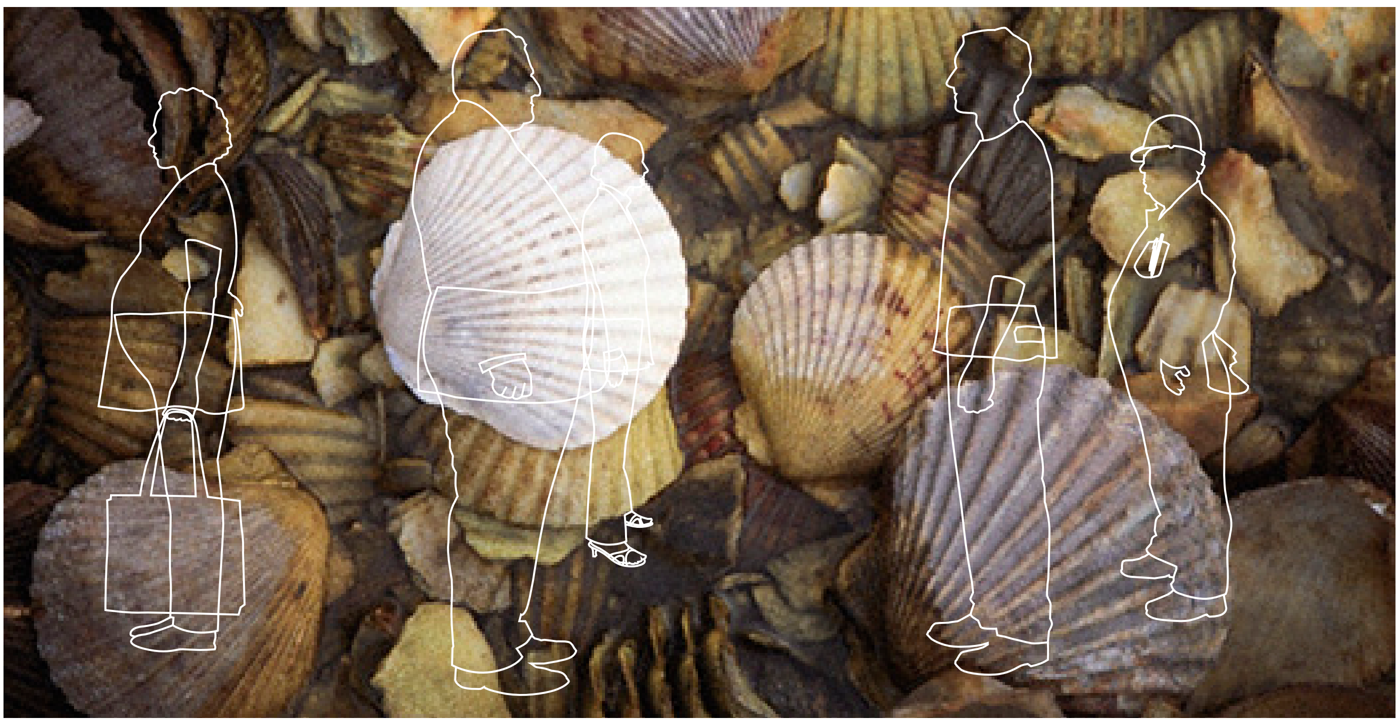
The Anthropometrics of Fit

ERGONOMIC CRITERIA FOR THE DESIGN OF THE AERON® CHAIR



A chair should fit the body like a piece of clothing. Ideally, a work chair should provide the personal fit of a shirt or a pair of pants. People shouldn't be required to "wear" chairs that are too big or too small.

What We Know

People vary widely in all their dimensions. Improperly fitted chairs can cause discomfort and contribute to health problems. People on the edges of the "normal" distribution curve for any dimension may not be well served by work chairs designed for people at the center of the curve.

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 99thpercentile 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 men 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.

Achieving a match between certain body dimensions and corresponding chair dimensions is crucial to the sitter's comfort and health. The wrong seat height can cause uncomfortable pressure on the backs of the thighs (Bush 1969). A seat pan that is too wide or too deep may prevent the sitter from taking advantage of armrests and backrest contours that help to transfer weight from the spine (Occhipinti et al. 1985, Andersson et al. 1974).

Most work chairs are designed on a "middle-out" model of anthropometrics intended to accommodate the middle 95 percent of the user population: from the 5th-percentile female to the 95th-percentile male. However, as British ergonomist Stephen Pheasant points out, there is no true 5th- or 95th-percentile person; someone who is at the 95th percentile for stature is likely to be at a different percentile on distribution curves for lower leg length or sitting elbow height. So a chair designed to accommodate the middle 95 percent on each of a succession of important dimensions could conceivably exclude a different 5 percent of users with each anthropometric constraint. The end result would be a chair that accommodates considerably less than 95 percent of its potential users.

Compounding the problem is the fact that the anthropometric data used by chair designers do not necessarily reflect the total adult population that will be using their product. This makes it virtually impossible to determine the actual percentage of users that will be fit for any given dimension. Commonly accepted anthropometric tables are based on samples of military personnel which (due to entry and retention criteria for size, age, and physical condition) tend to exclude very large and very small persons. Analyzing our own random sample of the U.S. civilian population, we found that a chair designed for the 5th-percentile female to 95th-percentile male—as defined by standard anthropometric data published by the U.S. military (Gordon et al. 1988)—would actually fit slightly less than 68 percent of the sample, even when considering only the four most crucial seating dimensions.

Using a measuring device we developed to gather our own anthropometric data, we took seven important measurements:

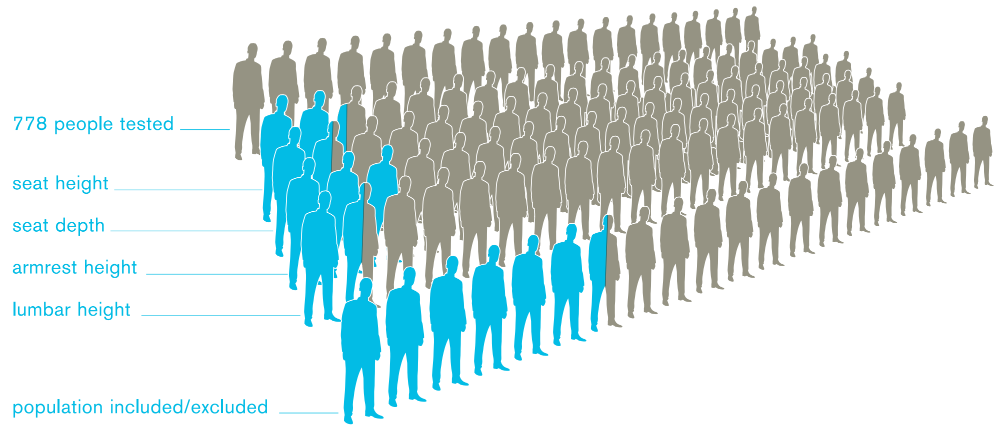
- popliteal height (lower leg length)
- seat depth (buttock to popliteal length)
- hip breadth
- midshoulder sitting height (back height)
- elbow height
- lumbar height
- lumbar depth

Of the 778 people we measured (Dowell 1995a), the 5th to 95th range excluded 11 percent for popliteal height, 7.5 percent for buttock-to-popliteal length, 15 percent for elbow height, and 7 percent for lumbar height. Taken all together, almost one-third of our sample had at least one dimension out of four that was either smaller than the 5th-percentile female or larger than the 95th-percentile male. / See Figure 1 /

Therefore

To be truly supportive of a large percentage of the working population, a work chair must accommodate people outside the 5th to 95th percentiles on distribution curves for several relevant body dimensions.

/ Figure 1 / Chairs theoretically designed to fit the 5th-percentile female to the 95th-percentile male actually fit far fewer people.



Population not accommodated

Population accommodated

Design Problem

Design a chair that fits smaller and larger people as well as it fits "average" people.

Most work chair designs try to accommodate people of different sizes and shapes with a series of mechanical adjustments. These adjustments have some obvious physical limitations. For example, while the variation in lower leg lengths of the adult American population spans more than six inches, chair height adjustment mechanisms generally are not engineered to provide more than four-and-one-half inches of adjustment.

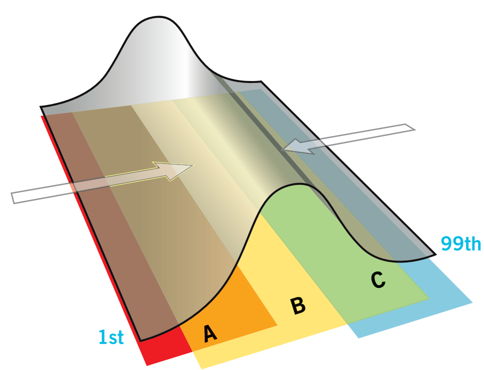
A chair that is designed to meet the needs of the hypothetical 50th-percentile person becomes less and less accommodating as it is adjusted toward the requirements of the (equally hypothetical) 5th-percentile female or 95th-percentile male. In addition, our own field observations indicate that the greater the range of adjustment provided, the greater the chance that a person will use the chair at an inappropriate setting. People are more likely to get proper support from a chair that requires only minor adjustments to fine-tune the fit.

Design Solution

Provide the same chair in three sizes; make the seat and backrest of material that automatically accommodates differences in body shape.

Concluding that no single chair could cost-effectively provide the necessary adjustment ranges to fit the 1st to 99th percentile for every important seated dimension, we designed the Aeron chair in different sizes, like a bicycle or a pair of shoes. Instead of following the traditional "middle-out" model, we took an "ends-to-the-middle" approach, / See Figure 2 / designing the smallest chair for the smallest user, the largest chair for the largest user, and, finally, a midsized chair to cover the range not accommodated by these two. By designing first for the extremes, we developed a chair that gives virtually every person a reasonably good fit, even if it's never adjusted. The range of fine-tuning adjustment required for each chair becomes both easily manageable and mechanically feasible.

To determine what the dimensions of the three chair sizes should be, we used available anthropometric data and collected our own. Based on our findings, we scaled the chair in three sizes. The A-size chair is designed to fit a 1st-percentile female for each of seven important dimensions. It adjusts to get larger. The C-size chair is designed to fit a 99th-percentile male in each dimension and adjusts to get smaller. / See Figure 2 /

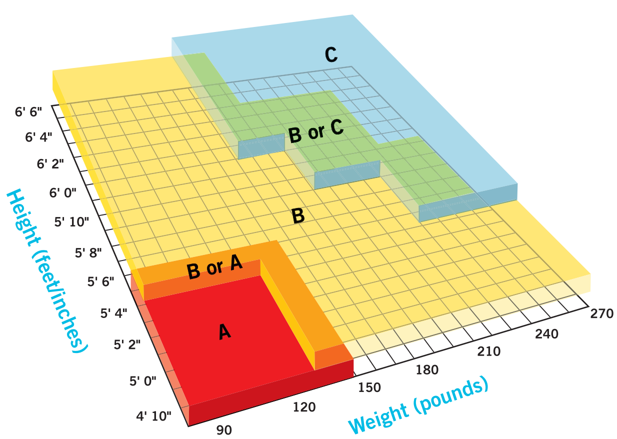


/ Figure 2 / An "ends-to-the-middle" approach to ergonomic design optimizes fit for people at the extremes as well as those at the peak of the anthropometric curve. The result is one chair in three sizes to fit users from the 1st-percentile female through the 99th-percentile male.

We built in the most adjustability for the dimensions where we found the greatest variation. For example, we found a considerable amount of diversity in lumbar heights (Dowell 1995a), so we designed a lumbar pad for the Aeron chair that allows an appropriate range of height adjustment within each of the three chair sizes.

In comparison to a chair designed for the 5th-to-95th percentiles, a 1st-to-99th design fits a surprisingly greater percentage of an actual user population. Applied to our own previously cited sample of 778 U.S. civilians, a 1st-to-99th design fit 95 percent of the sample on all four crucial dimensions, compared to the slightly less than 68 percent that would have been fit by a 5th-to-95th design.

Subsequent field studies using our measuring device examined the relationship between sizes of people and their preference for chair size (Dowell 1995b). Measurements of 224 people— in a sample that was evenly distributed between men and women and that closely reflected the distribution of the U.S. population on most dimensions—found that of all the anthropometric dimensions measured, height and weight had the strongest relationship to chair size preference. The relationship is strong enough to allow us to recommend a chair size based on those dimensions.
/ See Figure 3 /



/ Figure 3 / Aeron size recommendations based on user's height and weight

A person sitting in an appropriately sized Aeron chair begins with a fit that is fairly close to perfect. Adjustments for seat height, lumbar height and depth, arm height and width, and tilt tension enable the sitter to fine-tune chair dimensions and performance to personal preferences. Finally, the unique stretch of the resilient Pellicle® material of the seat and backrest automatically conforms to individual body contours.

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Credits

Bill Stumpf studied behavioral and physiological aspects of sitting at work for more than 30 years. A specialist in the design of ergonomic seating, his designs include the Ergon® chair introduced by Herman Miller in 1976 and, with Don Chadwick, the equally innovative Equa and Aeron chairs.

Codesigner of two groundbreaking ergonomic work chairs for Herman Miller, *Don Chadwick* has been instrumental in exploring and introducing new materials and production methods to office seating manufacture.

Bill Dowell, C.P.E., leads a team of researchers at Herman Miller. His recent work includes published studies of seating behaviors, seated anthropometry, the effect of computing on seated posture, the components of subjective comfort, and methods for pressure mapping. Bill is a member of the Human Factors and Ergonomic Society, the CAESAR 3-D surface anthropometric survey, the work group that published the BIFMA Ergonomic Guideline for VDT Furniture, and the committee that revised the BSR/HFES 100 Standard for Human Factors Engineering of Computer Workstations. He is a board-certified ergonomist.

For more information about our products and services or to see a list of dealers, please visit us at www.HermanMiller.com or call (800) 851 1196.