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Computer re-sampling for demographically representative user populations in anthropometry: a case of doorway and clear floor space widths

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Abstract. Anthropometric studies typically require a large number of individuals that are selected in a manner so that demographic characteristics that impact body size and function are proportionally representative of a user population. This sampling approach does not allow for an efficient characterization of the distribution of body sizes and functions of sub-groups within a population and the demographic characteristics of user populations can often change with time, limiting the application of the anthropometric data in design. The objective of this study is to demonstrate how demographically representative user populations can be developed from samples that are not proportionally representative in order to improve the application of anthropometric data in design. An engineering anthropometry problem of door width and clear floor space width is used to illustrate the value of the approach.

Keywords: anthropometry, engineering anthropometry, computer re-sampling

1. Problem definition

Ergonomists use anthropometric information to specify product and environmental requirements that are designed to accommodate user groups. Anthropometric studies are often time-consuming and expensive, requiring large numbers of individuals that are selected in a manner so that demographic characteristics such as gender, age, and ethnicity that may impact body size and function are proportionally representative of a potential or "target" user population [1] for a specific application.

This type of sampling approach does not allow for an accurate characterization of the distribution of body sizes and functions of small population subgroups who may become at some point the primary user populations for environments or products. Additionally, the demographics of user populations often change with time, and therefore anthropometric databases can become outdated.

The United States Americans with Disabilities Act Accessibility Guidelines (ADAAG) provides standards for the design of public built environments [2]. The minimum dimensions for door clearance and clear floor space widths were established in part based on the measured widths of manual wheelchairs users collected in the 1970s [3]. The current ADAAG requires 810 mm of clear width in doorways and 760 mm of clear floor space widths in a variety of other design specifications.

Since this time, a number of wheeled mobility technologies have been developed. These include such technologies as bariatric wheelchairs, power wheelchairs and scooters that have over the years become increasingly more popular. Recent anthropometric data about the sizes and function of manual and powered wheeled mobility device users suggests

Table 1.
Wheeled mobility device user groups as a percentage of the total sample (n=369) used in the anthropometric analysis of doorway and floor clearance widths.

Age	Gender	Manual Chair	Power Chair	Scooter	Total
18-64	Male	26.0%	18.2%	2.7%	46.9%
	Female	13.8%	13.3%	2.4%	29.5%
65 and over	Male	5.7%	3.8%	1.4%	10.8%
	Female	7.3%	4.3%	1.1%	12.7%
Total		52.8%	39.6%	7.6%	100.0%

Table 2.
Wheeled mobility device user groups as a percentage of the total population of wheeled mobility device users in the United States from previous studies [7, 8].

Age	Gender	Manual Chair	Power Chair	Scooter	Total
18-64	Males	16.1%	2.6%	1.8%	20.5%
	Females	17.0%	2.7%	3.1%	22.8%
65 and over	Males	17.2%	0.9%	1.8%	20.0%
	Females	33.0%	1.8%	1.9%	36.7%
Total		83.3%	8.1%	8.7%	100.0%

that powered wheeled mobility device users may require on average more space than manual wheeled mobility device users [4, 5].

The objective of this study is to demonstrate how demographically representative user populations can be developed from samples that are not proportionally representative in order to improve the application of anthropometric data in design. The methods are used to evaluate the U.S. standards for public doorway and clear floor space widths in order to illustrate the approach.

2. Method

Overall width was recorded for a sample of 369 manual wheelchair, power wheelchair and scooter users with an electromechanical measuring device [4, 6]. The sample was deliberately not proportionally representative of the U.S. population of wheelchair users in terms of device type used, age and gender in order to allow a large number of powered mobility device users to be included in the sample (see Tables 1 and 2). This sampling approach allowed a reasonable characterization of the distribution of body sizes and abilities of powered wheeled mobility device users, which may be valuable when attempting to design for this user group. However, it would not be advisable to use the overall sample to estimate of the percentage of U.S. wheeled mobility device users that would be accommodated by different doorway or floor clearance widths without accounting for the disproportionate sampling.

Matlab® software [9] was used to perform a "two-stage" statistical bootstrapping approach for which the sample of 369 device uses was re-sampled to create subsamples of 81 that were proportionally representative of the U.S. population of wheeled mobility device users in terms of gender, age (18-64, 65 and older) and device type used (manual chair, power chair and scooter). For each newly created subsample, the percentile values of the distribution for wheeled mobility device user width were recorded. This process was repeated 4000 times so that the error in the estimation of the mean and variability of the overall width due to the sampling approach could be assessed statistically.

The distributions of each of the widths for the demographically representative group and for each device user subgroup were then compared to the U.S. ADAAG clear doorway and clear floor space width requirements. The design standard was considered adequate if the required width clearance was larger than the 90th percentile values of the overall widths for the demographically representative group and for each of the device user subgroups.

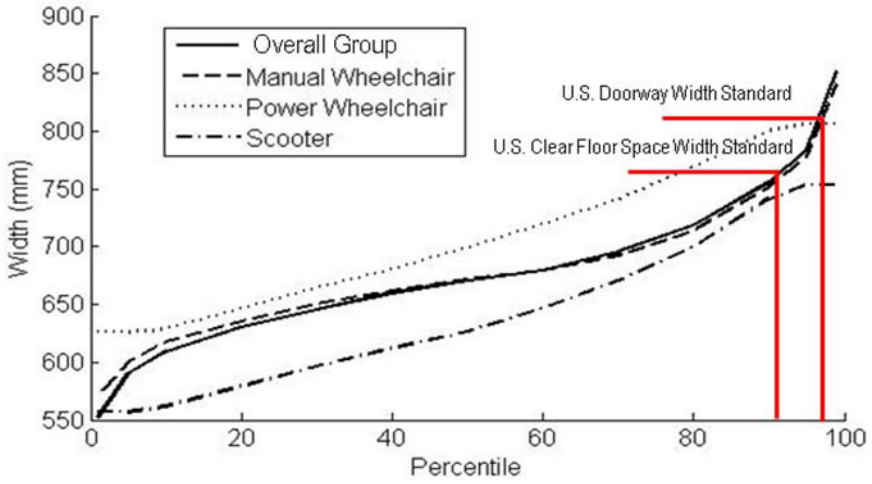

Fig 1. Percentile distributions of wheeled mobility device user widths for the demographically representative group and for each of the device user subgroups.

3. Results

The results demonstrated that the distribution of overall widths for the samples of wheeled mobility devices users that was representative of the U.S. population in terms of device type, age gender and age was on average lower than the initial sample, and closely followed the distributional properties of the sample of manual wheeled mobility device users (Figure 1). This was expected, due largely in part to the large percentage of manual wheeled mobility device users in the U.S. [8].

The U.S. standards for doorway widths were greater than the 90th percentile values of widths for the demographically representative group and for all of the device user subgroups. The U.S. standard for clear floor space was greater than the 90th percentile values for the demographically representative group, manual chair users and scooter users. However, approximately 20% of powered mobility device users had widths that exceeded the U.S. clear floor space width requirement.

4. Discussion

The approach described in this paper can be used for the anthropometric study of both an overall user group that is proportionally representative in terms of predetermined demographic variables and individual subgroups. Based on the design criteria applied in this study, the approach demonstrated that the overall population and individual subgroups of wheeled mobility users are accommodated in the doorway widths. However, a disproportionate number of powered wheeled mobility device users appear to be excluded in floor clearance width standards. The results suggest that the clear floor space requirements should be increased when powered wheeled mobility device users are the primary user group or in the future if the proportion of wheeled mobility device users grows to more significantly impact the overall wheeled mobility device user width dimensions.

One important methodological assumption of the computer re-sampling technique is that each subgroup is anthropometrically representative of its "subgroup population". There will be error in the generation of the demographically representative group's distribution when the anthropometric data set contains subgroups that are not anthropometrically representative of their respective "subgroup populations".

Nevertheless, these methods can assist engineers and policy makers who use anthropometric data of multiple subgroups when developing design specifications, or change design specifications as population demographics change.

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References

[1] HFES 300 Committee, Guidelines for Using Anthropometric Data in Product Design. Human Factors and Ergonomics Society: Santa Monica, CA, U.S., 2004.

[2] U.S. Architectural and Transportation Barriers Compliance Board, Americans with Disabilities Act (ADA) Accessibilities Guidelines for Buildings and Facilities: Washington, D.C., 2002.

[3] E. Steinfeld, S. Schroeder. and M. Bishop, Accessible Housing for people with walking and reaching limitations, Washington, DC: U.S. Department of Housing and Urban Development, 1979.

[4] V. Paquet and D. Feathers, An anthropometric study of manual and powered wheelchair users, International Journal of Industrial Ergonomics, 33 (3), 2004, 191-204.

[5] C. D'Souza, E. Steinfeld, V. Paquet and D. Feathers, Space requirements for wheeled mobility in public transportation: analysis of clear floor space requirements, Transportation Research Record: Journal of the Transportation Research Board, 2145, 2010, 66-77.

[6] D. Feathers, V. Paquet, and C. Drury, Measurement consistency and three-dimensional electromechanical anthropometry, International Journal of Industrial Ergonomics, 33 (3), 2004, 181-190.

[7] M. Brault, Americans With Disabilities: 2005 - Household Economic Studies. Current Population Reports 2008 from: http://www.census.gov/prod/2008pubs/p70-117.pdf.

[8] H. Kaye, T. Kang, and M. LaPlante Mobility Device Use in the United States. U.S. Department of Education, National Institute on Disability and Rehabilitation Research: Washington, D.C., 2000.

[9] MathWorks, Matlab® R2007b, 2007.