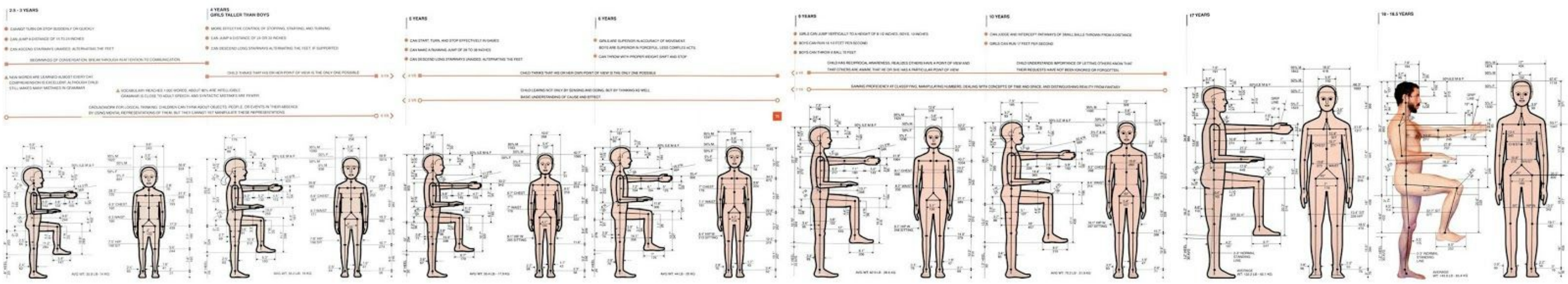


Topic 1: Human Factors & Ergonomics

Human Factors and Ergonomics are interchangeable terms – the term 'human factors' is more commonly used in some parts of the world, such as the United States, and the term 'ergonomics' is more widely used in other countries.

Human factors analyses the interactions between humans and other elements in a system, and then applies principles, information and data to a design to maximize human well-being and system performance.

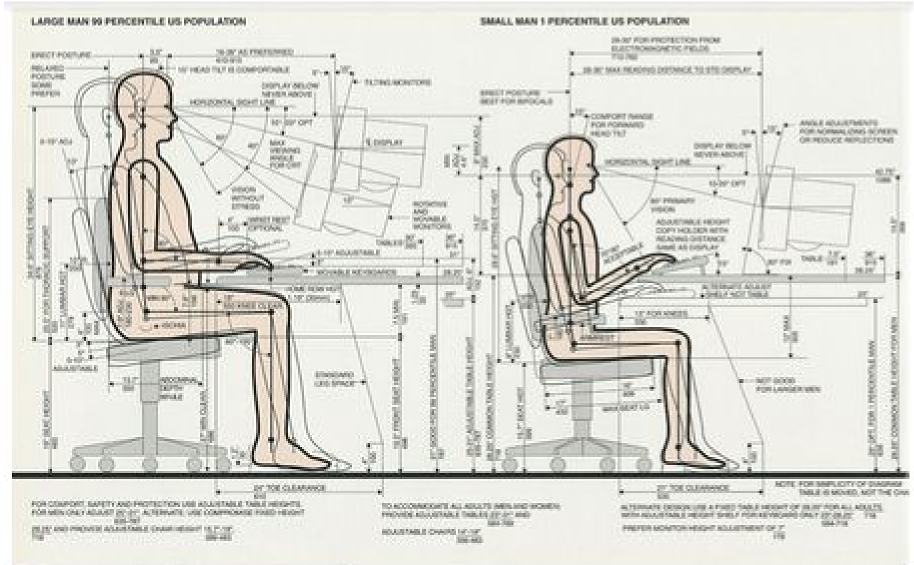
Human factors design ensures that products, organizations, environments and systems are compatible with the needs and limitations of people. This can help to reduce the stress on people, as they will be able to do things faster, more easily, more safely and make fewer mistakes.

Human Factors can be broadly classified into:

- Physical
- Cognitive / Psychological
- Organizational

Physical:

It is concerned with human anatomical, anthropometric, physiological and biomechanical characteristics as they related to physical activity. Relevant topics may include working postures, material handling, repetitive movements, work related musculoskeletal disorders, workplace layout, health and safety. Physiological human factors include such things as muscle strength and endurance in different body positions, visual acuity, tolerance to extremes of temperature, frequency range of human hearing, etc.



Cognitive / Psychological:

A proper fit of a product to a user does not end with physical interfaces. Cognitive / perceptual ergonomics is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. Relevant topics include mental workload, decision-making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system and Human computer interaction design.

Organizational:

It is concerned with the optimization of socio technical systems, including their organizational structures, policies, and processes.

Specific objectives of Ergonomics:

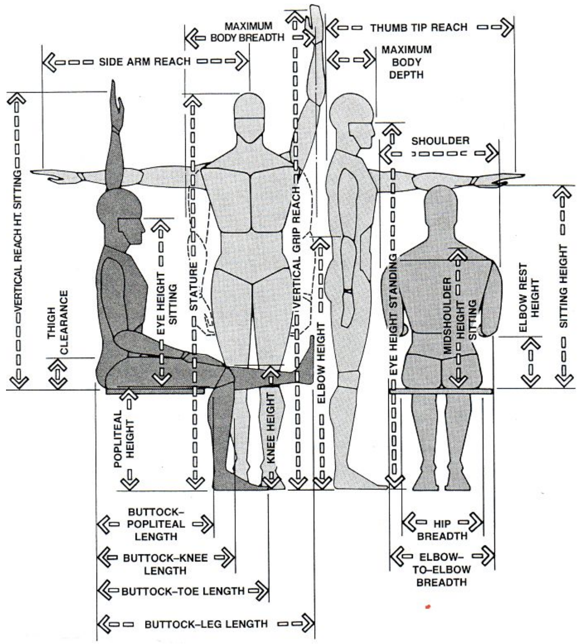
1. How activities /tasks are carried out

- effectiveness (completeness and accuracy),
- efficiency (speed and effort),
- engagement (pleasantness and satisfaction),
- error tolerance (error prevention and error recovery) and
- learnability (predictability and consistency)
- Improve system performance, reliability and maintenance.

2. How human values e.g. quality of life, are enhanced -

- improved safety,
- reduced fatigue and stress,
- increased comfort levels
- job satisfaction are enhanced.

Types of Dimensions



Static Dimensions

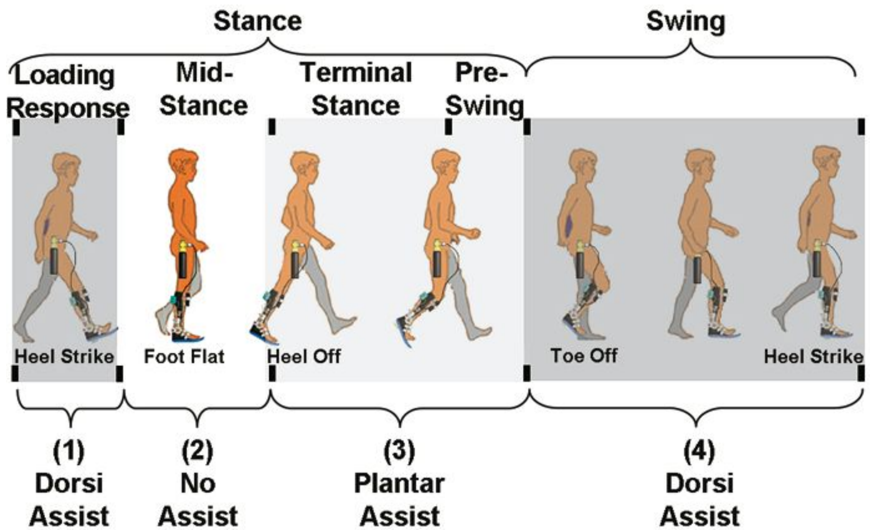
Static dimensions may be subdivided into circumferences, lengths, skinfolds, and volumetric measurements.

Dynamic Dimensions

Dynamic dimensions include link measurements, center of gravity measurements, and body landmark locations. Static and dynamic anthropometry are also referred to by the names structural and functional anthropometry, terms which more explicitly express the body and its action.

Static dimensions are taken with body parts held in fixed, standardized positions. These dimensions are easily obtainable but not so easily applied since design applications often involve the body in functional attitudes.

Dynamic dimensions are taken with the body at work, in motion or in workspace attitudes. These measurements are in more difficult to obtain with application limited to a particular workshop or movement studied. Functional dimensions account for interactions among body members. For example, the limit of functional arm reach is not due to arm length alone but is affected by shoulder movement, some trunk movement and the function to be performed by the hand.



NASA GENERAL ANTHROPOMETRICS & BIOMECHANICS RELATED DESIGN CONSIDERATIONS

http://msis.jsc.nasa.gov/sections/section03.htm#_3.3_ANTHROPOMETRIC_AND

3.2.1 Anthropometric Database Design Considerations

The following are considerations that must be made when using and applying anthropometric data.

- Percentile Range - Design and sizing of space modules should ensure accommodation, compatibility, operability, and maintainability by the user population. Generally, design limits are based on a range of the user population from the 5th percentile values for critical body dimensions, as appropriate. The use of this range will theoretically provide coverage for 90% of the user population for that dimension.

- User Population Definition - Anthropometric data should be established from a survey of the actual user population. In the case of space programs, it is difficult to define the user population. Past space programs have involved a small, select, and easily defined group. As the space program expands, the user population will expand and change. With improved environmental controls, physical fitness will be a less important criterion. Skills and knowledge will be more of a factor in selection. International participation will also influence the character of the user population. (In this document) the user population has not been defined. Data are provided for the 5th percentile Asian Japanese and the 95th percentile White or Black American male projected to the year 2000. This does not necessarily define the 5th and 95th percentile of the user population. The data in this document are meant only to provide information on the size ranges of people of the world. The Japanese female represents some of smaller people of the world and the American male some of the larger. Development of a predicted user population size range requires a statistical combination of an estimated mix of these data.

- Misuse of the 50th Percentile - There is an erroneous tendency to consider the 50th percentile dimensional data as sufficient to accommodate the majority of users. This must not be done. The 50th percentile dimensions will accommodate only a narrow portion of the population, not a majority of the users. The full size range of users must be considered.
- Summation of Segment Dimensions - Caution must be taken when combining body segment dimensions. The 95th percentile arm length, for instance, is not the addition of the 95th percentile shoulder-to-elbow length plus the 95th percentile elbow-to-hand length. The actual 95th percentile arm length will be somewhat less. The 95th percentile individual is not composed of 95th percentile segments. The same is true for any percentile individual. (Refer to Reference 16, p. VIII-5, for a more complete discussion of segment combinations).
- Percentiles within a category of data are exclusive. For example, a person who is 5th percentile body size does not necessarily have 5th percentile reach or joint movement.

Percentile range

That proportion of a population with a dimension at or less than a given value.

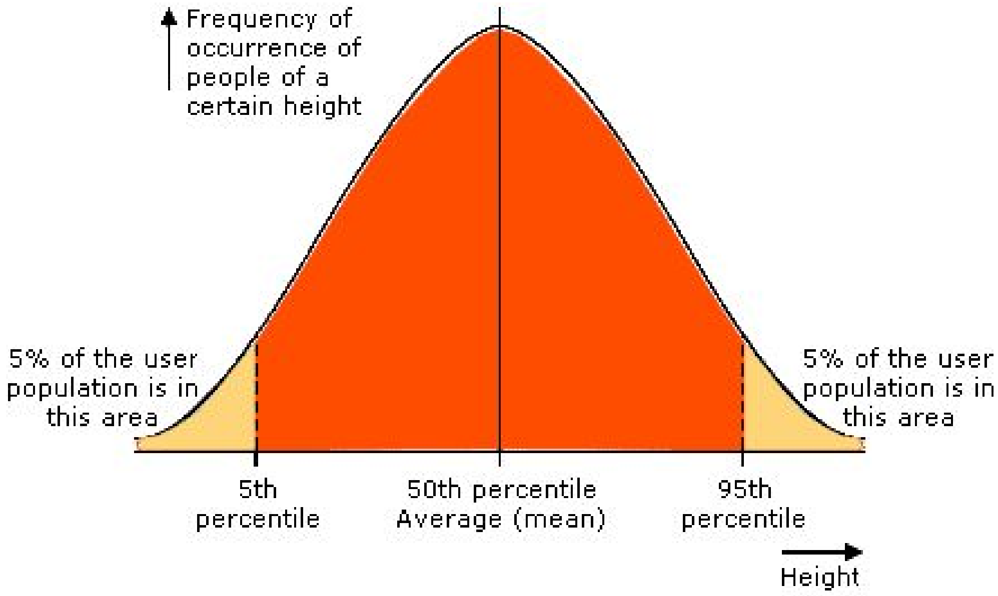
In a design context, designing for a percentile would be designing for the size that is greater than or equal to a certain percent of a size. For example, designing for the 95th percentile would be designing for the largest size that is greater than or equal to 95% of all possible sizes.

Percentiles are shown in anthropometry tables and they tell you whether the measurement given in the tables relates to the 'average' person, or someone who is above or below average in a certain dimension.

	Male			Female		
			Percentile			
Dimension	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**
Stature	1560	1655	1750	1450	1530	1610
Eye height	1445	1540	1635	1350	1425	1500
Shoulder height	1250	1340	1430	1075	1145	1215
Elbow height	965	1035	1105	895	955	1015
Hip height	765	830	895	700	755	810
Sitting height	850	900	950	800	845	890
Sitting eye height	735	785	835	690	735	780
Sitting elbow height	220	260	300	215	250	285
Thigh thickness	110	135	160	105	130	155
Buttock-knee length	500	550	600	485	530	575
Buttock-popliteal	410	470	510	405	450	495
Knee height	450	490	530	420	450	480
Popliteal height	360	400	440	325	360	395
Shoulder breadth	405	440	475	365	395	425
Hip breadth	280	305	330	270	305	340
Elbow span	790	870	950	715	780	845
Vertical reach (stand)	1805	1940	2075	1680	1795	1910
Vertical reach (sit)	1105	1185	1265	1030	1095	1160

If you look at the heights of a group of adults, you'll probably notice that most of them look about the same height. A few may be noticeably taller and a few may be noticeably shorter. This 'same height' will be near the average (called the 'mean' in statistics) and is shown in anthropometry tables as the fiftieth percentile, often written as '$50^{th\%}$ile'. This means that it is the most likely height in a group of people.

If we plotted a graph of the heights (or most other dimensions) of our group of people, it would look similar to this:



The graph shows the height of a group of adults. First, notice that the graph is symmetrical – so that 50% of people are of average height or taller, and 50% are of average height or smaller.

The graph tails off to either end, because fewer people are extremely tall or very short. To the left of the average, there is a point known as the 5th percentile, because 5% of the people (or 1 person in 20) is shorter than this particular height.

The same distance to the right is a point known as the 95th percentile, where only 1 person in 20 is taller than this height. So, we also need to know whether we are designing for all potential users or just the ones of above or below average dimensions. Now, this depends on exactly what it is that we are designing.

User Population

User Population: The range of users for a particular product or system. Large user groups may be defined by age, gender, physical condition, economic means etc. When considering a product designed for mass use, it is not good to rely on information collected from just a few people, as it is unlikely to be representative of the whole range of users. Therefore it is important to use 'sampling' across the population groups to gain information about potential users.

When deciding which user group sample to use for a product it is vital that you have identified all areas of the target audience and have given equal opportunity for users from all of these to partake. To further define the exact nature of a user group sample it is important to understand the characteristics that are important to the final evaluation. These characteristics are the ones that must be represented by the members of the sample.

Sampling

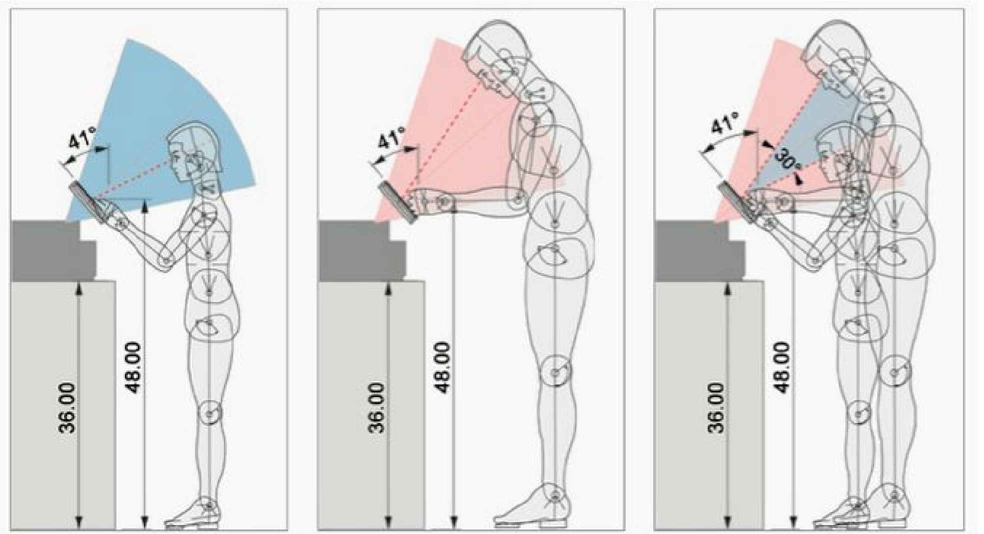
Surveys can only measure a sample of the people they are interested in. Samples sizes range from 10's to 1000's, depending on the scope and purpose. In order to have a good match between the sample and the 'population', generally a mix of random and targeted selection is used, to make sure for example that a minority group has enough representation. The larger the sample, the less likely it is to have an unexpected bias.

It's a characteristic of human variation that most people are near to the average, then there are proportionately fewer and fewer people towards the extremes. In ergonomics it is normally the extremes that we are interested in, because that is where any given aspect of a design will start to "not fit". The percentage of people who are smaller than a given size is called a "percentile", and typically designs are specified to fit from 1st/2nd/5th percentile to 95th/98th/99th.

What percentiles to use?

Deciding whether to use the 5th, 50th or 95th percentile value depends on what you are designing and who you are designing it for.

Generally, if you pick the right percentile, 95% of people will be able to use your design. For instance, if you were choosing a door height, you would choose the dimension of people's height (often called 'stature' in anthropometry tables) and pick the 95th percentile value – in other words, you would design for the taller people. You wouldn't need to worry about the average height people, or the 5th percentile ones – they would be able to fit through the door anyway.



5% female shown (China/Japan) 95% male shown (US/Europe) *both shown overlaid*

At the other end of the scale, if you were designing an airplane cockpit, and needed to make sure everyone could reach a particular control, you would choose 5th percentile arm length – because the people with the short arms are the ones who are most challenging to design for. If they could reach the control, everyone else (with longer arms) would be able to.

- What happens for excluded users - discomfort, inconvenience, danger etc? The more severe the consequences, the fewer exclusions you can allow.
- Do the excluded users expect this (e.g. a very tall person may be used to being cramped in an economy aircraft seat, but not in a luxury car)?
- Can you warn the excluded users?
- Are there degrees of exclusion that you should consider, beyond the basic target? For example, set 95th percentile for one non-critical dimension and 99th for another that is more crucial.
- How much would it cost to increase the design range?

Airport Kiosk Design Example

A constant problem for designers is the conflict between designing for as wide variety of people as possible, and, at the same time, helping the manufacturer to keep the production costs down.

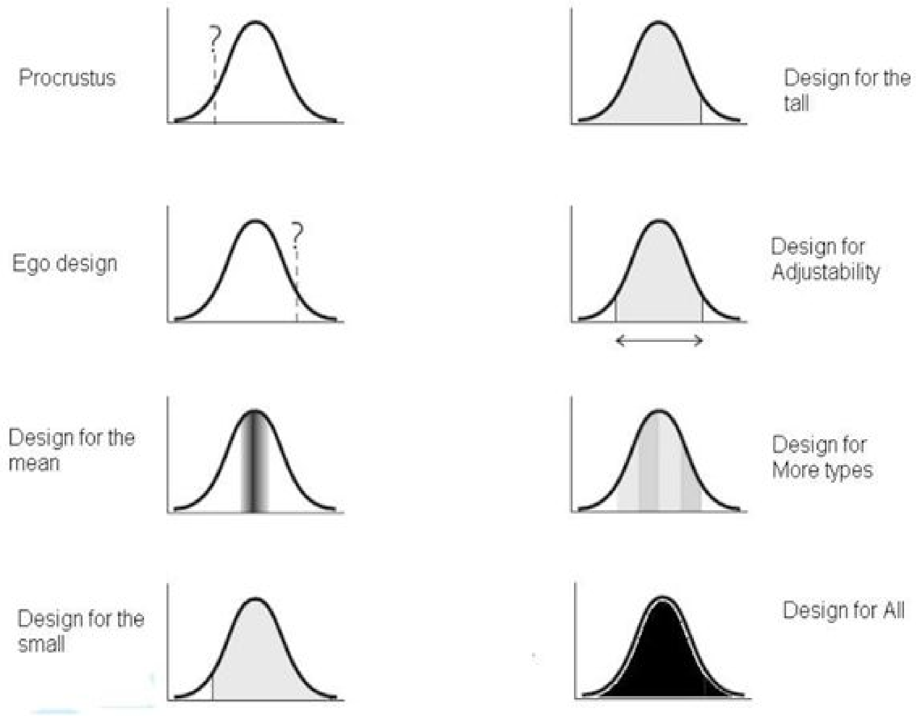
In physical product design, there are many constraints, but human physical characteristics are the most fundamental. Therefore, the most fundamental design question is, how do I design for the range of human physical constraints? For this, we turn to anthropometrics the measure of human body size and proportions.

Let's focus on one simple anthropometric variable - height. Actually, even height is not that straightforward as there are many types of height: stature (what we mean when we say height), eye height (distance from the ground to the eyes - important for display positioning), shoulder height, fingertip height (standing, with arms relaxed), and sitting elbow height, to name a few.

Suppose we are designing an interactive touch screen kiosk that will be used in an international airport terminal. It is expected that the kiosk users will include travelers from around the world, male and female, from children through elderly adults. While this may sound like the worst case scenario for physical design (and it is), it's also very typical. In this case we are going to focus initially on eye height because we want to set the display so that it can be viewed most easily without looking up or bending down too much. (Note that line of sight is optimally about 10 degrees below the horizontal plane.)

If we refer to anthropometric data tables we find quite a range in eye height, varying by nationality, age and sex. For example an average, 50th percentile Dutch man has an eye height of 1670mm, while an average, 50th percentile eight year old British girl has an eye height of 1165mm. That's over a 500mm difference, and those aren't even the most disparate populations! So how do we accommodate the diversity of physical characteristics?

The most basic approach, if we can even call it that, is **"Procrustus"**, which means that no attempt to accommodate the user has been made, and the user must adapt to the product, however it happened to be designed. Incidentally, this term comes from Greek Mythology, where Procrustes was fitted to a bed by sawing off his head and feet.



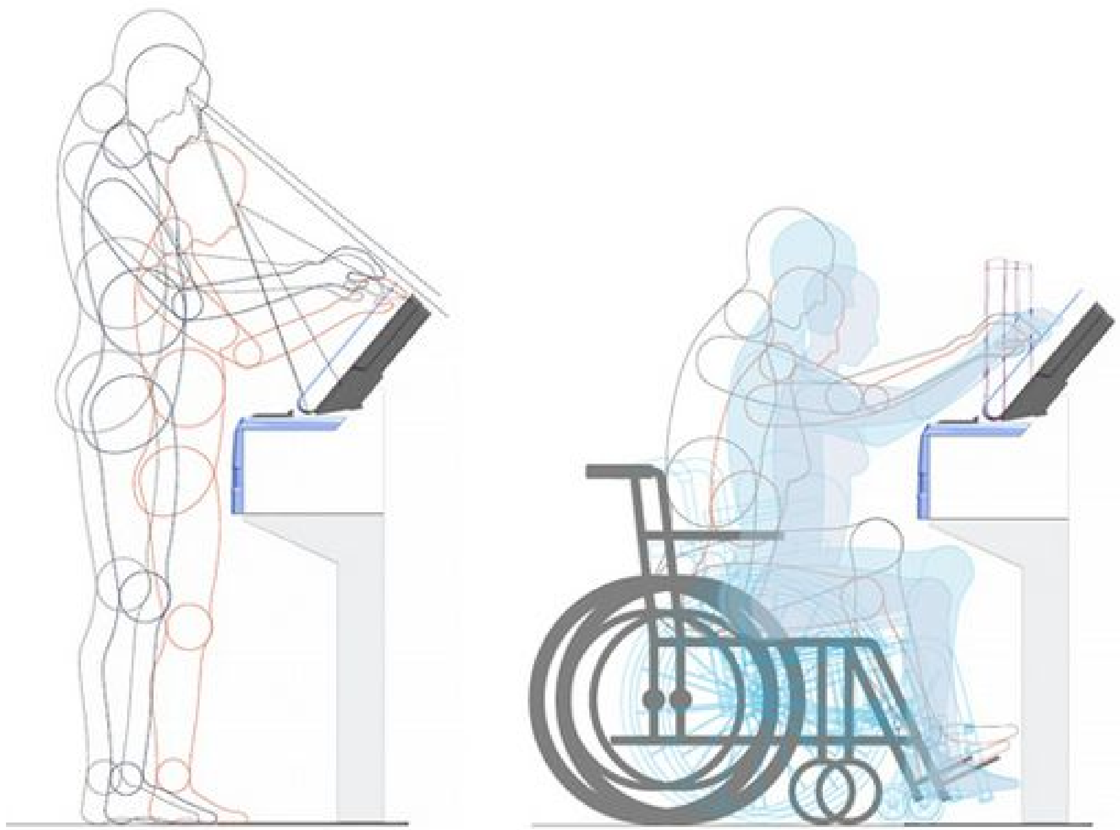
Only slightly better is the **Ego-design** approach, where the designer uses his or her own body as a reference. Now every designer does this to some extent for convenience, but it should serve only as a starting reference point.

Design for the mean sounds like a good idea - find the average eye height, and the majority of users will be accommodated. False assumption - as the diagram indicates, a majority of people are excluded by relying on the mean, with only a few falling into the sweet spot in the centre.

Designing for one end of the spectrum (small) or the other (tall), can work in some cases. For example, if you design a door to accommodate the tallest users, then by definition, those of shorter stature will fit as well, as clearance is a one-ended variable. But in our case, the appropriate height of a kiosk display is a two-ended issue - there is a hypothetical "too high" as well as a "too low".

Design for adjustability means that the product can accommodate a range of users, typically through a mechanical solution. For example, a tilting, height adjustable screen, or multiple interaction stations set at different eye heights. Of course adjustability in the physical world adds cost and complexity, and can lead to unreliable products, so is not always an available solution.

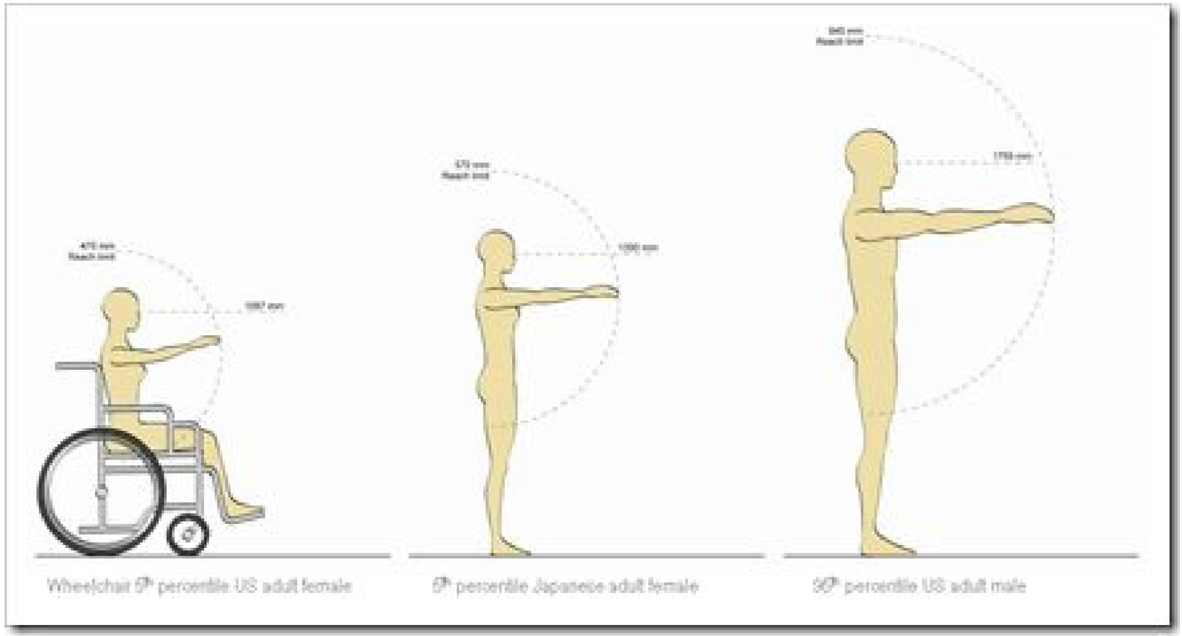
In the end, the most common solution is to **Design for More Types**. In practice this typically means defining a population and then fitting for a reasonable range within that population. Traditionally that range spans from the smallest fifth percentile to the largest 95th percentile. This includes a very broad range of users, but purposely excludes the most extreme 10% of the population (the largest 5% and smallest 5%) - the long tail, where a small number of outlier users can account for a significant design change.



Last, but not least is the ideal - **Design for All.** This means that the product can fit the entire range of an anthropometric characteristic. This is technically possible as humans are not infinitely variable in any dimension.

Range of sizes versus adjustability

The 50th percentile refers to one particular dimension. For example, someone may be average in height but not average in other dimensions.

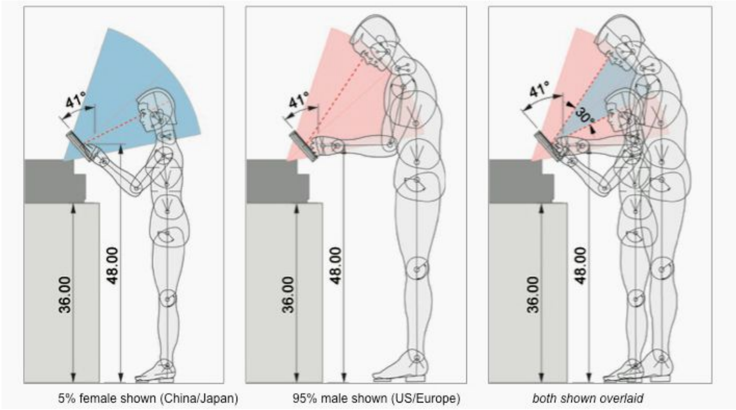


The assumption is made that every person in the $50^{th\%}$ile has perfect, equal ratios. Generally, no one is average in every respect. A person who is equal in height with the $50^{th\%}$ile may have the width of the $95^{th\%}$ile person and the reach of the $5^{th\ \%}$ile person.

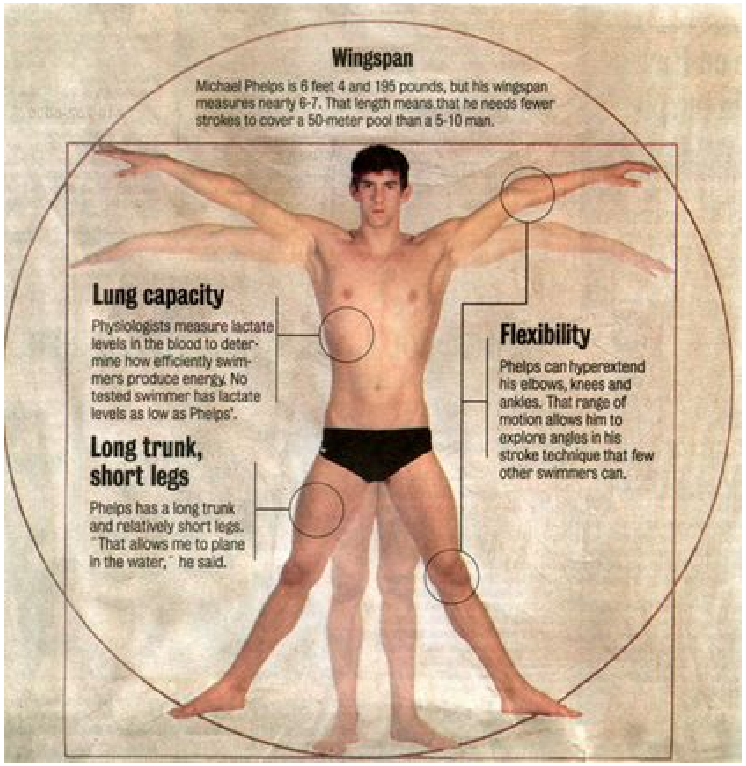
Designing for Multiple Anthropometric Dimensions

There are several body measurements that could be relevant for reaching a touch screen, but a practical one would be Forward Grip Reach distance - roughly the distance from the shoulder axis to the palm of the hand. With those two metrics in mind - eye height and forward grip reach - you could picture any user as the function of two perpendicular lines - a vertical line, representing the individual's eye height, and a horizontal line representing arm reach. This is illustrated right for a range of three different users - note that the wheelchair user has a sitting eye height compared with the two standing users.

While it might seem relatively straightforward as to how to situate the kiosk- place the screen at a distance and height that accommodates the greatest range of users - the story gets more complicated, because people are complicated. Not just complicated in a psychological sense, but in an anthropometrical sense as well. The factor that adds complexity is the lack of correlation among anthropometric measurements within people.



In interface design, you have to work within the constraints of a display. For example, a common resolution for web browsers is 1024 pixels x 768 pixels. Some older displays might be set at 800x600. So while the specific vertical and horizontal dimensions change, the relationship between height and width, or aspect ratio, remains constant at approximate;y 1.3 in both cases. So if you're taking a design originally intended for 1024x768 and then need to scale it down to 800x600, it will need to be reduced proportionally.



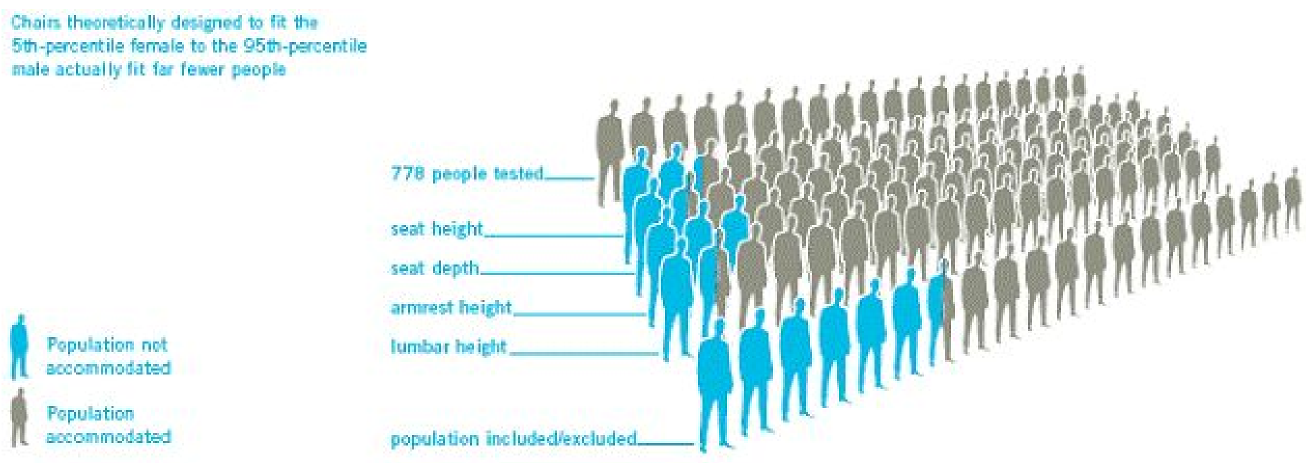
Human Factors design would be much easier if people had consistent "aspect ratios", but our body measurements are not predictably proportional or strongly correlated. Meaning the that all of the the tallest people in one dimension (such as eye height) do not always have the longest measurement for all other dimensions (for example, forward grip reach).

An extreme example, swimmer Michael Phelps has a reach that is longer than the majority of people of the same height. What this means is that for practical purposes, each anthropometric variable could be considered independent of others. (Note that the level of correlation among different metrics can vary - for example, different attributes of the hand are closely correlated to each other, but measurements of different limbs are weakly associated.)

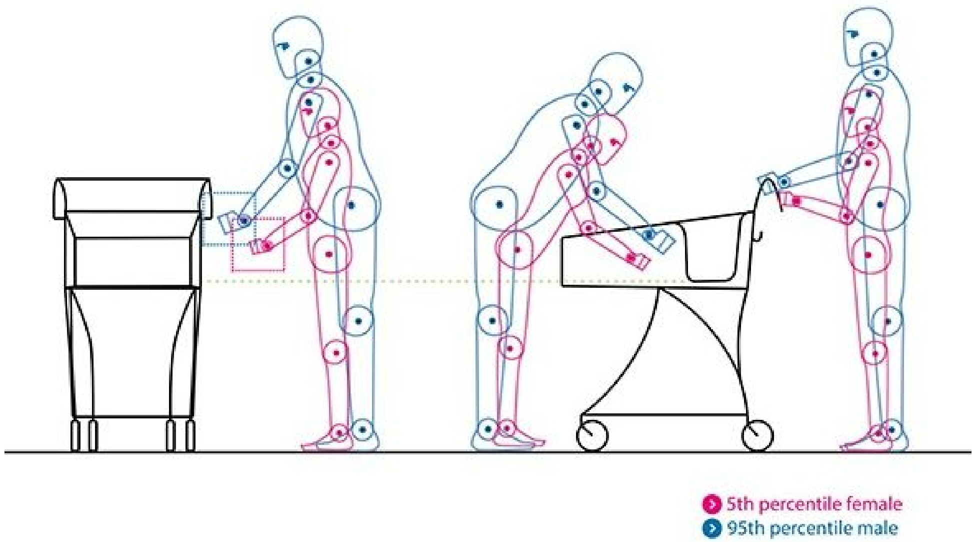
When setting an eye height that accommodates the lower 5% to upper 95% of that metric, and then a forward grip reach that accommodates the lower 5% to upper 95% for that particular metric, we are actually talking about two different groups of people. Only a subset of people who fall within the eye height range will also fall within the reach range, albeit a large subset, but below the 90% of the population we are striving to include.

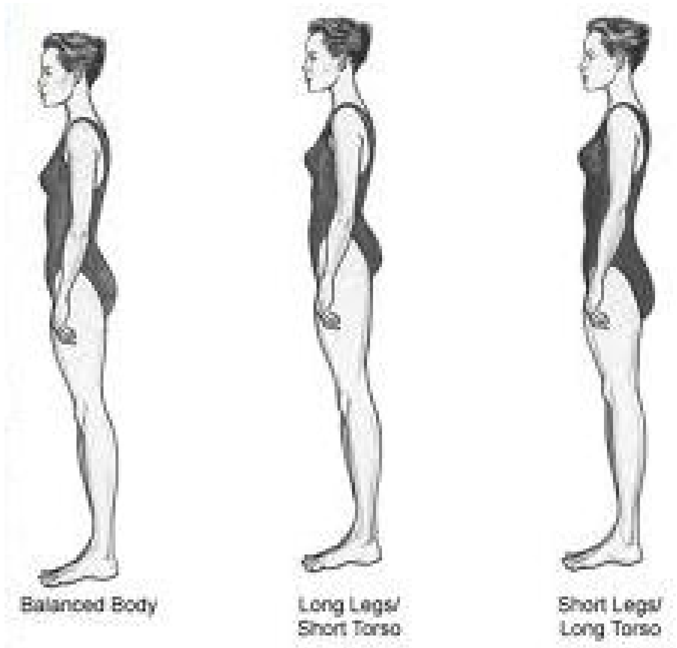
Another way of understanding this is described in the Herman Miller monograph on The Anthropometrics of Fit. The design focus in this case is fitting people to a chair rather than a touch screen kiosk, but the concept is the same. In the illustration (right) the back row represents all of the people who were the original intended audience for fitting a chair. Each row in front of that shows how a small percentage of people are excluded with each anthropometric variable (seat height, seat depth, etc.).

The front row shows the overlap of all four variables such that "almost one-third of our sample [in blue] had at least one dimension out of four that was either smaller that the 5th percentile female or larger than the 95th percentile male."



People vary considerably in shape as well as overall size. In addition to the 17 inches in height and 140 pounds in weight that separates a 1st-percentile female from a 99th percentile male (Gordon et al. 1988), there are gender-related differences in bone structure and weight distribution and infinite variations in limb lengths and body contours. Even among a group of people of the same gender, age, and stature, one finds significant variation in bodily proportions (Pheasant 1986). Two people of the same standing height, for instance, can appear to be of very different heights when seated, and their seated elbow heights may vary by as much as three or four inches.

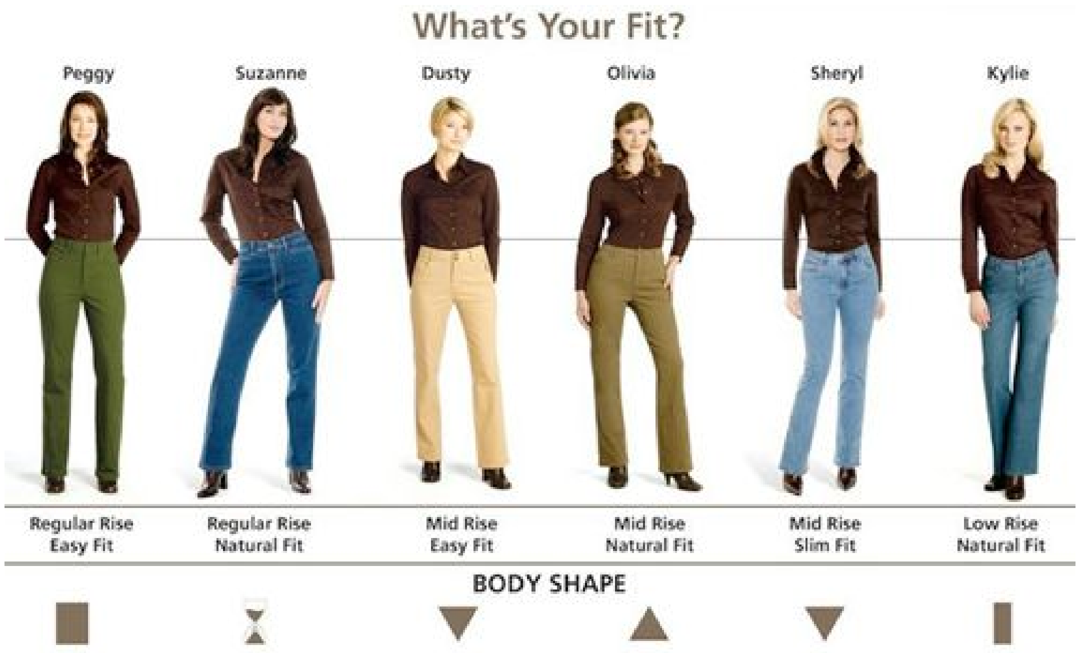




Practical Solutions

In practical terms there are three solution approaches: design multiple sizes, adjustability and satisficing.

Multiple Sizes



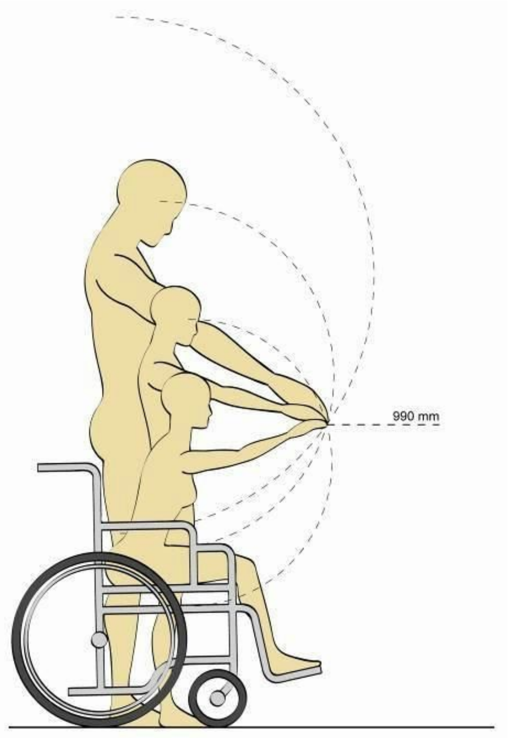
Multiple sizes, as it implies, creates a range of models, where each is targeted at a specific subset of the user population. The most extreme example of this (aside from bespoke, individualized designs) comes from clothing and footwear, where there are literally dozens of sizes and variations to enable a relatively close fit for the vast majority of the population.

Although the women in the photograph above are the same height they have different body shapes. The jeans are all cut differently. Varying from Regular rise to Low rise and Easy Fit to Slim fit. The combinations of these different cuts provide the women in the Photograph a choice of 6 different "fits" based on the same size waist and leg length.

For products such as furniture, this may be limited to three or four sizes, better known as small, medium and large. In fact, this was Herman Miller's solution to the chair fit problem - creating three different sizes allowed for fit of 95% of the population between the smallest 1st percent and highest 99 percent - a greater range then they had originally intended. During the design of the airport kiosk that we discussed earlier, one of the early proposed solutions was to create a two-sided kiosk with a "low" and "high" screen positions that could comfortably suit a wide range of users.

Adjustibility

Adjustability is really a special case of multiple sizes where the user (or an expert) modifies the fit at installation or during use. Most of us are familiar with adjusting the driver's seat in a car. These seats are not infinitely adjustable, but typically have three or more control points that can lead to a very wide range of positions, within the available space constraints. The downsides of adjustability are cost, reliability, and the extra work placed on the user to adjust the fit. Note, that many users may not always set the best fit for themselves.



Satisficing

Satisficing, is coming up with a single solution that fits the broadest range of users. In practice this tends to skew towards the smaller or shorter end of users because, larger users can always bend and smaller users may have physical limitations due to age or disability that take priority (legal and otherwise). Most designs for public spaces will take this approach, as in elevators, water fountains and ATMs.   For the kiosk, the best single solution is pictured below at a fixed height and distance that was manageable for a broad range of users:

MultiFit

Prototyping for Fit

Whether designing a single solution or multiple sizes, it is important to to follow a user-centered design process. There may be room in interface design for "genius-centered design", but there's no substitute for real-world measurement of physical fit. As in interaction design, prototyping can take many forms, depending on your goals and need for fidelity at each stage of the design process. For example, if the initial goal was simply to conduct a real-world test of key dimensions, then a simple sticker on a wall could serve as a "prototype" for display position. For more detailed issues, such as task-specific grips on a tool handle, foam mock-ups can be created and evaluated.

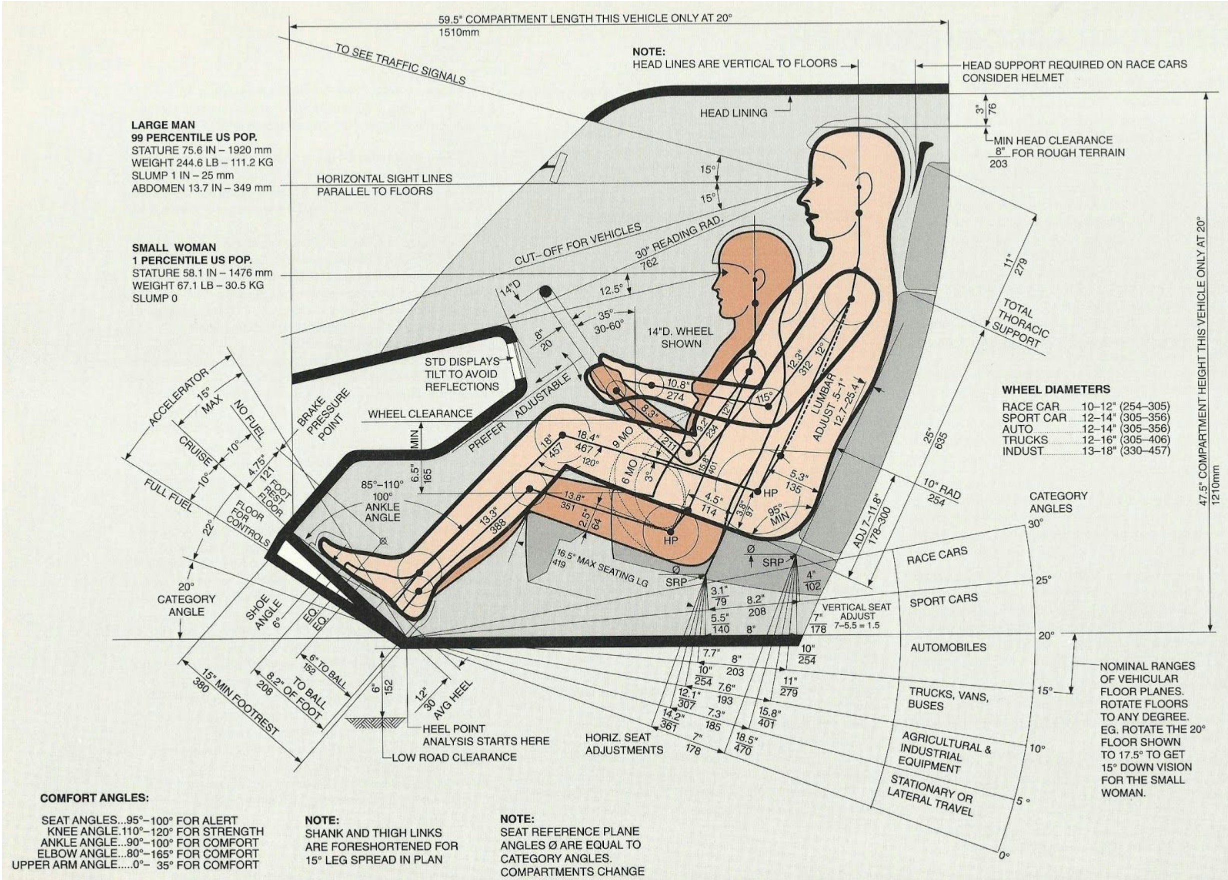
A typical UCD process for ergonomic fit would follow these steps, presented in an abbreviated form here:

- Define relevant populations (e.g. age range, nationality, sex)
- Define key dimensions or variable for fit consideration (e.g. height, reach, weight, etc)
- Determine boundary measures for each anthropometric dimension from reference data, from lower 5th to upper 95th percentile (keeping in mind that some dimensions, such as head clearance in a doorway, may be one-sided)
- Compare referenced dimensions with existing real-world products for reality check
- Apply dimensions to create mock-ups for initial, informal ergonomic feedback with users
- Refine design(s) to create foam or similar low-fidelity mock-ups for fit evaluation
- Continue to refine as needed/budgeted

Adjustable equipment - Example

Multivariate accommodation (fitting in several variables, e.g. in a car you need to fit in terms of sitting height, leg room, arm reach, viewing angles, hip breadth, thigh length) means that accepting 5% being designed out for each important dimension is not viable, because different people will be designed out for each variable.

People have different proportions. Those designed out because they are too tall may not be the same as those designed out because their arm reach is too short.



Designing for adjustability

Wherever possible, it is best to design adjustability into any workspace. An example is the interior of a car, where the driver's seat has height adjustment, and forwards and backwards adjustment, to comfortably fit as many users as possible.

For an adjustable range, we generally use:

- 5th percentile female for the lower limit,
- 95th percentile male for the upper limit.

Designing for extreme individuals

In some situations a specific dimension of a workspace layout becomes the limiting factor that may restrict the use of the workspace for some people. This limiting factor can either be designed for the minimum or maximum value for a population, depending upon what is required.

Design for the maximum

You should design for the minimum population when the minimum value (lowest) of the feature has to accommodate all users. For example, controls should be within reach of the smallest operator.

You should design for the maximum population when the maximum value (highest) of a feature has to accommodate all users. For example, the height of a doorway should allow all users to pass through without stooping or banging their head!

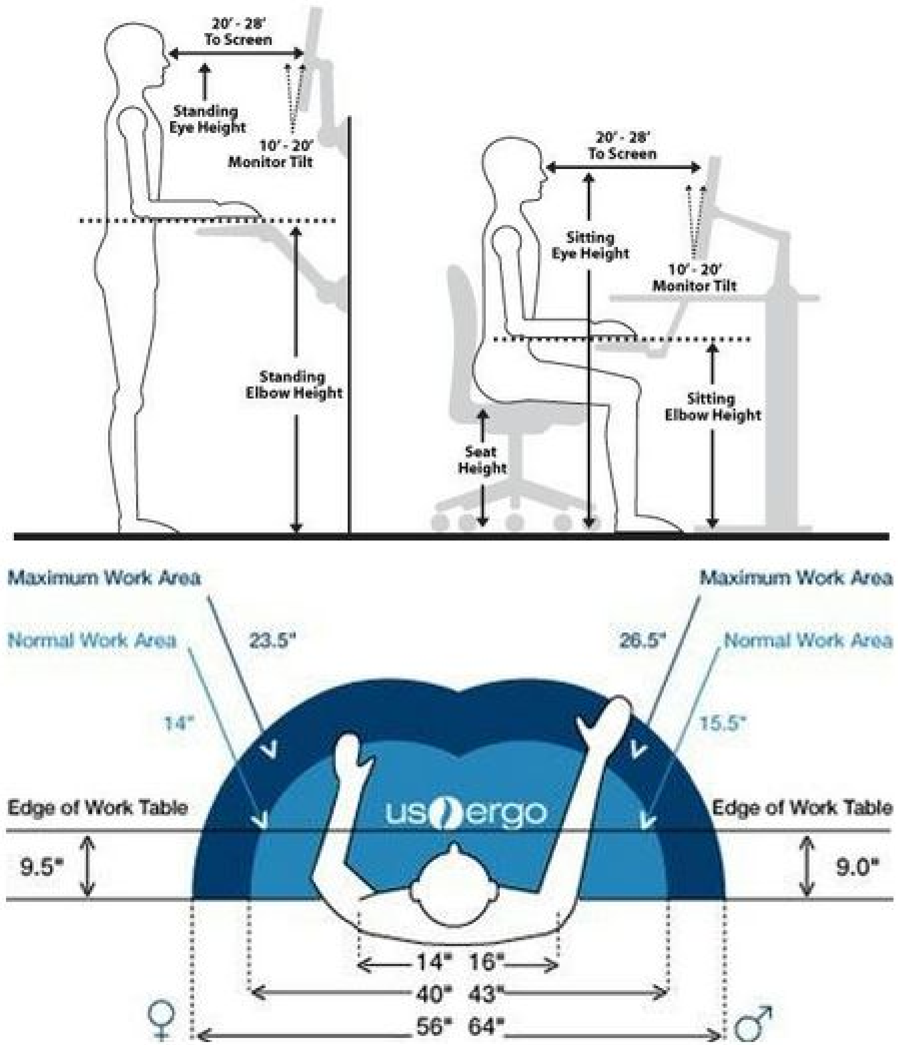
It is not usually practical to design layouts for all users (100%), so when setting the dimensions for a workspace layout use:

- 5th percentile female for minimum values,
- 95th percentile male for maximum values.

Workspace Envelope

A 'workspace envelope' is a 3-dimensional space within which you carry out physical work activities when you are at a fixed location. The limits of the envelope are determined by your functional arm reach which, in turn, is influenced by the direction of reach and the nature of the task being performed. Most of the things that you need to use to carry out your tasks should be arranged within this area.

Workspace envelopes should be designed for the 5th percentile of the user population, which means that 95% of users will be able to reach everything placed within the envelope.



<table>
<tr><th>SITTING</th><th>STANDING</th></tr>
<tr><td>

In general, the maximum work area is the area within comfortable reach of your extended arm, while the normal work area is within the limits of a comfortable sweeping movement of your arm, with your elbow bent at a right angle or less.
You should also consider any potential restraint caused by clothing that you might have to wear, as well as personal factors such as age, gender (women have greater flexibility than men), and any disabilities.
The type of task being performed also affects the boundary of the workspace envelope. For tasks that require the activation of a switch, it is common to use anthropometric measurements from the fingertip reach of the users to set the envelope boundary. However, where a grasping action is involved, the reach of the user is reduced as your fist has to be clenched.

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The limit of the workspace envelope for a standing user can be seen as the space in which an object can be reached and gripped comfortably, when you are standing up straight.
Your arms and hands are most powerful when your elbows are close to your sides and bent at right angles or more, that is, extended slightly. The work surface should allow this kind of posture for manual work requiring strength.
For precise, fine work, as well as for writing, drawing and reading, the work surface should be higher so that the elbows can be rested on it. This will also bring the work closer to your eyes.

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Some general principles for seated work:

Working with relaxed upper arms and elbows at approximately 90° provides comfort and helps maintain straight wrists, which reduces the strain of repetitive tasks.
Adjustable height work surfaces allow each user to fit the work surface to their own needs. If this is not possible, fix the work surface height to be at a level that places the working item, for example, a keyboard, at elbow height.
Make sure that there is adequate clearance for your thighs under the work surface.
Small users whose feet do not touch the floor when seated should have a footrest.
For fine work, requiring better visibility, the work surface can be raised, but elbow support must be provided.

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Some general principles for standing work:

For work that requires the application of force from the shoulder and back muscles, the work surface should be about 100-250mm lower than the level of the elbows.
For normal tasks that do not require much strength, the worktop should be about elbow height or just below.
For precision work, the work surface should be about 50-100mm above elbow height.
Precision work should preferably be done sitting, when the back muscles should be supported and relieved by suitable seating and elbow support. The provision of high stools allow users to alternate between a standing and a 'perched' position.
Adjustable height work surfaces allow each user to fit the work surface to their own needs. If this is not possible, design for the largest user, and supply platforms to those that are smaller.

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Vertical reach is limited by how far you can reach and grasp objects above or below your shoulder height without stretching or bending. Measurement of vertical reach is taken from the surface of your shoulder to the centre of your closed hand (or extended middle finger for button operation). Height of reach is used when positioning shelves for storage, handles or controls above head height.
Horizontal reach is measured in the same way, but about the horizontal plane.

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Clearance, reach and adjustability

Paying attention to ergonomics means removing barriers to productivity. Comfortable users stay at their desks or workstations longer, and complete more work in a given shift.

By adapting tasks, workstations, tools and equipment to fit the user, ergonomics seeks to reduce physical stress on a user's body and eliminate many potentially serious, disabling user-related musculoskeletal disorders (MSDs). If user tasks and equipment do not include ergonomic principles in their design, users may experience physical stress, strain and overexertion, including exposure to awkward postures, forceful exertions and repetitive motion.

Table 1 – MSD Risk Factors	
Force	Exerting excessive force can cause a variety of injuries.
Repetition	Excessive repetition of movements can irritate tendons and increase pressure on nerves.
Awkward postures	Positions that stretch physical limits can compress nerves and irritate tendons.
Static postures	Positions that a worker must hold for long periods of time can restrict blood flow and damage muscles.
Quick motions	Increased speed or acceleration when bending and twisting can increase the amount of force exerted on the body.
Compression or contact stress	Grasping sharp edges like tool handles can concentrate force on small areas of the body, reduce blood flow and nerve transmission, and damage tendons and tendon sheaths.
Recovery time	Inadequate recovery time due to overtime, lack of breaks, and failure to vary tasks can leave insufficient time for tissue repair.
Vibration	Excessive vibration from tools can decrease blood flow, damage nerves, and contribute to muscle fatigue. Whole body vibration can affect skeletal muscles and cause low-back pain.
Cold temperatures	Working in cold temperatures can adversely affect a worker's coordination and manual dexterity and cause a worker to use more force than necessary to perform a task.
Source: Adapted from Ergonomics: The Study of Work, U.S. Department of Labor, Occupational Safety and Health Administration, OSHA 3125, 2000.	

What are aiming for with your design?	Design examples:	Examples of measurements to consider:	Users that your design should accommodate:
Easy reach	Vehicle dashboards, Shelving	Arm length, Shoulder height	Smallest user: 5th percentile
Adequate clearance to avoid unwanted contact or trapping	Service Covers, Cinema seats	Shoulder or hip width, Thigh length	Largest user: 95th percentile
A good match between the user and the product	Seats, Cycle helmets, Pushchairs	Knee-floor height, Head circumference, Weight	Maximum range: 5th to 95th percentile
A comfortable and safe posture	Lawnmowers, Monitor positions, Worksurface heights	Elbow height, Sitting eye height, Elbow height (sitting or standing?)	Maximum range: 5th to 95th percentile
Easy operation	Screw bottle tops, Door handles, Light switches	Grip strength, Hand width, Height	Smallest or weakest user: 5th percentile
To ensure that an item can't be reached or operated	Machine guarding mesh, Distance of railings from hazard	Finger width Arm length	Smallest user: 5th percentile Largest user: 95th percentile

Qualitative Observations Issues in Field Research

Ergonomics for Interaction Designers: Part 3 Rob Tannen

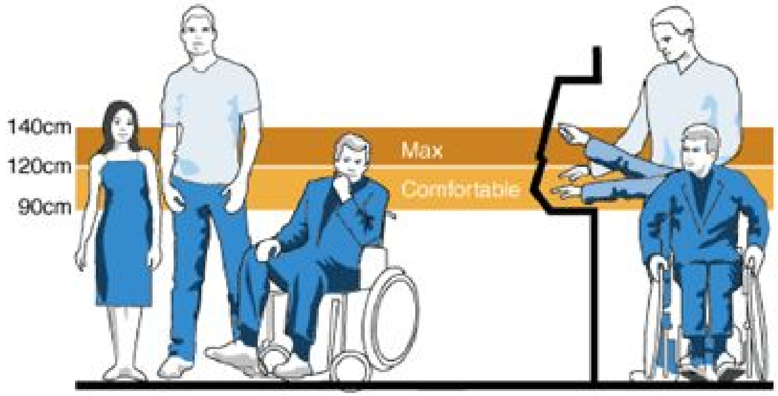
http://www.designingforhumans.com/idsa/2009/01/ergonomics-for-interaction-designers-part-3.html

While interaction designers will typically lack special training in ergonomic assessment methods, most will have some degree of familiarity, if not significant experience with user-centered methods including contextual observation (aka ethnographic field research) and usability testing. All of these methods share objective observation as a common data gathering method, and really only vary in the particular variables or characteristics that are the subject of study. And while anthropometric data is intrinsically quantitative, qualitative observational research can be applied to identify ergonomic issues. With these factors in mind, I've developed a basic set of ergonomic observational criteria to use as guidelines when evaluating design fit. The guidelines are inspired by Stephen Pheasant's cardinal rules of anthropometrics, extended to qualitative field research.

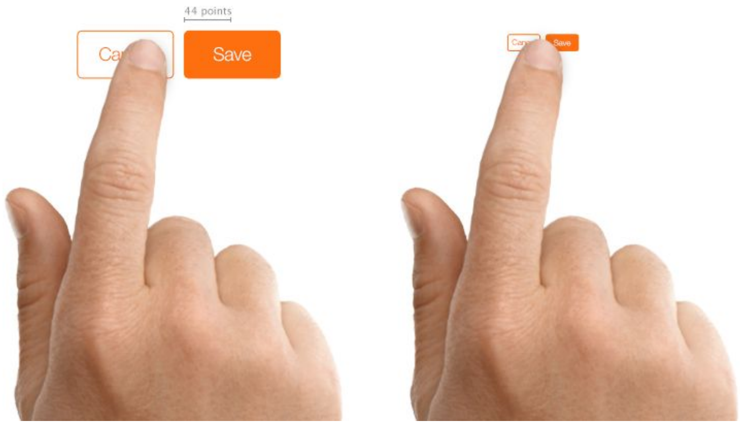
Pheasant advised focusing on Reach, Clearance, Posture and Strength. I'll explain how these can be applied to a consumer electronics device, the InterAction Labs SQWEEZE Game Controller, pictured above. The SQWEEZE is an accessory to the Nintendo Wii - inserting a Wii controller into the SQWEEZE unit allows the user to apply push/pull forces for gaming - think of drawing a bow string to shoot an arrow, for example. While the SQWEEZE was well designed by ergonomics standards, it makes for a good example for explaining the four anthropometric characteristics:

Reach

Reach typically refers to extending the arms and finger for effective control without over-extension. In the case of the airport Kiosk discussed earlier there's a clear potential for placing the touch screen at a height or distance that would be difficult for some people to access effectively.



That type of reach is a non-issue for handheld devices like the SQWEEZE, but other types of reach can come into play. In the case of two-handed devices, the distance between the handles needs to be appropriately set to accommodate a comfortable grip. For the SQWEEZE, this distance actually varied between the push and pull positions as the handles flexed inward and outward respectively. Similarly, the diameter of the handles affects the user's ability to adequately wrap his or her fingers around them; a smaller-scale, but just as important, reach issue.

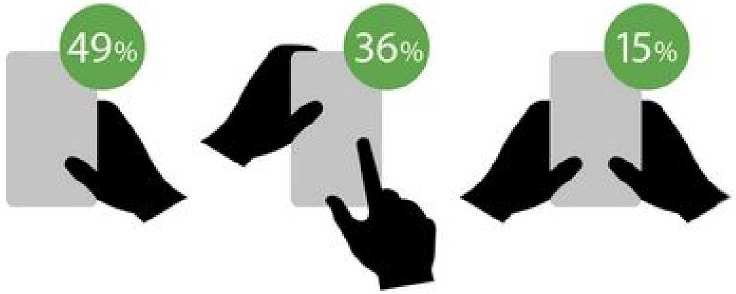


Clearance

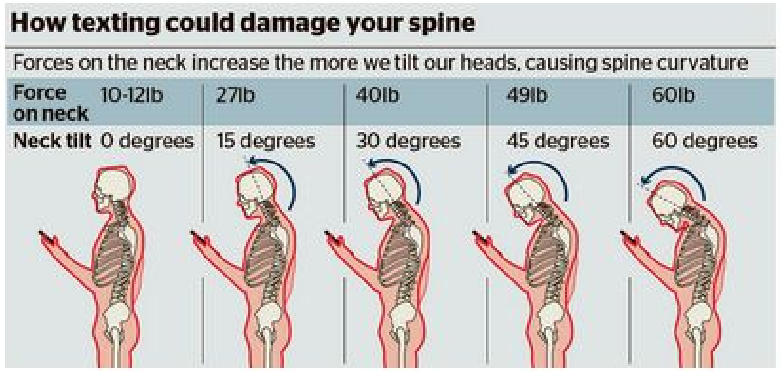
While reach is about making sure things are not too far away, clearance is primarily focused on making sure things aren't too close together. In interaction design terms, we might think of this as literal "white space".   There needs to be adequate room for the hands to move around the handles without bumping into anything, constraining usability or performance. Smaller touch targets are harder for users to hit than larger ones. When you're designing mobile interfaces, it's best to make your targets big so that they're easy for users to tap.

Posture

We tend to think of posture as a full-body issue; standing upright or bending. But in fact posture, defined as deviation from a natural, comfortable position, can be examined at the level of a specific limb or limb-segment. In handheld controllers, wrist posture is frequently the factor of interest. A design that forces the joints into contorted, unconformable positions, particularly for extended periods, is an ergonomic failure.



People hold and interact with mobile phones when performing actions such as playing music, listening to music, and browsing. In a recent study, there were large differences in behaviour: 49% of people held their phones with one hand, 36% literally embrace the phone using one hand to perform an action and 15% held the phone with two hands. People often changed the way they held their phone according to the tasks they were performing.



One-handed users only use their thumb to browse, those who hold the phone with two hands interact with the screen using the thumb or one of the fingers. In total, about 75% of people were interacting with the smartphone using a single thumb.

- Awkward postures – Positions that stretch physical limits can compress nerves and irritate tendons.
- Static postures – Positions that a worker must hold for long periods of time can restrict blood flow and damage muscles.
- Quick motions – Increased speed or acceleration when bending and twisting can increase the amount of force exerted on the body.

Strength

Strength was particularly important for the SQWEEZE as it's essentially a force transfer device. Testing with children indicated the device should not exceed 2.5lbs, but it also had to withstand up to 150lbs of crushing and pulling - the strength of a 90th percentile male. In more general terms, designs should avoid requiring significant exertion by the user, but need to have sufficient resistance to provide feedback and avoid accidental triggering, for example as on a mobile phone keypad.

- Force – Exerting excessive force can cause a variety of injuries.
- Repetition – Excessive repetition of movements can irritate tendons and increase pressure on nerves.

In the case of posture, we might look broadly at how someone approaches a kiosk from an overall body perspective, but then focus more narrowly on the deviation of the hands and fingers. Second, these factors are not independent of each other - in fact they are highly co-influential. For example, if there is limited visual access, then a user may change his or her body and limb postures to accommodate improved field-of-view, but in doing so, increase the extent of reach and reduce the effective transfer strength.

Feedback

Last, but not least, I add a fifth factor which goes beyond the physical, to the perceptual and cognitive: Feedback. Feedback refers to the user's ability to receive input on the impact of their actions on the interface or system. For the SQWEEZE this can mean the tactile, visual and even audible mechanical feedback that corresponds with using the device. For a touch screen kiosk, there is the perceived resistance of the touch service, and the feedback from the software responses.

Putting all this together, a person conducting observational research can use these five factors as a checklist for identifying potential ergonomic problems in real-time, or post-hoc (e.g. with video review).

Measured vs Perceived Fit

In more formal assessment situations, such as usability testing, there are a number of quantitative methods for measuring fit and identifying ergonomic problems or risks. But what seems well-designed on paper doesn't always result in well-received or usable. I've observed numerous situations where the "technical" ergonomic requirements of a design would suggest a good fit, but in reality, the majority of users preferred an alternative. There are various reasons for this ranging from individual differences, to preference for the familiar, to the influence of aesthetic design. It's not the reason for these outcomes that matters so much as the need to capture this input. In other words, it's just as important to measure subjective or perceived fit and comfort, as it is to measure anthropometric fidelity.

A number of surveys and guidelines have become available for measuring perceived comfort.

For example, a basic survey for hand tool comfort that covers factors from ease of use, to performance to....blisters. In practice, it's helpful to use a vetted survey like this as a starting point, and then add and subtract questions based on the particular needs of your product, users and tasks, paying attention to the FoRCePS issues described above. As with any user-research study, piloting and iterating the usability testing approach is as important as iterating the design itself.

Comfort descriptors

This hand tool:	Totally disagree	•	Disagree somewhat	•	Agree somewhat	•	Totally agree
Fits the hand	1	2	3	4	5	6	7
Is functional	1	2	3	4	5	6	7
is easy in use	1	2	3	4	5	6	7
Has a good force transmission	1	2	3	4	5	6	7
Is a high quality tool	1	2	3	4	5	6	7
Has a nice-feeling handle	1	2	3	4	5	6	7
Offers a high task performance	1	2	3	4	5	6	7
Provides a high product quality	1	2	3	4	5	6	7
Looks professional	1	2	3	4	5	6	7
Needs low hand grip force supply	1	2	3	4	5	6	7
Has a good friction between handle and hand	1	2	3	4	5	6	7
Causes an inflamed skin of hand	1	2	3	4	5	6	7
Causes peak pressure on the hand	1	2	3	4	5	6	7
Causes blisters	1	2	3	4	5	6	7
Feels clammy	1	2	3	4	5	6	7
Causes numbness and lack of tactile feeling in hand	1	2	3	4	5	6	7
Causes cramped muscles	1	2	3	4	5	6	7

Jam Jar Lid Case Study - Can't get the jelly jar open? By Lisa M. Martin

For the young, jar opening is generally a fairly small hassle of everyday life. For the elderly, the problem is greatly magnified. For instance, in a 2002 study1 in the Netherlands of 123 subjects aged 20-30 years and 627 subjects aged 50 or above, all of whom lived independently and had not required medical consultation in the three months prior to the study, 16.2% of the older subjects described themselves as having great difficulty opening jars, while 3.8% could not open them at all without help. Only 47.8% of the older subjects described themselves as having no problems.

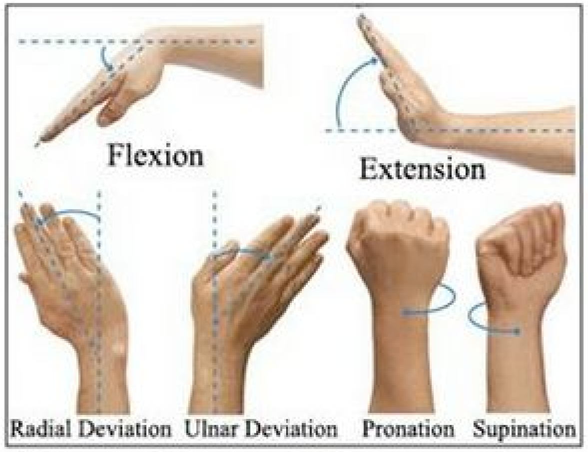


Figure 1: Primary wrist/forearm motions.

In the case of standard glass jars with circular lids, the problem lies in one's inability to apply sufficient torque (twisting force) to the lid using a combination of three primary wrist/forearm motions,2 as shown in Figure 1.

Though most of us assume that we open jars the "right" way, the breadth of "right" ways is actually quite large. In a study, 4 of 50 subjects opening jars with various lid diameters, researchers at the University of Sheffield found six distinct grip types, illustrated in Figure 2, in use: spherical, box, lateral, cylindrical, cylindrical with ring finger, and flipped cylindrical.

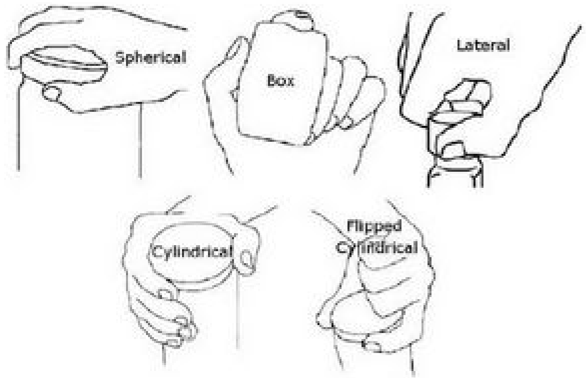


Figure 2: Illustration of grip types.[3,4]

As shown in Table 1, the selected technique varied with jar size. Beyond grip type, the hand placed on the lid varied even within same-handed sets of subject. In the previously mentioned Dutch study, nearly 78% of the right-handed subjects gripped the jar with their right hand and the lid with their left, while approximately 73% of lefties did the opposite.

Grip Type	Gherkin Jar (85 mm)	Curry Jar (75 mm)	Olive Jar (60 mm)
Spherical	24	19	13
Box	18	19	8
Lateral	5	7	20
Cylindrical	3	2	9
Cylindrical with Ring Finger		2	
Flipped Cylindrical		1	

Table 1: Preferred grip types of 50 subjects for various jars.[3]

This great variation in preferred technique complicates research into jar opening, and studies often must place restrictions on the way in which subjects open jars in order to standardise the test and/or acquire the desired measurements. This, of course, leads to unrealistic opening motions. In the Dutch study, however, subjects were allowed to hold the jar as they wished, using their preferred posture and, if desired, a surface on which to rest the jar. A special jar based on the dimensions of a jam jar found in Dutch supermarkets and rigged up with a torque transducer to measure the magnitude of the twisting force applied to its lid was used. Unsurprisingly, the force generated varied by age and gender, with the maximum recorded torque being 16.3 Nm and the minimum being 0.7 Nm. For the younger group, the mean and standard deviation for men and women were, respectively, 8.7 +/- 2.2 Nm and 5.6 +/- 1.4 Nm. Arbitrarily choosing the 70-74 year age group for comparison, one sees a decline to 5.4 +/- 2.1 Nm and 3.7 +/- 1.1 Nm, respectively. How does this relate to the real world? A Dutch jam producer cited in the study measured required opening torque for their jars to be between 2.9 and 5.5 Nm, numbers which corroborate the opening difficulties described by many study subjects.

Given what we know about jar opening kinematics; grip styles; and finger, hand, wrist, and forearm muscle strengths, what is the optimal approach to opening a jar? It seems there is no clear answer; but disregarding the effect of body and upper arm movements, results of studies on specific grip styles or relevant motions can provide tips:

- Those of us in the majority as spherical or box grippers should note that the radial deviators of the wrist can generate a greater moment than the ulnar deviators, 5 indicating that the right hand should be on the lid (assuming the lid hand provides the majority of rotation, while the jar hand is a stabiliser).

- Cylindrical grippers should note that one can generate a greater torque rolling the hand in the direction the fingers point when wrapped around the grip than in the reverse (33% more for a low-friction aluminium grip, or 53% more for a high-friction rubber grip),6 again indicating that the right hand on the lid would be most efficient.
- All grippers should consider the surface area of the hand/fingers in contact with the lid, as a greater contact area will lead to greater torque transfer (given constant grip strength and coefficient of friction)
- Finally, flipped cylindrical grippers may want to consider a new grip (only 1 in 50 used it, so I'll unscientifically suggest it's probably not a great idea!); and cylindrical with ring finger grippers might want to follow suit—as any pianist will confirm, the ring finger is notoriously weak.

http://www.brilliantbiomed.com/2009/09/cant-get-jelly-jar-open_19.html