Anthropometric Analysis for Ergonomic Design: Empirical Studies in Namibia

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Abstract

Anthropometric analysis is crucial for ergonomic engineering design. However, in the case of multi ethnic society, where published anthropometric data is non-existent, ergonomic design is a serious challenge. In addressing this gap, this research focuses on developing such data, which can inform the geometric design of workspaces and equipment. The study was undertaken on employees from selected workplaces in industry. In total, seventy nine (79) different body dimensions of volunteer workers were recorded based on predetermined landmarks. Measurements were done manually with volunteers in sitting and standing positions. The results give a sample of anthropometric characteristics of Namibian workforce on which workspace and equipment design can be based. The data was compared to that from the US which is a common market source of equipment (especially in mining). These results will contribute to formulation of part of a Namibian standard that incorporates ergonomic guidelines for the Namibian industry. Finally, this study demonstrated the need for a more comprehensive anthropometric survey for all worker population in all sectors of industry. This study has succeeded in establishing a guideline and methodology on which a more extensive anthropometric survey should be based.

Keywords
Anthropometric analysis, ergonomic design, empirical study, Namibia

1. Introduction
For effective and appropriate ergonomic engineering design, pertinent anthropometric data is crucial. As a result, developing such data for such purposes is imperative. It is essential to develop substantial anthropometric data which can inform the geometric design of workspaces and equipment (Del Prado-Lu, 2007; Robertson et al., 2008; This will have impacts on the psychosocial work environment, musculoskeletal health (Schneider, Irastorza, 2010; Golubovich et al., 2013; Denis et al., 2008) work effectiveness among workers, and productivity (Robertson et al., 2008; Garcia-Herrero et al., 2012; Botha and Bridger, 1998). However, there are some workplaces that are specific to given environments as dictated by anthropometric measurements of local populations. For instance, the design of aircraft seats, tractor cabins, office furniture and control panels, may necessarily need measurements that are unique to specific local ethnic groups. The specific requirements for these environments could provide opportunities to do local manufacturing of some components. Nonetheless, in some contexts, anthropometric data is rare, or even non-existent. Moreover, in a unique multi ethnic society, it may be difficult to develop a common anthropometry data for engineering design. Such is the unique situation in the Namibian context. In addressing this gap, the aim of this study was focused on developing anthropometric data, which can inform the geometric design of workspaces and equipment, in the Namibian context. Thus, the study was conducted covering selected workplaces in different parts of Namibia. In this endeavor, the research considered two objectives:

1. To determine the characteristics of both male and female workers in these selected workplaces that could be used for ergonomic and engineering design.
2. To compare with similar data from other selected regions of the world where possible.

It is hoped that the study will provide a platform towards building of an anthropometric database that will serve the purpose of ergonomic and engineering design among other uses. The design implications for the presented data are wide and varied. Decisions can be made on workplace and equipment design based on factual data presentation as opposed to accepting designs made for populations from other regions of the world. There is no known published anthropometric database currently existing in Namibia which could be used for ergonomic and engineering design purposes. This study will therefore help towards establishing data upon which engineering decisions and designs will be made regarding the selection and sizing of equipment, work processes and tools. It is hoped that a good match between these systems and human anthropometric characteristics will result in a significant increase in productivity, safer work places, motivated workers, and overall lower costs for the employer (Caple, 2010).

The rest of the paper is structured thus: The next section presents a brief outline of related studies. This is followed by an outline of our research methodology in Section 3. Results and discussions are presented in Section 4. Finally, Section 5 concludes the paper.

2. Related Literature

A few related case studies exist in the literature. For instance, in a study carried out in a garment factory in Canada, the researchers found out that participatory ergonomics intervention at a workplace can be cost beneficial to a company. Further it was observed that significant results could be achieved in worker behavior on issues of casual absences, first aid incidents, long term sickness, product quality and efficiency (Smith and DeJoy, 2012; Tompa et al, 2012). In the same vein, a study on clothing manufacturing company of 300 workers in Southern Ontario, Canada, reported a benefit-to-cost ratio of 5.5, with realized productivity increase of about by 5%, 50% reduction in compensation claims, and less complaints worker complaints in regards to work-related pain (Smith and DeJoy, 2012).

Requirements for the establishment of databases are provided by International Standards Organization (2000, 2012, 2008a, 2008b). A closely related study to the one reported in this document was done for the South African Mine Health and Safety Council. Due to its relevance and similarity to the Namibian industry as well as the practicality of use of the final results, this study will be based on that framework to determine anthropometric characteristics for the Namibian workforce.

Studies in the literature show that there are generally two distinct categories of methodologies. There are generally two distinct categories of methodologies (Frisancho, 2008;Chuan et al., 2010; Du et al., 2008; Hanson et al., 2009; Jacobshagen, 1981). The first is referred to as the traditional method. In this method readings are obtained through contact of the measuring instrument with the volunteer person's body part being measured. The skill of the data collector is vital in maintaining accuracy and data integrity. These data collectors have to be trained to a predetermined level before they can start taking measurements.

The second method makes use of 3D body scanners and there are numerous types of scanners on the market. Readings are taken automatically and data recorded and corrected electronically. The traditional method was used in this study (Iseri and Arslan, 2009).

3. Research Methodology

The study concentrated on selected workplaces and highlights the need for more comprehensive studies to establish a more comprehensive anthropometric database of possibly the entire Namibian workforce as is the norm based on standards guiding such information worldwide. The research was quantitative, experiment type of study where data was collected using predetermined instruments and methods that yielded statistical data as measurements (Cresswell, 2003).

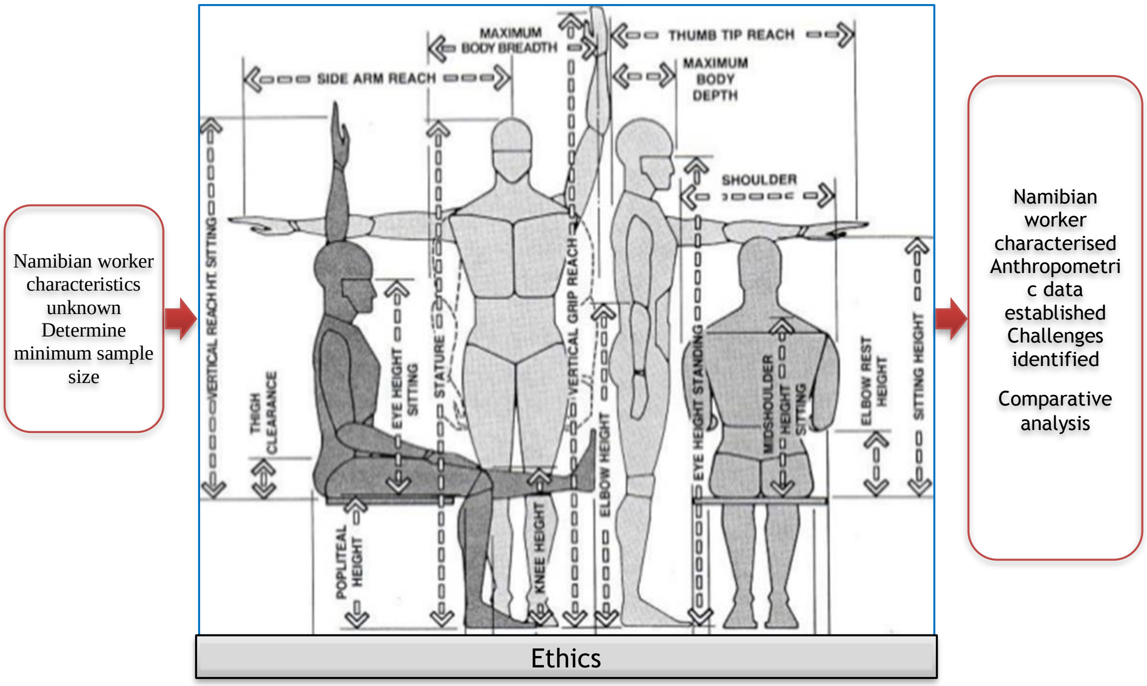

Figure 1. Anthropometric framework for the study

Figure 1 shows the general framework or approach followed in this research. The study starts with the absence of anthropometric data which is the motivation for its inception. In order to create that data a sample size is then determined based on predetermined formula. The data is then analyzed and compiled eventually being made available for use for engineering design. This data describes the Namibian worker and could then be part of the database that characterizes the anthropometric traits of the Namibian workforce.

Seventy nine dimensions were selected based on most relevant engineering dimensions required for design purposes. Data was collected and stratified mainly according to gender of the participants. The underlying motivation was that safety of the workplace can only be maintained and improved if it is taken into consideration at the design stage of the workplace or equipment. In order to achieve this, however, appropriate anthropometric data must be available.
The most challenging parameters for engineering are 5th percentile and 95th percentile. Estimation of these along with 25th, 50th, and 75th percentiles are given with 95% confidence levels while percentage precision of the mean is considered to be unity (ISO, 2012).

In practice, the number of measurements is determined from the given standard which describes the minimum number for technological ergonomic design. There are therefore seventy nine measurements that were chosen for the study for analysis, 81 including nationality and ethnic group where the volunteers belong.

The total employed population in the Namibian industry is given as 630, 094 as at the end of 2012 (Namibia Statistics Agency, 2013, 2014). A combined total of 49 volunteers were measured from various workplaces. The sample comprised of 35 male and 14 female volunteers was used considering the amount of time and resources available to the researcher to complete the task. Most of these came from the mining sector due to the ease of accessibility of workplaces related to the professional association of the researcher with the industry. All workplaces had an equal chance of being considered for sampling and choice of volunteers was based on willingness to participate by employees and their employers.

The study adhered to the standard presentation of anthropometric data which treats results from male and female volunteers separately for analyses. This implies therefore that two groups of characteristics for male and female will be simultaneously presented where possible. Variables measured were selected in accordance with prescribed standards. The level of relative accuracy required for precision (a) shall be taken as 1 while the level of confidence desired shall be 95%. The error estimation shall be 1% of the mean (Du et al., 2008).

The sample size was calculated according to the procedures outlined in ISO standards (2012, 2000, 2008a, 2008b), especially ISO 15535 (2012) with the general requirements for establishing anthropometric databases. The coefficient of variation of 22% was estimated from a pilot survey. The calculated number of participants for validity was 4 375. Due to constrained numbers of volunteers in the study, statistical manipulation of the limited sample was conducted using bootstrapping techniques to increase the sample size to the requisite size. The total number of participants who volunteered for this study is 35 male and 14 female selected from varied workplaces.

Data was collected following the minimum required number of measurements as given in ISO 8559 (2012). The data were measured and recorded on a data sheet. The data that was recorded in this research comprised of the following:

1. Demographic data which include gender, age, occupation, ethnic group and body mass.
2. Standing body measurement variables.
3. Sitting body dimensions variables.
4. Hand dimension variables.
5. Head measurements variables.
6. Foot dimension variables.

The next section presents findings, results and discussions on the implications of the research.

4. Results and Discussions

Human body dimensions are variable along ethnic, gender and age lines. The study has analyzed data from 49 participants from selected workplaces. This is far from being sufficient but in the absence of other information it symbolizes a good beginning.

This study addresses the lack of information to assist with proper designs of machinery where specificity is important or required and consequently promote productivity in the workplace. There are seventy nine variables that were measured from a single participant. These measurement results are intended for ergonomic design of various engineering products. However, the description and interpretation of the sample data given here is not intended to be prescriptive nor restrictive but to guide how the data may be utilized. To this end, only one characteristic data has been randomly chosen, presented and described for this purpose. It should therefore be recognized that the choice of these variables presented is in no way suggestive of any significance over the others.

For data to be normally distributive, the p value (recorded as "sig." in the table below) must be greater than 0.05 while as the Kurtosis and Skewness must lie between -1.96 and +1.96. The results indicate that most of the characteristics are normally distributed with the exception of a few. The "non – normality" of these few could be due to the small sample size as most are from the female volunteers' data set. The test results are given in Table 1.

Table 1. Results of Shapiro – Wilk test on selected characteristics

		Shapiro-Wilk Test		
		Statistic	δF	Sig.
Standing Height	Male	0.976	35	0.637
	Female	0.863	14	0.034
Body Mass	Male	0.963	35	0.284
	Female	0.976	14	0.942
Sitting Height	Male	0.967	35	0.374
	Female	0.941	14	0.426
Foot Length	Male	0.973	35	0.519
	Female	0.888	14	0.076
Thigh Clearance	Male	0.983	35	0.859
	Female	0.778	14	0.003

Due to small numbers in the sample, there are two characteristic results that are not conforming to test of normality. The standing height mean value for males in the sample is 1724.71 mm, standard deviation is 68.67 mm, minimum height for the sample is 1580 mm, and maximum height is 1860 mm. A summary of these results are presented diagrammatically in Figure 2.

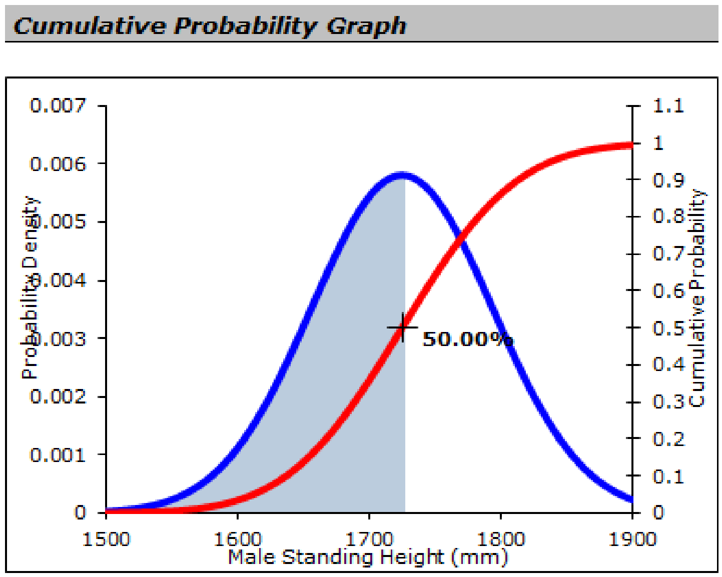

Figure 2. Standing height against cumulative probability and probability density for males

The sample data has a slightly negative Kurtosis of -0.32 while the Skewness is 0.17. The 5th percentile for standing height is 1624.5 mm, 50th percentile is 1725 mm and the 95th percentile is 1855 meaning that 95% of the sample and below are at most as tall as 1855 mm. Figure 3 gives the summary characteristics for the standing height.

Male Standing Height Data	
Mean	1724.71
Std Error of Mean	11.6074
Std Deviation	68.6705
Std Error of Deviation	6.64752
Minimum	1580
Maximum	1860
Skewness	0.16929
Kurtosis	-0.3191
Coefficient of Variation	0.03982
No. of Volunteers	35

Figure 3. Summary characteristics for standing height for male volunteers in millimeters

A summary of the percentile measures for standing height of male volunteers is presented in Figure 4. Such kind of data guides and determines design envelopes for the ergonomic measurements for work spaces and work products

Male	Percentile	Female
mm		mm
1624.5	5th Percentile	1500.05
1680	25th Percentile	1545
1725	50th Percentile	1572.5
1770	75th Percentile	1597.5
1855	95th Percentile	1746.75

Figure 4. A summary of the percentile measures for standing height of male volunteers

5. Conclusions and Further Research

Human body dimensions are variable along ethnic, gender and age lines. The study has analyzed data from 49 participants from selected workplaces. This is far from being sufficient but in the absence of other information it signifies a good beginning. Collecting anthropometric data is an extremely time consuming and costly exercise. However, the lack of properly designed machine and equipment may reduce performance and increase the frequency of work related injuries (Botha and Bridger, 1998; Robertson et al., 2008).

The results obtained in this research are intended for design of various outputs of ergonomic nature. For instance, some of the design outputs could be personnel protective attire, while some outputs could be a workstation layout. The description of a sample characteristic given gives an insight on how the data may be interpreted and utilized. The interpretation and description of the data given here are therefore not intended to be prescriptive nor restrictive but only to guide how the data may be interpreted and utilized. It should therefore be kept in mind that the choice is in no way suggestive of any significance of one variable (or a number of variables for that matter) over the others.
This research work resulted in the compilation of data which resembles characteristics of Namibian workers. For purposes of engineering and ergonomic design, this data gives a good starting point and guide for product design to suit requirements of national specificity. The same data can also be utilized to establish compliance with specified safety and ergonomic requirements. The study results contribute towards characterization of Namibian workers, which was not possible before. However, as workers' lifestyles change over time, their anthropometric characteristics will also change. This requires that the data be updated regularly. It is suggested that the next exercise be conducted using sample population which satisfies the statistical guidelines of validity. This study should also be done within a wider geographical spread as opposed to the current one which was selective. The data collected during this study provides a good basis for comparison between Namibian workers' characteristics, and those of their counterparts in other regions of the world. American marines' data in the form of ANSUR II, 2008 was used for this comparison due to its ease of access and is regularly updated. In conclusion it can be said that the study was successful and satisfied its intended objectives within reason.

Overall, the results from this research provides summaries of data intended for use on equipment design and safety which require body measurement input, wherever national specificity of design parameter is required.

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Biography

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