



Comparison of anthropometry of Brazilian and US Military population for flight deck design



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ABSTRACT

A valid anthropometric dataset is essential to optimize the design of personal equipment and aircrafts. Until recently there were no anthropometric data available for the Brazilian Air Force (FAB) pilot population, and hence international military data have often been used in Defense procurement specifications. Currently, the Brazilian Aeronautical Industry is designing military aircraft using legacy U.S. military anthropometric data. Some accommodation problems have been identified among FAB pilots, highlighting the necessity to investigate this possible issue.

The anthropometric data of the six critical body measurements indicative of cockpit design from the U.S. military legacy databases were compared one at a time to the FAB corresponding anthropometric data in three ways: *F*-test, *t*-test, and 5th – 95th percentile limits. This study aimed to verify whether the U.S. Military Personnel legacy databases are applicable to the Brazilian pilot population for aircraft cockpit design purpose.

Brazilian pilots were significantly ($p < 0.05$) different in body size when compared to the U.S. military personnel in legacy databases. The dimension that differ the most was Thumbtip Reach, demonstrating a difference in body proportion beyond that illustrated by the difference in body size.

The reported anthropometric analyses can be used as relevant consideration in product, workplaces, and system design. The U.S. legacy databases were considered inappropriate for ergonomic cockpit design for the Brazilian Air Force pilots.

Relevance to industry: When designing complex workplaces, systems, and personal protective devices, designers and ergonomists should use anthropometric data from a sample population that represents the body size variation expected in the target population. The anthropometric comparisons presented in this study are useful to design an ergonomic flight deck layout for both genders.

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1. Introduction

Up-to-date anthropometric data play a key role in design of environments and equipment used by people. The importance of anthropometric data for product efficacy and safety has been recognized by various industries worldwide (Guan et al., 2012; Hsiao, 2013; Lars et al., 2009; Nadadur and Parkinson, 2013; Parkinson and Garneau, 2016; Sadeghi et al., 2015).

Anthropometric data of pilots have been used for cockpit design

purposes mainly in the military field, since it can improve the pilots comfort as well as the mission fulfillment (Lee et al., 2013). Nevertheless, the bulk of military aircraft in use worldwide are built around the anthropometry of western aviators, predominantly from the United States. Most developing countries buy these aircraft off the shelf, and then go about trying to fit their aviators into a machine not designed for their users (Singh et al., 1995).

The ergonomic design process requires that we know the body dimensions relevant to the function of the equipment as well as whom it should fit (Sadeghi et al., 2015). However, these body dimensions are only helpful if they are taken from a sample population that represents the body size variation expected in the target population (HFES 300 Committee, 2004; Parkinson and Garneau, 2016). Thus, when designing for a specific population, we need to verify that anthropometric data from one group apply to another

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(Coleman and Blanchonette, 2011). In this sense, Marklin et al. (2010) reinforced the importance of developing anthropometric reference database for specific work groups.

Currently, the Brazilian Air Force (in Portuguese, Força Aérea Brasileira - FAB) is designing its military aircraft using some historical U.S. Male and Female Anthropometric Databases (USAF Male 1950, USAF Male 1967, US ARMY 1988, USAF Female 1968), which in this study will be referred to as the U.S. military legacy databases. The FAB has used statistics from the aforementioned military databases compiled in the Military Handbook of Anthropometry of US Military Personnel – MIL-HDBK-743A (Department of Defense, 1991) and used the percentile approach to estimate the cockpit accommodation dimensions. Although, this usage is based upon the presumption that U.S. and Brazilian military populations are anthropometrically similar, a dangerous presumption given the lack of evidence to support it and the known consequences resulting from poor ergonomic fit (Coleman and Blanchonette, 2011; Kennedy, 1982; Lee et al., 2013; Singh et al., 1995). Thus, using the U.S. data may be an inadequate approach for determining accommodation requirements for a population of Brazilian pilots.

Several studies corroborate this rationale, Lee et al. (2013) report that the anthropometric differences found between Korean helicopter pilots and US ARMY personnel justify the necessity to use specific Korean anthropometric data to develop an optimal and customized design for helicopter cockpit. Ziolk and Wawrow (2004) verified that a North American population database was not applicable to an Asian American population. In fact, several studies show that using regional databases in other non-related regions will generally cause problems (Marklin et al., 2010; Singh et al., 1995; Ziolk and Wawrow, 2004). Since each population consists of a unique mix of users, simply using information from an available database rather than obtaining the relevant information from the intended user population will probably result in sub-optimal ergonomic design. Additionally, existing surveys may be lacking data on certain body measures that are critical to the design task (Nadadur and Parkinson, 2013). However, if to get anthropometric data from the target population is not feasible it is possible to minimize the poor ergonomic effects by using a statistical validity to get the appropriate proportions of user groups in a combined sample.

Two possible explanations for problems with physical accommodation cited by Parkinson and Garneau (2016) are the use of inappropriate data (e.g. anthropometric data from a population other than the target one) or the use of outdated sources of anthropometric data.

The lack of accurate and specific anthropometric data for Brazilian military populations has been causing aircrew accommodation problems in the FAB, leading to the conclusion that the body size and body proportions of U.S. legacy databases and Brazilian military personnel are indeed different (da Silva, 2013). Despite being designed and manufactured with an accommodation envelope of 3rd/97th percentile using Anthropometry of USAF Flying Personnel, 1950 – WADC TR 52–321 (Hertzberg et al., 1954), it has been observed that the T-27 Tucano's cockpit does not adequately fit Brazilian pilots at the same anthropometric range for which it was designed (da Silva, 2013). The most commonly observed accommodation problems in the FAB for large pilots are a lack of overhead clearance to the canopy and inadequate clearance for legs in case of ejection. For small pilots, problems include a reduced external visual field and the inability to reach and execute some critical commands including inflight engine relight, fuel pumps, and radios – using arms and full rudder and brakes – using legs. One of the most critical problems detected due to lack of arm reach was the incapacity to actuate the elevator trim override switch (da Silva, 2013). It was estimated by da Silva (2010) that about 20% of

the current military male pilot population do not fit into the cockpit of the current FAB trainer aircraft (T-27 Tucano). This issue has forced the FAB to select trainee pilot candidates by size, and consequently, a large number of candidates have been excluded based upon the Tucano's anthropometric limitations – estimated an exclusion rate of about 30% for males and 85% of the female candidates, when considering the Brazilian general population (da Silva, 2010). Since at that time there was no up-to-date anthropometric database from Brazilian population, the estimated exclusion rate for both males and female candidates was calculated by using the Brazilian population height and weight range distribution from the 2010 National Demographic Census database (IBGE, 2010; da Silva, 2010).

This problem of poor accommodation has been exacerbated since 2004 by the inclusion of female trainees and pilots in the Brazilian Air Force Academy (AFA). Because the presence of female pilots is a relatively recent phenomenon in military history, starting in the 70's and only in 1993 they were allowed to fly combat aircraft, the majority of military aircraft worldwide have been designed on the basis of male anthropometric data. Since females are, in general, shorter and lighter than males, the use of only male data for designing and constructing cockpits has made it difficult for the female population to operate most aircraft. Thus, as can be seen in Brazilian Air Force, they face higher exclusion rates (about 85%) in the selection process due to their anthropometric dimensions (da Silva, 2010).

Designing aircraft cockpits to accommodate the wide range of body sizes and shapes existing in the U.S. population has always been a difficult problem for crew station engineers (Zehner, 2001). The difficulty can be explained by the physical attributes of the target population (great variability in body size and in proportions is observed), as well as by the multiple dimension domains that must be taken into consideration in the design of an aircraft cockpit. Zehner et al. (1993) stated that the critical dimensions which determine cockpit accommodation and that must be considered simultaneously are: sitting height; eye height, sitting; thumbtip reach; acromion height, sitting; buttock-knee length; and knee height, sitting; which is corroborated by others researchers (Blanchonette, 2013; Department of Defense, 2008; Hudson and Zehner, 1998; Kennedy and Zehner, 1995; Zehner, 1996).

Some authors (Blanchonette, 2013; Coleman and Blanchonette, 2011; Lee et al., 2013; Singh et al., 1995; Zehner, 1996) suggest that a customized anthropometric survey and an in-depth analysis of collected data are needed to develop an ergonomic cockpit design that properly accommodates a designated user population.

The objective of this study was to compare the anthropometric data recently collected on the Brazilian Air Force with corresponding anthropometric data reported in anthropometric surveys of the U.S. military (legacy databases). It is important to point out that the U.S. military legacy databases have been selected for comparison because the Brazilian Air Force and the Brazilian Aeronautical Industry are currently using such databases for cockpit design purposes.

Comparison between these databases are necessary in order to verify any significant morphological differences or similarities in order to determine whether cockpit design based upon legacy U.S. military anthropometric databases are appropriate for the FAB. The results can then be used for improvement in Brazilian product design both in military and general use.

2. Methods

2.1. Brazilian Air Force data

The lack of current, accurate data describing the body

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