3D anthropometric data collection for occupational ergonomics purposes: A review

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ABSTRACT: This paper presents a literature review of anthropometric data collection to address occupational ergonomics issues. One of the uses of anthropometry is to assess the negative effects associated with working postures. Using new techniques, such as 3D body scanners, it is possible to have very reliable data to use in the enhancement of workstation design or other ergonomic interventions, in order to prevent work-related musculoskeletal disorders.

1 INTRODUCTION

People spend most of their lives at work, therefore it is extremely important that the work environment is healthy, safe and comfortable in order to avoid occupational injuries and/or diseases. Optimising workplace design is also a central factor in ensuring workers’ efficiency and safety on the job. User-centered design approaches, where ergonomic principles and anthropometrics are considered, should be preferred (Wichansky, 2000). This type of design aims to minimise the stress imposed on the users and to eliminate harmful postures. When their workplaces are inadequate, users may experience Work-Related Musculoskeletal Disorders (WRMSD). Workers’ WRMSD are very prejudicial for companies since they are one of the major causes of reduced work capacity, absenteeism or productivity losses (Escorpino, 2008). Hence, user-friendly workplaces are decisive in workers’ welfare. In order to design this type of work environment, it is essential to have a full understanding of the human body and to create workplaces which are suitable for users taking into consideration different body dimensions and different activity requirements.

Anthropometry is the branch of the human sciences that deals with body measurements, such as size, shape, strength and working capacity (Pheasant, 2006). When applied in occupational studies the data acquired (anthropometric measurements) can be used to assess the interaction of workers with their tasks, tools, machines, vehicles, and Personal Protective Equipment (PPE). This last issue, PPE, is very important especially in regard to determining the degree of protection afforded against hazardous exposures. An inadequate fit of the personal protective equipment does not provide workers with sufficient protection from health and injury exposures, such as the case of face masks or hearing protection devices (Hsiao & Halperin, 1998). Thus, it is extremely important that the designs are compatible with normal anthropometric measurements of a workforce, since misfit could result in undesired incidents.

However, currently the amount of data on the size and shape of industrial workers is limited. Most of the data used by safety and ergonomics researchers are based on data drawn from studies of military personnel that are quite different from the average workforce populations. As anthropometric characteristics vary according to several factors (e.g. gender, age and race), creating anthropometric databases that reflect the full variation of the population typically requires considerable resources (time, know-how, funds, equipment and workforce, etc.). Nevertheless, nowadays, there are a growing number of anthropometric databases attempting to represent the characteristics of entire populations (Barroso et al., 2005). However, as the study of Hsiao et al. (2002) concluded, there are even significant anthropometric differences among occupational groups, meaning that, for example, a truck driver and a firefighter are, or can be,
anthropometrically different from each other and from the average civilian population. One of the many applications of anthropology for industrial/occupational design is the assessment of the body modifications that are associated with different working postures (sitting and standing). This paper aims to present a literature review with the identification of the negative effects underlying each working posture, as well as investigating the literature on studies designed to determine if they could be used to the appearance of the body, work since the reach is greater, the body weight can be used to apply forces, requires less space for the legs, the lumbar disk pressure is lower and can be maintained with little muscular activity. The investigation carried out by Balasubramanian et al. (2009) showed that during high mechanical assembling operations, operators demonstrated the appearance of fatigue in lower extremity muscles at a much faster rate in stationary standing than in dynamic standing. The same authors indicated that along with the fatigue the perceived pain and discomfort in the lower extremity muscles was also relatively high during the stationary standing. Other authors refer different effects of the prolonged stationary standing posture, such as the ones presented in Table 2. One of the most studied effects of prolonged standing posture is the appearance of varicose veins and leg cramps. Several studies demonstrated that the risk for varicose veins is associated with different aspects, e.g. age, female gender, family history, pregnancy, obesity and prolonged standing or sitting (Bebee et al., 2005; Abt et al., 2010). In the work of Balk et al. (2012), it has been shown that women had a higher prevalence of varicose veins and more twisted leg cramps than men. However, the occupational characteristics of the job could be more predictive of the prevalence of varicose veins than gender itself. Concerning nocturnal leg cramps, the same study showed that women had higher prevalence of leg cramps than men, regardless of their work posture.

### 2 COLLECTION OF ANTHROPOMETRIC DATA

The variance in body dimensions is frequently reported by calculating means, standard deviations, and percentiles (Roebuck et al., 1975). Despite being useful to create general and broad parameters for the design of workplaces and products, detailed fit information was missing for use in cases such as personal protective equipment. Until the development of 3D body scan technology anthropometric studies were conducted by manually measuring each study participant using tools, such as anthropometers, calipers, and tape measures. 3D body scanners have revolutionized anthropometric data acquisition, being more practical, accurate, fast and, comparatively, less expensive. There are several types of imaging techniques to create full body images. These imaging technologies, include 3D video silhouette images converted to 3D models, white light phase based image capture, laser-based image capture, and radio-wave linear array image capture (Trobou & Wells, 2007; Isokoski & Hwang, 2001). Body scanning systems normally consist of one or more light sources, one or more vision or capturing devices, software, computer systems and monitors to visualize the data captured (Danner & Water, 1998). In most cases, the 3D body scanner captures the outside surface of the human body by using optical techniques. This means that there is no longer the need for physical contact with the subject’s body, but the image based data collection introduces the question of privacy. There are different opinions regarding the privacy of the body scanner. If in the one hand it provides more privacy, since it avoids the need to actually touch the body, on the other hand the highly accurate images produced on the body are not available to view unless the person is scanned. The body scans are then processed into 3D models, which can be used for various purposes, including the creation of personalized medical devices or the development of ergonomic designs for various industries. However, these advances in anthropometric science and computer-based human-form modeling it is now possible to give a different perspective to the collection of anthropometric measurements.

#### 2.1 Body variations due to working posture

As can be imagined, the shape and size of the human body can be affected by repetitive physical activities performed during a working period. Moreover, the body may also be influenced by the working posture adopted during a working day, i.e. when people spend most of their time sitting or standing. The following considerations reflect the effects on the human body of excessive sitting and standing.

##### 2.2 Excessive sitting

There are many people who spend approximately 8 to 9h of their day in a sedentary behavior and a large part of this sedentary time is spent at work (Healy et al., 2011). Some studies demonstrated that most working adults spend 1/2 to 2/3 of their time at work in a sitting position (Tigbe et al., 2011). In some jobs the time spent on sedentary behavior can reach 90%, such as the case of call centers, reported in Toonmagis et al. (2012). Undoubtedly, sedentary behavior is directly related to obesity (P-Singh et al., 2011) and the negative health consequences have been shown to be independent of age (Katzmarzyk et al., 2009). An effect of prolonged sitting that has been very much analyzed is leg swelling (Table 1).

### Table 1. Effects of prolonged sitting.

<table>
<thead>
<tr>
<th>Author</th>
<th>Identified effects</th>
</tr>
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<tbody>
<tr>
<td>Potier et al., 1969</td>
<td>Volume increase causes hydrostatic pressure, thermal increase and obstruction of blood circulation</td>
</tr>
<tr>
<td>Shvartz et al., 1982</td>
<td>Clear’s seat compresses the veins in the thigh and hip areas, causing poor blood circulation to the legs</td>
</tr>
<tr>
<td>Seco et al., 1996</td>
<td>Higher lower leg swelling due to the activity level required to the leg muscles to sustain the body</td>
</tr>
<tr>
<td>Winkel &amp; Jorgensen, 1998</td>
<td>Swelling and discomfort of the lower extremities</td>
</tr>
<tr>
<td>Carpentier et al., 2004</td>
<td>Venous disorders and vascular effects</td>
</tr>
</tbody>
</table>

#### 2.3 Excessive standing

There are still many professions, such as retail workers, cleaners, security guards, supermarket checkout employees, quality control and assembly workers, and health care staff that require workers to adopt a standing posture during the whole workday (Balk et al., 2012). According to Balasubramanian et al. (2009), the standing posture can be divided in dynamic standing (in which a worker intermittently walks while on the job) and stationary standing (in which a worker does not walk, but stands still, while on duty). Most industrial jobs are characterized by a stationary standing posture, however, the dynamic ergonomic posture is not universally employed (Mensing & Kelton, 2001). Due to the increased activity required by the job, the standing posture provides a more stable condition for the low back by preserving the natural lordosis of the lumbar spine (Anderson, 1979). Standing also allows for dynamic use of the arms and trunk, which is better for handling loads, and enables workers to cover larger workspace areas because of the ability to move (Lehman et al., 2001). According to Bridger (1995), standing work is better than sitting work since the reach is greater, the body weight can be used to apply forces, requires less space for the legs, the lumbar disk pressure is lower and it can be maintained with less muscular activity. The investigation carried out by Balasubramanian et al. (2009) showed that during high mechanical assembling operations, operators demonstrated the appearance of fatigue in lower extremity muscles at a much faster rate in stationary standing than in dynamic standing. The same authors indicated that along with the fatigue the perceived pain and discomfort in the lower extremity muscles was also relatively high during the stationary standing. Other authors refer different effects of the prolonged stationary standing posture, such as the ones presented in Table 2. One of the most studied effects of prolonged standing posture is the appearance of varicose veins and leg cramps. Several studies demonstrated that the risk for varicose veins is associated with different aspects, e.g. age, female gender, family history, pregnancy, obesity and prolonged standing or sitting (Bebee et al., 2005; Abt et al., 2010). In the work of Balk et al. (2012), it has been shown that women had a higher prevalence of varicose veins and more twisted leg cramps than men. However, the occupational characteristics of the job could be more predictive of the prevalence of varicose veins than gender itself. Concerning nocturnal leg cramps, the same study showed that women had higher prevalence of leg cramps than men, regardless of their work posture.
3 DISCUSSION

Many of the effects mentioned before, such as foot and leg swelling, reduced circulation, varicose veins, and lower extremity discomfort are associated with both prolonged sitting and prolonged standing (Sadick, 1992). As such, it is important to note that a posture that causes pain or discomfort is generally harmful for workers since it can lead to WRSMSDs. These disorders will reduce the working capacity and can cause a decrease in productivity, losses and can lead to work disability (Escorpizo, 2008). King (2002) stated that the effects of maintaining several body positions for a long time are associated with absenteeism, lack of productivity and decreased well-being. It is possible to conduct a study of the variance in anthropometric measurements to assess if the workplace, as well as the working postures adopted, are contributing to the development of WRSMSDs. In these cases the use of 3D anthropometric data allows studying the workers’ postures and assessing the risk of developing WRSMSDs (Hasegawa et al., 2001; Messing & Kilbon, 2001; Chu & Wang, 2007). Using sit/stand chairs or workstations, wearing soft shoes, using tights/pantyhose, avoiding standing, foot rests, standing on soft surfaces or standing on floor mats are examples of improvements to the work environment that can be made to reduce leg swelling, discomfort and fatigue in the lower extremities (Hansen et al., 1998; Madeleine et al., 1998; Chester et al., 2002; King, 2002). Even though sit/ stand chairs can be a potential solution, their use might not be very effective, as shown in the work of Chip- ter et al. (2002) demonstrated that using a sit/stand chair caused a greater discomfort when compared to standing and sitting postures. Also, some publications showed that implementing sit/stand workstations in an office environment leads to lower levels of whole body discomfort without resulting in a significant increase in performance (Karakolli & Callaghan, 2013; Davis et al., 2009). Several publications showed that the shoe type likely plays an important role in discomfort while standing work. Many workplaces have installed soft shoes or floor mats in order to reduce the leg muscle discomfort during prolonged standing (Madeleine et al., 1998). Lin et al. (2012) discovered that subjective discomfort ratings were related to shoe type, shoe condition and sitting and standing posture. Making various proscribed leg movements (Lin et al., 2012), having frequent sitting breaks and including an optional seat or a footrest increases the variety of body positions available for a worker and encourages frequent changes between them, resulting in less discomfort and swelling in their lower extremities (Sarkia & Darias, 2010). The work from Winkel and Jorgensen (1998) demonstrated that leg and foot activity reduces swelling and increases the blood circulation. Thus, a static work posture, whether it is standing or sitting is discouraged as any movement or motion that causes varicose ulcers and discomfort are associated with standing work posture in important in reducing fatigue (Kroemer & Robinette, 1969). The study of Hansen et al. (1998) demonstrated that leg and foot movement increases the blood flow and in work posture are important in reducing fatigue (Kroemer & Robinette, 1969). The study of Hansen et al. (1998) further noted that sitting, standing, walking or working any motion or walking caused greater muscular discomfort than a combination of standing or walking tasks. Considering the differences between and similarities of the etiology and the choice of the tasks to be performed. At the same time ergonomic design should be considered since it might increase the risk of developing lower extremity disorders and may have a positive impact on productivity enhancement (Balasubramanian et al., 2009).

4 CONCLUSIONS

As workers’ productivity and well-being relies on working conditions, evaluating the negative effects caused by the work postures assumes a very important role. Working postures that are ‘wrong’ or extreme or that are adopted for long periods of time may result in WRSMSDs. Therefore, the correct working postures may put at risk companies’ competitiveness since they are and absenteeism. Accordingly, knowledge about the importance of correct working postures is essential. As such, being able to determine the anthropometric changes related to each work posture is one of the new concerns of anthropometry, improving ergonomic requirements. For this reason, it is now possible to use new measuring techniques, such as the case of 3D anthropometry data by using 3D scanners. This way, ergonomicists can reconsider the evaluation method from traditional anthropometry.

The authors of this paper are already involved in a research project, as part of a PhD project that is based on this identified need, i.e. the need to understand the implications of the working posture for the workers’ anthropometrics. In this project, aspects that are being considered are the determination of the modifications in the human body that occur with each posture (as well as understanding how quickly they happen) or identifying the anthropometric changes that can be more harmful for the workers. And last but not the least, determining the percentage of time that should be spent in each posture for the greatest health and productivity outcomes.

REFERENCES


Occupational hygiene and work safety in a shoe company in Campina Grande

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ABSTRACT: Damage to health and accidents can be devastating and disabling, resulting in illnesses caused by agents of physical hazards, ergonomic and chemicals present in the stage production of footwear, as well as accidents, leading to amputation of limbs and crushing. This study aims to identify environmental risks and recommend control measures upon propositions for improvements in a footwear industry in the city of Campina Grande—PB. The methodology covers literature, case study site visits, questionnaires, checklist and interviews with managers of the organization with a focus on environmental hazards in the machinery and usability of personal protective equipment, PPE. It was concluded that the company needs to create an Internal Commission for Accident Prevention, CIPA, introducing signaling areas of risk, as well as conduct trainings and capacity building for employees to implement measures of work safety in their jobs.

1 INTRODUCTION

The accident at work is considered the most important health problem around the world, to be potentially disabling and fatal and affect mostly young people or economically productive, which leads to social and economic consequences of high relevance to society.

Despite the severity of their negative consequences, workplace accidents continue to occur in high numbers and victimizing thousands workers. The work done unsafely, with risk of death or injury to the physical integrity of the worker, there is a decent job, because, according to the International Labour Organization, to be considered decent must be exercised safely.

In Brazil, the Work safety Law consists in 36 Regulatory Standards, complementary instruments, such as regulations and decrees as well as well as the consideration of the International Labour Organization, ratified by the country. Companies must comply with extensive laws Brazilian work safety and maintain on its staff a team responsible for this sector. This concern is justified, since damage to health and accidents can be devastating and incapacitating the worker linked to any productive sector, causing personal distress, social problems and economic losses for the country. Brazilian footwear industry consists of about four thousand companies, thus generating 260,000 jobs. It is estimated installed capacity of 560 million pairs per year, which 70% is allocated to the domestic market and 30% for export, with a total turnover of $ 8 billion per year.

Brazil stands as the third largest producer of shoes, according to the MTE (2010) have been reported 6,831 accidents in a population of 377,330 registered workers in the shoe industry, generating an incidence rate (18.1/1000). This rate, although higher than that considers all economic sectors of the country (15.0/1000), is much lower than the incidence rate for the industry in general (29.7/1000). These accidents occur as a result of unsafe conditions, which employees are exposed in the workplace and/or unsafe acts, which are acts committed by employees, resulting from ignorance of the risks, or attitudes that neglect the risk and danger. Measures to prevent these agents causing accidents deserve to be studied, since only the use of individual protection equipment (IPE), is not sufficient to minimize this accident scenario.

One can find in this industry, agents chemical, which causes damage through the use of toxic substances such as, glues, solvents, which can cause abnormal liver function, nervous system, blood and skin, as well as agents physical risks, such as exposure to excessive noise, causing changes in hearing, poor lighting and exposure to excessive heat, which can trigger vision problems and heat stress, respectively; agents ergonomic hazards such as awkward postures and repetitive movements, may cause RSI/MSD.

However, most of the injuries are from accidents typical of work by officers from mechanical injury,