Focusing on the structural aspect of the workplace, the examiner should be sitting and the bed and chair should remain adjustable like in the original position of figure 2. The redesign will also have an adjustable monitor, as shown in figure 10, which will display the images in color instead of black and white to increase accuracy. The monitor is adjustable through the use of a mechanical arm that is attached to the base of the equipment. Having adjustability, allows the examiner to configure the bed, chair, and monitor for optimal ergonomics, such as maintaining an elbow angle of 90 degrees, a neck angle of 0 degrees, and being positioned so that the midscreen of the monitor is 15 degrees down from the eye level of the sonographer. Along with adjustability, the sonographer should position the patient close to the edge of the bed where the examiner will be sitting in order to reduce arm abduction. The redesign also allows the sonographer access to both sides of the patient's bed to reduce any need of arm extension.

The redesign of the transducer tool depended on the negatives discovered in the tool evaluation checklist, figure 9. The redesign contains a rubber handle opposed to a plastic handle displayed in all the original designs. This improves overall grip while lowering the grip force needed. The handle is also around 1.5 inches in diameter to result in optimal use since the sonographer will need to use all five fingers to grip the handle and therefore producing the max amount of force. The redesigned transducer, shown in figure 11, is wireless to create ease of maneuverability and handling. The wireless tool results in optimal power grip force which contributes to the acceptable value of the CTD risk index for the redesign. The wireless transducer is battery operated and the batteries will be placed near the examiner at all times in order to not interrupt the production of an image. However, if interference of signals occurs during the examination, the redesigned monitor will display warning messages to relay to the sonographer that the image they are picking up is not accurate.

A possible improvement to the accuracy of diagnosis from the sonogram would be to increase sensitivity of the sonogram. It can signal when there is too much interference making the image inconclusive. This would be a conservative approach which would reduce the amount of false alarms that occur during testing. Misdiagnosis, or false alarms, with an ultrasound could lead to unnecessary surgeries or procedures that would be very costly in the medical field, compared to a missed diagnosis. Patients can always seek a different opinion of other doctors, but most surgeries are irreversible.

The combination of a wireless transducer with a rubber grip, reduced force, and total adjustability will entail that the sonographer will only be using about 20% of their maximum strength and therefore decreasing the chance of developing musculoskeletal disorders. All of these implementations that we have added to the redesign have produced a better integrated design of ultrasound sonography.

Figure 10: Redesigned monitor attached to mechanical arm

Figure 11: Redesigned Wireless Transducer

WORKSTATION EVALUATION CHECKLIST

FIGURE 8

Sitting Workstation

	Yes	No
1. Is the chair easily adjustable according to the following features:	•	•
a. Is the seat height adjustable from 15 to 22 inches?	⊙	•
b. Is the seat width a minimum of 18 inches?	⊙	•
c. Is the seat depth 15 to 16 inches?	⊙	•
d. Can the seat be sloped ±10• from horizontal?	⊙	•
e. Is a back rest with lumbar support provided?	⊙	•
f. Is the back rest a minimum of 8×12 inches in size?	⊙	•
g. Can the back rest be moved 7 to 10 inches above the seat?	⊙	•
h. Can the back rest be moved 12 to 17 inches from the front of the seat?	⊙	•
i. Does the chair have five legs for support?	⊙	•
j. Are casters and swivel capability provided for mobile tasks?	⊙	•
k. Is the chair covering breathable?	⊙	•
l. Is a footrest (large, stable and adjustable in height and slope) provided?	•	⊙
2. Has the chair been adjusted properly?	•	•
a. Is the seat height adjusted to the popliteal height with the feet flat on the floor?	⊙	•
b. Is there approximately a 90• angle between the trunk and thigh?	⊙	•
c. Is the lumbar area of the back support in the small of the back (~ belt line)?	•	⊙
d. Is there sufficient legroom (i.e., to the back of the workstation)?	⊙	•
3. Is the workstation surface adjustable?	•	•
a. Is the workstation surface roughly at elbow rest height?	⊙	•
b. Is the surface lowered 2 to 4 inches for heavy assembly?	⊙	•
c. Is the surface raised 2 to 4 inches (or tilted) for detailed assembly or visually intensive tasks?	⊙	•
d. Is there sufficient thigh room (i.e., from the bottom of the worksurface)?	•	⊙
4. Is sitting alternated with standing or walking?	•	⊙

Computer Workstation

	Yes	No
1. Has the chair been adjusted first, then keyboard and mouse, finally the monitor?	•	•
2. Is the keyboard as low as possible (without hitting the legs)?	•	•
a. Are the shoulders relaxed, upper arms hanging down comfortably and forearms are below horizontal (i.e., elbow angle >90•)?	•	•
b. Is a keyboard shelf utilized (i.e., lower than a normal 28 inch writing surface)?	•	•
c. Is the keyboard sloped downward so as to maintain a neutral wrist position?	•	•
d. Is the mouse positioned next to the keyboard at the same height?	•	•
e. Are armrests (adjustable in height at least 5 inches) provided?	•	•
f. If no armrests, are wrist rests provided?	•	•
3. Is the monitor positioned 16 to 30 inches (roughly arm's length) from the eyes?	•	•
a. Is the top of the screen slightly below eye level?	•	•
b. Is the bottom of the screen roughly 30• down from horizontal eye level?	•	•
c. Is the monitor positioned at a 90• angle to windows to minimize glare?	•	•
d. Can the windows be covered with curtains or blinds to reduce bright light?	•	•
e. Is the monitor tilted to minimize ceiling light reflections?	•	•
f. If glare still exists, is an antiglare filter utilized?	•	•
g. Is a document holder utilized for data transfer from papers?	•	•
h. Is the main visual task (monitor or documents) placed directly in front?	•	•

Standing Workstation

	Yes	No
1. Is the workstation surface adjustable?	•	•
a. Is the workstation surface roughly at elbow rest height?	•	•
b. Is the surface lowered 4 to 8 inches for heavy assembly?	•	•
c. Is the surface raised 4 to 8 inches (or tilted) for detailed assembly or visually intensive tasks?	•	•
2. Is there sufficient legroom?	•	•
3. Is a sit/stand stool (adjustable in height) provided?	•	•
4. Is standing alternated with sitting?	•	•

TOOL EVALUATION CHECKLIST

FIGURE 9

Basic Principles

		Yes	No
1.	Does the tool perform the desired function effectively?	⊙	•
2.	Does the tool match the size and strength of the operator?	⊙	•
3.	Can the tool be used without undue fatigue?	•	⊙
4.	Does the tool provide sensory feedback?	⊙	•
5.	Are the tool capital and maintenance costs reasonable?	⊙	•

Anatomical Concerns

		Yes	No
1.	If force is required, can the tool be grasped in a power grip (i.e., handshake)?	⊙	•
2.	Can the tool be used without shoulder abduction?	•	⊙
3.	Can the tool be used with a 90• elbow angle (i.e., forearms horizontal)?	⊙	•
4.	Can the tool be used with the wrist straight?	⊙	•
5.	Does the tool handle have large contact surfaces to distribute forces?	⊙	•
6.	Can the tool be used comfortably by a 5th percentile female operator?	⊙	•
7.	Can the tool be used in either hand?	⊙	•

Handles and Grips

		Yes	No
1.	For power uses, is the tool grip 1.5 - 2 inches in diameter?	•	⊙
	a. Can the handle be grasped with the thumb and fingers slightly overlapped?	•	⊙
2.	For precision tasks, is the tool grip 5/16 - 5/8 inches in diameter?	•	•
3.	Is the grip cross section circular?	•	⊙
4.	Is the grip length at least 4 inches (5 inches if gloves are worn)?	•	⊙
5.	Is the grip surface finely textured and slightly compressible?	•	⊙
6.	Is the handle nonconductive and stain free?	⊙	•
7.	For power uses, does the tool have a pistol grip angled at 78• ?	•	•
8.	Can a two-handled tool be operated with less than 20 pounds grip force?	•	•
9.	Is the span of the tool handles between 2¾ - 3¼ inches?	•	•

Power Tool Considerations

		Yes	No
1.	Are trigger activation forces less than 1 pound?	•	•
2.	For repetitive use, is a finger strip trigger present?	•	⊙
3.	Are less than 10,000 triggering actions required per shift?	⊙	•
4.	Is a reaction bar provided for torques exceeding ...		
	a. 50 inch-pounds for in-line tools?	•	•
	b. 100 inch-pounds for pistol-grip tools?	•	•
	c. 400 inch-pounds for right-angled tools?	•	•
5.	Does the tool create less than 85 dBA for a full day of noise exposure?	⊙	•
6.	Does the tool vibrate?	⊙	•
	a. Are the vibrations outside the 2 - 200 Hz range?	⊙	•

Miscellaneous and General Considerations

		Yes	No
1.	For general use, is the weight of the tool less than 5 pounds?	⊙	•
2.	For precision tasks, is the weight of the tool less than 1 pound?	•	•
3.	For extended use, is the tool suspended?	•	⊙
4.	Is the tool balanced (i.e., center of gravity on the grip axis)?	⊙	•
5.	Can the tool be used without gloves?	⊙	•
6.	Does the tool have stops to limit closure and prevent pinching?	⊙	•
7.	Does the tool have smooth and rounded edges?	⊙	•