

# A Comparison of Six Ultrasound Systems with Regard to Conformance to the Industry Standards for the Prevention of Work-Related Musculoskeletal Disorders in Sonography

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**Objective:** To evaluate six premium and high-end ultrasound systems with regards to ergonomic features for the reduction of musculoskeletal disorders and for conformance to the Industry Standards for the Prevention of Work-Related Musculoskeletal Disorders in Sonography.

**Methods:** Six leading ultrasound systems (Philips iU22, GE Voluson 730 Expert, GE Logiq 9, Siemens Antares, Siemens Sequoia, Toshiba Aplio) were evaluated using the developed Industry Standards. Operational definitions were developed for the general guidelines within the Industry Standards in order to assess conformance to the Equipment Control Measures. Results: The greatest differences among the systems studied were in the range of anthropometric accommodation offered for monitor and control panel height adjustment. These provided the greatest amount of accommodation for seated workers, and ranged between 3% and 57% for a world user population. The ability to accommodate the full range of control height adjustment ranged between 5% and 71% for a world user population. The six systems were generally comparable with regard to the remaining recommendations of the Industry Standards, e.g., push/pull force less than 50 pounds, provision of footrests, etc.

**Conclusions:** The Philips iU22 system offered the best overall anthropometric accommodation. It was also the only system that met the Industry Standards recommendation for independent height adjustment of the monitor and control panel and for the full range of viewing distances.

**M**usculoskeletal symptoms are common among sonographers and sonologists. Several studies indicate that neck and back problems are much more frequent than are hand and wrist disorders. They also consistently associate twisting/bending the neck and torso, abducted/non-neutral postures of the shoulder and applying pressure with the transducer with musculoskeletal discomfort. A common theme to the recommendations made in these studies is that system components should adjust to accommodate the varying sizes of users that might be expected to use them.

Recently the Society of Diagnostic Medical Sonographers sponsored a Consensus Conference on Work-Related Musculoskeletal Disorders (WRMSD) in Sonography. This conference produced a document entitled Industry Standards for the Prevention of Work Related Musculoskeletal Disorders in Sonography (Industry Standards). The Industry Standards provide guidelines for both the design of ultrasound systems and for work practices for use by sonographers and sonologists that reduce the risk of musculoskeletal disorders. An essential component of the Industry Standards is adjustability, particularly of monitors and controls, in order to accommodate neutral working postures for the range of expected users.

This study describes a comparison of six commonly used ultrasound systems with regard to ergonomic features for the reduction of musculoskeletal disorders and with regard to conformance to the Industry Standards.

## **Methods**

Six representative ultrasound systems were evaluated using the developed Industry Standards. The same investigator evaluated all systems, taking static measurements of the system (no sonographer involvement) during a period of approximately three weeks at five locations, typically clinics or hospitals.

The Industry Standards establish guidelines for evaluating the ergonomic design of ultrasound workstations: Equipment Control Measures. Parts A through D of the Equipment Control Measures pertain to ultrasound system components (System, Control Panel, Monitors and Transducers, respectively). Part E describes examination tables and part F relates to chairs.

Some recommendations in the Industry Standards are quite specific; for example, the limit of push or pull forces necessary to move a cart to a maximum of 50 pounds force. Other parts of the Industry Standards take the form of more general guidelines: for example “Fully adjustable equipment that suits the anthropometrics (of or relating to the study of human body measurements, especially on a comparative basis) of the population and is specific to the demographic area of the users.” In order to compare the ultrasound systems, operational definitions were developed for the general guidelines within the Industry Standards using a standard anthropometric reference<sup>1</sup> in order to assess conformance to the Equipment Control Measures.

## Results

Tables 1–5 summarize the observations made of the six ultrasound systems. The greatest differences among the systems studied are in the range of anthropometric accommodation that they offer for monitor and control panel height adjustment. All the systems appear to be optimized for seated work, in line with the recommendations made by Magnavita<sup>2</sup> and Craig<sup>3</sup>.

Of the six systems studied, the Philips iU22 does the best job of addressing anthropometric accommodation for monitor and control heights, although no system covers the complete height adjustment range for seated or standing work for the world population.

The iU22 system covers the greatest percentage of the recommended monitor height adjustment range for the world population, standing or seated. The Aplio system covers the greatest percentage of the recommended control height adjustment range for the world population, standing, and the iU22 covers the greatest range of the control panel height for the world population, seated.

All of the six systems are generally weak with regard to handle height; however, the relative low frequency of use makes this less a concern than the monitor height, control panel height and reach considerations.

The Philips iU22 system is the only system in which the monitor height and control panel height can be adjusted independently. The iU22 is also the only system that allows positioning the monitor over the entire 18–30 inch viewing distance recommended in the Industry Standards. Finally, the iU22 system offers wireless, hands-free adjustment of controls through the use of voice control technology.

## Ultrasound Systems Conformance to Industry Standards for the Prevention of WRMSD

**Table 1.** System Monitor Height Adjustment Range as Percent of Accommodation Range for World Population

Element	System Adjustment Range In Inches					
	Antares 51-57	Aplio 55.5-61	Logiq 9 53.5-61.5	iU22 53-63	Sequoia 53-58.5	Voluson 730 54.5-54.5
Monitor Height, Standing (Range: 50 – 70.5 in.)	29%	27%	39%	49%	27%	2%
Monitor Height, Seated* (Range: 47 – 64.5 in.)	34%	31%	46%	57%	31%	3%

\*Adjusted seat height

**Table 2.** System Control Height Adjustment Range as Percent of Accommodation Range for World Population

Element	System Adjustment Range In Inches					
	Antares 31-37	Aplio 35.5-41	Logiq 9 30.5-38.5	iU22 31.5-38.5	Sequoia 33-38.5	Voluson 730 36.5-36.5
Control Height, Standing (Range: 34.5 – 47.3 in.)	20%	43%	31%	31%	31%	4%
Control Height, Seated* (Range: 31.5 – 41.4 in.)	56%	56%	61%	71%	56%	5%

\*Adjusted seat height

**Table 3.** Comparison of Six Ultrasound Systems with Regard to Part B of the Equipment Control Industry Standards - Control Panel

Element	System					
	Antares	Aplio	Logiq 9	iU22	Sequoia	Voluson 730
Separate articulation from monitor	N	N	N	Y	N	N
Control layout allows right or left hand use	Y	Y	N	Y	Y	N
Font size discernable	Y	Y	N	Y	Y	Y
Leg clearance	N	N	N	N	N	N

**Table 4.** Comparison of Six Ultrasound Systems with Regard to Part C of the Equipment Control Industry Standards – Monitors

Element	System					
	Antares	Aplio	Logiq 9	iU22	Sequoia	Voluson 730
Separate articulation from control panel	N	N	N	Y	N	N
Tilt adjustable	Y	Y	Y	Y	Y	Y
Visual distance 18–30 inches	N	N	N	Y	N	N
Allows use of external (secondary) monitor	Y	Y	Y	Y	Y	Y

**Table 5.** Comparison of Six Ultrasound Systems With Regard to Part A of the Equipment Control Industry Standards - Ultrasound System

Element	System					
	Antares	Aplio	Logiq 9	iU22	Sequoia	Voluson 730
Casters have central locking position	Y	N	N	Y	Y	N
Casters have 2-wheel, 4-wheel and braked positions	Y	Y	Y	Y	Y	Y
Recording devices minimize users' reach ( $\leq 26.4$ " )	Y	Y	Y	Y	Y	Y
Cables do not interfere with system adjustment	Y	Y	Y	Y	Y	Y
System has footrest	Y	Y	Y	Y	Y	Y
Unobstructed access to transducer holder	Y	Y	Y	Y	Y	Y
Cables do not interfere with access to equipment	Y	Y	Y	Y	Y	Y
Port connector within reach	Y	Y	Y	Y	Y	Y
Push or pull force required to move system less than or equal to 50 lbf.	Y	Y	Y	Y	Y	Y

## Discussion

Surveys of sonographers and sonologists have provided descriptions of the occurrence of musculoskeletal symptoms, the anatomic location of the symptoms, and the activities that appear to cause musculoskeletal discomfort. Musculoskeletal symptoms among this group are pervasive. Approximately fifty to ninety percent of sonographers or sonologists are experiencing work-related musculoskeletal discomfort at any given time and approximately eighty percent of sonographers or sonologists have experienced musculoskeletal discomfort during their career.<sup>2,4-10</sup> Clearly this is an issue of concern to all persons concerned with sonography.

The most frequent activities that cause WRMSD while scanning are sustained shoulder abduction, sustained twisting of the neck and trunk, applying sustained pressure with a transducer, repetitive twisting of the neck to look from the patient to the monitor, and gripping the transducer.<sup>6</sup> These symptoms can be grouped into three clusters: neck and intrascapular pain, upper extremity pain (shoulder to fingertips), and visual discomfort/headache. Shoulders and necks are the predominate location of musculoskeletal discomfort, with neck and shoulder symptoms as much as 4-5 times more predominant than hand and wrist related symptoms.<sup>9</sup>

Equipment design, work practices and sonographer demographics are all related to the occurrence of musculoskeletal symptoms. Experience with similar working situations, such as computer workstations, has shown that these types of problems are quite tractable and can be addressed by workstations designed to adjust to accommodate the range of sizes of expected users. The lessons learned in computer workstation design emphasize the criticality of providing a sufficient range of adjustment to allow placement of monitors and input devices (controls) in positions relative to the individual user that facilitate neutral working postures.<sup>13,15,16</sup> Concurrently, the individual user must be trained in the appropriate adjustment and use of the system's adjustment capability.

Biomechanical stress due to working posture is clearly implicated as a causal factor for musculoskeletal discomfort in ultrasound work. The research underscores the importance of sufficient adjustability of the workstation; particularly the height of the control panel and monitor so as to facilitate working postures that minimize biomechanical stress to the user. Ultrasound scanning workstations should be adjustable in order to allow a range of users to achieve neutral working postures. It has been demonstrated that adjusting the ultrasound workstation lessens the amount of discomfort experienced by sonographers. Seated work provides more comfort<sup>3</sup>, and both a comfortable chair and an upright position of the body protect against neck and back pain.<sup>2</sup>

Control panels should be height adjustable and able to be rotated.<sup>12</sup> Monitors must be height adjustable, separate from the control panel with appropriate degree of tilt to enable standing or seated users to achieve neutral posture of their necks.<sup>14</sup> Thus, monitor position relative to the user's eyes and control position is an important component of the upright position of the body. Prevention of upper back and shoulder pain involves making adjustments to the monitor and patient while maintaining a comfortable resting position for the arms and shoulders. Both the patient table and the system control panel should be adjusted to allow an optimal angle for the elbow.<sup>8</sup> The monitor should be placed directly in front of the sonographer at eye level.<sup>11</sup> In order to accomplish this, monitors must be height and tilt adjustable, as well as laterally adjustable.

Knowing the location and relative frequency of symptoms is useful in identifying potential causes of the discomfort. The clear goal for the ultrasound system designer is to reduce the exposure of the sonographer to shoulder abduction (as when reaching to a patient or control panel), twisting the neck/torso (as when looking at a monitor), and applying pressure with the transducer. Specifically, the monitor should adjust to the user's eye height and the control panel should adjust to the user's elbow height. Both should be placed directly in front of the user in order to eliminate twisting of the neck and torso.

### **Conclusion**

In this study the systems varied most in their ability to accommodate users ranging between the 5<sup>th</sup> and 95<sup>th</sup> percentiles, and provide the greatest amount of accommodation for seated workers. The ability to accommodate the full range of monitor height adjustment for seated workers ranged between 3% and 57% for a world user population. Similarly, the ability to accommodate the full range of control height adjustment ranged between 5% and 71% for a world user population.

The Philips iU22 system offered the best overall accommodation. It was also the only system that met the Industry Standards recommendation for independent height adjustment of the monitor and control panel and for the full range of viewing distances. The six systems were generally comparable with regard to the remaining recommendations of the Industry Standards.

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Abbreviations: WRMSD, work-related musculoskeletal disorders

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