Original Article

Static anthropometry: Current practice to determine aircrew aircraft compatibility

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ABSTRACT

Anthropometry is one of the vital tools in determining the selection of military aviators, including in the Indian Air Force. Anthropometric measurements are strictly followed due to limitations of the cockpit layout and the available ejection systems. This allows rejection of aspirants for fighter flying during basic flying training itself. However a few are found unfit to fly certain types of fighter aircraft even later. This leads to wasted flying effort and cost to the exchequer despite of stringent anthropometric evaluation, including mandatory cockpit trials for the borderline cases. This study aimed to review the existing anthropometry procedures followed at an aero-medical training centre for selection of fighter pilots. Two sets of anthropometric data, of the same population of fighter trainee pilots, were reviewed twelve months apart. This data was analyzed within the purview of the existing guidelines for static anthropometry and the final fitness, based on the cockpit trials. The study revealed that there was an evident increase in all the anthropometric measurements after one year of initial measurements. Mean increase in height, sitting height, leg length and thigh length was 0.6 cm (+ 0.7), 0.4 cm (+ 0.5), 0.5 cm (+ 0.7) and 0.5 cm (+0.8), respectively. Mean increase in weight was 1.6 Kg (+2.9). From an initial 62.60% of the trainee pilots found fit for flying all types of fighter aircraft; after one year only 57.39% of those initially examined remained fit for the same. 27.82% of trainee pilots were found unfit to fly Trainer a fighter, primarily because of the sitting height limitations. However, this group was found fit to fly Trainer B fighter which can accommodate higher percentile of pilot population. Based on the findings of this study, various anthropometric variables and other factors responsible for rejection are discussed. Sitting height was found to be the determining anthropometric variable for selection of pilots for fighter training. Suggestions, based on the body of work elsewhere and advances in imaging and simulation technology, for reduction in the rejection rate for pilots for fighter training are made.

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Anthropometry is one of the vital tools in determining the selection of military aviators. The need for stringent anthropometric selection criterion is meant to ensure aircrew aircraft compatibility during training and later, without compromising individual comfort and safety. Indian Air Force (IAF) follows an exhaustive protocol to determine the fitness of trainee pilots for fighter aircraft. This includes laying down range of standard static anthropometry measurements, anthropometric limitations (in cm) for various fighter aircraft and cockpit / encapsulation trials for determining the aircraft stream for the trainee pilots [1, 2].

The divergent aircraft inventory of IAF, including utilization of both indigenous and aircraft from abroad for fighter training, it is necessary that the right man fits into the right machine. Besides the recent induction of Hawks, vintage MiG aircraft play an important role during the early training of the fighter pilots. For ease of reference, two of the MiG aircraft used for fighter training are referred as Trainer A and Trainer B. The anthropometric requirements for different aircraft vary. Hence, one of the stumbling blocks for budding pilots is their anthropometric measurements. To obviate wastage

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at a later date, and for the sake of economy, compulsory anthropometric evaluation coinciding with medical fitness for training has been mandated at regular interval [1]. This also caters for the growth spurt due to military training during late adolescence of the trainee pilots.

Despite strict compliance with the laid down guidelines for anthropometric evaluation, there have been occasions when some trainee pilots were rejected during their flying training for the fighter stream, whereas others were found unfit to continue flying certain types of fighters [Personal Communication]. This has become all the more relevant with introduction of light weight integrated helmet (LWIH), in place of the old two piece helmet used by the majority of fighter pilots. In one of the trials of sitting height (SH) measurement with LWIH, it was found that the helmet adds between 2 - 5 cm to SH [3]. Another trial report on Trainer B aircraft did not find any variation in SH with LWIH compared to two piece older helmet [4]. It is known that SH is the determining factor for the overhead clearance, design eye point (DEP) and the range of adjustment of the seat height for adequate vision inside and outside the cockpit. Thus SH invariably is the final determinant in most of the cases for fitness for training in fighters, whether helmet adds to the SH or not.

This study reviewed the existing anthropometry procedures'; including evaluating whether SH is the determining anthropometric variable, in selection of pilots for fighter training. The study also aimed to address whether the latest advances in imaging and simulation technology can help define the aircrew aircraft compatibility better than the existing procedure.

Material and Methods

This retrospective study evaluated the available anthropometric measurements of trainee pilots at one of the Aero Medical centers with the sole purpose to evaluate the vital anthropometric measurements determining the selection for fighter flying. This sample population included 115 male subjects, who had opted for fighter flying.

Two sets of anthropometric measurements for the sample population, exactly after an interval of twelve months, were taken at this centre, as per the laid down policy [1]. The measurements were taken by the same group of evaluators during the period of observation, yet inter-observer and intra-observer variation can not be completely ruled out. The measurements were taken any time from 0800 to 1700 hour; hence diurnal variation can not be ruled out either.

All the anthropometric measurements were taken on the same anthropometric platform as per the standard protocol [5]. The anthropometric measurements for the purpose of the present study were height, sitting height, leg length, and thigh length [1]. All the measurements were recorded in cm, up to the nearest mm, as per the standard recording methods [6]. The weight in Kg was measured on a standard spring balanced scale. The subjects were stripped to their undergarments during the measurements.

For ease of presentation, descriptive statistics has been used.

Results

Table 1 shows the latest standard measurements for the sample population. Table 2 shows the initial standard measurements for the sample population. Table 3 shows the mean difference and the range between the latest and the initial standard measurements for the sample population. The mean gain in height for the subjects was 0.6 cm (+ 0.7), and the mean gain in weight was 1.6 Kg (+ 2.9). This gain in height and weight

Table 1: Latest anthropometric measurements of the sample population (n

Variable	Mean	SD	Coefficientof Variation	Range
Height (cm)	173.7	4.99	2.872	162.7-184.8
Sitting Height (cm)	90.94	2.61	2.870	85.5-97.7
Leg Length (cm)	106.75	4.01	3.756	99.0-115.2
Thigh Length (cm)	58.7	2.13	3.628	53.0-65.0
Weight (Kg)	63.52	6.84	10.768	50.0-86.5

Table 2: Initial anthropometric measurements of the sample population (n = **115)**

Variable	Mean	SD	Coefficientof Variation	Range
Height (cm)	173.0	4.95	2.861	162.5-184.4
Sitting Height (cm)	90.54	2.55	2.816	85.3-97.5
Leg Length (cm)	106.24	3.99	3.755	99.0-115.0
Thigh Length (cm)	58.29	2.13	3.654	51.3-64.5
Weight (Kg)	61.95	5.49	8.861	48.0-77.0

Table 3: Mean difference between latest and initial anthropometric measurements of the

Variable	Present Measure Mean(SD)	Previous Measure Mean (SD)	Difference in Measurements Mean(SD)	Difference in Measurements Range
Height (cm)	173.7 (+4.99)	173.0(+4.95)	0.6 (+0.7)	0-5.1
Sitting Height (cm)	90.94 (+2.61)	90.54 (+2.55)	0.4 (+0.5)	0-3.1
Leg Length (cm)	106.75 (+4.01)	106.24 (+3.99)	0.5 (+0.7)	0-4.0
Thigh Length (cm)	58.7 (+2.13)	58.29 (+2.13)	0.5 (+0.8)	0-5.2
Weight (Kg)	63.52 (+6.84)	61.95 (+5.49)	1.6 (+2.9)	-7.0-17.0

was from the mean increase in age from 21 years (+ 0.68) to 22 years (+ 0.68) (Table 3). The mean increase in SH was 0.4 cm (+ 0.5) from mean 90.54 cm (+2.55) to 90.94 cm (+ 2.61) between the two measurements made after a gap of a year (Table 3). The mean increase in LL over a period of one year was 0.5 cm (+ 0.7) from mean 106.24 cm (+ 3.99) to 106.75 cm (+ 4.01). The mean increase in TL was 0.5 cm (+ 0.8) from mean 58.29 cm (+ 2.25) to 58.70cm (+ 2.13) between the two measurements over one year.

Table 4 shows the tentative fitness for fighter flying based on both the sets of SH measurements, as per the policy guidelines [1].

Table 5 shows the anthropometric requirements as per laid down policy [1] and the requirement for cockpit trials, based on the anthropometric measurements, to determine aircrew aircraft compatibility.

The final outcome of aircrew aircraft compatibility after the cockpit / encapsulation trials revealed that all the trainee pilots who underwent cockpit trials for Trainer A (n = 32; 27.82%) were found unfit, whereas all those for Trainer B (n =

Table 4: Distribution of sitting height measurements as per policy guidelines

SH for Aircraft Type fitness for different	< 91.5 cm	91.5-93.5 cm	93-94 cm	>94.1 -<96.0cm	>96.1cm*	Total Number (115)
	n (%)	n(%)	n (%)	n (%)	n (%)	n (%)
Previous SH	72(62.60%)	32(27.82%)	12(10.43%)	7(6.08%)	3(2.60%)	126**
Latest SH	66(57.39%)	32(27.82%)	11(9.56%)	12(10.43%)	3(2.60%)	124**
Remarks***	Fit of all Aircraft	Cockpit Trials for Trainer A	Cockpit Trials only for Operational	Cockpit for Trainer B flying	Underwent Cockpit Trials for Trainer B	

NOT

Pilots with SH more than 96.0 cm underwent cockpit trials for Trainer B, as a one time requirement. They were found fit and continued fighter flying. Otherwise, trainee pilots with SH more than 96.0 cm are recommended unfit for fighter flying

Total number is more than the number of trainee pilots, since cockpit trials are mandated for both Trainer A and operational flying for pilots with SH between 91.5 cm to 93.5 cm and 93.0 cm to 94.0 cm, thus some pilots undergo both trials.

Cockpit trials are mandatory after basic flying training to ascertain fitness for fighter flying. It may however be resorted to after one year as well, at the discretion of evaluation center, when the pilot is already undergoing training for fighter flying.

Table 5: Aircrew aircraft compatibility as per anthropometric measurements of the sample population (n

Variable	Policy Limits (Range) |1|	Latest Measurements Range	Aircrew unfit for fighter training, based on guidelines alone N (%)	Aircrew for cockpit trials (Refer Table 4 above) n (%)
Height (cm)	> 162.5	162.7-184.8	Nil	Nil
Sitting Height (cm)	81.50-96.0	85.5-97.7	9(7.82%)	44* (38.26%)
Leg Length (cm)	99.0-120.0	99.0-115.2	Nil	Nil
Thigh Length (cm)	<64.0	53.0-65.0	01(0.86%)	01 (0.86%)
Weight (Kg)	As per nomogram for age group and height	50.0-86.5	**NA**	NA

Note: * Total number is less than the arithmetic sum. as reported -ore than one in table 4 above, since some pilots who underwent trials for aircraft type are counted as a single unit

':: 8.69%) were found fit for further training on -.-at aircraft type.

Discussion

The static anthropometric measurements for ve **IAF** pilot selection viz. height, SH, LL and TL e the greatest value in connection with spaces - :he aircraft. The other important measurements -:ch complete this list are arm length, and seat --eadth or seated hip width [9]. Stature or height is a significant measurement not only for military bearing, but along with weight reflects good correlation with most of the anthropometric parameters and the physical strength [7]. Yet, it is mandatory that the stated measurements are recorded as per standard protocol [1]. This is to ensure that any one factor does not become a cause for rejection after a pilot has been selected for fighter flying.

Table 6: Comparative anthropometric measurements between the sample population (n = 115) of present study with an earlier study (n = 106) |7|

Variable	Present Study Mean (SD)	Present Study Coefficient of Variation	Earlier Study [7] Mean (SD)	Earlier Study [7] Coefficient of Variation
Height (cm)	173.7 (+4.99)	2.872	173.0 (+5.28)	3.052
Sitting Height (cm)	90.94 (+2.61)	2.870	89.97 (+2.97)	3.306
Leg Length (cm)	106.75 (+4.01)	3.756	108.26 (+4.55)	4.209
Thigh Length (cm)	58.7 (+2.13)	3.628	58.67 (+2.03)	3.462
Weight (Kg)	63.52 (+6.84)	10.768	69.5 (+8.34)	12.011

Measurement technique using the IAM anthropometry platform has been long validated and are routinely used at all the IAF evaluation centers [6]. A comparison of anthropometric measurements with an earlier study [7] based on similar sample population (n = 106) of aircrew between the age of 20 to 54 years is placed as table 6. As is evident that there was minimal variation seen between present study and an earlier one [7]. Though means of both the studies are similar, there is a difference in the coefficient of variation. Thus, it can be said that the inter-observer variation between different evaluation centers is not likely to be a major cause of error, although possibility of such variations exists. Moreover in the present study, data for both sets of anthropometry measurements has been taken from the same center, using the same anthropometric platform and by and large, with same set of observers.

The analysis of the data of the sample population in this study revealed that there is a marginal increase in all the recorded anthropometric measurements (Table 1, 2 and 3). It is noteworthy that SH measurements have the least co-efficient of variation 2.870 (table 1) and 2.816 (table 2). This reflects that this data is more consistent, uniform, stable, homogenous and less variable. Yet, an increase in SH during a period of one year leads to increase in number of trainee pilots likely to be unfit for either Trainer A or Trainer B.

There have been occasions when pilots have been found unfit to continue fighter training at a later stage, especially for Trainer A, and infrequently for Trainer B. Besides the wasted flying efforts and the cost to the exchequer, there is delay in determining the future course of training for the affected pilot. In order to obviate such situation, the fighter trainee pilots undergo repeat anthropometry during basic fighter training, to weed out those who might have continued to grow or gain weight from being selected for further training predominantly on Trainer A. Yet repeated anthropometric measurements have failed to screen a few fighter trainee pilots from becoming unfit for further training.

The primary reason for such occurrences in Trainer A is primarily cockpit layout and the safety concerns for the pilots in case of an ejection. An occasional case of being unfit in Trainer B was primarily due to lowering of SH requirement by 0.5 cm, after modification of personal survival pack (PSP) as per the revised geographical location of the training squadron. However, one factor that must be considered is an increase in the anthropomorphic measurements due to continued growth in early adulthood. This is evident since mean increase in height, sitting height, leg length and thigh length was 0.6 cm (+ 0.7), 0.4 cm (+ 0.5), 0.5 cm (+ 0.7) and 0.5 cm (+ 0.8), respectively (Table 1, 2 and 3). So also, there were 62.60% of the trainee pilots initially found fit for flying all types of fighter aircraft; after one year only 57.39% remained fit for the same.

Mean increase in weight was found to be 1.6 Kg (+ 2.9). This could be because of changes in lifestyle for the pilots, especially after commissioning. This leads to increased weight, mostly in the form of body fat. Static anthropometry may well serve the purpose it is meant for, so long as the selected aircrews maintain their measurements, but increase in weight and body fat redistribution is inevitable. Increased weight may ?e the result of decline in physical activity levels of i.e. military training days, once a pilot continues focusing on his chosen profession. Moreover, resides subtle changes or redistribution in body fat, static anthropometric measurements could further compromise a pilot inside the cockpit by factors like seat inclination, restraint mechanism [8] or type : the PSP on the seat pan.

The major reason for higher rate of rejection Trainer Abut and higher rate of fitness for Trainer 5 during cockpit / encapsulation trials is the difference in the ejection systems. Hence safety concerns for both the aircraft types are different. The type of ejection system available in the Trainer A is semi-capsular ejection system. This requires that the safety criterion of minimum 5 cm distance between top of the helmet and a metallic plate located little below the canopy and just above the ***helme***ted head must be strictly adhered to during. Spit trials [1]. Trainer B, on the other hand, has conventional ejection system where the sequence ejection seat firing is activated after the canopy jettisons, on pulling the ejection seat main firing handles. In case of failure of automatic canopy jettison, it has to be manually jettisoned. Thus there is break possibility of a through-canopy ejection. Hence the existing safety criterion of minimum 3cm distance between top of the helmet and canopy suffices. This is evident as per the final outcome of cockpit trials where all the trainee pilots who underwent cockpit trials for Trainer A were rejected (n = 32) for further flying; and among those who underwent trials for Trainer B were found fit (n = 10). It is also evident that a higher numbers undergo trials for Trainer A, because this group of SH percentile constitutes the majority of trainee pilots [2].

Restriction for selection for fighter training based on SH primarily determines that the selected trainee pilots are neither likely to foul their heads with canopy during routine operations, nor the sitting posture shall compromise their safety during ejection. In addition, appropriate SH ensures that all round vision and control reaches are not compromised. SH, thus emerged as the vital determining factor for selection of pilots for further training in fighter aircraft. This is a known fact and has been reaffirmed by this study (Table 5).

Other measurements, although vital for flight control and safety, are less likely to be a cause for rejection for fighter flying (Table 5). Amongst them, TL is crucial, with a maximum permissible limit of 64 cm. This is vital for the clearance of the knees for rudder operations as well as to prevent fouling of the knees during ejection to avoid egress injuries of the lower limb. On the other hand, LL may be a redundant factor. LL is meant to determine the ease of rudder pedal operations and adequate leg room. United States (US) Air Force does not require measurement of LL for its pilots, and pilots of US Army undergo measurement of functional LL [10].

It is established that the corresponding percentile values of parameters can be estimated for specified percentile of stature with regression equations while using specified proportions [7, 11, and 12]. With the available exhaustive database of the IAF pilot population during their early period of training, coinciding with early adulthood and the likely growth spurts, the expected growth pattern utilizing the regression equation can be worked out. This can be correlated with other factors like regional differences, physical built and gender biases to arrive at the growth curve during the pilot training stage for the IAF. Once validated such a tool shall help a fresh applicant for pilot training to be evaluated once, with projected recommendations for fitness for likely aircraft stream be made objectively. This need has become more imperative with the likelihood of women joining the fighter stream in near future.

Such a step would also obviate the need for repeated static anthropometric measurements and cockpit trials for fighter flying. However such a bold step also requires absolutely accurate methods of measurement. Accuracy of measurement can be achieved with the help of existing digital imaging and simulation technology [13, 14]. This shall require digital acquisition of anthropometric measurements, with laser or infra red camera. There are commercial 3-D optical sensing devices available for such purpose. This includes Laser Scanning Triangulation, Moiré Fringe Contouring, Phase Measuring Profilometry and Digital Stereo Photogrammetric [13].

The data acquisition must not focus on static anthropometry but dynamic three dimensional measurements. The acquired image must then be developed into individual digital mannequin, to be fitted into CAD generated aircraft specific cockpit. Such a marriage of dynamic image acquisition and cockpit simulation shall provide accurate prediction of anthropomorphic fitness of the trainee pilot for the specific fighter aircraft. The investment in development of such system, once functional, shall easily be offset be saved man-hours for undertaking anthropometric measurements at different stages and cockpit trials. A spin off of such digital system could be its use in design and development of personal flying clothing tailored to individual needs.

Conclusion

This paper analyzed two sets of anthropometric measurements of same sample population of trainee pilots. This was to evaluate the vital anthropometric measurements that determine the selection for fighter flying. The study reaffirmed that sitting height is the determining anthropometric factor in selection of pilots for fighter training. Since IAF continues to use Trainer A, an aircraft with strict anthropometric requirements, chances of a higher rejection of trainee pilots for fighter flying shall persist. It is recommended that the existing methods of static anthropometric measurement must give way to digital imaging techniques. Development of dynamic image acquisition and cockpit simulation system shall provide accurate prediction of aircrew aircraft compatibility.

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