BODY MEASUREMENTS IN RELATION TO COCKPIT DESIGN

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The paper deals with the major conclusions arising from the statistical analysis of 22 body measurements of 691 airmen. Besides the upper and lower 95 per cent confidence limits for these characters, the regression equations for (i) body a-eight on the measure nent of abdomen, shoulder, elbow, seat maximum below hips and total height and (*ii*) total height on knee height and thigh height, have also been given.

The cockpit of an aeroplane should be so designed that the pilot feels comfortable in his movements while performing his normal duties in the cockpit. Such a design can best be made by taking into consideration the relevant body measurements of the prospective pilots. The data available from other countries like the U.K. and the U.S.A. is not of much avail in this respect as an average Indian is different from the Americans or the British in regard to shape and size.[1,2] Therefore twenty projection measurements along with weight and height were collected for 691 airmen. The data collected were statistically analysed. The purpose of the present paper is to bring out a few salient features and conclusions of the statistical analysis in order to make it easily accessible to those interested in such statistical study.

The twenty two measurements/characteristics were:

1. Top of head to floor
2. Sitting height
3. Seat to floor
4. Shoulder to seat
5. Elbow to seat
6. Knee height
7. Eye to top of head
8. Thigh
9. Total leg
10. Heel on floor with leg extended
11. Forearm
12. Total arm
13. Chest
14. Abdomen
15. Head
16. Shoulder
17. Elbows
18. Seat maximum below hips
19. Span Akimbo
20. Maximum span
21. Total height
22. Body weight

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HOMGENEITY

Confidence limits for the above characters, based on the whole data, will be misleading unless the data is homogeneous. Homogeneity, therefore, was tested first. For this the entire data was classified according to four age groups (18—25 years, 25—30 years, 30—35 years and above 35 years) and also according to suitable groups of the states of origin. Geographical proximity, food habits and racial homogeneity were the guiding considerations for the latter. The groups were (*i*) Bengal, Bihar and Assam; (*ii*). Bombay and Madhya Pradesh; (*iii*). Madras, Mysore and Kerala; (*iv*). Punjab and Delhi; and (*v*). Uttar Pradesh.

An examination of the data, however, revealed that almost all the characters attain a kind of stability by the age of 18. This is true even for the body weight which is snpposed to increase with age. Perhaps, this is due to regular P.T. exercise taken by airmen. There were a few exceptions *e.g.*, in Bengal and Madras, character No. 7 showed a significant difference among the age groups. On the whole, it looked as if the age group classification could be conveniently removed. This conclusion has also been reached at by Patwardhan[2].

The homogeneity for the other classification was tested by the standard analysis of variance technique of forming the between and within groups sums of squares. This was carried out for only five characters *viz.*, 1—4 and 9. The M.S.S. (Mean Sum of Squares) are recorded in Table 1. The 5th group consists of only one state *viz.*, Uttar Pradesh and hence it has no degrees of freedom (d.f.).

The significance of these sum of squares (S.S.) was tested by using the within age-group S.S. for different constituent states (suitably aclded together) as error S.S. All were found to be insignificant. The M.S.S. for between stategroups are given in Table 2.

TABLE 1

WITHIN GROUP BETWEEN STATES M.S.S.

Group No.	1	2	3	4
d.f.	2	1	2	1
Character No.				
1	3738·15	61·3	643·35	137·8
2	2586·15	19·1	1101·80	87·0
3	197·50	130·0	223·65	4·0
4	307·60	35·3	679·40	28·2
9	1657·65	2613·6	1305·50	1908·3

TABLE 2

BETWEEN STATE GROUPS (D.F. 4) M.S.S.

Character No.	M.S.S.	Error M.S.S.
1	21361·9	1706·14
2	18991·6	834·76
3	1089·2	479·74
4	8967·4	651·94
9	10698·8	2010·69

All these are significant. This, therefore, confirms that the grouping of states is completely satisfactory from the point of view of homogeneity, as the within S.S. is insignificant and the groups vary too much. The graphs for some of the characters which show a marked variation in the state groups are as shown in Figs. 1—6.

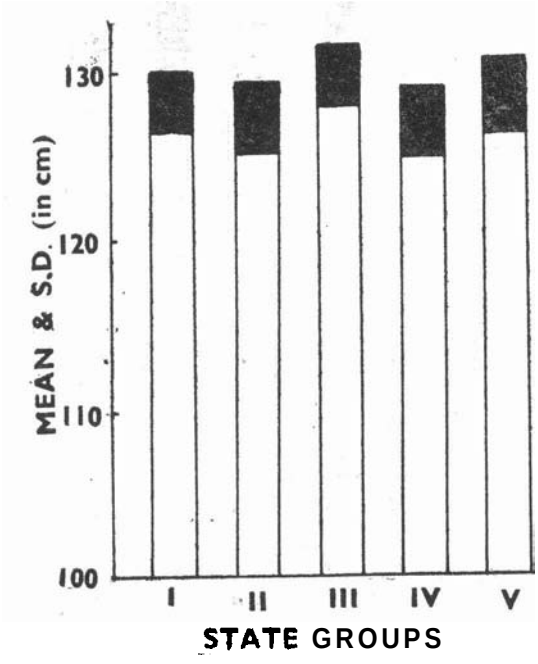

Fig. 1—Body measurement: Top of head to floor [□—mean; ▩—S.D.]

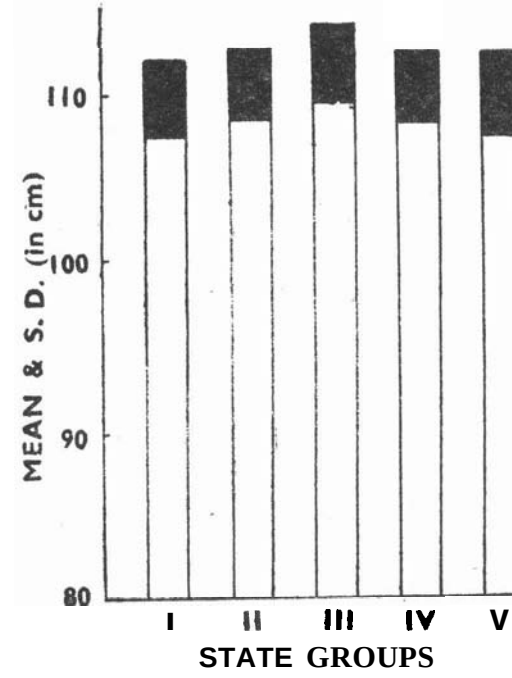

Fig. 2—Body measurement: Total leg [□—mean; ▩—S.D.]

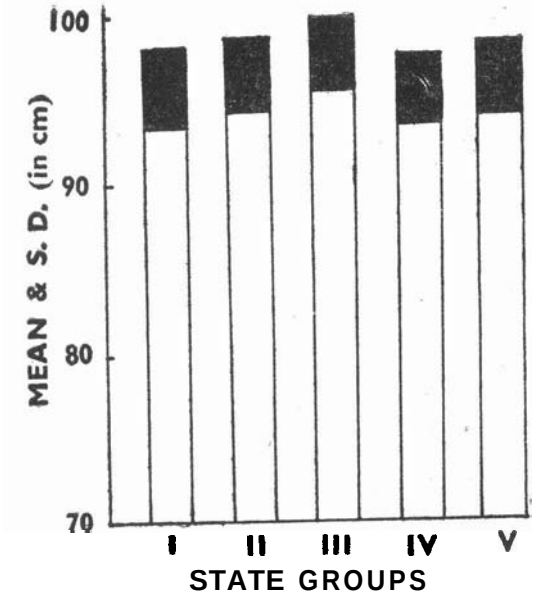

Fig. **3—Body** measurement: Heel on floor with leg extended □—mean; ▩—S.D.]

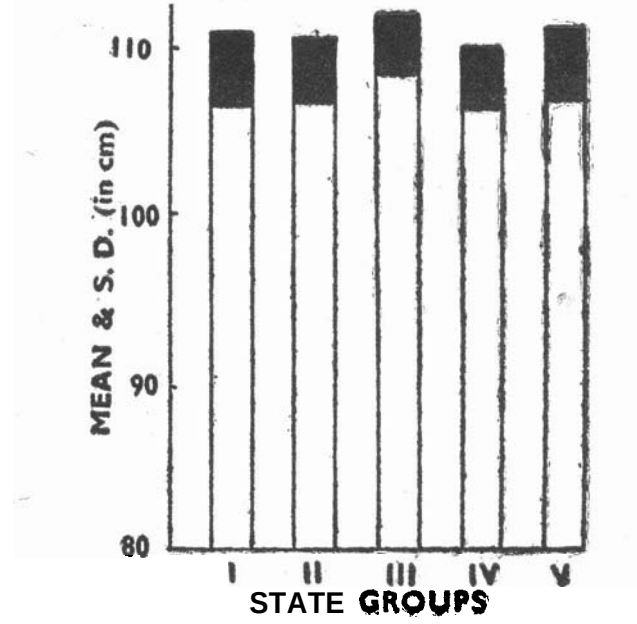

Fig. 4--Body measurement: Span akimbo [□—mean; ▩—S.D.]

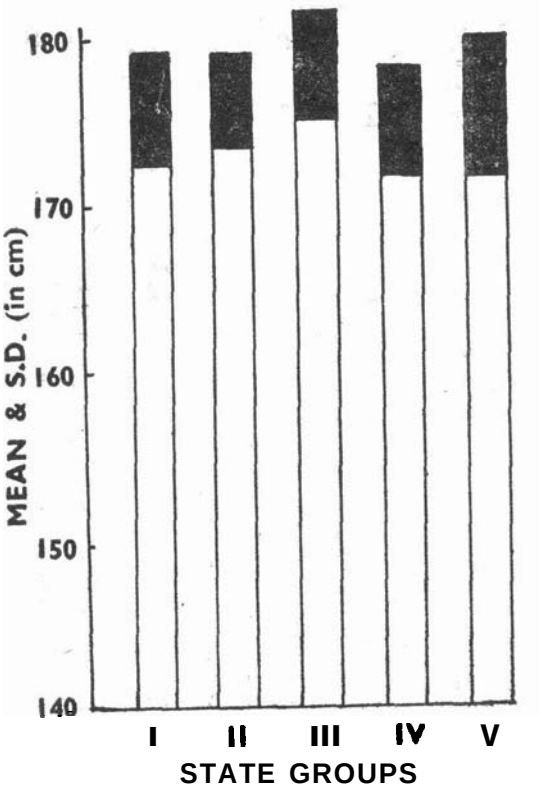

Fig. 5—Body measurement: maximum span [□—mean; ▩—S.D.]

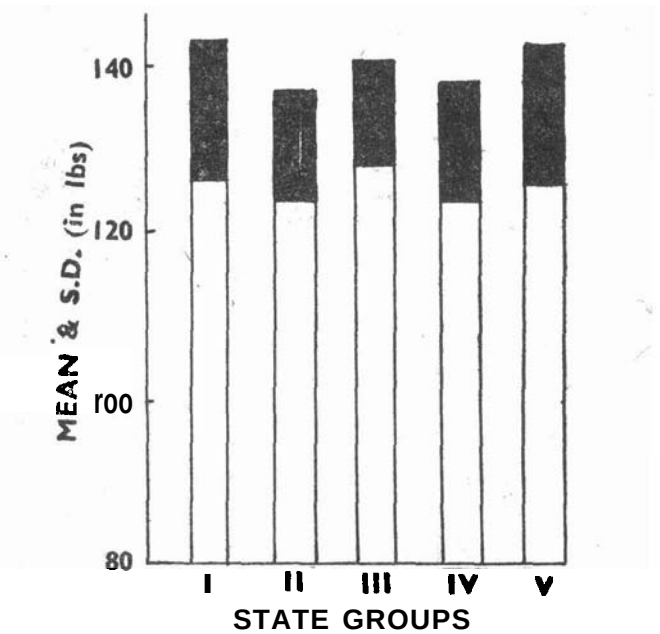

Fig. G—Body measurement; body weight [□—mean; ▬—S.D.]

CONFIDENCE LIMITS

The mean, standard deviation and standard error for all the 22 characters were calculated for the state groups separately and also for the combined data. The minimum height requirement for the I.A.F. personnel is 5 ft. This has the effect of truncation on the distribution of the characters and it can be calculated by following Fisher's method. However, it was found that the truncation effect was quite negligible and was, therefore, ignored.

A remarkable feature was that the Punjab group is significantly higher than the average for many of the characters.

For cockpit designs, instead of the actual mean values of the characters, confidenoe limits are likely t o be more useful. Table **3,** therefore, gives 95 per cent confidence limits for all the characters. Since the state groups were found to be different from one another, the limits given are the lowest of the lower limits and the highest of the upper limits for the state groups.

This gives an idea of the measurements and the variation observed in different characters among the Indian Air Force personnel for fixing the size of clothing and other stores used by the Air Force. They can also be used for anthropometric comparisons of measurements taken by others in India and abroad. A comparison between these limits and the limits for the R.A.F. personnel indicates that the average values of the characters are certainly higher for the latter.

TABLE 3

95% CONFIDENCE LIMITS

Character No.	Confidence limits	
	Lowest (cm)	Highest (cm)
1.	117·40	135·57
2.	80·41	94·34
3.	34·37	43·47
4.	53·19	64·86
5.	18·08	28·02
6.	49·70	59·76
7.	8·61	13·61
8.	52·66	63·21
9.	98·15	118·60
10.	84·17	104·24
11.	48·07	61·46
12.	75·56	90·66
13.	19·60	25·08
14.	19·44	26·76
15.	13·63	16·87
16.	37·79	46·38
17.	36·97	48·33
18.	32·87	40·85
19.	98·74	115·94
20.	155·30	188·00
21.	91·29	156·60
22.	155·99	180·21

CORRELATION AND REGRESSION

The correlation analysis of the data was carried out by grouping the characteristics into two broad classes:

(1) Height-like measurements: 1—12, 19, 20 and 21.

and (2) Girth-like measurements: 13—18.

Correlations between all the characters in each of these classes were calculated. Almost all of them were found to be highly significant, though of varying magnitudes. Correlation of weight and total height with the girth-like body measurements was also calculated. The high correlation suggested the regression of body weight (X_1) on the total height (x_2), abdomen (X_3), shoulder (x_4), elbow (x_5) and seat maximum below hips (x_6). The regression equation was found to be

$$x_1 = 124{\cdot}20 + 0{\cdot}72\ (x_2 - 168{\cdot}37) + 2{\cdot}94\ (x_3 - 23{\cdot}06) + 1{\cdot}73\ (x_4 - 42{\cdot}10) + 1{\cdot}20\ (x_5 - 42{\cdot}52) + 1{\cdot}39\ (x_6 - 36{\cdot}77)$$

This linear relationship accounts for more than 80 per cent ot the variation in body weight. The partial regression coefficients are all significant at 1 per cent level. They measure

the partial rates of increase of body weight with respect to the characters in the regression equation. The multiple correlation coefficient of x_1 with x_2 to x_6 was found to be as high as 0.88.

The regression equation of the total length (x_1) on kneeheight (x_2) and thigh (x_3) was found to be

$$x_1 = 108{\cdot}58 + 1{\cdot}17\ (x_2 - 54{\cdot}77) + 0{\cdot}68\ (x_3 - 58{\cdot}24)$$

In this oase, too, the partial regession coefficient is highly significant. The characters x_2 and x_3 satisfactorily account for a major portion (75%) of the variation in x_1. The multiple correlation coefficient is 0·87.

CONCLUSION

Above are the principal findings of the statistical analysis. Additional details like histogram (representation of the frequency distributions of the characters) and graphical presentation of the anaylsis of variance results were also worked out.

REFERENCES

1. MAJUMDAR, N.C., "Thermal insulation of clothing and tolerance time to cold **stress**" *Indiun. J. Physiol.*, **7** (1953), **205.**

2. PATWARDHAN, V. N., "Nutrition in India". Bombay, *I.J.M.S.* (1052).