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## BIOMEDICAL ENGINEERING | RESEARCH ARTICLE

# Eastern bodies in western cockpits: An anthropometric study in the Oman military aviation

Yousuf M. Al Wardi<sup>1\*</sup>, Sasirajan Jeevarathinam<sup>2</sup> and Saleh H. Al Sabei<sup>1</sup>

**Abstract:** Anthropometric selection standards of aviators in the Royal Air Force of Oman (RAFO) were assimilated from the selection standards utilized by western defence forces and aircraft manufacturers. Gradual Omanization of RAFO aircrew has led to the placement of eastern bodies in western cockpits and hence high recruit rejection rates due to incompatible anthropometric standards. This study was carried out to gain some evidence-based data on this domain. The anthropometric data of 2,296 Omani recruits from 2003 to 2012 were collected and statistical analysis was performed to analyze the distribution of anthropometrically fit and unfit candidates. 86% ( $n = 1,968$ ) fulfilled the RAFO anthropometric fitness standards for aircrew duties and the remaining 14% ( $n = 328$ ) were unfit due to non-compliance in one or many of the anthropometric parameters. 7% ( $n = 158$ ) of the candidates had standing height below 165 cm and 3/4th ( $n = 112$ ) of these candidates were unfit in one or many of the other RAFO anthropometric parameters. This study has provided a platform to understand the discrepancies involved in selection of eastern bodies for western cockpits. This also adds impetus to the concept of periodical updating of military recruitment standards to aid the development of the ideal man-machine interface. This approach will take into account national policy, the significant trends in body sizes of the general population and the procured aircraft profile of the country.

### ABOUT THE AUTHORS

Yousuf M. Al Wardi and Saleh H. Al Sabei are Aviation Medicine Consultants and Sasirajan Jeevarathinam Aviation Medicine Specialist with Royal Air Force of Oman. In Royal Air Force of Oman, we focus on studies aimed to determine proper integration of local man power resources into machinery purchased from developed countries to execute mission safely and efficiently. The focus of the present study is to highlight the regional anthropometric differences in this part of the world and dilemmas involved in utilizing the machinery developed by western countries as per the local anthropometric surveys. We are also focusing on the study to analyze the disability pattern in local population which is responsible for their rejection from being a military aircrew. Such research work in this developing part of the world assists in this endeavor to develop efficient defense personnel considering the local resources and limitations of procured technology.

### PUBLIC INTEREST STATEMENT

Royal Air Force of Oman (RAFO) is one of the developing forces in the Middle East region and like any other forces, RAFO facilitates the optimization of human-machine interface to accomplish mission as well as flight safety. Research work on this domain facilitates the reasonable balance between the efficient usage of available local manpower resources and the procured aircraft profile from western world. The implications of such similar research work are very acknowledged throughout the world and the insights from this present study also provides significant scope to adopt certain modifications in local manpower selection to suit the procured machine from developed world due to ethnic differences in anthropometry compared to different parts of world influenced by various lifestyle factors. Such studies will allow in better understanding of technicalities faced during usage the developed country produced machinery in this part of world using local manpower resources.

AQ1

**Subjects: Ergonomics & Human Factors; Work Design - Ergonomics; Administration and Management; Ethnicity and Culture; Occupational Health & Safety**

**Keywords: anthropometric; flight safety; selection standards; Omani candidates**

### 1. Introduction

It is a well-known fact that optimization of aircrew-aircraft compatibility is of prime importance in military aviation in order to precisely execute the tasks as well as to maintain flight safety. There is a boom in the market for military aircraft due to competition among developing countries to strengthen their military power (The Dwight D., 2015). As in most Middle Eastern Countries, Oman too had established its Air Force using western aircraft and its personnel (Royal Air Force of Oman, n.d). The expansion of the Royal Air Force of Oman (RAFO) driven by Oman's economic growth was facilitated by deployment of experienced defence personnel from UK, USA, etc. (Loan Officers Program) in Oman to encourage the training of Omani man power. Since the 1980's, increasing socio-economic status, education, and motivation among Omanis has facilitated the replacement of expatriate workers with trained Omani personnel under Omanization policy, which in turn boosts self-reliance in local human resources and ensures low unemployment rates in local youth (Analysis of Omanization, 2016; What is Omanization, 2016). This policy had an impact in all fields of RAFO, thereby causing gradual cessation of "Loan Officers" (The RAFO Evolution, 2016).

It is an obvious fact that western military aircraft manufacturers would have had their cockpit workspace designed from the anthropometric data of their local population or adjusted as per the data supplied by customer defence forces so as to achieve a balance between optimum aircraft performance and effective aircrew selection from the general population (Ross, Blanchonette, Olds, & Stratton, 2007; Singh, Peng, Lim, & Ong, 1995). Anthropometric selection standards of aviators in RAFO were formulated from the selection standards utilized by western aircraft manufacturers. No documentation of aircrew-aircraft incompatibility issues in RAFO were found which could be due to the fact that these trained "Loan Officers" were operating similar aircrafts (Scottish Aviation Pioneers, BAC Strikemaster, Hawker Hunter, Jaguar, F16, Lockheed C-130J, C-130 Hercules, NH90, Bell 206, Bell 429, BAE Hawk, etc.) in Oman similar to in their native countries. Gradual Omanization of RAFO aircrew personnel has led to the placement of eastern bodies in western cockpits and hence a dilemma of increased recruit rejection rates in order not to compromise the critical machine-man interface due to incompatible anthropometric standards. The anthropometric data from middle-eastern countries is limited. Until now, there has been no published study on anthropometric data of Omani aircrew recruits and hence this study was carried out to gain some evidence based data on this domain.

The aim of the study was to obtain comprehensive anthropometric data of Omani recruits and to analyze the pattern of rejection rates anthropometrically. This study was also done to further explore the scope for any need to revise the anthropometric guidelines for RAFO aircrew selection in order to efficiently scrutinize the available local manpower resources without compromising the optimum cockpit-human interface. In addition, this anthropometric survey data will serve as a data-base for future extended analysis.

The aircraft cockpit is seen as one of the most complex workstations. Cockpit design and layout requires the knowledge of human anthropometric dimensions to facilitate aircrew-aircraft compatibility. Hence, anthropometry is considered crucial in the process of selection of aviators in the military setting (Choi, Zehner, Hudson, & Fleming, 2009; Lee et al., 2013; MacMillan, 2006; Sharma, Raju, & Agarwal, 2007; Singh et al., 1995). The critical anthropometric dimensions for aircrew selection practiced in most defence forces are: sitting height, arm length (functional reach), leg length (buttock-heel) and thigh length (buttock-knee). It has been stated that cockpit anthropometric criteria for aircraft developed in western countries are based on the 5th and 95th percentile data of U.S and British personnel (MacMillan, 2006; Singh et al., 1995). Also it is stated that aircraft design engineers make their cockpit so that only approximately 12-15% of the general population is too small or too

large to operate the aircraft (MacMillan, 2006). It is well documented that changes in life styles, nutrition, and racial mix of a population has led to secular changes in the body dimensions of the human race in different regions of the world and the Arab Gulf States may be no exception (Bartholomew, 1980; Himes, 1979; Tanner, Hayashi, Preece, & Cameron, 1982; Tomkinson, Clark, & Blanchonette, 2010). These changes might have a significant effect in the military and civilian aviation fields, because recruiting anthropometry standards in most defence forces, including RAFO, have been in place for many years without change. This adds impetus for the acute need to review these standards in order to facilitate optimum man-machine interface in military aviation.

The RAFO anthropometric standard limits practiced since establishment (which were actually adopted from the Royal Air Force) are a standing height of 162 to 188 cm, sitting height of 86.5 to 101 cm, arm reach of 74 to 90 cm, thigh length of 56 to 66 cm and leg length of 100 to 120 cm. Adoption of these limits in aviator selection is still believed to facilitate an effective workspace environment to safely execute the critical tasks of flying as well as procedures during aircraft emergencies (The Armed Forces of Medical Services Headquarters, 2001).

## 2. Methods

Omani recruits for aircrew selection were initially screened for standing height. 3,000 candidates underwent screening for aircrew selection during the period from 2003 to 2012. The process of aircrew selection took place in the same medical centre with the anthropometric measurements been taken by the same experienced staff using a manual anthropometric rig under supervision by the Station Medical Officer. The RAFO recruiting anthropometry standard limits the standing height between 162 and 188 cm. So, only 2,296 candidates who had standing height within these limits were selected for full anthropometric assessment. These anthropometric data of the recruits were collected retrospectively from the recruitment files maintained in the medical centre of the RAFO recruitment station. The recruits were only male as there are no female pilots in RAFO. The study had ethical approval from the commander of the RAFO. The letter for approval was obtained.

The data was subsequently collated and analyzed using Statistical Package for the Social Sciences (SPSS) software version 20. The data was encoded initially prior to feeding it into the SPSS sheet and was then screened for any incomplete or missing data. There were no erroneous or missing data so data analysis was carried out on all cases.

Descriptive statistical analysis of all variables was carried out and results tabulated as means, median, standard deviations and percentiles. Fulfillment of RAFO anthropometric standards among recruits was further analyzed to corroborate further rejection rate. Subsequently, the recruits were divided into two subgroups using a standing height of 165 cm as cut-off for further comparative analysis of rejection rates and the causes of anthropometric unfitness with respect to the rest of the candidates.

## 3. Results

Out of 3,000 Omani candidates who underwent initial screening for standing height standard, 704 candidates did not fulfill the criteria giving an initial screening rejection rate of 23.4%. Among the remaining 2,296 candidates for aircrew selection, the mean age, mean body weight and mean BMI noted were 20.10 years (SD = 2.34), 64.09 kg (SD = 9.52) and 21.65 (SD = 3.06) respectively. The mean values of 5 aviation significant anthropometric parameters like Standing height, Sitting height, arm reach, Thigh length, and Leg length were 171.95 cm (SD = 4.95), 90.31 cm (SD = 2.74), 77.07 cm (SD = 3.33), 58.6 cm (SD = 2.99) and 104.93 cm (SD = 4.05) respectively. 86% ( $n = 1968$ ) fulfilled all the RAFO anthropometric fitness standards for aircrew duties and the remaining 14% ( $n = 328$ ) were unfit due to non-compliance with one or many of the five anthropometric parameters used for aircrew selection in RAFO.

The mean, standard deviation, and percentile distribution of anthropometrically fit and unfit candidates are tabulated respectively in Tables 1 and 2.

**Table 1. Distribution of anthropometrically fit candidates (n = 1,968)**

		Standing height (cm)	Sitting height (cm)	Arm reach (cm)	Thigh length (cm)	Leg length (cm)
Mean		172.83	90.68	77.61	58.83	105.54
Std. deviation		4.57	2.57	2.90	2.19	3.81
Minimum		162.50	86.50	74.00	56.00	100.00
Maximum		188.00	99.00	90.00	66.00	120.00
Percentiles	3	165.00	86.50	74.00	56.00	100.00
	5	166.00	86.50	74.00	56.00	100.00
	50	172.50	90.50	77.00	58.50	105.00
	95	181.37	95.00	83.00	63.00	113.00
	98	183.00	96.80	85.00	64.00	114.50

**Table 2. Distribution of anthropometrically unfit candidates (n = 328)**

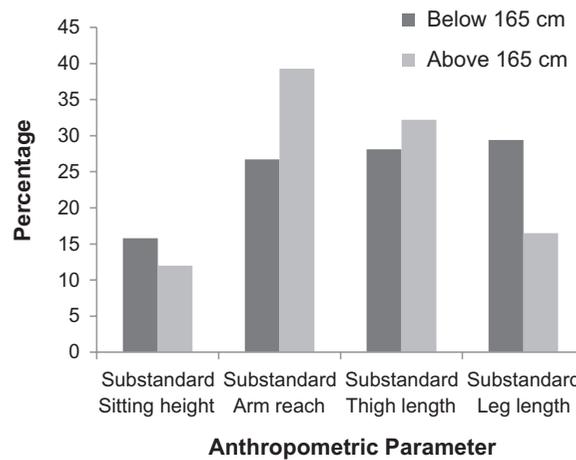
		Standing height (cm)	Sitting height (cm)	Arm reach (cm)	Thigh length (cm)	Leg length (cm)
Mean		166.65	88.04	73.89	57.20	101.24
Std. deviation		3.68	2.62	3.93	5.62	3.49
Minimum		162.30	76.50	51.50	50.00	94.50
Maximum		188.50	98.70	87.00	88.00	120.00
Percentiles	3	162.50	84.00	69.46	53.00	96.50
	5	163.00	84.00	70.00	53.50	97.00
	50	166.00	88.00	73.75	56.00	100.50
	95	173.56	92.50	80.91	68.55	107.40
	98	179.00	94.29	83.13	81.63	110.75

The statistical analysis of segregated data of candidates whose standing height was up to 165 cm is depicted in Table 3. 7% (n = 158) of the candidates had a standing height below 165 cm. 3/4th (n = 112) of these candidates were unfit in one or many of the other RAFO anthropometric standards i.e. Sitting height, Arm Reach, Thigh Length, and Leg length. These constituted 34% of all

**Table 3. Distribution of candidates below 165 cm standing height**

		Standing height (cm)	Sitting height (cm)	Arm reach (cm)	Thigh length (cm)	Leg length (cm)
n		158				
Mean		163.73	87.14	74.15	56.03	99.94
Std. deviation		0.66	1.94	2.53	3.21	2.16
Minimum		162.30	76.50	68.50	50.00	94.50
Maximum		164.90	92.60	82.50	86.00	108.00
Percentiles	3	162.50	83.89	70.00	53.00	95.89
	5	162.50	84.00	70.00	53.50	96.49
	25	163.20	86.50	72.00	55.00	98.60
	50	163.90	87.00	74.00	56.00	100.00
	75	164.20	88.03	75.00	56.50	101.00
	95	164.71	90.03	79.24	58.00	104.03
	98	164.88	91.48	80.20	60.97	105.00

**Figure 1. Substandard anthropometric causes of unfitness.**



anthropometrically unfit candidates. Of these 158 candidates below 165 cm, about half of them ( $n = 75$ ) were anthropometrically unfit due to multiple substandard anthropometric parameters.

The percentage distribution of anthropometric unfitness in those two sub-groups mentioned earlier is depicted in Figure 1. The majority of the anthropometric rejection in both groups was due to the failure to satisfy the minimum limit of anthropometric aircrew recruitment standards, except for the 10 candidates with standing height above 165 cm having thigh length measurement above standards limits for aircrew selection.

#### 4. Discussions

This study provides the preliminary understanding of the anthropometric distribution of Omani candidates for aircrew selection in the Oman armed forces and provides important data for aeromedical consideration. They are discussed in succeeding paragraphs.

##### 4.1. Recruitment anthropometric rejection rate

In this study, it was noted that 14% of Omani candidates who underwent detailed anthropometric evaluation were unfit in at least one anthropometric parameter as per current RAFO standards. This is in addition to an initial rejection rate of 23.4% based on standing height alone. Similar results were found in a study of Indian Air Force aircrew candidates (Patil & Taneja, 2006).

These findings are also supported by the literature where it is described that military aircraft engineers design the cockpit so that only 12–15% of the population should be too small or too large to operate the aircraft (MacMillan, 2006). On the other hand, the total rejection rate of Omani candidates anthropometrically being 37.4% adds weight to the concern that procured western aircraft designed with respect to their native anthropometric data might not facilitate optimum utilization of manpower of eastern country populations like Oman for aircrew selection.

##### 4.2. Anthropometric incompatibilities

The literature suggests that anthropometry is a major consideration in military flying and the fitness standards are laid to facilitate aircrew-aircraft compatibility and flight safety. In this study, it is evident that anthropometric incompatibility is a major concern for disqualification in aircrew selection similar to several other studies (Patil & Taneja, 2006; Venkatesh, Taneja, & Pant, 2006). From this study, it is shown that substandard leg length and substandard arm reach were the leading causes of rejection for those below 165 cm and those above 165 cm standing height respectively. The second leading cause in both groups was substandard thigh length. A similar pattern is noted in other studies (Patil & Taneja, 2006; Singh et al., 1995; Venkatesh et al., 2006).

#### 4.3. Anthropometric selection criteria and percentiles

As stated earlier, the aircraft cockpit is designed to nominally accommodate the 5th to 95th percentile of the population across aviation significant anthropometric parameters. It is understandable that a single individual may not have all the anthropometric parameters within the percentiles suitable for aircrew selection and hence faces the possibility of rejection (MacMillan, 2006). But the body growth trends over the last 100 years among the global population may be skewed by cultural mix, intergenerational, racial, and shape differences (Tomkinson et al., 2010). Hence, there may be a significant possibility of anthropometric differences (particularly segmental differences) between western and middle-eastern populations. This may give rise to serious ergonomic problems when utilizing the same machinery (Singh et al., 1995). In this study, it was found that those who passed the RAFO aircrew standard for standing height but failed in other aviation significant anthropometric parameters had the minimum recruitment standard measurement around 50th percentile. Henceforth, the findings of this study also suggest this ideology regarding body dimensions of Omani candidates.

#### 4.4. Revision of RAFO anthropometric guidelines

In this study, it was found that 112 out of 158 candidates whose standing height was below 165 cm failed in one or multiple other aviation significant anthropometric parameters. The aircraft bought from developed countries delineates the need for specific limits of anthropometric parameters in aircrew to facilitate efficient aircrew-aircraft compatibility which cannot be compromised. Hence, significant rejection of these candidates below 165 cm standing height has given the scope for revision of RAFO anthropometric standards for aircrew selection in terms of standing height to be fixed between 165 and 188 cm. This change in aircrew recruitment protocol would help to reduce unnecessary workload at the medical center of the RAFO recruitment station.

### 5. Conclusion

This anthropometric survey study is the first of its kind in RAFO and has provided a platform to understand the selection of Omani aircrew in terms of their accommodation in western aviation cockpit operations. The findings of this study add impetus to the need for periodical updating of military recruitment standards to aid development of the ideal man-machine interface. This approach will take into consideration national policy: the secular trends in body sizes of the general population and the procured aircraft profile of the country. Future detailed studies of this nature in this organization may act as a tool to provide accurate anthropometric data to the aircraft manufacturer so as to optimize the recruitment process among the general population and utilize maximum efficient manpower resources.

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