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Anthropometry of the Canadian adult population: Developing comprehensive, updated normative-reference standards

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ABSTRACT

Introduction: Applications of structural anthropometric measurements include user-centered design, health risk appraisal and assessment of biological maturity. It is important that anthropometric normative-reference standards are current, comprehensive, and population specific. Previous work by Pheasant (1996) included thirty-six anthropometric measurements to create a comprehensive and comparable list of data. However, Canadian studies have included nineteen or less body dimensions, and relatively small sample sizes. The aims of this investigation were to create current and comprehensive anthropometric normative-reference standards for a young Canadian adult population and to analyze the differences in anthropometric data between subjects in this study and those of a previous study on a similar population.

Methods: Thirty-six structural body dimensions were manually measured on a sample size of 197 male and 204 female Ontario, Canada university-aged subjects. Descriptive statistics were reported based on sex and independent samples *t*-tests were used to compare the anthropometric dimensions of the current study with that of a similar, previous study on Nova Scotia, Canada university-aged subjects.

Results: Percentiles and standard deviations of the subjects' 36 body dimensions were tabulated and are reported based on sex. For example, male and female 50th percentile values for stature are 1783 mm and 1641 mm, respectively. All differences in body dimensions between both male populations were statistically significant at $p < 0.01$. All but four differences in body dimensions between both female populations were statistically significant at $p < 0.01$.

Discussion & Conclusions: The current study was able to present anthropometric normative-reference standards of a large Canadian sample that are more comprehensive and current than known to exist. Moreover, as there were many significant differences between the current (Ontario) and previous (Nova Scotia) populations' anthropometric data, it is suggested that a Canada wide study be investigated.

Relevance to industry: As the most comprehensive Canadian data available, the reported anthropometric measurements may be used as a relevant consideration in product and environment design. Interpretation of findings from the comparison of anthropometric data between geographic regions within Canada also suggest that ergonomic design using province specific anthropometric data may result in improved workplace safety and productivity.

1. Introduction

The science of human body measurement is better known as anthropometry. It is an important branch of ergonomics particularly concerned with body size, shape, strength and working capacity (Pheasant, 1996). Structural anthropometric measurements are based on standard fixed postures of the human body, and are used by ergonomists to design products and environments that match the unique physical constraints of their users (Pheasant, 1996). Product and environment users and stakeholders may experience numerous benefits as a result of the implementation of user-centered design, including improved workplace safety and efficiency (Hendrick, 2003). In addition to facilitating ergonomic design, structural anthropometric measurements are applicable in other significant instances such as prediction of health risk (Janssen et al., 2002) and assessment of biological maturity (Mirwald et al., 2002).

When presented in percentiles, anthropometric normative-reference standards serve as a source of easily interpretable information for

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professionals to apply (Gray and Gray, 1979), such as how an ergonomist would apply these standards in user-centered design. For instance, a recent study took 76 structural anthropometric measurements of 801 male agricultural workers with a mean age of 30.8 ± 10.7 years from northeastern India and applied these measurements in the design of eight agricultural tools and equipment (Dewangan et al., 2010). The maximum permissible height for a crop-feeding device was designed based on the subject pools' 5th percentile value of standing elbow height (92.5 cm), so that 95% of the operators would not be required to bend over in trunk flexion when using the device (Dewangan et al., 2010). Bending over the crop-feeding device is a man-machine relationship observed in this specific case to have a correlation with hand injury (Dewangan et al., 2010). Notable limitations of the study included the use of only male subjects, as well as a focus specifically on tasks in agriculture, narrowing the scope of transferability of the data.

It is important for anthropometric reference standards to be characteristic of the user population (Pheasant, 1996). Normative reference standards of one demographic population (e.g., elderly European males) may not be sufficient for designing environments and products for another demographic population (e.g., young Canadian females). There are many examples of efforts to collect demographic-specific anthropometric data that have been made by researchers (e.g., Burr and Phillips, 1984; Del-Rio-Navarro et al., 2007; Khadem and Islam, 2014; Loos and Lefevre, 2000; Purkait, 2011). However, not all reference standards are current, which is an important factor in ergonomic design (Pagano et al., 2015). Researchers in a study compared relatively current (2015) and previous (1977) anthropometric data of children from the United States, and found that there were large increases in measurements of body width and circumference, specifically of the torso, arms and legs (Pagano et al., 2015). Conversely, measures of body length (e.g., knee height, stature, and upper arm length) and measures of length, width, and circumference of the head, face, hands and feet did not demonstrate as significant of a change (Pagano et al., 2015). Comparisons were made by examining the percent differences in plots of anthropometric data versus age from a previous large-scale study (Pagano et al., 2015) The authors of the study concluded that ergonomic designs developed using bygone anthropometric reference standards may be inadequate (Pagano et al., 2015). A limitation of the study was that the population of the children representative of the 2015 sample was created using an anthropometric synthesis technique; a technique that combined linear regression models with principal component analysis. Although accurate, the synthesis technique has several limitations (e.g., it is limited by the linearity of the analysis methods and assumes normality in the regression residuals) and thus highlights the need for large-scale studies using manual measurements (Pagano et al., 2015). Further intricacies of the anthropometric synthesis technique are beyond the scope of the current paper. Nonetheless, it was apparent that anthropometric reference standards need to be demographic-specific and current.

To date, most Canadian anthropometric research and survey analysis has taken into consideration a relatively small number of anthropometric measurements, namely, stature and weight. The Canadian Health Measures Survey (CHMS) is a biennial collection of Canadian health information including anthropometric data. The measurements of the CHMS represent one of the most comprehensive collections of Canadian anthropometric data and include standing height, weight, waist circumference and neck circumference measurements (Statistics Canada, 2015). However, these data are insufficient for thorough user-centered environment and product design, as many design processes require the consideration of other anthropometric measurements (e.g., knee height, fingertip height, and chest depth). Knee height may be applied to the clearance required beneath the underside of tables; fingertip height may be applied to the lowest acceptable level for finger-operated controls; and chest depth may be applied to the clearance between seat backs and obstructions (Pheasant, 1996). These are merely three instances of the applicability of a few selected anthropometric measurements. Since humans vary greatly in body dimensions and task requirements, truly comprehensive anthropometric data must take into account many body dimensions in the user-centered design process. Pheasant (1996) accounts for 36 body dimensions that possess practical significance in the design of environments. Thus, anthropometric studies should include a greater number of measurements similar to Pheasant (1996) to create a more comprehensive and comparable list of data to be used in the design of environments and products.

A more recent study by Behara and Das (2012) represents the only relatively comprehensive and detailed structural anthropometric data of Canadian adults available, to the authors' knowledge. In their study, they aimed to present structural anthropometric percentiles of Canadian adults that may be readily applied in user-centered design (Behara and Das, 2012). Their study involved collecting data from 40 male subjects (18–34 years of age) and 40 female subjects (17–33 years of age) from universities in Nova Scotia, Canada (Behara and Das, 2012). Nineteen body dimensions that were believed to possess practical significance in ergonomic design were manually measured using a photographic method, and were presented in percentile rankings (Behara and Das, 2012). However, a similar study with a larger sample size and more comprehensive measures (e.g., Pheasant (1996) 36 body dimensions) would produce more accurate, reliable, and comprehensive anthropometric data (Behara and Das, 2012). Some notable dimensions not included in the Behara and Das (2012) study were knee height and fingertip height, for which the significant applicability of these specific measurements was previously discussed.

Canada is a nation that is continually growing in size and diversity (Gushulak et al., 2011). Therefore, the first purpose of this investigation was to obtain a larger, more current and comprehensive set of Canadian anthropometric normative-referenced standards than which currently exists. The development of these norms could result in improved ergonomic design, prediction of health risk, and assessment of biological maturity. The second purpose of this study was to analyze the differences in anthropometric data between subjects in the current study and those of a similar Canadian adult population (Behara and Das, 2012). This was done to determine if the larger sample in the current study would produce statistically significant differences in anthropometry from the previous Canadian sample, and thus, if the results from the previous sample were reproducible. Furthermore, differences in anthropometry between the current study (university-aged Ontario, Canada adults) and the previous Canadian study (university-aged Nova Scotia, Canada adults) could indicate a between provincial difference, and thus, if a Canadian wide study should be investigated.

2. Methods

2.1. Subjects

In a laboratory-controlled environment at an Ontario university, 197 male and 204 female subjects agreed to participate and have their data included in this study. Each subject (age range 19–28 years) completed an informed consent approved by the university's research ethics board.

As suggested by the ISO 15535 standard (International Organization for Standardization, 2012), values from a previous study on a similar population (Behara and Das, 2012) were used to estimate the minimum number of subjects, N, required for each body dimension. The value of N was calculated using the following formula:

$$N = \left(\frac{1.96 \times CV}{a}\right)^2 \times 1.534^2$$

where CV is the coefficient of variation and a is the percentage of relative accuracy desired. Table 1 depicts the level of accuracy, based on sex, at which the collected sample sizes in the current study met or