

## Female anthropometry - Perceived problems in aviation

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*Selecting women for existing cockpits is important for safe and effective flying. Ergonomic parameters of 140 women candidates of Indian Air Force (IAF) for aircrew and ground duties were studied and compared with those of their male counterparts and with other air forces. The 95th percentile IAF women and USAF women shows significant difference in various anthropometric parameters. The aeromedical implications as far as aircrew selection, compatibility with existing aircraft cockpit and protective flying clothing assemblies are discussed.*

**Key Words :** Skin fold thickness, percentage body fat.

Human performance results on the "interaction of variables" such as the task, the environment, the individual and so on, amongst which gender is another one to be now considered. For the present we do not have enough information to determine whether or not the gender variable is relevant with the piloting task. At one time only men could become operational pilots in the Indian Air Force (IAF). This policy was based more on traditional and social practice than on any scientific basis. The changing role for

women within most societies have caused military planners to consider an expanded occupational potential for women in the military.

The decision to recruit women in the IAF raises certain questions about their physical and physiological performances at the aircraft controls. There are also certain relevant aspects related to anthropometric considerations which require to be investigated in order to get a sound scientific approach for future projects.

### Material and Method.

Static anthropometric measurements were taken for 140 female candidates who were selected to join IAF. The age group of all these female subjects were between 19 to 23 years. Using a portable anthropometer, specific measurements of body dimensions were carried out by standard techniques [1]. Based on their anthropometric dimensions, their compatibility to various cockpits were studied and limitations determined.

Skin fold thickness from four body sites, i.e. biceps, triceps, subscapular and anterior superior iliac spine, were measured using

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skin calipers and percentage body fat was calculated by the method of Durnin Woomersely. [2]

Four anthropometric dimensions were selected as critical for entry. They were stature, sitting height, leg length and thigh length. Accommodation assessments were based on aircraft requirements for head clearance, leg reach and clearance. Weight measurements were also carried out to study the correlation between body fat percentage and body weight.

## Results

Anthropometric criteria that must be satisfied for current IAF aircrew are listed in Table I.

Table I

### Anthropometric Criteria for Fitness

Parameter	Minimum Value (cm)	Maximum Value (cm)
Height	162.5	--
Sitting Height	81.5	96.0
Leg Length	99.0	120.0
Thigh Length	--	64.0

The anthropometric parameters based on the analysis of data pertaining to 140 women candidates for aircrew and ground duty compared with that of percentile population of Indian Pilots of IAF are presented in Table II.

Table II  
Percentile distribution of  
Anthropometric Data

Parameter	Number	5PPP	50PPP	95PPP
<b>Stature</b>				
IAF(M)	2020	163.0	171.4	181.3
IAF(F)	140	151.8	161.2	169.5
<b>Sitting Height</b>				
IAF(M)	2020	84.0	88.9	94.3
IAF(F)	140	80.5	83.6	89.3
<b>Leg Length</b>				
IAF(M)	2020	100.0	106.6	114.9
IAF(F)	140	92.6	99.9	108.1
<b>Thigh Length</b>				
IAF(M)	2020	55.2	58.6	62.6
IAF(F)	140	51.5	56.2	59.7
<b>Weight</b>				
IAF(M)	2020	46.3	56.5	71.8
IAF(F)	140	43.8	53.1	67.8
<b>Functional Arm</b>				
Reach				
IAF(M)	2020	76.2	81.4	87.7
IAF(F)	140	68.3	74.0	80.8

PPP : Pilot Percentile Population

From this Table it is seen that 50th percentile Indian female falls below the aircrew entry standards in stature. Comparing Indian male pilot population to female candidates, it is seen that 50th percentile IAF male pilots approximately correspond to 95th percentile female candidates in sitting height and functional arm reach. The 5th percentile IAF male pilots correspond to 50th percentile female candidates in leg length. Seeing these Tables it is reasonable to conclude that over half the female pilot population will be excluded from aircrew selection.

No formal lower limit for thigh length was determined in IAF, as no problems were envisaged within the normal IAF male aircrew size range. Similarly, functional arm reach was not considered a critical criterion for aircrew selection. If however lower limit of thigh length and functional arm reach are considered, then a greater percentage of female population will be excluded from aircrew entry.

The weight and mean percentage body fat (PBF) of Indian female candidates is compared with that of USAF female and male trainees in Table III. It is noticed that body fat content is higher in women for a lower weight resulting in lower lean body mass.

Table III

Percentage body fat of IAF Females and USAF females and males.

Variables	Number	Weight (Kg)	PBF(%)
Ind(F)	86	51.1	21.7
USAF (F)	90	57.7	24.3
USAF(M)	90	78.7	14.0

Discussion

To ensure accommodation of pilots in aircraft crew stations, aircrew are selected on the basis of specific anthropometric standards. The most common selection criteria are minimum and maximum acceptable limits for several anthropometric dimensions. Selected crew, whether male or female must be able to operate all IAF aircrafts. It must be remembered that critical training aircraft must be flown before moving on to other types.

It is evident from the result that clear differences exist between male and female physical measurements. Applying anthropometric criteria to male and female population yielded acceptance figures of 95th and 50th percentile respectively [3]. Females being shorter than males experience fewer incompatibility problems with head clearance, however they undergo a much larger rejection than males do due to their substandard sitting height and leg length. In Canadian Forces, the reason for medical rejection of female candidates is mainly anthropometry [4].

Our aircraft cockpits are generally designed to accommodate men rather than women. The range of body size that can be accommodated by modern aircrafts is limited by many factors. Current standards which exclude the smallest 5% of male population would exclude approximately 50% of female population. Extending the design range would accommodate a greater percentage of women. A range of 35.30 cms would be required to accommodate all but the shortest 5% of women and all but tallest 5% of men [5]. This would increase cost. But cost of equipment/aircraft modification would depend on system being modified. The issue is not simply one of gender. Women are not simply proportionately smaller than men. Although 50th percentile woman approximately corresponds to 5th percentile man, in stature she will probably have larger hips and chest depths and smaller hands. Female hip circumference is often proportionately larger than torso length or chest girth. Women also have shorter arm length than men of same height.

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females might not be compatible with ejection seats. For example the seat of T-38 will tend to rotate backwards when ejecting a crew member weighing less than 63 kg. Gragg in his technical report on ejection seat testing for females had said women might more easily sustain spinal injuries when using standard ejection seats [6]. However no injury has been reported in USAF among women on ejection seat trainer [7].

Current standards do not always represent what is actually required to meet the specifications of operational aircrafts. Aircrafts vary widely with respect to what sizes are accommodated. For example a recent Canadian study demonstrated that 94% of females and only 61% of males fit adequately in the CT - 33 Silver Star [8]. This was because many males had inadequate head clearance. By comparison only 19% of Canadian males and 10% of females fit in the CH - 136 Kioma, and this is due to insufficient leg length [9]. It is clear that an investigation of the anthropometry limitation for individual aircraft is required to determine the acceptable limits for individuals at lower end of aircrew entry standards.

Another problem in integrating women into the pilot force is personal and protective equipment. Increasing the number of sizes at the smaller end of scale can only partially solve the problem. The smallest size helmet now available may not fit snugly and may sit higher on the female head causing instability during +Gz acceleration and ejection. Differing facial dimensions can cause difficulty with mask or goggle seals. G suits are manufactured for those with stature of 162.5 cms, which is the minimum

height acceptable for entry into IAF. This value corresponds to approximately 50th percentile female value.

It is believed that strength will also play an important role. One of Gen. Hap Arnold's original concern was that women might not be capable of strength required to manipulate flight controls in aircraft such as B-17 [9]. But Jacqueline Cochran argues that not only is muscular strength becoming less and less of a factor in piloting of our planes, but selected women in large numbers are available who have sufficient size and strength for those tasks [7]. Few studies have been performed simulating actual aviation environment. The FAA studied the ability of women to meet current strength limits of aircraft controls in realistic flight simulator. Out of 24 women, 19 were able to maintain the required 150 lbs of rudder pressure for 30 seconds required for controls of civil aircraft [10]. However, a 1981 study of strength of 61 male and 61 female volunteers meeting USAF height and weight criteria for pilot demonstrated that female arm strength was much less than that of males and often below military design criteria. But leg strength was usually sufficient to meet the necessary criteria. Men and women obtained similar benefits from strength training programmes [11].

This great difference in strength of males is accounted by males' greater lean body mass. It is noticed that body fat content is higher in women for a lower weight resulting in lower lean body mass. Male-female strength differences may become of less operational significance in cockpits of modern fly by wire aircraft. Studies have demonstrated that gender free standards can be developed [12].

### Conclusion

To offer female aircrew a selective career on account of size would be discriminating against their male counterparts. It has always been possible for waivers to be granted to aircrew with excellent potential but who are outside one or more anthropometric limitations. The other alternative is to send women through the appropriate distinctive training for jets, helicopters or transport based on their anthropometric limitations.

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