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Inbreeding Effects on Mean of Metrical Traits Among the Children of Aligarh in North India

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INTRODUCTION

The study of genetic of quantitative characters follows many approach. The use of anthropometric characters are quite common phenomenon in the study of the population among human biologist (Barrai et al., 1964; Mukherjee, 1984; Neel et al., 1970; Panthmanathan et al., 1990). The previous study has brought out the conformity of the present data with the hypothesis of inbreeding depression of means for some quantitative characters. It is also indicates that such effects of inbreeding for two successive generation tend to be greater than that of inbreeding for a single generation. This suggests that inbreeding depression increases with increase in the level of inbreeding.

Therefore, it is necessary to examine whether the measurements affected by inbreeding show a linear regression on inbreeding coefficients, that is whether the rates of depression are uniform throughout the entire range of inbreeding or if there is any change in that rate with the change in the inbreeding levels. Furthermore, it may also be worthwhile to examine if the rare exceptions from indications of inbreeding depressions in studied traits fit with the hypothesis of non-linear inbreeding effects rather than with the assumption of complete overwhelming of inbreeding depression by the influence of concomitant socio-economic factors which are known to vary between populations.

MATERIALS AND METHODS

The samples are chosen from urban sections of Muslim in Aligarh district from North India. Seven anthropometric traits viz., body weight (kg), standing height (cm), sitting height (cm), head circumference (cm), head length (cm), head breadth (cm) and chest circumference (cm), have been selected for the present study. In total 1182 subjects of both male and female sex were measured for the study. A total of 690 individuals were males including 243 non-inbred (N1) (individuals for whom consanguineous relationships between parents could not be traced in the pedigrees are referred as N1), 133 second cousins, 146 first cousins once removed and 168 first cousins. The number of female sample is 492 including 140 non-inbred (N1), 122 second cousins, 115 first cousins once removed, 115 first cousins. Combined inbreeding sample size are 447 for males and 352 for females. Again the samples were distributed through age between 6 to 11 years. The age was calculated from nearest birth date from the school registration book. Apprehensive, un-cooperative, crying children were obviously excluded from the study.

All the subjects came from a typical low income group of families. They lived together with them in the same or adjacent households and by profession were lock makers. Thus the gene pool, the food and work environments of the compared groups were more effectively controlled. Therefore, the level of economy do not display an association between inbreeding and socio-economic status.

The subjects were usually measured on their respective birthdays but in some cases they were examined ± 10 days around the birth date concerned. The techniques were used for measurements as described by Weiner and Lourie (1981) for the International Biological programme. The measurements were taken using standard anthropometric tools.

The coefficients of inbreeding (F) was calculated from the pedigree data using slightly modified Wright's (1922) formula : $F = \sum (1/2)^n (1+F_a)$, where n is the number of persons along the path through common ancestor connecting the two parental gametes and F_a is the inbreeding coefficient of that common ancestor. However, the rare cases with same values of F in common ancestors were left out from this study. Details can be found in Badaruddoza and Afzal (1998 and 1999). A modified 't' – test and 'z' score were used to show the difference between the inbred and non-inbred groups on different parameters. The analysis of variance has been applied to test the significance both linear regression of the measurements on F and also of the deviations form linearity.

RESULTS

The analysis shows that the mean values of all anthropometric traits consistently decreases with the increase of inbreeding coefficient in both sexes in all age groups (Table 1-7). The differences of mean between non-inbred (F=0) and pooled inbred groups (F>0) are statistically significant at least at 5% probability level. The exceptions to this rule is seen specially for head length and head breadth (Table 5 and 6). Similarly, in the sitting height among male group, the mean differences are not significant except in age group at 6 years. Furthermore, if the problem of small samples is removed by obtaining the 'z' scores of the traits, there is no exception

Table 1: Means and Standard Errors (SE) for Body Weight (in kg) among non-inbred and inbred children with different coefficients of inbreeding (aged 6-11 years)

	6 Yr.			*7 Yr.*			*8 Yr.*			*9 Yr.*			*10Yr.*			*11Yr.*		
	No.	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*
								MALE CHILDREN										
NI	37	16.11	0.63	35	18.11	0.81	38	19.23	0.79	40	21.98	0.76	44	23.64	0.79	49	25.55	0.80
2C	17	13.75	0.94	21	14.86	1.04	24	18.11	1.14	21	20.02	1.15	26	21.57	1.29	24	23.62	1.30
1C1	20	13.54	0.86	22	14.22	1.19	20	17.39	1.19	25	19.46	1.36	29	20.98	1.27	30	22.92	1.20
1C	25	11.97	0.83	27	14.02	1.10	31	16.36	1.05	30	18.74	1.29	30	20.55	1.27	25	22.77	1.39
IN	62	12.96	0.52	70	14.33	0.66	75	17.19	0.66	76	19.33	0.76	85	21.00	0.75	79	23.09	0.76
't'		3.85a			3.62b			1.98			2.47c			2.42c			2.23c	
								FEMALE CHILDREN										
NI	18	12.33	0.65	21	13.11	0.54	22	14.82	0.51	25	17.17	0.53	26	19.33	0.58	28	20.50	0.43
2C	15	10.05	0.76	18	11.64	0.74	22	13.65	0.60	21	15.20	0.69	23	17.72	0.73	23	18.94	0.58
1C1	13	09.28	0.83	15	10.82	0.90	15	13.65	0.79	20	14.67	0.78	26	17.03	0.80	26	18.53	0.68
1C	15	08.49	0.90	19	10.33	0.89	20	12.59	0.82	21	14.05	0.82	20	16.22	1.08	20	18.12	0.96
IN	43	09.24	0.50	52	10.92	0.50	57	13.28	0.44	62	14.63	0.45	69	17.03	0.51	69	18.54	0.43
't'		3.77a			2.98b			2.29c			3.65a			2.98b			3.26b	

NI = Non-inbred (F = 0); 2C = Second Cousin (F=0.0156); ICI = First Cousin once Removed (F=0.03125); IC = First Cousin (F = 0.0625); IN = Total inbreeding; 't' = Between NI and IN; Significance level a, p < 0.001; b, p < 0.01; c, p < 0.05.

Table 2: Means and Standard Errors (SE) for Standing Height (in cm) among non-inbred and inbred children with different coefficients of inbreeding (aged 6-11 years)

	6 Yr.			*7 Yr.*			*8 Yr.*			*9 Yr.*			*10Yr.*			*11Yr.*		
	No.	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*
								MALE CHILDREN										
NI	37	116.99	1.23	35	120.18	1.50	38	120.79	1.43	40	123.35	1.45	44	126.65	1.49	49	128.59	1.48
2C	17	114.52	1.97	21	115.75	2.28	24	118.84	2.15	21	122.11	2.33	26	123.40	2.23	24	125.50	2.58
1C1	20	113.78	1.71	22	115.11	2.34	20	118.29	2.42	25	120.08	2.49	29	122.58	2.42	30	125.29	2.30
1C	25	113.07	1.63	27	114.21	2.16	31	117.27	1.97	30	119.38	2.16	30	121.74	2.46	25	124.19	2.54
IN	62	113.69	1.04	70	114.95	1.33	75	118.04	1.27	76	120.36	1.37	85	122.53	1.40	79	125.0	1.45
't'		2.05C			2.61c			1.44			1.50			2.01			1.73	
								FEMALE CHILDREN										
NI	18	101.19	1.40	21	102.45	1.08	22	112.9	0.91	25	115.62	0.74	26	117.63	0.98	28	120.30	1.14
2C	15	97.79	1.76	18	100.85	1.34	22	109.28	1.28	21	110.40	1.06	23	113.51	1.40	23	115.98	1.61
1C1	13	97.39	1.99	15	100.23	1.80	15	107.41	1.84	20	109.63	1.50	26	111.15	1.53	26	113.37	1.67
1C	15	97.41	2.06	19	98.89	1.61	20	105.49	1.75	21	106.89	1.63	20	109.66	1.55	20	111.19	1.94
IN	43	97.53	1.16	52	99.95	0.93	57	107.45	0.94	62	108.96	0.83	69	111.50	0.88	69	113.60	1.02
't'		2.01			1.75			4.17a			5.99a			4.65a			4.38a	

NI = Non-inbred (F = 0); 2C = Second Cousin (F = 0.0156); ICI = First Cousin once Removed (F = 0.03125); IC = First Cousin (F = 0.0625); IN = Total inbreeding; 't' = Between NI and IN; Significance level a, p < 0.001; b, p < 0.01; c, p < 0.05.

Table 3: Means and Standard Errors (SE) for Sitting Height (in cm) among non-inbred and inbred children with different coefficients of inbreeding (aged 6-11 years)

	6 Yr.			*7 Yr.*			*8 Yr.*			*9 Yr.*			*10Yr.*			*11Yr.*		
	No.	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*
								MALE CHILDREN										
NI	37	63.30	0.85	35	63.01	1.11	38	64.98	1.29	40	66.02	1.12	44	66.87	1.11	49	68.20	1.03
2C	17	60.66	1.27	21	61.30	1.48	24	62.94	1.70	21	64.68	1.69	26	65.35	1.53	24	66.49	1.48
1C1	20	60.23	1.25	22	61.07	1.48	20	62.65	1.87	25	63.68	1.62	29	64.93	1.48	30	66.04	1.44
1C	25	59.88	1.16	27	60.51	1.37	31	62.14	1.54	30	63.23	1.53	30	64.31	1.46	25	65.80	1.60
IN	62	60.20	0.73	70	60.92	0.85	75	62.57	0.99	76	63.78	0.95	85	64.84	0.87	79	66.10	0.88
't'		2.77b			1.49			1.48			1.53			1.44			1.55	
								FEMALE CHILDREN										
NI	18	58.41	0.98	21	59.02	0.77	22	59.52	0.53	25	61.20	0.61	26	62.63	0.58	28	63.79	0.60
2C	15	51.80	1.17	18	53.39	1.11	22	57.89	0.77	21	58.47	0.83	23	60.14	0.78	23	61.43	0.83
1C1	13	51.47	1.30	15	53.08	1.35	15	56.87	1.18	20	58.06	1.25	26	58.86	1.09	26	60.43	1.08
1C	15	51.63	1.35	19	52.35	1.35	20	55.89	1.14	21	56.62	1.28	20	58.31	1.36	20	58.80	1.34
IN	43	51.64	0.76	52	52.92	0.75	57	56.91	0.60	62	57.71	0.67	69	59.12	0.64	69	60.14	0.64
't'		5.46a			5.69a			3.26b			3.85a			4.06a			4.16a	

NI = Non-inbred (F = 0); 2C= Second Cousin (F = 0.0156); ICI = First Cousin once Removed (F = 0.03125); IC = First Cousin (F=0.0625); IN = Total inbreeding; 't' = Between NI and IN; Significance level a, $p < 0.001$; b, $p < 0.01$; c, $p < 0.05$.

Table 4: Means and Standard Errors (SE) for Head Circumstances (in cm) among non-inbred and inbred children with different coefficients of inbreeding (aged 6-11 years)

	6 Yr.			*7 Yr.*			*8 Yr.*			*9 Yr.*			*10Yr.*			*11Yr.*		
	No.	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*
								MALE CHILDREN										
NI	37	50.10	0.61	35	51.96	0.97	38	52.59	0.34	40	53.34	0.46	44	53.81	0.42	49	55.22	0.41
2C	17	48.62	1.00	21	49.31	1.26	24	50.27	0.48	21	51.54	0.70	26	51.90	0.58	24	53.52	0.61
1C1	20	47.81	0.96	22	48.73	1.26	20	49.61	0.76	25	50.71	0.79	29	50.73	0.68	30	52.76	0.66
1C	25	47.36	0.94	27	48.08	1.16	31	49.33	0.80	30	50.13	0.96	30	51.36	0.82	25	52.44	0.91
IN	62	47.85	0.57	70	48.65	0.69	75	49.70	0.42	76	50.71	0.51	85	51.31	0.42	79	52.88	0.43
't'		2.70c			2.78b			5.35a			3.83a			4.21a			3.94a	
								FEMALE CHILDREN										
NI	18	49.88	0.55	21	50.85	0.71	22	51.19	0.50	25	52.09	0.56	26	53.48	0.44	28	54.25	0.65
2C	15	45.79	0.81	18	47.67	0.87	22	49.21	0.59	21	50.22	0.69	23	50.87	0.60	23	52.40	0.88
1C1	13	45.18	0.98	15	47.23	1.03	15	48.75	0.96	20	49.39	0.82	26	50.24	0.63	26	50.17	0.91
1C	15	44.40	1.00	19	45.65	1.08	20	48.13	0.96	21	49.39	0.89	20	50.24	0.87	20	50.17	1.05
IN	43	42.12	0.56	52	46.80	0.60	57	48.71	0.49	62	49.67	0.48	69	50.45	0.41	69	50.91	0.56
't'		9.87a			4.36a			3.54b			3.28b			5.04a			3.89a	

NI = Non-inbred (F=0); 2C= Second Cousin (F=0.0156); ICI =First Cousin once Removed (F=0.03125); IC=First Cousin (F=0.0625); IN = Total inbreeding; 't' = Between NI and IN; Significance level a, $p < 0.001$; b, $p < 0.01$; c, $p < 0.05$.

to this rule of significant reduction of the mean value on inbreeding for different anthropometric traits (Table 8).

The level of significance of inbreeding effects and the significance of linear and non-linear components are examined by analysis of variance and regression analysis. The age composition for samples of different inbreeding levels do not differ significantly at 5% probability level between age groups ($\chi^2 = 4.46$, df 15 and 3.55 df 15 respectively for males and females), the anthropometric data for specific levels of inbreeding from the different age groups are pooled for analysis of variance within and between F levels (Table 9 and 10). This do not show significant difference between inbreeding levels in any of the seven anthropometric character at any age group in either sex at 5% level of probability.

This is obviously because of the fact that the sample size of each inbreeding class in each age group is not large enough to show significant

Table 5: Means and Standard Errors (SE) for Head Length (in cm) among non-inbred and inbred children with different coefficients of inbreeding (aged 6-11 years)

	6 Yr.			*7 Yr.*			*8 Yr.*			*9 Yr.*			*10Yr.*			*11Yr.*		
	No.	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*
MALE CHILDREN																		
NI	37	17.75	0.46	35	19.09	0.46	38	20.06	0.46	40	20.32	0.50	44	21.01	0.48	49	22.30	0.47
2C	17	16.93	0.71	21	17.16	0.63	24	17.68	0.63	21	17.96	0.77	26	18.08	0.71	24	18.64	0.76
1C1	20	16.57	0.71	22	16.94	0.71	20	17.26	0.79	25	17.66	0.75	29	17.86	0.70	30	18.37	0.71
1C	25	16.56	0.70	27	16.83	0.72	31	17.22	0.69	30	17.46	0.75	30	17.88	0.78	25	18.27	0.84
IN	62	16.66	0.42	70	16.96	0.41	75	17.38	0.41	76	17.66	0.45	85	17.93	0.43	79	18.42	0.45
't'		1.75			3.32b			4.40a			3.95a			4.78a			5.96a	
FEMALE CHILDREN																		
NI	18	16.49	0.55	21	17.18	0.65	22	17.73	0.67	25	18.16	0.71	26	18.70	0.52	28	18.96	0.59
2C	15	15.93	0.69	18	16.61	0.74	22	17.13	0.68	21	17.48	0.72	23	17.70	0.52	23	18.26	0.68
1C1	13	15.69	0.77	15	16.45	0.98	15	17.01	1.07	20	17.30	0.86	26	17.63	0.47	26	18.02	0.80
1C	15	15.48	0.82	19	16.03	1.03	20	16.75	1.02	21	17.20	1.03	20	17.49	0.71	20	17.80	0.83
IN	43	15.70	0.45	52	16.35	0.55	57	16.96	0.54	62	17.32	0.51	69	17.61	0.33	69	18.03	0.46
't'		1.11			0.97			0.89			0.96			1.77			1.24	

NI = Non-inbred (F = 0); 2C = Second Cousin (F = 0.0156); ICI = First Cousin once Removed (F=0.03125); IC = First Cousin (F = 0.0625); IN = Total inbreeding; 't' = Between NI and IN; Significance level a, $p < 0.001$; b, $p < 0.01$; c, $p < 0.05$.

Table 6: Means and Standard Errors (SE) for Head Breadth (in cm) among non-inbred and inbred children with different coefficients of inbreeding (aged 6-11 years)

	6 Yr.			*7 Yr.*			*8 Yr.*			*9 Yr.*			*10Yr.*			*11Yr.*		
	No.	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*
MALE CHILDREN																		
NI	37	14.51	0.44	35	15.10	0.31	38	16.48	0.45	40	17.72	0.49	44	19.17	0.55	49	19.28	0.53
2C	17	13.51	0.67	21	13.72	0.57	24	14.15	0.69	21	14.33	0.76	26	14.45	0.77	24	14.89	0.88
1C1	20	13.29	0.65	22	13.54	0.59	20	13.77	0.85	25	14.10	0.75	29	14.28	0.73	30	14.68	0.84
1C	25	13.34	0.70	27	13.37	0.60	31	13.73	0.58	30	13.97	0.64	30	14.30	0.76	25	14.62	0.94
IN	62	13.37	0.40	70	13.53	0.35	75	13.87	0.40	76	14.11	0.42	85	14.33	0.44	79	14.72	0.52
't'		1.92			3.36a			4.33a			5.59a			6.87a			6.14a	
FEMALE CHILDREN																		
NI	18	13.11	0.60	21	13.91	0.61	22	14.24	0.66	25	14.50	0.60	26	14.83	0.65	28	15.09	0.56
2C	15	12.74	0.80	18	13.25	0.63	22	13.69	0.80	21	13.99	0.79	23	14.16	0.85	23	14.58	0.80
1C1	13	12.57	0.98	15	13.15	0.95	15	13.57	1.03	20	13.82	0.78	26	14.10	0.84	26	14.38	0.78
1C	15	12.40	0.97	19	12.72	0.92	20	13.38	1.03	21	13.72	0.96	20	14.01	1.07	20	14.18	1.12
IN	43	12.57	0.55	52	13.03	0.50	57	13.54	0.56	62	13.84	0.50	69	14.09	0.54	69	14.27	0.53
't'		0.66			1.12			0.81			0.85			0.88			1.06	

NI = Non-inbred (F = 0); 2C = Second Cousin (F = 0.0156); ICI = First Cousin once Removed (F = 0.03125); IC = First Cousin (F = 0.0625); IN = Total inbreeding; 't' = Between NI and IN; Significance level a, $p < 0.001$; b, $p < 0.01$; c, $p < 0.05$.

level of the small differences between F levels observed in the data. However, variance between F levels is always larger than the variance within F levels for each traits and ages.

In all the seven measurements of anthropometric traits among males (Table 9) in pooled data of all ages studied, both the linear regression of measurements of F and the deviation from the linearity are found to be significant at least at 5% probability level, except that the deviation from the linearity of inbreeding effect has a lower significance for sitting height and head length.

In the case of female (Table 10) a similar trend has been observed except for head length and head breadth, again in which the non-linear component of change mean with F have a significance level lower than $p = 0.05$.

DISCUSSION

An overall significance reduction of means has been observed in inbred series for seven

Table 7: Means and Standard Errors (SE) for Chest Circumference (in cm) among non-inbred and inbred children with different coefficients of inbreeding (aged 6-11 years)

	6 Yr.			*7 Yr.*			*8 Yr.*			*9 Yr.*			*10Yr.*			*11Yr.*		
	No.	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*	*No.*	*Mean*	*SE*
								MALE CHILDREN										
NI	37	54.31	0.90	35	57.32	0.88	38	59.44	0.76	40	62.67	0.83	44	63.98	0.75	49	65.37	0.74
2C	17	51.78	1.32	21	54.68	1.15	24	57.77	0.98	21	60.95	1.14	26	61.84	1.04	24	63.80	1.10
1C1	20	51.02	1.26	22	54.22	1.19	20	57.32	1.09	25	59.98	1.07	29	61.40	1.08	30	63.62	1.02
1C	25	49.82	1.24	27	52.95	1.21	31	56.13	1.02	30	59.22	1.18	30	61.08	1.20	25	62.86	1.28
IN	62	50.74	1.76	70	53.86	0.70	75	56.97	0.61	76	59.95	0.68	85	61.42	0.66	79	63.43	0.67
't'		3.03b			3.08b			3.53c			2.53c			2.56c			1.94	
								FEMALE CHILDREN										
NI	18	50.92	0.67	21	54.08	0.49	22	57.48	0.66	25	58.97	0.70	26	59.91	0.72	28	62.24	0.66
2C	15	49.73	0.88	18	52.74	0.81	22	55.71	0.88	21	57.17	0.98	23	58.80	0.86	23	60.85	0.99
1C1	13	49.02	0.99	15	52.25	0.90	15	55.21	0.92	20	56.60	1.17	26	58.70	0.99	26	60.65	1.10
1C	15	48.59	1.00	19	51.12	0.94	20	54.41	0.87	21	55.98	1.21	20	58.15	1.22	20	60.23	1.27
IN	43	49.12	0.57	52	52.00	0.53	57	55.12	0.52	62	56.58	0.66	69	58.57	0.66	69	60.59	0.66
't'		2.05c			2.88b			2.81b			2.48c			1.37			1.77	

NI = Non-inbred (F = 0); 2C = Second Cousin (F = 0.0156); ICI = First Cousin once Removed (F = 0.03125); IC = First Cousin (F = 0.0625); IN = Total inbreeding; 't' = Between NI and IN; Significance level a, $p < 0.001$; b, $p < 0.01$; c, $p < 0.05$.

Table 8: Means and standard Errors (SE) of 'z' scores for different anthropometric traits on F > 0 among the male (M) and Female (F) children

Variables	*Sex*	*NI*	*SE*	*IN*	*SE*	*'t'*
Body weight	M	-0.123	0.04	-0.145	0.03	0.44
	F	0.334	0.07	-0.170	0.05	5.86a
Standing height	M	0.240	0.04	-0.120	0.03	7.20a
	F	0.623	0.09	-0.130	0.06	6.96a
Sitting height	M	0.256	0.06	-0.054	0.04	4.30a
	F	0.714	0.13	-0.160	0.08	5.73a
Head circumference	M	0.401	0.11	-0.233	0.08	4.66a
	F	0.658	0.08	-0.125	0.11	5.76a
Head length	M	0.500	0.07	-0.139	0.05	7.43a
	F	0.203	0.10	-0.026	0.06	1.96c
Head breadth	M	0.453	0.08	-0.221	0.06	6.74a
	F	0.157	0.09	-0.033	0.05	1.85d
Chest circumference	M	0.291	0.08	-0.170	0.06	4.61a
	F	0.386	0.15	-0.171	0.09	3.20b
Number studied	M	243		447		
	F	140		352		

NI = Non-inbred (F = 0); IN = Total inbreeding (F>0). Significance level a, $p < 0.001$; b, $p < 0.01$; c, $p < 0.05$; d, $p < 0.10$

anthropometric measurements. The result of the present study confirm the appreciable inbreeding depression especially among the offspring of first cousin on weight, standing height, head circumference, head length, head breadth and chest girth.

In the view of the strong earlier suggestion of inbreeding depression (Badaruddoza and Afzal, 1993, 1999; Mukherjee, 1984; Rao et al., 1975; Schull and Neel, 1965; Strochal, 1971) in quantitative traits in case of adequately controlled data the present results amply strengthen the hypothesis of an average recessiveness of the genes with negative effects. However, the level of significance depends upon the sample size, especially when the value is small, and both linear and non-linear components in the change of mean with inbreeding has to be found as a general feature of the anthropometric variation. The present result shows a systematic indication of linear and non-linear effects. The estimates of inbreeding effects on anthropometric traits available so far are based on the assumption that the means are linear functions of the inbreeding coefficients. However, the present investigation in the pooled data both linear regression on F and deviation from linearity are found to be significant at the same time for all the measurements except sitting height in male and head breadth in female children. Individual population samples may not be large enough to bring out the significance (at $p = 0.05$) of both the sum of square due to linear regression and non-linear deviation in all cases. The linear component of the inbreeding effects, as shown in the formula of Crow and Kimura (1970) may represent the effect of overall recessivity of the genes with 'minus' effects while the non-linear component is attributable to intensification of selection due to increasing mortality of small

Table 9: Analysis of total variance of the anthropometric measurements into within and between inbreeding groups and latter into that due to linear regression and deviation from linearity: and the significance of variance ratio among male children

Source of Variance	*Sum of Squares*	*df.*	*Mean sum of Squares*	*Variance ratio*
Body Weight				
Total	25016.64	689		
Between inbreeding groups	3295.81	3	1098.60	34.69a
Due to regression on F	1238.44	1	1238.44	39.11a
Deviation from linearity	2057.36	2	1028.68	32.48a
Residual(Within inbreeding groups)	21720.83	686	31.66	
Standing Height				
Total	82463.58	689		
Between inbreeding groups	3390.15	3	1130.05	9.80a
Due to regression on F	2177.53	1	2177.53	18.89a
Deviation from linearity	1212.62	2	606.31	5.26b
Residual(Within inbreeding groups)	79073.43	686	115.26	
Sitting Height				
Total	39421.72	689		
Between inbreeding groups	976.71	3	325.57	5.80a
Due to regression on F	873.74	1	873.74	15.59a
Deviation from linearity	102.97	2	51.48	00.92
Residual (Within inbreeding groups)	38445.01	686	56.04	
Head Circumference				
Total	11743.55	689		
Between inbreeding groups	1401.27	3	467.09	30.98a
Due to regression on F	1086.42	1	1086.42	72.06a
Deviation from linearity	314.85	2	157.42	10.44a
Residual (Within inbreeding groups)	10342.28	686	15.07	
Head Length				
Total	8452.50	689		
Between inbreeding groups	1130.01	3	376.67	35.28a
Due to regression on F	1106.86	1	1106.86	103.69a
Deviation from linearity	23.15	2	11.57	1.08
Residual (Within inbreeding groups)	7322.49	686	10.67	
Head Breadth				
Total	8793.98	689		
Between inbreeding groups	1715.85	3	571.95	55.43a
Due to regression on F	1626.13	1	1626.13	157.60a
Deviation from linearity	89.72	2	44.86	4.35a
Residual (Within inbreeding groups)	7078.13	686	10.31	
Chest Circumference				
Total	22182.73	689		
Between inbreeding groups	1434.56	3	478.18	15.81a
Due to regression on F	1194.92	1	1194.92	39.50a
Deviation from linearity	239.64	2	119.82	3.96c
Residual (Within inbreeding groups)	20748.17	686	30.24	

Significance level a, $p<0.001$; b, $p<0.01$; c, $p<0.05$.

foetus or as Levins (1959) suggest greater homozygosity of recessive modifier genes with 'plus' effects.

KEY WORDS Inbreeding. Metrical Traits. North Indian Children.

ABSTRACT The present study has brought out the conformity of the hypothesis of inbreeding depression of means for certain anthropometric character. This suggests that inbreeding depression increases with increase in the level of inbreeding. In the present investigation the mean values of each of the seven measurements are compared between the subjects of both sexes (690 individuals males and 492 were females) representing different levels of inbreeding between six age groups, 6 to 11 years.

REFERENCES

Badaruddoza and Afzal, M.: Inbreeding depression and intelligence quotient among North Indian children.

Table 10: Analysis of total variance of the anthropometric measurements into within and between inbreeding groups and latter into that due to linear regression and deviation from linearity and the significance of variance ratio among female children

Source of Variance	*Sum of Squares*	*df.*	*Mean sum of Squares*	*Variance ratio*
Body Weight				
Total	5721.02	491		
Between inbreeding groups	527 .38	3	175.79	16.51a
Due to regression on F	458.96	1	458.96	43.12a
Deviation from linearity	68.42	2	34.21	3.21c
Residual(Within inbreeding groups)	5193.64	488	10.64	
Standing Height				
Total	23288.52	491		
Between inbreeding groups	3053.71	3	1017.9	24.54a
Due to regression on F	2735.42	1	2735.42	65.96a
Deviation from linearity	318.29	2	159.14	3.84c
Residual(Within inbreeding groups)	20234.81	488	41.46	
Sitting Height				
Total	10914.57	491		
Between inbreeding groups	1947.04	3	649.01	35.31a
Due to regression on F	1689.90	1	1689.90	91.96a
Deviation from linearity	257.14	2	128.57	6.99a
Residual (Within inbreeding groups)	8967.53	488	18.37	
Head Circumference				
Total	6771.93	491		
Between inbreeding groups	1658.41	3	552.80	52.75a
Due to regression on F	1267.85	1	1267.85	120.99a
Deviation from linearity	390.56	2	195.28	18.63a
Residual (Within inbreeding groups)	5113.52	488	10.48	
Head Length				
Total	6200.43	491		
Between inbreeding groups	84.51	3	28.17	2.24
Due to regression on F	74.10	1	74.10	5.91c
Deviation from linearity	10.41	2	5.20	0.42
Residual (Within inbreeding groups)	6115.92	488	12.52	
Head Breadth				
Total	7444.90	491		
Between inbreeding groups	118.41	3	39.47	2.62
Due to regression on F	49.41	1	49.41	3.29c
Deviation from linearity	69.0	2	34.50	2.29
Residual (Within inbreeding groups)	7326.57	488	15.01	
Chest Circumference				
Total	9830.60	491		
Between inbreeding groups	861.39	3	287.13	15.62a
Due to regression on F	326.19	1	326.19	17.74a
Deviation from linearity	535.21	2	267.60	14.56a
Residual (Within inbreeding groups)	8969.20	488	18.38	

Significance level a, $p<0.001$; b, $p<0.01$; c, $p<0.05$.

Behav. Genet., **23**: 343-347 (1993).

Badaruddoza and Afzal, M.: Effects of inbreeding on mortality: A North Indian Study. *J. Hum. Ecol.*, **9**: 463-466 (1998).

Badaruddoza and Afzal, M.: Age-specific differences in blood pressure among inbred and non-inbred North Indiana Children. *J. Biosci.*, **24**: 177-184 (1999).

Barrai, I., Cavalli – Sforza, L.L. and Mainard, M.: Testing a model of dominant inheritance for metric traits in man. *Hered.*, **19**: 651-668 (1964).

Crow, J.F. and Kimura, M.: *An Introduction to the Population Genetic Theory.* Harper and Row Publishers, New York 591 pp (1970).

Levins, R.: Discussion. *Eugen Quart.*, **6**: 109-111 (1959).

Mukherjee, D.P.: Inbreeding and genetics of quantitative traits in Man, (pp 533-561) in K.C. Malhotra and A. Basu (Eds.), *Human Genetics and Adaptation*, ISI, Calcutta 1984).

Neel, J.V., Schull, W.J., Yamamoto, M., Vachidaa, S., Yanase, T. and Fujiki, N.: The effects of Parental consanguinity in Hirado, Japan 11. Physical development, tapping rate blood pressure, intelligence quotient and

school performance. *Am. J. Hum. Genet.*, **22**: 263-287 (1970).
Panthmanathan, G., Prakash, S. and Chhibber, S.R.: Single occasion means of height and weight of Sri Lankan Tamil Children from Jaffna. *Ann. Hum. Biol.*, **17**: 107-113 (1990).
Rao, D.C., MacLean, C., Morton, N.E. and Yee, S.: Analysis of family resemblance V. Height and weight in North Eastern Brazil. *Am. J. Hum. Genet.*, **27**: 509-520 (1975).
Schull, W.J. and Neel, J.V.: *The Effects of Inbreeding on Japanese Children*. Harper and Row, New York (1965).
Strouhal, E.: Anthropometric and functional evidence of heterosis from Egyptian Nubia. *Hum. Biol.*, **43**: 271-287 (1971).
Weiner, J.S. and Lourie, J.A.: *Practical Human Biology*. Academic Press, London (1981).
Wright, S.: Coefficients of inbreeding and relationship. *Am. Nat.*, **56**: 330-338 (1922).

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