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ANTHROPOMETRY FOR PERSONS WITH DISABILITIES: NEEDS IN THE TWENTY-FIRST CENTURY

Bruce Bradtmiller, Ph.D.
Anthrotech
Yellow Springs, Ohio

ABSTRACT

Anthropometry, the study of human dimensions, is useful for product and workspace design. Anthropometric data for people with disabilities is largely fragmented and difficult to use. We assess the current state of anthropometric research on people with disabilities and identify where the resources fall short of the needs. We outline a program for addressing those needs.

INTRODUCTION

Anthropometry, the study of human dimensions, has many uses in design. Since its ascendancy in the period following World War II, engineering anthropometry has been used to aid in the design of aircraft cockpits, automobile interiors, office and factory workstations, as well as homes and public buildings. What unites that list of domains is that they are all workspace dimensions – a place that the human must fit into. Anthropometry can also be used to aid in the design of products which fit onto the wearer. Examples include general clothing, protective clothing, helmets of many types, gloves, masks, shoes, boots and so on.

The design of products to fit onto the wearer is often characterized by sizing. That is, a bicycle helmet may be available in three sizes. Yet the design of workspaces, including all those domains listed above, are generally not sized; all human diversity is to be accommodated with only one size. There is one height for a doorway; there is one height for a counter in the kitchen. There is often one place from which the assembly-line worker must reach his part or her tool. Some workspaces are adjustable. One can think of so-called ergonomic office seating, or the 6-way power seat found in many automobiles. Newer factories have adjustable workstations, even on the assembly line. Adjustability has generally not found its way into the home environment, however.

Clearly, people with disabilities exhibit anthropometric variability; in some critical dimensions, like reaches, people with disabilities show greater variability than others. Yet designers often do not include this important and variable population in a design unless they are specifically designing a wheelchair-accessible restroom or other targeted space. For the most part, designers, architects and building planners have not deliberately avoided accommodating people with disabilities; they have been hampered by a lack of appropriate anthropometric data on which to craft a truly universal design. This paper will document current anthropometric resources on people with disabilities, and identify what needs still exist. I will close by outlining a research plan designed to address those needs.

CURRENT RESOURCES

There are a number of studies on basic anthropometry of people with disabilities and of the elderly. Most of these have relatively small sample sizes (under 100), which make it risky to generalize to a whole population for design purposes (1, 2). Some have larger samples, but are not from U.S. populations, and are therefore of limited utility (3). Still others (4) have adequate sample sizes, but have dimension lists that are focused on specific applications such as seating, so the usefulness of the resulting data base is restricted.

More than the lack of dimensions and small sample sizes, there is a problem in comparability of dimensions among studies. In an extensive review, Goswami (5) found that there was little uniformity or standardization among measurement techniques. This makes it impossible either to compare data from different studies, or to combine data from different studies to approximate a national general data base.

A number of the studies cited above compared a disabled sample to a non-disabled sample, either measured by the same techniques or taken from the published literature. In every case, the conclusion was drawn that there are important differences between the disabled and non-disabled populations. These differences are sufficiently large that the plentiful anthropometric data available for the non-disabled population should not be used for design tasks where the intended user population has a variety of disabilities.

It is now becoming understood that the very measurement techniques used for the non-disabled population are inappropriate for the disabled population. This is because standard procedures often require specific subject positions that this population may not be able to hold. Reaches, for example, a critical class of design dimensions, are very different when the starting position is sitting in a wheelchair instead of standing. There has been some work on developing appropriate techniques (6, 7), but these tend to be fairly application specific. Further, as Goswami (5) pointed out, there is little correspondence between techniques developed in different laboratories.

There is a fair body of literature on range of motion and kinematics (8). Because of the intense and time-consuming nature of data collection in this field, sample sizes over 20 individuals are rare. This makes generalization to the population difficult. I might also add that some of this information is misplaced with respect to design. Specifically, much of the effort is directed towards the path a limb takes from point A to point B. That pathway information is very useful clinically and therapeutically, but is considerably less important from a design point of view. We need to know how far away we can place the object at point B; we generally do not need to know how the user gets his or her limb to that point.

Finally, there have been some anthropometric studies aimed specifically at product and design. A number have focused on ramp design and placement (9), and others on the design of wheelchairs (10). The work in seated workspace design has centered on computer workstations (11). The limitation of all these studies is that the number of dimensions is restricted, quite reasonably, to the focus of the specific design. The result of this focus, however, is that there is no general large data base of Americans with disabilities.

NEEDS ASSESSMENT

A major nationwide anthropometric survey of individuals with disabilities should be conducted. Such a study would be designed to collect information including body sizes, reach capabilities, range of joint motion, strength, and visual field data from several thousand children and adults, aged two and older with a wide variety of disabilities. The resulting database would be widely useful to engineers, architects, designers, and manufacturers of products that allow people with disabilities and the elderly to live independently. Such an undertaking would, of course, require a large number of dollars. But compared to the current loss of human potential due to the inaccessibility of jobs, workspaces and living spaces, and the inadequate or unsafe fit of protective products, the dollar cost is relatively low. Certainly the cost-benefit analysis for such a survey would be extremely positive. We recommend the large survey here as a long-term goal. There are a number of ways to achieve the goal. One of these is cooperative government and industry funding. This mechanism is becoming more frequently used in other arenas, and should work here as well.

For the time being, we are recommending a pilot study whose purposes would include: 1) to provide specific anthropometric data on a general U.S. population of people with disabilities; and 2) to provide the groundwork to support expanded anthropometric surveys in the future by establishing sampling strategies, and by standardizing measuring techniques and data handling procedures.

A PROSPECTUS

An anthropometric survey of this population presents a variety of challenges not encountered in similar studies of non-disabled subjects, but on the whole, planning and organization are the same for both. The major tasks to be completed in the planning stage of any survey are the following:

- Select the target population.
- Establish a sampling strategy.
- Select and define the dimensions to be measured.
- Establish and test measuring techniques.
- Determine allowable errors for measuring each variable.

Target Population

One of the drawbacks of previous studies is that they have been very specific in nature. While each was scientifically sound for its purpose, the limited scope makes it difficult to generalize to the larger population. That said, perhaps the most difficult problem presented by this population is its diversity. Disabilities may be caused by a wide variety of diseases and injuries, as well as environmental and congenital conditions. Although a full-scale survey should be very general, and not limit the nature of disability, it may make sense to limit the population in a pilot study. However, one of the critical purposes of any anthropometry pilot study is to discover the amount of the variation that will need to be sampled in the full-scale survey. So, if the pilot study population is to be limited, then it should be limited in a way that will preserve the anthropometric variability present in the larger population. It may be that the earlier studies may provide some guidance in how best to accomplish this.

Recruitment of appropriate subjects must be carefully planned for, even when such subjects are widely available. In this case, appropriate subjects are not widely available. Arrangements will have to be made to seek out appropriate subjects in places where they are likely to be found in some numbers. One goal of major nationwide surveys is to maximize the diversity of the target population in the sample, not only with regard to sex, age, and racial/ethnic diversity but also with regard to geographic spread. For a pilot study – and perhaps even for larger future studies – geographic diversification is not likely to add anything useful to the variability of the sample. It should be possible to recruit enough subjects in or near any large city.

Sampling Strategies

Sampling involves the process of selecting a group of individuals thought to be representative of an entire population. To put it another way, the small number of individuals in a given sample must reflect a significant amount of the variability extant in the entire population. Accurate sampling is critical to the creation of a database that can be applied successfully to the purposes for which it is intended. As has been noted, the variability of the target population in this country is very great.

There are a number of sources of information on the size of various U.S. populations with disabilities, including the National Health Interview Survey (NHIS). Publications of various associations representing specific disabilities also produce statistics, but these reports do not give the kind of categories that would be useful in developing a sampling plan.

Ordinarily in sampling for anthropometric surveys, a multi-dimensional matrix is drawn up to make sure that all critical sources of anthropometric variability are accounted for in the eventual sample. In the Army's most recent anthropometric survey, for example (12), the matrix included sex, race and age. This is because these three demographic parameters account for much of the anthropometric variability in a non-disabled population. While the matrix approach is useful for the population of interest here, the same three parameters are not particularly effective. This is because the type of disability has much more to do with eventual body size and shape differences than does race. Age and sex are still important in defining a population of people with disabilities, so those parameters remain.

Dividing a wheelchair population into significant groups for sampling purposes is problematic. One approach is that suggested by Kumar (13) in Table 1. When developing this into a sampling strategy for a pilot study, one would select the most frequent 4 or 5 conditions, and group the rest into a category "Other". For a full-scale survey, with a more complex sampling strategy, one would be able to use more specific categories, and reduce the number in the "Other" group. Following this scenario, a sampling matrix might look like the one shown in Table 2. This is based on a total sample of approximately 250 subjects of a single sex. The figure would be repeated for the other sex, for a total of 500 subjects.

TABLE 1
Frequency of Medical and Physical Conditions Necessitating Wheelchair Use

CONDITION	PERCENT
Arthritis	28
Organic nervous disorder	14
Cerebral vascular disease	13
Bone injuries and/or deformities	11
Lower limb amputation	9
Cerebral palsy	8
Traumatic paraplegia	7
Respiratory and cardiovascular disease	5
Obesity, congenital errors, spinal injury	5

TABLE 2
Hypothetical Sampling Matrix

AGE	ARTHRITIS	ORGANIC NERVOUS	CEREBRAL VASCULAR	BONE INJURIES	OTHER	TOTAL
18-25	17	9	8	7	21	62
26-38	18	9	8	7	21	63
39-50	17	9	8	7	21	62
50-65	18	8	9	8	22	65
TOTAL	70	35	33	29	85	252

Kumar's distribution is based on data that were gathered in the U.K. Similar information for the U.S., if available, should be used in an actual sampling plan.

There are a number of ways to establish a reliable sample size. These include the familiar power curve, as well as formulas that estimate a specific *n*. In either case, the results will be largely

the same. The assumption in either approach is that we understand the level of anthropometric variability in the population. That is why we should not artificially reduce variability in a pilot survey. We need to have the results of the pilot survey to estimate accurately the variability in the population as a whole.

Selection of Dimensions

Based on our survey of the literature, and contacts with people working in the area, the single most needed anthropometric datum, by far, is arm reach. Sitting height is also important for drawing up standards, as are some dozen other assorted variables such as grip strength and foot length. Planning and executing even a relatively small anthropometric survey is a costly undertaking, and if it is to be done, the addition of a reasonable number of variables for which there will clearly be other uses, such as wheelchair design, will not significantly add to the cost. For this survey we suggest variables that fall into five categories:

- basic body size descriptors
- reach and functional reach measurements
- arm and hand strength measurements
- field of vision measurements
- wheelchair-plus-user measurements

A recommended dimension list is available but space does not permit its inclusion here.

Measurement Techniques

This can be one of the most important outcomes of the pilot study. We can envision a cooperative nationwide full-scale study conducted simultaneously by a number of investigators. While this is not as desirable as having the same investigators collect all the data, it might be an acceptable and more cost-effective alternative. Such an approach is only feasible if each investigative team uses exactly the same measurement techniques. This is why the sound development and clear documentation of measurement techniques is so critical, and why this can be one of the most critical results of the pilot study.

We recommend developing the techniques in conjunction with users of the anthropometric data. This will assure that dimensions are defined in the most effective way. At the same time, it is important to define the dimensions to minimize the opportunity for observer error. Although it has not been feasible until recently, we now recommend documenting measurement techniques using a digital video camera. Images and clips can then be easily shared with other investigators over the internet. We also recommend establishing allowable observer error for each dimension. This will allow new investigators to judge whether their practice has been sufficient and whether they are ready to begin actual data collection.

CONCLUSION

The development of a nationwide anthropometric data base for people with disabilities is a crucial component for the successful accommodation of this population. As such a survey would be a significant undertaking, we have recommended beginning with a pilot study, and have outlined some of the factors which need to be considered in planning a successful anthropometric survey.

In the longer term, we see the results of this data collection being used to drive the development of digital human models. Such models will be the design platform in coming decades.

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Bruce Bradtmiller
Anthrotech
503 Xenia Avenue
Yellow Springs, OH 45387