**What to measure? Review of measurements in anthropometric studies of elderly populations**

Stephen Ward

Faculty of the Built Environment, University of New South Wales, Australia

**Abstract**

**Background:** Anthropometric studies of elderly populations have been undertaken in a number of countries in response to the increasing proportion of the elderly and promotion of inclusive approaches to design – sometimes called ‘design for all’.

**Aim:** This study is a review of selected anthropometric studies of the elderly with a focus on comparing what measurements were included in the studies, rather than on the actual data collected. It is essentially a literature review undertaken in the planning phase for a new anthropometric survey.

**Method:** A literature search was undertaken and selected studies compared and discussed.

**Results and conclusions:** A variety of different approaches to providing anthropometric data for design applications are revealed. Also evident is the need for care in selecting and defining measurements, so that data can be compared between studies.

**Background**

Anthropometric studies have been undertaken in many countries and collected data have informed development of ergonomic standards and guidelines now used in the design of buildings, interiors, and transport. Many studies to date have given particular attention to adult working-age populations, typically up to the age of 65, reflecting the need for data applicable to design of workplaces and work equipment.

Studies of children, elderly and impaired sub-populations have also been undertaken and provide important additional data to address particular needs and support a design-for-all approach that extends beyond the workplace and the working population. The increasing proportion of elderly people in the Australian population means that more attention needs to be given to the design of products, housing and environments that are better adapted to older people. A media release in 2008 by the Australian Bureau of Statistics [1] stated that the proportion of the Australian population who are 65 years or older is expected to be 23% to 25% by 2056, up from 13% in 2007. Similarly, people aged 85 years or older will make up 5% to 7% of the population in 2056 compared with only 1.6% in 2007. Comparable trends and predictions are reported in other countries.

The present study discusses findings of a literature review in the planning phase of a proposed anthropometric survey of elderly Australians which is part of a project to support improvements to the design of homes, and particularly bathrooms, with the intention of enabling an ageing population to live at home longer. Selected anthropometric studies of elderly populations have been reviewed to compare the measurements that have been included in the studies and discuss different approaches to methods that are revealed in those studies. The rationale for this review is to help establish the measurements and variables to be included in the proposed Australian study. Related to the question of what to measure are considerations of how anthropometric data can be transferred to future design problems and contribute to tools and guidelines intended for designers.

Three important issues to consider in planning any anthropometric survey are: 1) consistency – the measurement definitions and methods of data collection should conform to recognised standards so that data from one study may be reasonably compared with data from another; 2) applicability – the measurements chosen should be relevant to the design issues to which the data will be applied and; 3) Innovation – the opportunities for doing things differently and better by adopting new technologies or addressing new problems.

**Consistency**

The first of these considerations, consistency, is typically addressed by adopting standard definitions of measurements and methods. The International Organisation for Standardisation (ISO) has published a number of standards relating to anthropometric data, noting in the introduction to ISO 15535:2006 [2] that, “Difficulties arise in comparing one study with another because either the methods used differ or are not sufficiently well described”. ISO 15535 sets out requirements for collecting demographic details of subjects as well as measurements and for formatting of databases and reports. It refers to ISO 7250-1:2008 [3] for definitions and methods for a set of basic human body measurements. ISO 15535 recommends adoption of these definitions and requires that measurements additional or different to those in ISO 7250 should have their definitions and methods clearly described. An immediate benefit is obtained by following a standard in that reporting requirements are simplified and ambiguity is reduced for those who later wish to use the data or compare results of one study with another. Where

**Corresponding author:** Stephen Ward. Email – stevew@fbe.unsw.edu.au
The ways in which the data are presented for transfer to tools and resources for design. Innovation may follow from devise different methods of measurement. An example is a study of users of wheelchairs and mobility scooters [4] which functional dimensions of reach and clearance were measured with the subject seated in their mobility device. In this example forward reach was measured with reference to the outermost front limits of the wheelchair or scooter whereas ISO 7250 defines forward reach as measured from a vertical plane in contact with shoulder blades and buttocks. Measuring from the wheeled mobility device in this case is arguably more relevant to design problems, such as placement of controls that have to be reached by a person in a mobility device.

Innovation

The third consideration is the opportunity for innovation in the ways in which data are collected and transferred to tools and resources for design. Innovation may follow from or prompt changes in:

- The design questions to be addressed. If quite different future design possibilities are envisaged then different information may need to be obtained in an anthropometric survey.
- Tools and methods for data collection. An example is 3D body scanning where the body surface size and shape are captured as 3-dimensional point cloud data and dimensions are later extracted from identified landmarks on the body surface. Landmark locations for 3D scanning have been specified in ISO 20685:2010 [5] in order to obtain measurements from 3D scans that are comparable to measurements defined in ISO 7250 and obtained with conventional manual methods of measurement.
- Types of data collected. Non-traditional types of data can be included in a survey. For example, photographs, video and motion-capture data may be included or linked to an anthropometric database.
- The ways in which the data are presented for transfer to design purposes. Anthropometric data, traditionally presented as summary statistics tables, can be presented in other ways such as drawings, templates, digital human models and interactive databases.

The relatively recent use of electronic databases as a means of storing and disseminating data have made it possible to keep data intact for each individual subject in a study and the included demographic details allow data to be filtered for analysis of sub-populations. For example, the Civilian American and European Surface Anthropometry Resource (CAESAR) study [6] collected, among other demographic variables; place and date of birth, occupation, education level, income, marital status, and number of children.

This present study is a review and comparison of selected anthropometric studies of elderly populations and populations with disabilities associated with ageing. The aim of the present study is primarily to compare the choice of measurements in each study rather than the collected data itself. The authors of some of the studies in this review have made their own comparisons of their data with those from other populations. Methods of measurement are also of interest where it appears that a new or non-standard method has been used to accommodate the elderly subjects.

Method

Studies for comparison were selected from publications already known to the author, cited in other publications and found in a literature search undertaken through Health and Safety Science Abstracts (Proquest) with keywords, ‘elderly’ or ‘aged’, ‘anthropometry’ and ‘design’. The studies selected all included subjects over 65 years old and report data collected later than 1990. Included studies also have an evident orientation towards design applications in the aims of the study and in the discussion and selection of variables. Not included in the selection were publications providing estimates of dimensions derived from compilations of other studies and using ratio scaling methods to fill in missing data. The studies selected for comparison are listed in Table 1.

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<thead>
<tr>
<th>Authors</th>
<th>Country</th>
<th>Sample</th>
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<tr>
<td>Steenbekkers and Beijerse (eds) [7]</td>
<td>Netherlands</td>
<td>627 elderly subjects (303 male and 324 female) aged 50 and over, sampled in age groups 50-59, 60-69, 70-79 and 80+. 123 younger adults (55 male and 68 female) aged 20-30 years were included in the study for comparison.</td>
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<tr>
<td>Kothiyal and Tettey [8]</td>
<td>Australia</td>
<td>33 males aged 65-92 (mean age 76) and 138 females aged 65-92 (mean age 77.5)</td>
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<tr>
<td>Jarosz [9]</td>
<td>Poland</td>
<td>106 female subjects aged 60-96 sampled in age groups 60-69, 70-79 and 80+</td>
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<tr>
<td>Hu et al [10]</td>
<td>China</td>
<td>50 male and 58 female subjects, Data compared in age ranges 65-69, 70-74 and 75+ years.</td>
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<tr>
<td>Steinfeld et al [4]</td>
<td>USA</td>
<td>Total 495 wheeled mobility device users including 170 (68 male and 102 female) aged 65+</td>
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<tr>
<td>Marshall et al [11]</td>
<td>UK</td>
<td>100 subjects including 46 over the age of 60, about half of these with impairment</td>
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These studies were reviewed to identify the types of measurements included and compare aims and methods.
Results
A summary of the types of measurements and variables included in each study are shown in Table 2. Further description of some of the studies is provided in the discussion that follows.

In Table 2 a dot (•) indicates that the type of measurement indicated in the column heading was included in a study. However, this does not necessarily mean that the measurements were defined the same way in different studies. The number of measurements included in a category is also variable from one study to another.

Discussion
It can be seen from Table 1 that there are differences in the minimum age of subjects considered to be ‘elderly’ in the different studies. Steenbekkers and Beijsterveldt [7] included subjects from the age of 50 whereas others have chosen either 60 or 65 as the lower age limit for their sample.

In Table 2 there are six studies listed. The first four of these were conducted with elderly subjects described as ‘healthy’. That is, they were living independently and evidently able to adopt the standing and sitting postures required for anthropometric measurements. The last two studies in Table 2, by Steinfeld et al [4] and by Marshall et al [11], differ from the first four in that they included subjects with impairments. All of the subjects in the study by Steinfeld et al were dependent on wheeled mobility devices and Marshall et al used a mixed sample of ambulant subjects and wheelchair users. These two studies reveal innovative approaches to collection and reporting of data and are discussed in more detail below.

Steenbekkers and Beijsterveldt [7] have included the most different types of variables as well as detailed description of their methods and the reasons for considering each variable to be ‘design-relevant’. They refer to the then current version of ISO 7250 for definitions of the static measurements, adopting 23 of the 56 dimensions specified in ISO 7250. The standard only defines static measurements so Steenbekkers and Beijsterveldt refer to other sources for measurement methods of other variables and, in some cases, have defined their own. The psychomotor variables in their study were measured with tests of hand steadiness, eye-hand coordination, reaction time and balance. The sensory variables measured were visual acuity, visual contrast sensitivity, auditory capacities and tactile discrimination. A short term memory test and a colour preference test were used as measures of cognitive variables. Task capability measurement involved a long list of common tasks in daily living such as opening packages, making a bed or hanging out laundry. Subjects were asked to rate their difficulty with each task on a 5-point scale and a composite score was calculated. This is an unusual type of measurement for an anthropometric study, but is a measure with clear relevance to design.

The study of Australian elderly by Kothiyal and Tettey [8] includes 22 static body dimensions using definitions from Pheasant [12]. The illustrated definitions provided by Pheasant, appear mostly the same as in ISO 7250 but some differences can be found. For example, hip breadth is described by Pheasant as measured in a sitting posture whereas in ISO 7250 there are separate definitions for hip breadth sitting and hip breadth standing. This dimension may be relevant to design applications such as, for example, determining the distance between armrests of a seat so it is important to know which definition has been used. Kothiyal and Tettey have not stratified their sample according to age bands so the results, as published, do not reveal differences between age groups within the sample which includes subjects from 65 to 92 years of age.

Jarosz, in her study of Polish elderly women [9] uses age classifications 60-69, 70-79 and 80+ years and compares the mean and SD values of collected measurement between these age bands. Definitions of the 33 static dimensions measured appear to follow ISO 7250 although this is not stated. Results are presented in summary tables with 5th and 95th percentile values included. Comparisons are made with dimensions from another study of Polish adult women under 60 years old and some recommendations are made for designing for a combined population that includes working age and elderly. The older women were generally smaller in stature and reach, but larger in waist and hip circumference.

The anthropometric study of Chinese elderly by Hu et al [10] adopts 47 definitions for static body dimensions from a Chinese national standard equivalent to ISO 7250. To these are added measurements of hand grip strength, torso lifting strength and leg lifting strength. The strength measurements were based on methods established by others but modified, for safety, such that subjects were not asked to sustain their maximum voluntary force for several seconds. Hu et al note

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<tr>
<th>Authors</th>
<th>Weight</th>
<th>Standing posture</th>
<th>Seated posture</th>
<th>Body segments</th>
<th>Grip</th>
<th>Reach</th>
<th>Dynamic reach zones</th>
<th>Joint angle ranges</th>
<th>Strength</th>
<th>Psychomotor skills</th>
<th>Sensory capacity</th>
<th>Cognitive measures</th>
<th>Step height/length</th>
<th>Task capability</th>
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<td>Steenbekkers and Beijsterveldt [7]</td>
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Table 2. Summary comparison of variables measured.
that there are very few strength data available for the elderly around the world. This would seem to be an important variable for design as it known that strength decreases in older age.

The Anthropometry of Wheeled Mobility project by Steinfeld et al [4] is useful for comparison despite it not being, essentially, a study of elderly anthropometry. All subjects in the study were users of a wheeled mobility device (WhMD) – a wheelchair, powered wheelchair or mobility scooter but only 170 of the 495 subjects were aged 65 years or older. The study is of interest as an example of devising alternate measurement definitions and methods when needed to address particular design problems. Subjects were measured in their WhMD with a digitizing arm to record 3-dimensional locations of body landmarks. This enabled measurements to be taken quickly within the space constraints of the WhMD device and some measurements referred to part of the device, such as an axle centerline. Functional clearance dimensions included reach zones from the device and the clear floor space needed for a 360 degree turn. Reach zone data are expressed in diagrams that show a grid in each reach plane with numerals indicating the percentage of subjects able to reach each cell of the grid. Thus the data are provided in a way that relates to common problems of design for WhMD users. Similar methods could be applied to anthropometry of ambulant elderly people who, as age increases, are more likely to be limited in their functional reach zones or unable to stand erect for conventional anthropometric measuring methods.

The HADRIAN (Human Anthropometric Data Requirements Investigation and Analysis) database described by Marshall et al [11] presents a different approach to transferring collected data to design. The sample of approximately 100 subjects selected for the database is deliberately diverse, rather than being representative of a population segment. The age of people in the database ranges from 18-89 years, with about half the sample over 60 years of age. More than half of the sample had some form of impairment and some of these were wheelchair users. The database includes static body dimensions (and wheelchair dimensions where appropriate), strength, joint movement ranges and dynamic reaches of each person as well as photographs and video clips of each subject undertaking standardised kitchen-based tasks such as lifting items into or out of an oven. Information from the database is presented visually and designers are encouraged to consider subjects individually and assess how those individuals would, or not, be accommodated by a design. Thus a case-by-case application of data is promoted rather than establishing percentile ranges for dimensions. Transfer of information to design is further assisted by the option of coupling a Digital Human Modelling (DHM) system to the database so that each person can be represented with their unique dimensions and movement capabilities as an articulated model a Computer Aided Design (CAD) system. Information is best transferred to designers with an interactive database. A web-based version is proposed for the HADRIAN system, but not yet implemented.

Conclusion

A number of anthropometric studies of elderly populations, or at least including a substantial elderly component in the sample, have been reviewed to identify what has been measured to compare differences in the way information is presented for design. This has been done with a view to informing the choices to be made in the development of a new study. Different approaches are possible and choices will depend on a number of factors such as resources available for the study and the immediate design problems to be addressed. However, some tentative recommendations are offered on the basis of what can be learned from the review of other studies. These could be stated as:

1. Follow ISO standards for measurement definitions and where possible to maximize comparability of results with past and future studies by others. This can be done whether or not 3D scanning technologies are employed for data collection.
2. Describe in detail any new measurement definitions and methods used.
3. Include detailed demographic data for subjects in the database, again to maximize comparability of results in the future.
4. Include task-based measures particularly as they relate to known design problems to be addressed. This could include, for example, video, motion capture and questionnaires responses.
5. Keep all information together in a database format to allow both statistical analysis and ‘drilling down’ to individual subject characteristics.

References


