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Accuracy, precision and reliability in anthropometric surveys for ergonomics purposes in adult working populations: A literature review

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ABSTRACT

Anthropometric surveys are the most common method of gathering human morphometric data, used to design clothing, products and workspaces. The aim of this paper was to assess how current peer reviewed literature addresses the accuracy, reliability and precision regarding manual anthropometric surveys applied to adult working populations in the field of ergonomics. A literature review was performed in two electronic databases for finding relevant papers. A total of 312 papers were reviewed, of which 79 met the inclusion criteria. The results shown that the subjects of these publications are poorly addressed, so that only 27 studies mentioned at least one of the terms and none of the studies evaluated all of the terms. Only one paper mentioned and assessed precision and reliability of the measurement procedure. Furthermore, none of the publications evaluated accuracy. Moreover, the reviewed papers presented large differences in the factors that affect precision, reliability and accuracy. This was particularly clear in the measurer technique/training, measurement tools, subject posture and clothing. Researchers in this area should take more rigorous approaches and explicit indicators with their results should be presented in any report. Relevance for industry: It is important that scientific literature related to manual anthropometric measurements uses methods for assessing measurement error, since these data are often used to design clothing and workspaces as well as to calibrate non manual methods such as 3D scanners.

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1. Introduction

Anthropometry is the branch of the human sciences that deals with body measurements: measurements of body size, shape, strength and working capacity (Pheasant and Steenbekkers, 2005). The characteristics of any given population will depend upon a number of factors, of which the most relevant ones from an ergonomics point of view are: gender, age, ethnicity and occupation (Pheasant and Steenbekkers, 2005). All of these aspects must be considered in order to match the designs of products, environments and systems, as a whole. The physical characteristics of target users (Garneau and Parkinson, 2016) have to be considered to allow the workplaces and products to be suited to the workers' body size and motion (Kroemer and Grandjean, 1997). The criteria that define a successful outcome to the design process falls into three main groups: comfort, performance, and health and safety. These three factors together benefit the companies' productivity and efficiency (Pheasant and Steenbekkers, 2005).

Currently, anthropometry is considered as an important factor for the prevention of several work-related problems. This matter is being addressed by specific international technical standards (ISO, 2008, 2010a, 2010b, 2013) and other technical standards that take into account anthropometry for prevention of diseases and accidents (ISO, 2000, 2002, 2003). Additionally, there are even standards for specific industrial sectors like control rooms (ISO, 2011) and healthcare (ISO, 2012a). There are several large anthropometry databases, some of the most relevant ones being mentioned in ISO (2010b), such as the CAESAR database that considered US and European populations (Harrison and Robinette, 2002; Robinette et al., 2002). Furthermore, ISO (2010b) also includes databases from other countries like Japan, Korea, Thailand, Italy, Kenya. All the databases presented in ISO 7250-2 collected anthropometric measurements with either just manual techniques (Thailand, Germany, Italy, Japan, Kenya, Korea), with 3D scans (US), or both techniques (Netherlands). Other highly relevant large sources of anthropometric data are the ANSUR, MC-ANSUR and ANSUR II surveys, where military personnel were measured (Gordon et al., 1988, 2012; 2013). Likewise, NASA has collected large amounts of data, for their interspace shuttle designs (NASA, 1978) and even for specific sectors such as truck drivers (Guan et al., 2015). Similar research efforts have also produced large anthropometric databases using civilians of other countries such as Korea (Korean Agency for Technology and Standards, 2004) and Japan (Research Institute of Human Engineering for Quality Life, 2007).

Manual measurements of anthropometric characteristics are commonly used due to their main benefits: relatively low cost compared to more automated equipment like 3D scans; ease of measurements and the need for less complex equipment. However, manual anthropometric techniques can present issues related to human measurement errors (Sicotte et al., 2010). When anthropometrical measures are repeated the two sources of variation are: biological variation of individuals – that cannot be avoided – and technical variations – that can be avoided. The variability on the anthropometrical measurements caused by variations on the technique execution is responsible for a higher incidence of error (Perini et al., 2005).

Anthropometry is very sensitive to measurement error (Villamor and Bosch, 2014). To avoid the variability of the measures and reduce measurement error, the World Health Organization proposed the following quality assurance measures (WHO, 2006): (i) standardized data collection methodology, (ii) rigorous training and monitoring of data collection personnel, (iii) frequent and effective equipment calibration and maintenance, and (iv) periodic assessment of anthropometric measurement reliability. Furthermore, the International Standard Organization (ISO) developed some standards (ISO, 2008, 2013) that provide a description of anthropometric measurements which can serve as a guide for ergonomists to make possible comparisons between international population segments.

Published scientific literature use several terms to define anthropometric measurement error. Regardless of the terms used, the effects of measurement error can be mainly categorized depending by the extent to which the repeated measures give the same value or the extent to which a measure departs from the true value (Ulijaszek and Kerr, 1999).

1.1. Repeated measures: precision and reliability

While there are several definitions of precision and reliability in the published literature (Habicht et al., 1979; Heymsfield et al., 1984; Mueller and Martorell, 1988; Norton and Olds, 1996; Ulijaszek and Kerr, 1999; Wong et al., 2008), they may confuse readers since they are very similar, thus, for the purposes of this paper, we defined the precision according to Norton and Olds (1996). Precision is a characteristic of a specific measurer executing a specific measurement technique on a specific body dimension (Norton and Olds, 1996). Reliability has the same features plus being dependent on the individual differences (Norton and Olds, 1996). These individual differences are grouped by dependability term. Dependability is a function of physiological variation, such as biological factors, that can modify the reproducibility of the measure, even if the technique does not vary (Sicotte et al., 2010; Ulijaszek and Kerr, 1999). One example of dependability is the variation of stature in the same subject, between hours of the day, despite of the technique used to take it, as stature decreases throughout the day (Tillmann and Clayton, 2001). Since reliability is usually measured using coefficients, its indicators will be, in general, more correlated in highly heterogeneous subjects than for a group of more similar ones (Pederson and Gore, 1996). Another difference is that precision measurements may be used in subsequent calculations (i.e. confidence intervals, sample size), while measures of reliability, conversely, are just technique indicators and should not be used for further calculations (Pederson and Gore, 1996). According to Pederson and Gore (1996) precision is the most basic indicator of an anthropometrist's expertise or ability. When the levels of precision are quoted in a technical report, the readers should be given both the results and the acceptable standards in order to assess the precision of each variable (Norton and Olds, 1996). For example, according to the International Society for the Advancement of Kinanthropometry