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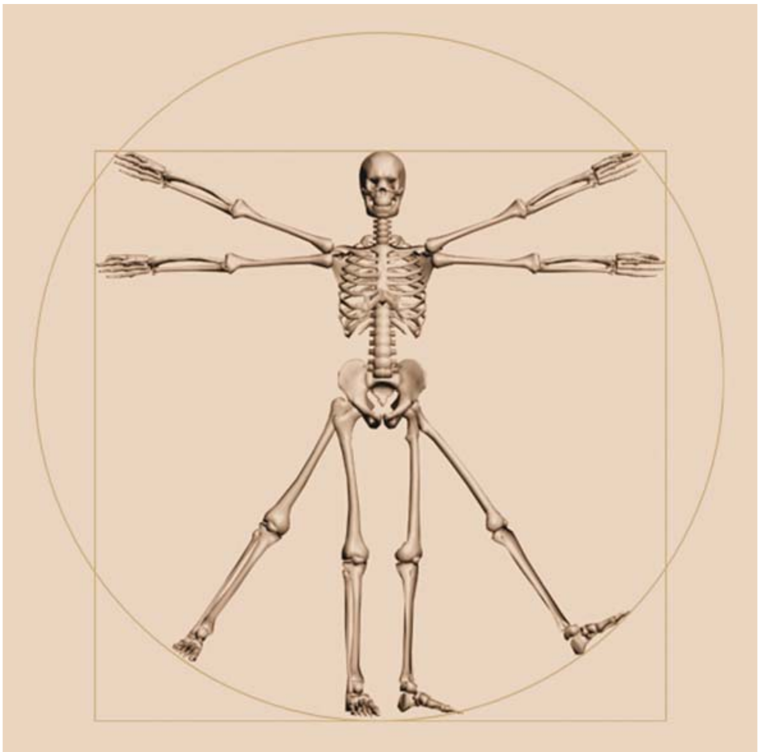

Ergonomics and Design
A Reference Guide

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Introduction from Allsteel

Here at Allsteel, we believe the interaction between the user and the product is one of the primary concerns of the product design process.

Our goal is to continue to develop products that respond to not only the issues that confront office workers every day, but the size and shape of the person working, the work that is being done, the positions that are most common, and with attention to universal design concerns.

While there are many different methods of ergonomic research and theory used to develop products that solve common workplace problems, we hope this reference helps to clarify some of the concepts and methodologies used in our process. It is our goal to provide a better understanding of how the science of Ergonomics is used to make products that help employees work more comfortably, efficiently, and effectively.

For more information on office-related ergonomics, contact the Ergonomics Group at Allsteel (ergonomics@allsteeloffice.com), or www.allsteeloffice.com/ergo.

Product Design Ergonomics 101

The word ergonomics comes from two Greek words:

- ERGO: meaning work
- NOMOS: meaning laws

Ergonomics is a science focused on the study of human fit, and decreased fatigue and discomfort through product design. Ergonomics applied to office furniture design requires that we take into consideration how the products we design fit the people that are using them. At work, at school, or at home, when products fit the user, the result can be more comfort, higher productivity, and less stress.

Ergonomics can be an integral part of design, manufacturing, and use. Knowing how the study of anthropometry, posture, repetitive motion, and workspace design affects the user is critical to a better understanding of ergonomics as they relate to end-user needs.

This reference will explain some of the human factors that can be observed and should be applied to ergonomic product design.

Anthropometric Measurements

Introduction

Anthropometry is the science that measures the range of body sizes in a population. When designing products it is important to remember that people come in many sizes and shapes.

Anthropometric data varies considerably between regional populations. For example, Scandinavian populations tend to be taller, while Asian and Italian populations tend to be shorter.

Percentile Humans

Anthropometric dimensions for each population are ranked by size and described as percentiles.

It is common practice to design for the 5th percentile (5th%) female to the 95th percentile (95th%) male.

The 5th% female value for a particular dimension (e.g. sitting height) usually represents the smallest measurement for design in a population.

Conversely, a 95th% male value may represent the largest dimension for which one is designing.

The 5th% to 95th% range accommodates approximately 90% of the population.

To design for a larger portion of the population, one might use the range from the 1st% female to the 99th% male.

Figure 1 shows comparisons of percentile males and females. For a listing of other anthropometric measurements of percentile humans, see Table A1 in the Appendix on page 47.

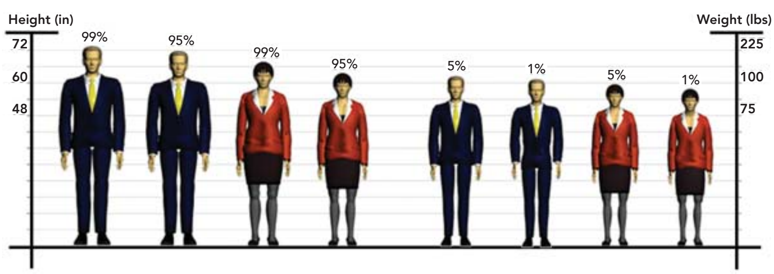


Figure 1. The relative sizes of different percentile humans. Data is from Dreyfuss, Kroemer, and Woodson texts referenced at the end of this handbook.

Anthropometric Databases

Anthropometric datasets compare people of different ages and occupations. Data in anthropometric databases may represent static dimensions, such as "lower leg length" or functional dimensions such as "reach."

Figure 2 and Table 1 show common ranges of measurements used in office furniture design.

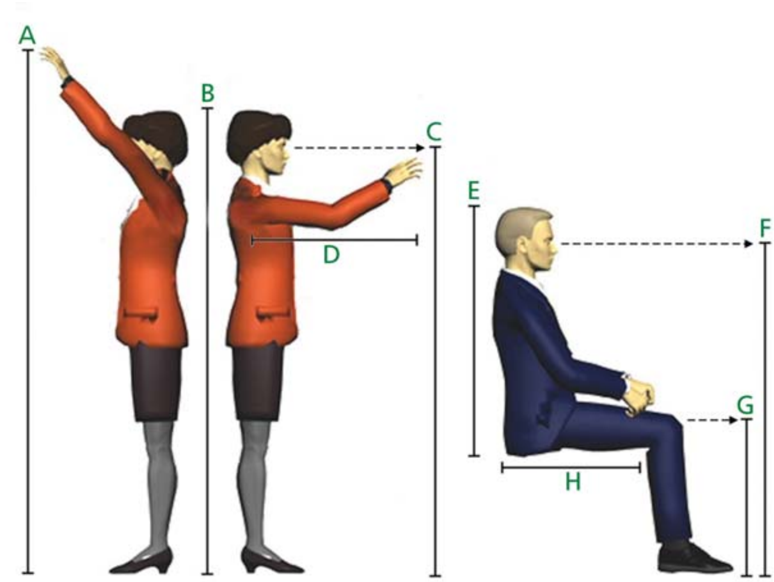


Figure 2. Common office environment posture measurements. Values are in Table 1.

Measurement	Letter	Female	Male
Standing Overhead Reach	A	74.9″ – 86.8″	81.2″ – 93.7″
Standing Height	B	60.2″ – 68.4″	64.8″ – 73.5″
Standing Eye Height	C	56.9″ – 65.0″	61.4″ – 69.8″
Standing Forward Reach	D	30.8″ – 36.1″	33.8″ – 39.5″
Sitting Height	E	31.3″ – 35.8″	33.6″ – 38.3″
Sitting Eye Height	F	42.6″ – 48.8″	46.3″ – 52.6″
Sitting Knee Height	G	19.8″ – 23.2″	21.4″ – 25.0″
Seat Depth	H	16.9″ – 20.4″	17.7″ – 21.1″

Table 1. Anthropometric measurements (including allowances for clothing) of small and large males and females, from BIFMA Ergonomics Guidelines, 2002. All measurements are in inches.

The most commonly referenced database used in design is from military data collected in the late 1970s and throughout the 1980s, and is known as the Natick studies or ANSUR database. Other databases exist that were collected using civilian data.

In 2000, the Civilian American and European Surface Anthropometry Resource (CAESAR) was compiled by the Society of Automotive Engineers (SAE) to measure civilian populations. CAESAR contains anthropometric data and 3D body scans of over 4,000 individuals from North America and Europe.

Business and Institutional Furniture Manufacturer's Association (BIFMA) and many ergonomics textbooks reference the Natick (military) studies for design purposes, but some groups are using CAESAR data with increasing frequency.

Allsteel uses both the Natick and CAESAR datasets to guide design. More emphasis is being placed on the CAESAR database because it is more representative of today's office population than the Natick databases. BIFMA and others still reference Natick measurements, so we use a combination of the two at Allsteel.

Considerations

When using anthropometric measurements in design, consider two points:

1. How recently data was collected
2. Type of population measured

First, some data may have been collected over 25 years ago, and measurements such as height or weight may have changed in the current population.

Secondly, the population one is designing for may not be represented by the anthropometric database being referenced. For example, ANSUR data may not be applicable in designing a table used by elderly individuals.

Anthropometric measurments should be a guide for design.

Anthropometric Resources

The following resources provide additional information about anthropometry.

Internet

- BIFMA, bifma.org
- CAESAR, store.sae.org/caesar
- Size USA, sizeusa.com

Books

- *Handbook of Human Factors and Ergonomics*, 2nd Edition, Salvendy, 1997
- *Human Factors Design Handbook*, 2nd Edition, Woodson, Tillman, Tillman, 1992
- *The Measure of Man and Woman*, Henry Dreyfuss Associates, 2002

Software Programs

- ANTHROPOS and RAMSIS, human-solutions.com
- DELMIA Safework, delmia.com
- ErgoForms, ergoforms.com
- Jack Human Modeling, ugs.com
- LifeMOD Biomechanics Modeler, lifemodeler.com
- ManneQuinPRO, nexgenergo.com

Common Workplace Postures

There are common postures found in the office environment that can be considered when designing workplace products or space. This section reviews guidelines for these postures:

- Standing
- Sitting
- Reaching
- Moving

Standing

Some users may need or want to stand while at their workstations. If this is the case, an appropriate desk can be designed and selected for the type of work being performed.

Desk height for a standing operator can range from 28-43" (Grandjean, 1997) depending on whether the desk is for precision, light, or heavy work.

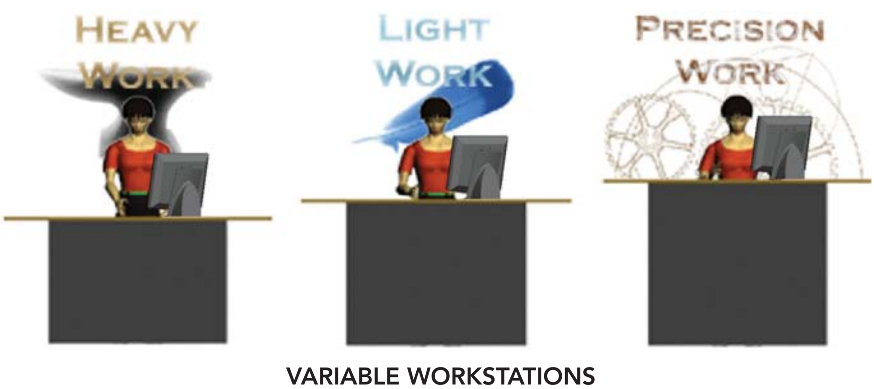


Figure 3. Different worksurface heights can be used depending on the type of work performed.

When selecting desk height it is important to remember that the top line of text on a computer monitor should be located at eye level or slightly below. (see Figure 10 on page 31).

Sitting

Knowing what parameters to design for while the user is seated can help increase the comfort of the user. Common seated anthropometric measurements can be seen in Figure 4 on page 13.

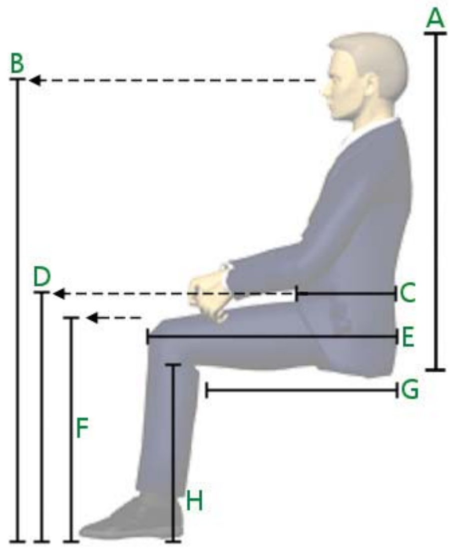


Figure 4. Common anthropometric measurements for the seated position. Use Table 2 for values.

Measurement	Letter	Female 5th – 95th%	Male 5th – 95th%	Overall Range 5th – 95th%
Sitting Height	A	31.3" – 35.8"	33.6" – 38.3"	31.3" – 38.3"
Sitting Eye Height	B	42.6" – 48.8"	46.3" – 52.6"	42.6" – 52.6"
Waist Depth	C	7.3" – 10.7"	7.8" – 11.4"	7.3" – 11.4"
Thigh Clearance	D	21.0" – 24.5"	23.0" – 26.8"	21.0" – 26.8"
Buttock-to-Knee	E	21.3" – 25.2"	22.4" – 26.3"	21.3 – 26.3"
Knee Height	F	19.8" – 23.2"	21.4" – 25.0"	19.8" – 28.0"
Seat Length/Depth	G	16.9" – 20.4"	17.7" – 21.1"	16.9" – 21.1"
Popliteal Height	H	15.0" – 18.1"	16.7" – 19.9"	15.0" – 19.9"
Seat Width	Not Shown	14.5" – 18.0"	13.9" – 17.2"	13.9" – 18.0"

Table 2. Values for 5th to 95th percentile males and females in the seated position used in designing seating. Use Figure 4 for visualization. Data from BIFMA Ergonomics Guidelines, 2002. All measurements are in inches.

Spine and Lumbar

Maintaining the neutral, or standing shape of the lumbar, or lower spinal area, is important for comfort and posture. Chairs can give appropriate and correct lumbar support. This seated lumbar support will help the spine maintain an S-shaped curve similar to the spine's shape when standing (as seen in Figure 5.)

Figure 5. Appropriate S-shaped curve of the spine.

Posture

Correct seated posture is a continual debate with ergonomic professionals. Some say that users need to have a 90-90-90 degree placement for the elbow, hip, and knee joints, respectively.

Others feel that a variation in this placement is better, as long as it does not lead to slouching or hunching over.

A good seated posture is one that is comfortable and does not put a lot of stress or strain on the user's buttocks, back, or arm muscles, and allows the user's feet to be on the floor.

Reaching

While sitting or standing, an individual at work will usually have to reach for something.

The section on Common Workplace Motions discusses the details of healthy and unhealthy reach zones (see page 17).

The workstation, and parts that go with workstations (such as overhead storage and pedestals), should allow the majority of movement of the user's body joints within healthy zones.

When designing products, consider how much individuals will have to reach in order to minimize awkward or unhealthy positions.

Moving

Users will move around in their environment to file papers, answer a phone, or stretch. An occasional break from sitting is encouraged because it helps to stimulate muscles, and increases blood flow, which decreases fatigue.

The space in a cubicle or desk area should allow the chair to move around easily. Also, a wheelchair may need to turn around or move in the office space, requiring a 60" diameter turning radius and at least 36" of passage width (refer to Figure 6). Please see Design for Universal Consideration section for more specific information on wheelchairs and other Universal Design topics.

Chairs and other devices in the workspace can allow the user to easily get up and move around without having to move armrests, adjust other chair settings, or put undue stress on the body.

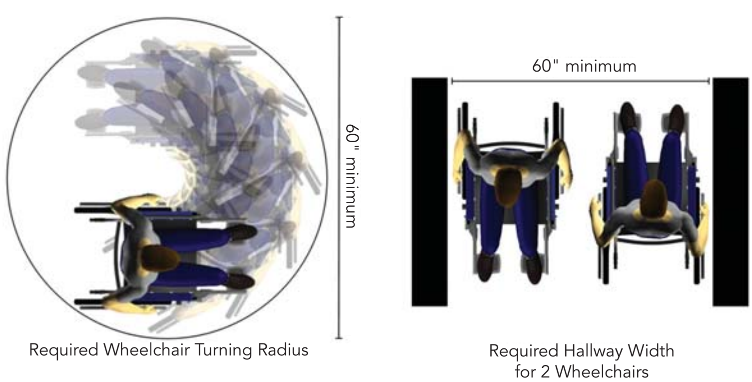


Figure 6. Minimum space requirements for wheelchair use.

Common Workplace Motions

Ultimately, the workplace should be comfortable for users and adapt to their needs as much as possible. Workplace products designed with this in mind can lead to higher worker productivity and lower risk of injury and illnesses.

The human body has a natural range of motion (ROM). Movement within the proper ROM promotes blood circulation and flexibility which could lead to more comfort and higher productivity. Despite the need to promote motion, users should try to avoid repetitive movements and certain extremes in their ROM over long periods of time.

By considering both ROM and repetitive motion, products can be designed to operate within the optimal ranges to help reduce the occurance of fatigue and muscle disorders.

Good and Bad Zones

There are 4 different zones that a user might encounter while sitting or standing:

- Zone 0 (Green Zone) Preferred zone for most movements. Puts minimal stress on muscles and joints.
- Zone 1 (Yellow Zone) Preferred zone for most movements. Puts minimal stress on muscles and joints.
- Zone 2 (Red Zone) More extreme position for limbs, puts greater strain on muscles and joints.
- Zone 3 (Beyond Red Zone) Most extreme positions for limbs, should be avoided if possible, especially with heavy lifting or repetitive tasks.

These zones are ranges where body limbs can move freely. Zones 0 and 1 include smaller joint movements, while Zones 2 and 3 represent more extreme positions.

Zone 0 and Zone 1 are preferred for most movements to occur. Zones 2 and 3 should be avoided when possible, especially for repetitive and heavy tasks. Motion in these ranges puts more strain on muscles and tendons and could lead to the development of musculoskeletal disorders.

Figure 7 shows the ROM for common joint movements. Zone 0 is in green, Zone 1 is in yellow, and Zone 2 is in red. Zone 3 is anywhere beyond the red. Table A3 in the Appendix on page 49 shows the numerical values for each Zone.

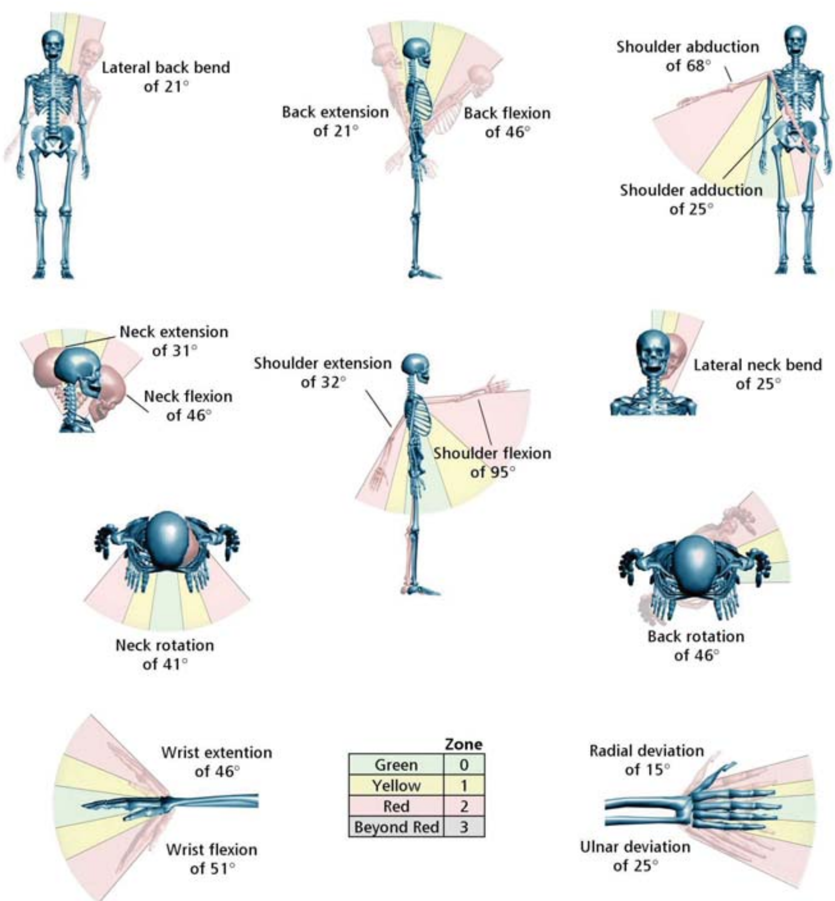


Figure 7. Various ranges of motion for different joints. For exact values of each Zone, see Table A3 in the Appendix on page 49.

Repetitive Motions

If repetitive tasks are necessary, minimizing the number of continuous movements can help reduce the risk of injuries. There is no specific number for minimum daily repetitions. The factors affecting repetitive tasks include user's muscle strength, amount of force required, and type of task. Additionally, decreasing the amount of force required to perform a task will also lower the risk of pain and musculoskeletal disorders.

The Chaffin text (listed in References on page 53) shows that depending on the length of grip, males and females can generate different amounts of force (see Fig. 11.9 on page 447 of Chaffin). There is no standard for minimum force on grip, just a suggestion that altering the dimensions of the grip can influence the amount of force needed to complete one task or effectively use the product. On page 43 of Dreyfuss, there is a diagram of different controls and guidelines for force and resistance.

Reaching for Objects

Because of the repetitive nature of workplace tasks, it is very important to be aware of how far, how often, and in what posture a person is reaching for an object. The majority of the work should be performed in Zones 0 and 1, as mentioned previously in this section.

Cumulative Trauma Disorders

Cumulative trauma disorders (CTDs) may occur in both office and manufacturing settings. CTDs are injuries due to repetitive motions, stresses, and actions. Following are some considerations to help reduce the likelihood of occurrence:

- Eliminate tasks that require fast, highly repetitive arm movements or that impose sustained static postures
- Beware of pressure points where the wrist, forearm, or other parts of the body contact an edge or hard feature on a desk or table
- Minimize shoulder flexion and abduction
- Minimize holding weighted objects in hands
- Reduce or eliminate forceful applications of heavy peak exertions
- Require workers to take frequent breaks

Office Furniture Guidelines for Fit and Function

When designing office furniture there are many things to consider and several sources to reference for ergonomic principles, anthropometrics, fit, and function of a product.

One common and widely recognized source for this kind of information is The Business and Institutional Furniture Manufacturer's Association (BIFMA). There are several documents that are helpful in deciphering the reasoning and/or theory behind the BIFMA guidelines and specifications.

While BIFMA is a common source for this kind of information, other organizations and research studies are good sources for ergonomic and anthropometric information. The Human Factors and Ergonomics Society (HFES), and the Civilian American and European Surface Anthropometry Resource (CAESAR), have suggested additional and alternative anthropometric dimensions for product design. Refer to tables A4 and A5 on pages 50 and 51, respectively, or hfes.org.

Anticipate Actions

Think ahead and envision the actions that individuals might perform while using or interacting with the device being designed.

Visualizing the user's actions will help define benefits or concerns with a design.

Some general actions to anticipate are:

- Reach
  - How far is the user supposed to reach?
- Sight
  - How much is the user able to see?
- Placement of product
  - Is it located in a convenient place? Is it accessible and within the user's ROM?
- Body position
  - Is the user in an uncomfortable position? Is the user in the appropriate zones?

During early design stages, the product can be tested on different subjects to verify anthropometric fit and improve the design with items not originally considered.

Chairs

BIFMA's guidelines for seating are very general and allow for different design interpretations.

The suggested BIFMA measurements are illustrated in Figure 8 and listed in Table 3 on page 24. These guidelines are based on the Natick military studies using 5th to 95th percentile females and males. Suggestions from other authors using different anthropometric datasets can be found in Table A4 of the Appendix on page 50.

Seat Height

The seat height should allow the user's feet to be comfortably supported by the floor or a proper footrest.

Seat Depth

Seat depth should be deep enough so that the region behind the knees (also referred to as the popliteal area) is not hitting the front of the seat. Two ways to prevent popliteal contact are:

1. Fixing the overall depth of the chair
2. Creating a depth adjustment

Adjusting the seat depth on a chair should be a natural motion that does not strain the user.

Separating the armrests from the moveable seat can allow the armrests to be used as leverage for easily changing the seat depth while seated.

The controls for seat depth movement should be intuitive and easy to use, and not require excessive bending to reach. For example, a seat adjustment control like those found in automobiles could help achieve this simplicity.

Seat Width

The seat should be wide enough to accommodate a user's hips and clothing, and comfortably allow use of the armrests.

Figure 8. Measurements from BIFMA guidelines used for ergonomic chairs. See Table 3 for values. (Allsteel Sum™ task chair pictured)

		Specifications		
		Measurement	BIFMA Guideline	Allsteel Sum Chair
Seat Height	A	Popliteal height + Shoe allowance	15.0″ – 19.9″	15.0″ – 22.25″
Seat Depth	B	Buttock-popliteal length – Clearance allowance	No deeper than 16.9″ (fixed) 16.9″ included (adjustable)	15.0″ – 18.0″
Seat Width	C	Hip breadth, sitting + Clothing allowance	No less than 18″	18.0″
Backrest Height	D	None	At least 12.2″	24.0″
Backrest Width	E	Waist breadth	14.2″	16.0″
Backrest Lumbar	F	None	Most prominent point 5.9″ – 9.8″ from seat pan, in and out 1	Infinite through ht. of back (AutoFit™ technology)
Armrest Height	G	Elbow rest height	6.9″ – 10.8″ 7.9″ – 9.8″	7.0″ – 11.0″
Armrest Length	H	None	None	10.5″
Distance Between Armrests	I	Hip breadth, sitting + Clothing allowance	18″ (fixed) 18″ included (adjustable)	16.5″ – 19.0″

Table 3. Specific BIFMA chair design guideline measurements. See Figure 8 for visualization. All measurements are in inches.

Backrest

The seat back should conform to the contour of the person's spine and give support to the back to alleviate stress on back muscles while seated. Generally, it should be high enough to reach the shoulder blades, wide enough to support the waist breadth, and have a lumbar support to maintain the natural lordotic curvature of the lumbar spine (refer to Figure 5 on page 14).

Chair Range of Motion

The seat and backrest should allow for varied seated postures. This can be accomplished by allowing a rearward tilt of the back. A minimum 10° rearward tilt (between 90° and 115°) is preferable. Some chairs also allow the seat to tilt at the same time.

The only guidelines for seat tilt measurement is to ensure the torso-to-thigh angle is not less than 90°, and that the seat angle is between 0-4° reward tilt.

Armrests

Armrests help relieve neck, shoulder, and back stress. Armrests can provide good surface area for the arm to contact so that pressure between an arm and armrest is minimized.

The armrests should be adjustable up and down, as well as in and out. This allows for more customization and better control of comfort.

Chair Controls

The controls are important, but the fewer and more intuitive they are, the better it can be for the user.

A round knob usually means that it should be turned. A flat lever usually means it should be pulled or pushed. Some controls are also easier for individuals with disabilities to use than others (refer to the Universal Design Considerations section on page 33).

Graphic icons could be placed on the controls to show the user how to operate each lever or device. Images, rather than text, for instructions can prevent the need to translate instructions when selling products in different countries. In addition, it can be a quicker and easier way to communicate.

The tension in the controls should allow for minimal user effort to activate them. Controls should also be easy to reach and visible to the user.

Desks and Worksurfaces

BIFMA also includes ergonomic guidelines for desks and worksurfaces. They describe the minimal measurements for a seated desk, and the minimal considerations for standing work. These measurements can be found in the first parts of Table 4 on page 30.

The guidelines list specific recommendations for computer workstations.

Additional and alternative guidelines from other sources can be found in Table A5 on page 51 of the Appendix.

Seated Work

The BIFMA guidelines for seated work list the minimum measurements needed to accommodate 90% of the population. Like seating, they are guidelines and can be used to direct design of worksurfaces.

The result of BIFMA guidelines is that a desk should at least accommodate the dimensions of Figure 9.

Figure 9. Bounding box for the minimum dimensions of a seated desk according to BIFMA standards (see Table 4 on page 30). Adapted from BIFMA Document G1-2002. (Allsteel #19® task chair referenced)

Standing Work

The guidelines for standing work relate to clearance for the feet when standing next to a desk or worksurface.

If designing a manual sit-to-stand work desk, the height adjustment mechanism should be placed so that the user does not strain his or her back when adjusting the worksurface height.

Workstation Heights (Standing and Sitting)

Adjustable desks can be used to support an operator's work. Placement of objects on the worksurface should be considered to avoid movements that prolong periods of muscle contraction.

Depending on the type of work to be performed at a standing workstation, different heights can be used as seen in Figure 3.

For heavy work, the table can be at a height that allows good leverage for lifting and moving objects.

For precision work, the desk height can be higher than normal because this work will involve small movements and the worker will need to focus closely on the workpiece.

When standing at a workstation, movement is important so that blood does not pool in the legs. Installing anti-fatigue mats can help distribute the weight of the body from the feet to the floor mats.

Computer Stations

When a user is at a computer workstation, whether seated or standing, the top of the monitor should be at the user's eye level. The interaction between the height of the monitor and the user's eyes is complex because of interdependencies between seat height, monitor height, user height, etc. The BIFMA guidelines elaborate more on this complexity.

These guidelines can be combined with the seated and standing work guidelines for general sizing of desks and workstations (see Table 4 on page 30).

Storage and Files

Filing cabinets should allow a user to open and close the doors with minimal effort. The handles should be designed so that they are easy to grasp and operate.

Figure 14 on page 38 shows the dimensions that are recommended by Woodson and Dreyfuss for a filing cabinet handle that is protruding and one that is flush.

Overhead storage bins can be attached at a reasonable height so the user will not have to reach too high, yet be out of the way from interfering with desk space.

Accessories

Some common office furniture accessories are keyboard trays, mouse pad holders, and pedestals.

The keyboard tray and mouse pad holder should be adjustable for height, depth, and tilt angle. The placement of these holders can allow the user to place computer accessories in comfortable positions where there is minimal strain to the back, arms, and wrists.

Additionally, clearance for the thighs under the keyboard tray can be included in the design.

When designing pedestals or other accessories that go underneath the desktop, the designer can anticipate actions of the user. For example, adding a handle that allows for easy pulling of a mobile pedestal can be a helpful feature.

		Letter	Specifications: Measurement	Specifications: BIFMA Guideline
Seated Work	Height for Thighs	A	Thigh clearance + Shoe allowance + Popliteal height	At least 26.8″
Seated Work	Depth for Knees	B	Buttock-knee length – Abdominal extension depth	No less than 17″
Seated Work	Width for Thighs	Not Shown	Hip breadth, sitting + Movement allowance + Clothing allowance	No less than 19.8″
Seated Work	Height at Foot Level	C	Lateral malleolus height + Shoe allowance	4.2″
Seated Work	Depth at Foot Level	D	Buttock-popliteal length + Foot length – Abdominal extension depth	No less than 23.5″
Standing Work	Height at Foot Level	C	Lateral malleolus height + Shoe allowance	4.2″
Standing Work	Depth at Foot Level	Not Shown	None	6.5″
Standing Work	Width at Foot Level	Not Shown	Hip breadth, sitting + Movement allowance	19.8″
Support Surfaces for Computer Desks	Sitting Height for Input Devices (Desk)	F	Popliteal height + Elbow rest height, sitting + Shoe allowance – Input device thickness	22.2″ – 28.5″ (adjustable) 28.5″ (non-adjustable)
Support Surfaces for Computer Desks	Sitting Height for VDTs (Eye Height)	G	Eye height, sitting + Popliteal height + Shoe allowance	Complex interdependencies; allow top of screen at eye level; approximate height: 42.6″ – 52.6″
Support Surfaces for Computer Desks	Standing Height for Input Devices (Desk)	Not Shown	Elbow rest height, standing + Shoe allowance – Input device thickness	36.7″ – 45.6″
Support Surfaces for Computer Desks	Standing Height for VDTs (Eye Height)	Not Shown	Eye height, standing + Shoe allowance	Complex interdependencies; allow top of screen at eye level; approximate height: 56.9″ – 69.8″
Support Surfaces for Computer Desks	Viewing Depth	H	None	No less than 15.7″ from VDTs to eyes

Table 9. BIFMA guidelines for desks and worksurfaces. Measurements can be visualized using Figure 10 on page 31. All measurements are in inches.

Figure 10. See Table 4 on page 30 for visualization of BIFMA desk and worksurface guidelines. (Allsteel #19 task seating pictured)

Resources for Designing Ergonomic Products

Internet

- BIFMA, bifma.org
- OSHA (Occupational Safety and Health Administration), osha.org

Books and Reports

- ADA Standards for Accessible Design, 28 CFR Part 36, July 1, 1994
- BIFMA Ergonomics Guideline for VDT (Visual Display Terminal) Furniture Used in Office Workspaces, Document G1-2002
- BIFMA Ergonomics Guideline: Ultimate Test for Fit
- *Ergonomics*, Kroemer, Kroemer, Kroemer-Elbert, 2001
- *Human Factors Design Handbook,* 2nd Edition, Woodson, Tillman, Tillman, 1992
- *The Measure of Man and Woman*, Henry Dreyfuss Associates, 2002

Universal Design Considerations

Most people experience some degree of physical limitation at some point in life, such as broken bones, sprained wrists, pregnancy, or aging. Others may live with a limitation or impairment every day.

When considering product design, designers can recognize the special needs of different users, including individuals with disabilities. Issues concerning accommodations for individuals with disabilities are becoming more prevalent, and employers may be required to make accommodations for these individuals at worksites and in other public spaces.

The Americans With Disabilities Act (ADA) does not specify any requirements for office furniture to accommodate individuals with disabilities. Therefore, it is incorrect to state that office furniture products are "ADA compliant."

Designing with all people in mind is a principle that is referred to as Universal Design, and is important to consider in product design. This section will provide some Universal Design guidelines.

Wheelchairs

Designing for wheelchair use requires extra floor space. Following are some guidelines to consider when designing for wheelchair users (Dreyfuss, 2000; 28 CFR Part 36):

- Clear floor space
  – 30" x 48"
- Doorway clearance
  – 36" (preferred)
- T-shaped space for 180° turns
  – 36" width in each corridor
  – 60" (minimum) depth
- Turning space for wheelchair (Figure 6)
  – 60" diameter
- Hallway width (Figure 6):
  – 36" (minimum) – one wheelchair
  – 60" (minimum) – two wheelchairs

For a common-sized wheelchair, the seat height is 18-22", and the overall width is 22.5-27.0". These values can help in designing furniture, adjusting worksurface heights, and accommodating access for wheelchair users. Sitting in a wheelchair and working at a desk or table may require extra reaching. Figure 11 and Table 5 illustrate some guidelines when considering minimum reach envelopes for wheelchair users (Dreyfuss, 2000).

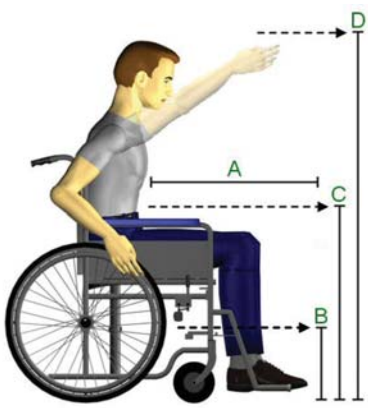


Figure 11. Guidelines for wheelchair users sitting at a worksurface. Use Table 5 for values.

Measurement	Letter	Value
Desk Depth	A	20″ – 25″
Lower Reach Height (minimum)	B	9″
Desk Height	C	27″ – 34″
Shelf Height (maximum)	D	48″

Table 5. Measurements for wheelchair use. Use Figure 11 for visualization. Data from Dreyfuss, 2000. All measurements are in inches.

- Forward approach (toes touching wall)
  - High reach: 48" (maximum)
  - Low reach: 15" (minimum)
- Side reach, with 10" maximum distance between chair and wall
  - High reach: 54" (maximum)
  - Low reach: 9" (minimum); 15" (preferred)

Crutches, Canes, and Walkers

Some individuals need assistive walking devices such as crutches, canes, or walkers. A minimum width of 36" for passage down a hallway or in a workplace is needed for each of these.

Studies have shown that 48" is the preferable hallway width for people using crutches, canes, or walkers (Figure 12). It is also important to keep these areas clear of obstructions. With all walking aid devices, the risk of a fall and further injury is a concern.

Objects that would hinder the proper use and maneuverability of walkers must be moved and cleared from passages and hallways.

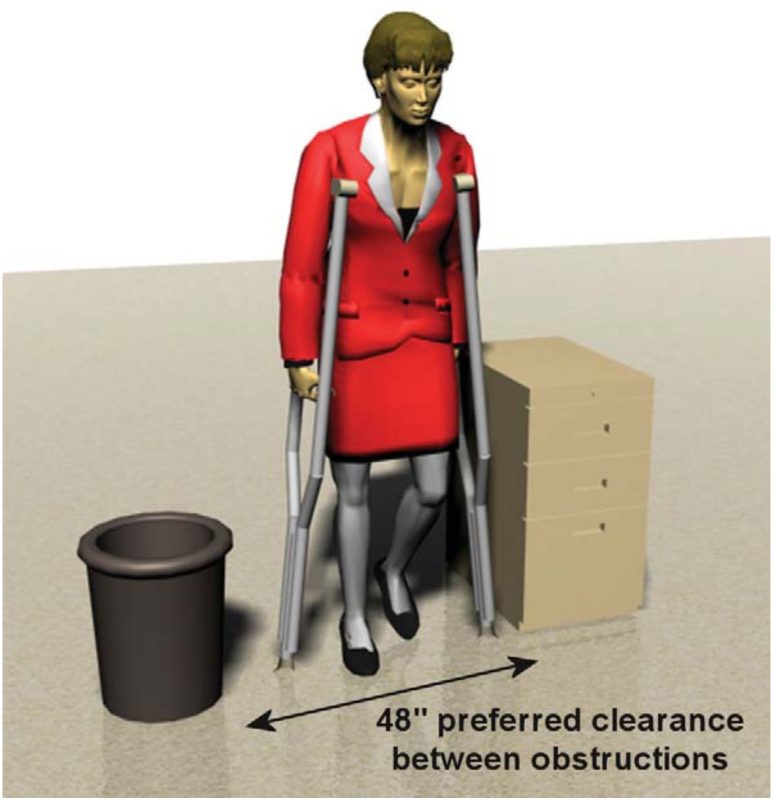


Figure 12. Walkways should be clear of objects for individuals with crutches, canes, or walkers.

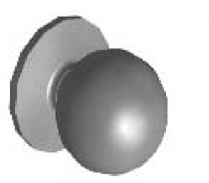
Knobs, Handles, and Controls

The knobs, handles, and controls for products need to be easy to use and intuitive. Some individuals are unable to grip tightly, while others may have a prosthetic hand that cannot easily turn a knob.

Figure 13 shows the differences between an L-shaped door handle and a round knob. An L-shaped handle allows access to a greater number of users.

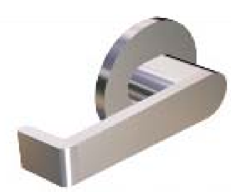
Door handle variation for consideration

Rounded surface requires strong grip pressure and the ability to fully turn handle.



Standard commercial door knob

L-shaped handle requires no grip and only a simple downward push to activate the mechanism.



Easy-access commercial door handle

Figure 13. The door handle on the right is usually a better Universal Design than the standard round knob on the left.

Handles can also be used to open drawers and cabinets. Hand and finger clearance should be considered when specifying the size and depth of a handle (Figure 14). Some items to consider are noted below.

- A minimum clearance of 1" should be between the knob and the door to allow easy operation
- The handle or knob should be shaped so that it is easy to grab, pull, or push

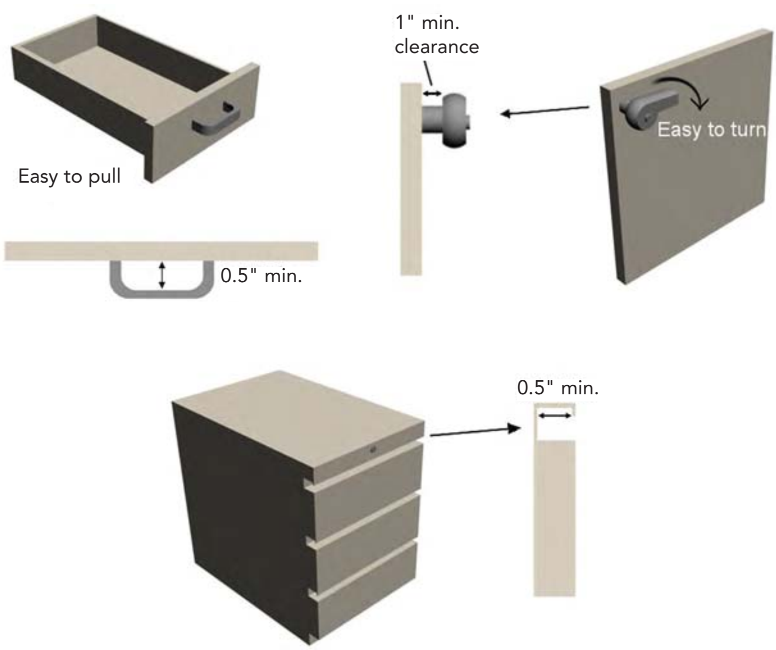


Figure 14. Handles and knobs should allow sufficient hand and finger clearance, and be easy to operate.

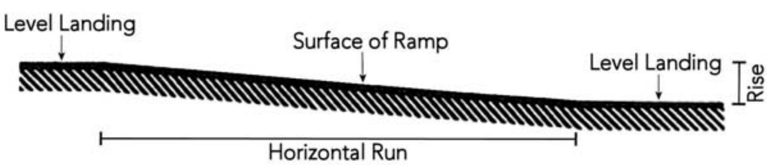
Access Ramps and Stairs

Stairs and access ramps are commonplace in most office and industry workplaces when an elevator is not available to travel from floor to floor.

General guidelines for stair and ramp dimensions can be found in Figure 15. More detailed information can be found on the ADA's Accessibility Guidelines for Buildings and Facilities (ADAAG) website (ada.gov).

Access Ramp

- Maximum slope: 1:12 (for every 1" of rise, 12" of run); 1:16 or 1:20 are preferred
- Maximum rise for any run should be 30"



Slope	Maximum Rise Inches	Maximum Horizontal Run Feet
1:12 to < 1:16	30	40
1:16 to < 1:20	30	40

Figure 15. Access ramp dimensions, adapted from 28 CFR Part 36 (1994), Appendix A, Figure 16.

Stairs

- Uniform riser heights
- Uniform tread widths with no less than 11" width (from riser to riser)

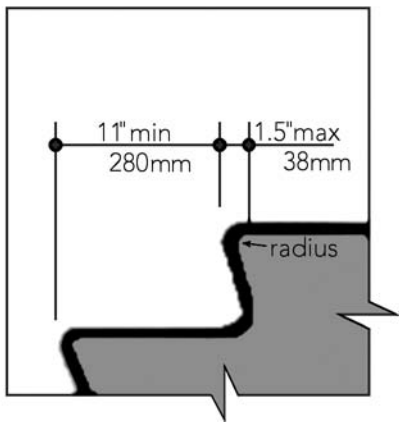


Figure 16. Acceptable nosing and flush riser for stairs, adapted from 28 CFR Part 36 (1994), Appendix. A, Figure. 18.

Landing

- Should be at least the width of the ramp or stair
- Minimum of 60" clearance (60" x 60" if there is a change in direction)

Handrails

- If rise is greater than 6" or horizontal projection is longer than 72", there must be a handrail on both sides
- Handrail must be parallel to ground surface
- 1.5" clearance between wall and railing
- Mounted 34-38" above ground surface

Resources on Universal Design

Internet

- ADA's Accessibility Guidelines for Buildings and Facilities (ADAAG), access-board.gov, ada.gov
- Center for Universal Design, North Carolina State University, ncsu.edu/www/ncsu/design/sod5/cud/
- OSHA Regulations, osha.gov
- University of Buffalo Center for Inclusive Design and Environmental Access (IDEA), ap.buffalo.edu/idea/

Books and Reports

- *ADA Standards for Accessible Design*, 28 CFR Part 36, July 1, 1994
- *Ergonomics*, Kroemer, Kroemer, Kroemer-Elbert, 2001
- *Human Factors Design Handbook*, 2nd Edition, Woodson, Tillman, Tillman, 1992
- *The Measure of Man and Woman*, Henry Dreyfuss Associates, 2002

Conclusion

Many of the items included in this reference can help engineers, designers, and others create products and spaces that will be more ergonomic for the user and increase user comfort. Others can use this tool for general information and guidelines on ergonomics and design.

Many other references can be consulted to obtain additional information on these topics. This booklet has mentioned a few of those sources, which can be found in the References section on page 53.

For more information regarding ergonomics, contact the Ergonomics Group by email at Ergonomics@allsteeloffice.com, or see our website www.allsteeloffice.com/ergo.

Glossary

Abduction: To draw or spread away from a position parallel to the midline axis of the body or median of the limb.

Adduction: To draw or pull near to a position parallel to the midline axis of the body or median of the limb.

Anthropometry: The study of human body measurements, usually applied to the comparison of measurements.

BIFMA: Business and Institutional Furniture Manufacturer's Association; a group that addresses common concerns in the furniture industry.

Carpal Tunnel Syndrome: A condition caused by compression of the median nerve in the wrist region of the hand and characterized by weakness, pain, and disturbances of sensations in the hand.

Ergonomics: An applied science concerned with designing and arranging objects people use in a safer and more efficient manner.

Extension: An unbending movement around a joint or limb that increases the angle between the bones of the limb at the joint.

Flexion: A bending movement around the joint or limb that decreases the angle between the bones of the limb at the joint.

Intuitive: Known or perceived without thought into functionality.

Kyphosis/kyphotic: Exaggerated back curvature of the thoracic region of the spinal column.

Lordosis/lordotic: Exaggerated forward curvature of the lumbar and cervical regions of the spinal column.

Metacarpal: A bone or part of the hand that typically contains five elongated bones when all the digits are present.

Musculoskeletal Disorders (MSDs): Disorders related to the musculature and skeleton caused by repetitive tasks, awkward movements, or other events.

Nosing: The front edge of a stair where the riser and tread meet.

Popliteal: Of or relating to the back part of the leg behind the knee joint.

Radial: Developing or moving uniformly around a central axis (joint).

Range of Motion (ROM): The horizontal distance or extent from which the extremes of movement are measured.

Rotational: The turning of a body part about its long axis as if on a pivot.

Torso: The trunk or midsection of a body.

Ulnar: Relating to the ulna (forearm bone on the side of the little finger).

Riser: The vertical portion of stair that adds height to each step.

Tread: The horizontal portion of a stair that is stepped on.

VDT: A visual/video display terminal; also a term for a computer monitor or similar device.

Universal Design: a philosophy that all products and space should be designed to accommodate as many people as possible with little or no extra cost.

Appendix

	Female					Male				
	Dreyfuss		Woodson			Dreyfuss		Woodson		
	1%	99%	5%	50%	95%	1%	99%	5%	50%	95%
Height	58.1″	69.8″	59.0″	62.9″	67.1″	62.6″	75.6″	63.6″	68.3″	72.8″
Weight	93.0	217.6	104.0	139.0	208.0	100.3	244.0	124.0	168.0	224.0
Standing Eye Height	54.0″	65.1″	57.3″	60.3″	65.3″	58.5″	70.9″	60.8″	64.7″	68.6″
Standing Overhead Reach	64.5″	NA	73.0″	79.0″	86.0″	NA	85.7″	82.0″	88.0″	94.0″
Standing Forward Reach	23.5″	NA	29.7″	31.8″	34.1″	NA	32.5″	31.9″	34.6″	37.3″
Sitting Height	30.8″	37.1″	30.9″	33.4″	35.7″	32.7″	39.3″	33.2″	35.7″	38.0″
Sitting Eye Height	26.8″	32.2″	27.4″	29.3″	31.0″	28.7″	34.5″	28.7″	31.3″	33.5″
Buttock-to-Popliteal	16.5″	21.1″	17.0″	18.9″	21.0″	17.8″	21.6″	17.3″	19.5″	21.6″
Buttock-to-Knee	19.8″	25.5″	20.4″	22.4″	24.6″	20.8″	26.5″	21.3″	23.3″	25.2″
Sitting Popliteal Height	15.0″	18.0″	14.0″	15.7″	17.5″	15.5″	19.5″	15.5″	17.3″	19.3″
Sitting Knee Height	17.3″	22.4″	17.9″	19.6″	21.5″	18.8″	24.5″	19.3″	21.4″	23.4″
Thigh Clearance	NA	NA	4.1″	5.4″	6.9″	NA	NA	4.3″	5.7″	6.9″
Waist Depth	7.5″	13.0″	5.8″	6.6″	7.9″	7.9″	13.7″	7.1″	9.7″	12.3″
Elbow Rest Height	NA	NA	7.1″	9.2″	11.0″	NA	NA	7.4″	9.5″	11.6″
Sitting Hip Breadth	11.2″	18.3″	12.3″	14.3″	17.1″	11.4″	16.9″	12.2″	14.0″	15.9″
Forearm-to-Forearm Breadth	NA	NA	12.3″	15.1″	19.3″	NA	NA	13.7″	16.5″	19.9″
Hand Thickness at Metacarpal	NA	NA	0.8″	1.0″	1.1″	NA	NA	1.1″	1.2″	1.3″

Table A1: Measurements of Percentile Humans
These are measurements comparable to the BIFMA guidelines taken from the Natick study. Dreyfuss (see References) used 1st and 99th percentile data from several civilian and military datasets from the 1970s to the 1990s. Woodson (see References) used 5th, 50th, and 95th percentile data from primarily 1980s military data. Numbers here can be used as a guide for design. All measurements are in inches except for weight, which is in pounds.

Anthropometric Measurement	Practical Application
Height	Height of panel wall
Weight	Weight limits for seating
Standing Eye Height	Visual obstructions/displays
Standing Overhead Reach	Accessibility of high shelves
Standing Forward Reach	Reach conditions
Sitting Height	Overhead clearance; sitting panel height
Sitting Eye Height	Height of top of monitor
Buttock-to-Popliteal	Seat depth
Buttock-to-Knee	Knee clearance
Sitting Popliteal Height	Seat height
Sitting Knee Height	Knee clearance under worksurface
Thigh Clearance	Clearance between thighs and bottom of worksurface
Waist Depth	Clearance between backrest and workstation edge
Elbow Rest Height	Armrest, keyboard, or writing surface height
Sitting Hip Breadth	Seat widths
Forearm-to-Forearm Breadth	Seat and armrest widths
Hand Thickness at Metacarpal	Hand clearance in a handle, slot

Table A2: Layman Use of Anthropometric Measures
Anthropometric measurements and their possible application in product design.

		Range of Motion Zones			
	Movement	0	1	2	3
Wrist	Flexion	0 – 10	11 – 25	26 – 50	51+
	Extension	0 – 9	10 – 23	24 – 45	46+
	Radial Deviation	0 – 3	4 – 7	8 – 14	15+
	Ulnar Deviation	0 – 5	6 – 12	13 – 24	25+
Shoulder	Flexion	0 – 19	20 – 47	48 – 94	95+
	Extension	0 – 6	7 – 15	16 – 31	32+
	Adduction	0 – 5	6 – 12	13 – 24	25+
	Abduction	0 – 13	14 – 34	35 – 67	68+
Back	Flexion	0 – 10	11 – 25	26 – 45	46+
	Extension	0 – 5	6 – 10	11 – 20	21+
	Rotational	0 – 10	11 – 25	26 – 45	46+
	Lateral Bend	0 – 5	6 – 10	11 – 20	21+
Neck	Flexion	0 – 9	10 – 22	23 – 45	46+
	Extension	0 – 6	7 – 15	16 – 30	31+
	Rotational	0 – 8	9 – 20	21 – 40	41+
	Lateral Bend	0 – 5	6 – 12	13 – 24	25+

Table A3: Range of Motion
Data for this table was modified from Chaffin, 1999 and Woodson, 1992. These are the actual angular measurements of body joints in each of the four Zones for range of motion. Use Figure 7 on page 18 to visualize these ranges. All measurements are in degrees.

Chair Specification	Anthropometric Measurement	Suggested Amounts	
		Dreyfuss	Woodson
Seat Height	Popliteal height + Shoe allowance	14.5″ – 19.0″	15″ – 18″
Seat Depth	Buttock-popliteal length – Clearance allowance	16″	16″
Seat Width	Hip breadth, sitting + Clothing allowance	16″ – 22″	19″
Seat Pan Angle	None	0 – 4° rearward (fixed)	0 – 5°
Backrest Lumbar	None	7.0″ – 11.5″; In/out 0.6″ – 0.8″	7.0″ – 10.0″
Backrest Height	None	At least 13″; over 25″ for upper body support; 36″ for head support	At least 8″ 34″ for head support
Movement of Seat and Backrest	None	90 – 105°	90 – 105°
Armrest Height	Elbow rest height	7.5″ – 10.0″; 8.5″ fixed	8.5″ fixed
Armrest Length	None	10″ – 12″ forward of seat reference point	12″
Distance Between Armrests	Hip breadth, sitting + Clothing allowance	19″ minimum	19″

Table A4: Other Chair Specifications
Values used in Dreyfuss and Woodson texts to show anthropometric chair design measurements. These values can be compared to the BIFMA guidelines outlined in Table 3 on page 24. All measurements are in inches unless otherwise noted.

Clearance for Seated Work

Height for Knees	25″ minimum
Depth for Knees	12.2″ – 18.0″
Width for Thighs	18.3″
Height at Foot Level	4″
Depth at Foot Level	18.7″ – 24.0″ (front of worksurface to toes)

Clearance for Standing Work

Height at Foot Level	4″
Depth at Foot Level	4″
Width at Foot Level	None

Support Surfaces Heights for Input Devices and VDTs

Sitting Height for Input Devices	23″ – 31″ (adjustable) 28.3″ (non-adjustable)
Sitting Height for VDTs	26.3″ – 34.6″ (seat to eyes)
Standing Height for Input Devices	36″ – 42″
Standing Height for VDTs	55.4″ – 72.0″
Sitting or Standing Depth for VDTs	16″ – 36″

Table A5: Dreyfuss Worksurface Specifications
Values in Dreyfuss' text showing suggested anthropometric measurements for worksurfaces. These values can be compared to the BIFMA guidelines outlined in Table 4 on page 30. All measurements are in inches.

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