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RESEARCH ARTICLE

PREDICTINGFINAL STATURE AND BIOLOGICAL PARAMETERS FOR SCHOOL CHILDREN OF JESSORE DISTRICT IN BANGLADESH

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Abstract

Objective: The purpose of the present study was to predict the final stature and biological parameters for the school children from Jessore district in Bangladesh.

Study Design: The primary data on stature collected from 89 subjects longitudinally,using two-stage sampling strategy.

Place and Duration of Study: This study was placed on Jessore district in Bangladesh and duration from November 2006 to November 2018.

Material and Method: Bootstrap resampling method was used for addressing the population estimate. The software IBM SPSS 26 was used to estimate the parameters of the BTT growth model.

Results: For Bangladeshi boys, the adolescent phase was started from the age 10.77 years with stature 136.87 cm and velocity 4.04 cm/year and attended the peak velocity 6.05 cm/year with stature 152.76 cm at the age 13.96 year and the growth process will be resulted with the final stature 171.33 cm at the age 25 years. For girls, the adolescent phase was started from the age 11.48 years with stature 141.93 cm and velocity 3.83 cm/year and attended the peak velocity 3.90 cm/year with stature 147.64 cm at the age 13.94 year and the growth process will be resulted with the final stature 158.20 cm at the age 25 years. The Age of takeoff in children growing at higher rate than American but lower than 'European and British' for boys but for girls, it was higher rate.

Conclusion: These results can be used to treatment and observing the child's growth in Bangladesh as well as in the world.

Introduction:-

Final stature is a pick stature which cannot change over life of a man. It is very important for people to know the future height because if they know the future, they will be able to choose which profession they will be able to work with. Also it is important to know the height from birth to adulthood to confirm if the growth is going well or not. For this reason,predicting final stature and biological parameters of school childrenis very important.Comas Juan (1930) discussed the growth of various organs of human body at age 0-18 years in his famous book Physical Anthropology for the developed countries.Count (1943) proposed a Count Growth model had been applied within

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the age range three months to seven years in human stature of Chinese children.Bock et al. (1973) approximated by the sum of two (double) logistic components for the data from the Fels growth study to fit the individual curves for growth in recumbent length/stature from one year to maturity.Greulich (1976) showed that the differences between the American-born and the native Japanese adults were relatively smaller than they had been during childhood, due to both an acceleration in the growth rate of the native Japanese and a concomitant decline in that of the American-born Japanese during the intervening years.McGregor and Billewiez (1982) described height growth curves from the age of 5 to 25 years were fitted for 55 boys and 62 girls, indicating that puberty is much delayed in Gambian adolescent in comparison to British and West Bengal data. Malina et al. (1985) found positive correlation among the development maturity indicators included ages at peak velocity for stature, sitting height, leg length and weight from a longitudinal sample of 177 Polish boys examined at annual intervals from 1961 to 1972. Jolicoeur et al. (1988) proposed a seven-parameter asymptotic JPPS growth model (curve) was expressed with respect to total age, passes through the origin, and fits infants as satisfactorily as older children using longitudinal data on the height of 13 boys and 14 girls from 1 month to 19 years of age. Lindgren and Hauspie (1989) showed that both boys and girls had been gaining more weight than height, especially around the ages at which peak velocity generally occurs. Ashizawa et al. (1994) estimated the diversity of adolescent growth, spline-smoothed individual velocity curves of stature, body weight and chest circumference of 44 girls in Tokyo, of which menarche was recorded correctly. Takai (1993) studied 6300 Japanese children for describing the velocity of the Tanner-Whitehouse 2 skeletal maturity and this maturity velocity curves showed single peak around the adolescent period exclusive of a bimodal curve for girls' RUS velocity. Bock et al. (1994) described the triphasic generalized logistic model by summing up three phases of growth; early, middle and adolescent. This model was popularly known as BTT (Bock-Thissen-du Toit) model. Cameron et al. (1994) had conducted a study on adolescent growth in height, fatness and fat patterning was investigated in sample of 79 rural South African black children studied longitudinally from 6- 18 years. Kasai et al. (1995) provided that an overall increasing trend is apparent for stature and weight; and girls in 1985 attained peak growth earlier, by 1.08 years and 0.40 year per decade.Kato et al. (1998)suggested that the greatest height of an individual measurement was the most effective definition of 'final stature' for practical use.Ali and Ohtsuki (2001) extracted the growth parameters from estimated distance and velocity curve for each individual using triphasic generalized logistic (BTT) growth model and predict adult stature based on biological parameters using forward stepwise model and found that the adult stature depend on SPHV and STO for both boys and girls who had with and without mid growth spurt.Ali et al. (2004a) extracted biological variables from the fitted triphasic generalized logistic model (BTT model) and found that significant inter-correlations among the biological variables. For the Japanese boys on average, 47.8%, 38.7%, and 13.5% of the adult stature were completed respective during the early, middle and adolescent growth phases, but for the girls, these percentages were 44.0%, 42.9%, and 13.1%, respectively. Also, they found that the average predicted adult stature of Japanese boys was 172.59 cm and that of girls was 159.68 cm for Japanese population.Ali et al. (2004b) used the stepwise regression approach to predict the final stature of Japanese children from the distance curve using the sample of 509 boys and 311 girls. After removing the outliers and influential data points, regression equations were highly cross validated, and they proposed prediction equations for the final stature of Japanese boys and girls, separately. Chiaki et al. (2004) found that Japanese boys (13.5-17.5 years old) were taller and have relatively longer legs than Japanese girls in the same age group.Rahman et al. (2004) proposed six prediction equations of adult stature on growth parameters (an improvement of Ali-Ohtsuki equations) had been established for Japanese boys and girlsthrough fitting double phasic growth (JPA-2) and triphasic generalized logistic (BTT) models.Hui et al. (2011) showed that the average weight and height for both boys and girls from urban, suburban and rural areas had significantly increased in most age groups during the past 20 years; the average chest circumference increased slightly, ranging from 0.0 to 2.0 cm. Chirwa et al. (2013) found that the Jenss-Bayley and the polynomial models did not fit well to growth measurements in the early years, with very high or very low percentage of positive residuals and the Berkey-Reed model fitted consistently well over the study period. From the above literature, predicting of final stature and biological parameters of school children in Bangladesh are totally undone. So, there exist scope of analysis for predicting final stature and biological parameters of school children of Jeshore district in Bangladesh. Therefore, the purpose of the present study is to predict the final stature and biological parameters of school children of Jeshore district in Bangladesh.

Material And Methods:-

Data

The two-stage sampling strategy was used to select the sampling units from the population. Jessoresadarupazila was selected by random form 08 upazilas of Jessore district. Only 07 schools were taken by random out of 135 primary schools from Jessoresadarupazila.Data was collected longitudinally from November 2006 to November

2018.Children from 'class one' in the year 2006 of every selected school were considered as the sample observations.Different growth information of all the children was taken from the direct measurements taken at their School and parent's information was collected from their residence. But only age and corresponding stature were used in this research paper.If any subject (child) was absent in the school then we had to go to their own residence or grandfather's or other relative's house as necessary. All measurements have taken with minimum pressure by instruments. Every measurement was repeated three times and the average value was considered as the data.Name of the selected schools are appended below:

1. Polytecnic Primary School,
2. Mollapara Govt. Primary School
3. BadshaFoysal Institute.
4. Chawlia Govt. Primary School,
5. RupdiaShaheedSmrity Kinder Garten School,
6. Zirat Govt. Primary School, and
7. Paddabila Govt. Primary School.

Why Btt Growth Model

Many different growth models were employed in human growth analysis for investigating the nature of growth, estimation, and prediction of final stature. Therefore, a suitable model must be selected to accomplish this objective.According to Jolicoeuret al. (1992), JPA-2 model provided the best fit when compared with other structural growth models.But, Ali and Ohtsuki (2001) and Rahman et al. (2004) found that BTT model was better than JPA-2. Therefore, BTT growth model is considered here.

BTT growth model

The sum of three generalized logistic terms is the Bock-Thissen-du Toit (BTT) model. The form of the logistic term is:

$$\frac{a}{\left[1+\exp\left\{-\left(bt+c\right)\right\}\right]^{d}}$$

where*t* is the time (age) variable, *a*is the amount of growth contributed by the term, the quantity$z = bt + c$ in the exponential function is the "logit", *b* and *c* are its slope and intercept, respectively, and *d* is a fixed shape constant.

Bock et al. (1994) described the triphasic generalized logistic model by summing up three phases of growth; early, middle and adolescent. This triphasic generalized logistic model can be written as:

$$y=\frac{a_1}{\left[1+\exp\left(-b_1t\right)\right]^{d_1}}+\frac{a_2}{\left[1+\exp\left(-b_2t-c_2\right)\right]^{d_2}}+\frac{a_3}{\left[1+\exp\left(-b_3t-c_3\right)\right]^{d_3}}$$

where, the set of parameters (a_1, b_1, c_1), (a_2, b_2, c_2) and (a_3, b_3, c_3)refer to the parameters of early, middle and adolescent phases of growth, respectively.

For BTT model (Bock et al., 1994):

Velocity:

$$\frac{\partial y}{\partial t}=\frac{a_1d_1b_1e^{(-b_1t-c_1)}}{\left(1+e^{(-b_1t-c_1)}\right)^{d_1}\left(1+e^{(-b_1t-c_1)}\right)}+\frac{a_2d_2b_2e^{(-b_2t-c_2)}}{\left(1+e^{(-b_2t-c_2)}\right)^{d_2}\left(1+e^{(-b_2t-c_2)}\right)}+\frac{a_3d_3b_3e^{(-b_3t-c_3)}}{\left(1+e^{(-b_3t-c_3)}\right)^{d_3}\left(1+e^{(-b_3t-c_3)}\right)}$$

Acceleration:

$$\frac{\partial^2 y}{\partial t^2}=\frac{2a_1d_1^2\left(e^{(-b_1t-c_1)}\right)^2b_1^2}{\left(1+e^{(-b_1t-c_1)}\right)^{d_1}\left(1+e^{(-b_1t-c_1)}\right)^2}-\frac{2a_1d_1\left(e^{(-b_1t-c_1)}\right)b_1^2}{\left(1+e^{(-b_1t-c_1)}\right)^{d_1}\left(1+e^{(-b_1t-c_1)}\right)}+\frac{2a_1d_1\left(e^{(-b_1t-c_1)}\right)^2b_1^2}{\left(1+e^{(-b_1t-c_1)}\right)^{d_1}\left(1+e^{(-b_1t-c_1)}\right)^2}$$

$$+\frac{2a_2d_2^2\left(e^{(-b_2t-c_2)}\right)^2b_2^2}{\left(1+e^{(-b_2t-c_2)}\right)^{d_2}\left(1+e^{(-b_2t-c_2)}\right)^2}-\frac{2a_2d_2\left(e^{(-b_2t-c_2)}\right)b_2^2}{\left(1+e^{(-b_2t-c_2)}\right)^{d_2}\left(1+e^{(-b_2t-c_2)}\right)}+\frac{2a_2d_2\left(e^{(-b_2t-c_2)}\right)^2b_2^2}{\left(1+e^{(-b_2t-c_2)}\right)^{d_2}\left(1+e^{(-b_2t-c_2)}\right)^2}$$

$$+\frac{2a_3d_3^2\left(e^{(-b_3t-c_3)}\right)^2b_3^2}{\left(1+e^{(-b_3t-c_3)}\right)^{d_3}\left(1+e^{(-b_3t-c_3)}\right)^2}-\frac{2a_3d_3\left(e^{(-b_3t-c_3)}\right)b_3^2}{\left(1+e^{(-b_3t-c_3)}\right)^{d_3}\left(1+e^{(-b_3t-c_3)}\right)}+\frac{2a_3d_3\left(e^{(-b_3t-c_3)}\right)^2b_3^2}{\left(1+e^{(-b_3t-c_3)}\right)^{d_3}\left(1+e^{(-b_3t-c_3)}\right)^2}$$

Biological Parameter

For the estimate of biological parameters, fitting was exempted from parametric growth models. In order to establish individual growth patterns and estimate the biological parameters of growth curves, it is necessary to apply special analytical methods to longitudinal growth data. The biological parameters were Age at takeoff (ATO), Age at Mid Childhood Maxima (AMCM), Velocity at Mid Childhood Maxima (VMCM), Height at Mid Childhood Maxima (HMCM), Age at Takeoff (ATO), Velocity at Takeoff (VTO), Stature at Takeoff (STO), Age at Pick Height Velocity (APHV), Pick Height Velocity (PHV), Height at Pick Height Velocity (HPHV) and Final Stature (FS).

Distance curve

The line graph of stature against age is called distance curve. This curve helps us to get idea about stature change with age.

Velocity

Velocity is a directed term; it has a direction and a magnitude and is indicated by the letter*v*. Velocity as directed term is defined as the ratio of the directed displacement Δt to the required timeΔt, i.e.

$$v = \frac{\Delta r}{\Delta t}$$

The direction of *v* is the same as the direction of the displacement.

Acceleration

Acceleration is the second derivative of growth model with respect to time (Age).

Mathematically

Acceleration=$\frac{d^2y}{dt^2}$

Final Stature

After 25 year age, the stature cannot change significantly over time. So, the asymptotic value of stature from the fitted distance curve at age 25 year is considered as the final stature.

Simulation

To meet the interest of population parameters from a small sample, simulation study is useful. Here, bootstrap method (n = 1000) is considered.

Results:-

The BTT model was also used to estimate the final stature and biological parameters of boys and girls. The stature and age were considered as dependent and independent variables, respectively. Using SPSS software and initial values of the shape parameters (d_1=0.75,d_2=0.75, and d_3=1.20), the BTT model was fitted for each dataset. The estimated parameters with standard error of residuals for each set of data were shown in Appendix. The smallest values of mean of residuals indicated that the model was more precisely estimate the parameters as well as final stature and biological parameters (Appendix).

Table 1:- Descriptive statistics and their bootstrap values of estimated parameters of BTT growth model for boys.

Parameters	Boys					Bootstrap (n=1000)			
	Mean	SD	SEM	95% CI for Mean		Mean	SEM	95% CI for Mean	
				Lower	Upper			Lower	Upper
a_1	99.51	20.43	3.50	92.38	106.63	99.43	3.48	92.23	106.07
b_1	1.89	0.93	0.16	1.57	2.22	1.89	0.16	1.62	2.25
c_1	0.27	1.16	0.20	-0.13	0.68	0.28	0.19	-0.16	0.58
a_2	36.34	12.46	2.14	31.99	40.69	36.38	2.12	32.21	40.65
b_2	0.61	0.26	0.04	0.52	0.70	0.61	0.04	0.53	0.70
c_2	-8.59	3.87	0.66	-9.94	-7.24	-8.62	0.66	-10.02	-7.36
a_3	35.79	22.76	3.90	27.85	43.73	35.86	3.87	28.03	43.66
b_3	0.64	7.56	1.30	-1.99	3.28	0.63	1.26	-1.99	3.23
c_3	-6.58	7.02	1.20	-9.03	-4.13	-6.57	1.18	-9.01	-4.49

Note: SD means Standard deviation, SEM means standard error of mean and CI means confidence interval. Source: Calculated by the authors.

Table 2:- Descriptive statistics and their bootstrap values of estimated parameters of BTT growth model for girls.

Parameters	Girls					Bootstrap (n=1000)			
	Mean	SD	SEM	95% CI for Mean		Mean	SEM	95% CI for Mean	
				Lower	Upper			Lower	Upper
a_1	109.57	8.78	1.51	106.51	112.63	109.50	1.56	106.29	112.30
b_1	2.14	1.09	0.19	1.76	2.51	2.13	0.18	1.84	2.54
c_1	0.49	0.16	0.03	0.43	0.55	0.49	0.03	0.43	0.54
a_2	31.37	12.02	2.06	27.18	35.57	31.33	2.09	27.35	35.58
b_2	0.64	0.33	0.06	0.52	0.76	0.64	0.06	0.54	0.76
c_2	-7.94	4.78	0.82	-9.61	-6.27	-7.96	0.83	-9.75	-6.48
a_3	16.12	11.20	1.92	12.21	20.03	16.24	1.90	12.58	20.03
b_3	0.95	1.26	0.22	0.51	1.38	0.94	0.22	0.43	1.32
c_3	-10.48	5.78	0.99	-12.50	-8.47	-10.43	0.96	-12.38	-8.53

Note: SD means Standard deviation, SEM means standard error of mean and CI means confidence interval. Source: Calculated by the authors.

The descriptive statistics for the estimated parameters for both boys and girls are shown in Table 1 and 2, respectively. The mean values of early, middle and adolescent phases of growth were (99.51, 1.89, 0.27), (36.34, 0.61, -8.59) and (35.79, 0.64, -6.58), respectively for boys (Table 1). Also, the set of values were (109.57, 2.14, 0.49), (31.37, 0.64, -7.94) and (16.12, 0.95, -10.48) were showed the values of early, middle and adolescent phases of growth for girls, respectively (Table 2).

Biological parameters of BTT Model

At first, we fitted the BTT model for each dataset of 45 longitudinal boys. Using this fitted model, we constructed the distance and velocity curve for each dataset. Among the 45 sets of boys, only 18 sets of boys data showed biological parameters. Similarly, only 12 dataset of girls shows biological parameters among 44 datasets. The datasets for boys and girls were not showed biological parameters due to may be irregular pattern of growth. The distance and velocity curves for the subject number 1 of boys were shown in figure 1. The rest 29 graphs (boys 17 graphs and girls 12 graphs) of distance and velocity curves for both boys and girls were not shown here, but are preserved to the authors.Descriptive statistics for biological parameters and final stature for both boys and girls are shown in Table 3 and 4, respectively. From these Tables, the maximum variations occurred at height at takeoff (HTO), followed by height at mid childhood maxima (HMCM), final stature (FS) and height at pick height velocity (HPHV) for both boys and girls except girls at final stature (FS). The minimum variations occurred in velocity of takeoff (VTO) for boys but in age at mid childhood maxima (AMCM) for girls. The mean age at takeoff in children were growing at an average rate 10.77 years in boys and 11.48 years in girls. The peak height velocity was 6.05cm/y in boys and 3.90 cm/y in girls. The height at mid childhood maxima (HMCM) occurred 124.53 cm for boys but 128.17 cm for girls. The height at takeoff (HTO) represented at 136.87 cm for boys and 141.93 cm for girls. Finally, the final statures for boys and girls were found 171.33 cm and 158.20 cm, respectively.

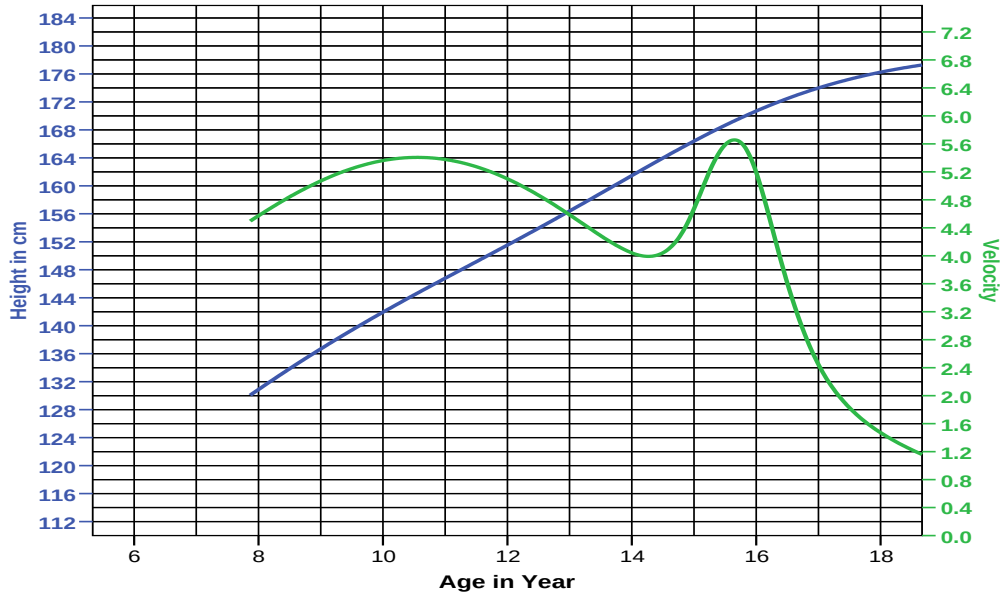

Figure 1:- Distance and velocity curve for the subject number 1 of boys.

Table 3:- Descriptive statistics and their bootstrap values of biological parameters using BTT Growth Model for boys.

Biological Parameters	Longitudinal sample for Boys					Bootstrap (n=1000)			
	Mean	SD	SEM	95% CI for Mean		Mean	SEM	95% CI for Mean	
				Lower	Upper			Lower	Upper
AMCM	8.29	0.94	0.21	7.84	8.74	8.29	0.20	7.88	8.69
VMCM	5.67	0.98	0.22	5.20	6.14	5.66	0.22	5.22	6.11
HMCM	124.53	7.55	1.73	120.89	128.17	124.57	1.69	121.12	127.80
ATO	10.77	1.30	0.30	10.15	11.40	10.78	0.30	10.22	11.39
VTO	4.04	0.63	0.14	3.74	4.35	4.05	0.14	3.75	4.33
HTO	136.87	9.05	2.08	132.50	141.23	136.91	2.05	132.91	140.94
APHV	13.96	0.86	0.20	13.54	14.37	13.96	0.20	13.59	14.38
PHV	6.05	0.94	0.22	5.60	6.50	6.05	0.21	5.62	6.45
HPHV	152.76	5.48	1.26	150.12	155.40	152.75	1.27	150.25	155.11
FS	171.33	5.53	1.27	168.67	173.99	171.28	1.29	168.65	173.84

Note: Notations and source are the same as in Table 4.

Table 4:- Descriptive statistics and their bootstrap values of biological parameters using BTT Growth Model for girls.

Biological Parameters	Longitudinal sample for Girls					Bootstrap (n=1000)			
	Mean	SD	SEM	95% CI for Mean		Mean	SEM	95% CI for Mean	
				Lower	Upper			Lower	Upper
AMCM	8.85	0.82	0.25	8.30	9.41	8.86	0.23	8.41	9.32
VMCM	6.72	0.71	0.21	6.24	7.20	6.73	0.21	6.31	7.10
HMCM	127.41	6.60	1.99	122.97	131.84	127.44	1.89	123.63	131.22
ATO	11.48	1.17	0.35	10.69	12.26	11.48	0.35	10.91	12.25
VTO	2.82	1.16	0.35	2.04	3.60	2.81	0.33	2.13	3.46
HTO	141.93	7.49	2.26	136.90	146.96	141.96	2.24	137.47	146.64
APHV	13.94	1.02	0.31	13.25	14.62	13.93	0.30	13.41	14.58
PHV	3.90	1.32	0.40	3.01	4.78	3.89	0.39	3.06	4.57
HPHV	147.64	5.18	1.56	144.16	151.12	147.65	1.53	144.86	150.90
FS	158.20	4.32	1.30	155.30	161.10	158.20	1.31	155.85	160.90

Note: SD means Standard deviation, SEM means standard error of mean and CI means confidence interval. *AMCM* = Age at Mid Childhood Maxima, *VMCM* = Velocity at Mid Childhood Maxima, *HMCM* = Height at Mid Childhood Maxima, *ATO* = Age at takeoff, *VTO* = Velocity at Takeoff, *HTO* = Height at Takeoff, *APHV* = Age at Pick Height Velocity, *PHV* = Pick Height Velocity, *HPHV* = Height at Pick Height Velocity and *FS* = Final Stature. Source: Calculated by the author.

Discussion:-

The BTT model was used to estimate the final stature and biological parameters of boys and girls.The smallest values of mean of residuals indicated that the BTT growth model was more precisely estimate the parameters as well as final stature and biological parameters (Appendix). At onset of adolescent phase, girls were taller than boys, on average, but finally the girls became shorter than boys. This might be happened due to the lower growth velocity of girls than boys in the adolescent phase.

The comparison of biological parameters between Bangladeshi (this study) and American and 'European and British' for both boys and girls were shown here. Table 6 represents the mean and standard deviation of biological parameters of Bangladeshi, American and 'European and British' boys. The value of Age at takeoff (ATO) of Bangladeshi boys were higher than American but lower than 'European and British' boys. The values of Height at Takeoff (HTO), Pick Height Velocity (PHV), and Final Stature (FS) of Bangladeshi boys were smaller than both American and 'European and British' boys. The value of Age at Pick Height Velocity (APHV) and Pubertal height gain (PHG) of Bangladeshi boys were higher than both American and 'European and British' boys.

Table 6:- Mean and standard deviation of estimated biological parameters of Bangladeshi, American and European British boys.

Biological Parameter	BGD		American		European and British		BGD minus American	BGD minus European
	Mean	SD	Mean	SD	Mean	SD	Mean	Mean
AMCM	8.29	0.94	-	-	-	-	-	-
VMCM	5.67	0.98	-	-	-	-	-	-
HMCM	124.53	7.55	-	-	-	-	-	-
ATO	10.77	1.30	10.45	1.47	12.05	0.85	0.32	-1.28
VTO	4.04	0.63	-	-	-	-	-	-
STO	136.87	9.05	144.00	-	146.09	6.33	-7.13	-9.22
APHV	13.96	0.86	13.57	1.11	13.91	0.84	0.39	0.05
PHV	6.05	0.94	9.49	1.44	8.80	1.05	-3.44	-2.75
HPHV	152.76	5.48	-	-	-	-	-	-
FS	171.33	5.53	177.00	-	173.64	6.11	-5.67	-2.31
PHG	34.46	8.61	33.00	-	27.56	3.54	1.46	6.9

Note: SD = Standard deviation, PHG = Pubertal height gain (cm), BGD = Bangladeshi, *AMCM* = Age at Mid Childhood Maxima, *VMCM* = Velocity at Mid Childhood Maxima, *HMCM* = Height at Mid Childhood Maxima, *ATO* = Age at takeoff, *VTO* = Velocity at Takeoff, *HTO* = Height at Takeoff, *APHV* = Age at Pick Height Velocity, *PHV* = Pick Height Velocity, *HPHV* = Height of Pick Height Velocity and *FS* = Final Stature. Source: Berkey et al. (1993), Tanner and Whitehouse (1976), and calculated by the authors.

Table 7:- Mean and standard deviation of estimated biological parameters of Bangladeshi, American and European British girls.

Biological Parameter	BGD		American		European and British		BGD minus American	BGD minus European
	Mean	SD	Mean	SD	Mean	SD	Mean	Mean
AMCM	8.85	0.82	-	-	-	-	-	-
VMCM	6.72	0.71	-	-	-	-	-	-
HMCM	127.41	6.60	-	-	-	-	-	-
ATO	11.48	1.17	9.25	1.15	10.30	0.95	2.23	1.18
VTO	2.82	1.16	-	-	-	-	-	-
HTO	141.93	7.49	138.00	-	137.91	7.02	3.93	4.02
APHV	13.94	1.02	11.49	1.17	11.89	0.90	2.45	2.05

PHV	3.90	1.32	8.14	1.25	8.13	0.78	-4.24	-4.23
HPHV	147.64	5.18	-	-	-	-	-	-
FS	158.20	4.32	163.00	-	163.16	5.94	-4.80	-4.96
PHG	16.07	7.84	25.00	-	25.25	4.14	-8.93	-9.18

Note: Notations and source are the same as in Table 6.

Table 6 represents the mean and standard deviation of biological parameters of Bangladeshi, American and 'European and British' girls. The values of Age of takeoff (ATO), Stature of Takeoff (STO) and Age at Pick Height Velocity (APHV) of Bangladeshi girls higher than both American and 'European and British' girls. The values of Pick Height Velocity (PHV), Final Stature (FS) and Pubertal height gain (PHG) of Bangladeshi girls smaller than both American and 'European and British' girls.

Age at takeoff in children growing at higher rate than American but lower than 'European and British' for boys but for girls, Age at takeoff had higher growth rate than that of both American and 'European and British' girls. Peak height velocity for Bangladeshi boys and girls were smaller than both American and 'European and British' children.

Conclusion:-

The longitudinal data on body heightof Bangladeshi boys and girls from 6 to 18 years of age were collected individually from Jessore district in Bangladesh. The mean values of statureof boys and girls were increased over times (year). The BTT model showed that, for boys data, the mean values of early, middle and adolescent phases of growth were (99.51, 1.89, 0.27), (36.34, 0.61, -8.59) and (35.79, 0.64, -6.58), respectively for boys. Also for girls, the set of values were (109.57, 2.14, 0.49), (31.37, 0.64, -7.94) and (16.12, 0.95, -10.48) for early, middle and adolescent phases of growth, respectively.

Fitted models showed that the statures at 108.0952 cm and 110.7253 cm were the starting points of Bangladeshi adolescents' growth cycle. The mean of the final statures were 178.27 cm and 158.12 cm for the respective boys and girls. The average final statures using BTT model were 171.25 cm and 156.53 cm for boys and girls,respectively.The mean age at takeoff in children growing at an average rate was; 10.77 years in boys and 11.48 years in girls. The peak height velocity was6.05cm/y in boys and 3.90 cm/y in girls. The height at mid childhood maxima (HMCM) occurred as 124.53 cm for boys but 128.17 cm for girls. The height at takeoff (HTO) represented at 136.87 cm for boys and 141.93 cm for girls. Thus, for Bangladeshi boys, the adolescent phase was started from the age 10.77 years with stature 136.87 cm and velocity 4.04 cm/year and attended the peak velocity 6.05 cm/year with stature 152.76 cm at the age 13.96 year and the growth process will be resulted with the final stature 171.33 cm at the age 25 years. For girls, the adolescent phase was started from the age at 11.48 years with stature 141.93 cm and velocity 3.83 cm/year and attended the peak velocity 3.90 cm/year with stature 147.64 cm at the age 13.94 year and the growth process will be resulted with the final stature 158.20 cm at the age 25 years.

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Conflict of interest:

None declared.

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Appendix

Table A1: Estimated Values of BTT growth model for boys

Sub	a_1	b_1	c_1	a_2	b_2	c_2	a_3	b_3	c_3	Mean of Res	SD of Res	FS
1	109.289	2.310	0.506	66.340	0.359	-4.077	4.955	2.291	-35.835	0.012	0.618	179.650
2	105.290	1.984	0.496	18.455	1.173	-15.891	47.274	0.399	-3.062	0.000	0.293	170.960
4	98.006	2.383	0.555	14.630	1.452	-19.761	52.706	0.355	-2.575	-0.023	0.619	165.240
5	121.311	2.164	0.535	36.474	0.643	-8.905	8.117	2.498	-20.423	0.000	0.727	165.880
10	64.964	1.218	0.323	33.620	0.525	-7.388	71.984	0.421	-1.291	0.000	0.515	170.490
11	112.079	2.040	0.523	36.201	0.324	-4.365	32.418	0.471	-4.010	0.000	0.375	180.180
16	90.390	0.532	0.016	28.350	0.464	-7.330	53.698	0.312	-1.801	0.002	0.219	171.940
17	116.513	2.001	0.499	46.769	0.566	-8.375	4.980	1.620	-14.262	0.000	0.280	168.190
30	111.163	1.984	0.498	40.288	0.525	-7.723	24.018	0.970	-6.975	-0.002	0.314	175.350
31	113.807	0.259	1.740	30.022	0.431	-4.368	28.035	0.425	-5.322	0.001	0.311	171.710
33	118.307	1.675	0.491	30.424	0.638	-8.610	25.229	0.740	-5.960	-0.016	0.508	173.950
35	120.315	2.124	0.513	29.296	0.947	-15.915	26.791	0.588	-6.291	0.036	0.955	176.390

36	67.865	1.774	0.467	35.538	0.367	-5.971	70.881	0.237	-0.701	-0.012	0.546	173.090
37	109.192	2.259	0.539	34.087	0.405	-4.871	22.994	0.608	-4.798	0.000	0.295	166.170
38	108.657	1.995	0.500	66.610	0.359	-3.802	-8.095	29.707	-8.126	0.000	0.433	166.960
41	116.419	2.000	0.498	44.459	0.442	-6.149	9.306	0.752	-6.375	0.000	0.611	170.020
43	105.129	2.076	0.521	41.032	0.576	-8.359	25.781	0.912	-6.518	-0.014	0.707	171.900
44	51.528	1.989	0.499	37.409	0.423	-5.834	78.883	0.555	-3.021	-0.010	0.515	168.400
51	111.720	2.081	0.501	52.850	0.548	-8.111	17.389	1.072	-8.606	-0.020	0.572	181.860
52	95.968	0.838	0.324	24.801	0.566	-8.858	46.554	0.427	-3.760	0.009	0.426	167.210
54	88.256	1.873	0.492	34.907	0.760	-11.442	53.470	0.388	-2.283	-0.001	0.303	176.590
55	64.027	1.879	0.484	45.905	0.624	-10.102	64.566	0.312	-1.275	0.021	0.591	174.330
57	57.914	1.910	0.496	41.975	0.442	-6.225	71.850	0.241	-1.126	0.008	0.439	170.930
59	103.029	0.823	0.319	12.941	1.003	-14.507	47.475	0.421	-3.756	0.004	0.426	163.390
62	85.327	5.950	1.117	27.357	0.980	-14.596	56.528	0.396	-2.456	-0.001	0.601	169.170
67	108.976	3.021	0.672	30.778	0.573	-8.235	25.971	0.706	-5.609	0.001	0.252	165.670
68	113.294	2.152	0.567	44.308	0.698	-10.282	12.820	1.519	-12.960	0.000	0.401	170.400
71	125.085	2.069	0.507	19.887	0.507	-6.524	20.660	1.591	-15.558	-0.022	0.816	165.610
72	106.554	1.957	0.494	32.204	0.628	-9.397	33.901	0.428	-3.052	0.000	0.388	172.610
75	90.085	1.511	0.426	40.444	0.359	-4.975	50.172	0.193	-1.107	0.008	0.589	178.910
80	106.940	1.975	0.487	31.613	0.284	-3.812	30.632	0.427	-3.791	-0.002	0.350	168.420
83	71.560	1.734	0.474	54.586	0.557	-7.648	49.456	1.019	-5.403	0.002	0.724	175.540
85	129.443	0.595	-2.227	45.163	0.627	-7.730	3.956	-31.425	-14.476	0.135	1.182	173.840
89	84.773	1.198	-5.542	25.833	0.885	-12.087	51.459	0.246	-1.148	-0.002	0.481	161.670
Mean	**99.505**	**1.892**	**0.274**	**36.340**	**0.608**	**-8.595**	**35.789**	**0.642**	**-6.580**	**0.003**	**0.511**	**171.254**

Table A2:-Estimated Values of BTT growth model for girls

Sub	a_1	b_1	c_1	a_2	b_2	c_2	a_3	b_3	c_3	**Mean of Res**	**SD of Res**	**FS**
3	85.723	1.983	0.499	53.122	0.063	0.063	19.688	1.400	-12.772	0.023	0.576	152.240
6	114.769	1.932	0.490	20.734	0.845	-12.048	31.659	0.745	-6.085	0.000	0.453	167.160
7	106.651	1.985	0.492	28.853	0.583	-7.949	18.175	1.022	-8.184	0.000	0.285	153.660
8	104.936	1.796	0.473	23.451	0.247	-1.963	27.974	0.705	-6.255	0.003	0.189	156.130
13	102.085	2.002	0.498	12.172	1.376	-19.212	42.087	0.451	-3.448	0.009	0.429	156.330
14	101.500	2.074	0.633	66.900	0.494	-4.204	-15.496	2.177	-14.465	-0.009	0.405	152.890
18	108.042	1.520	0.441	40.031	0.418	-4.163	6.685	1.307	-12.375	-0.004	0.421	154.710
19	121.658	2.129	0.533	18.384	0.793	-11.188	14.646	1.759	-15.948	0.000	0.364	154.690
22	99.026	2.033	0.514	45.156	0.367	-3.447	8.729	2.398	-18.166	-0.003	0.393	152.810
23	124.181	0.791	0.338	33.221	0.946	-9.893	2.486	1.350	-21.760	0.022	0.694	159.890
24	105.714	2.004	0.499	37.378	0.610	-8.446	17.161	1.371	-10.511	0.000	0.687	160.230
26	108.083	1.699	0.453	22.562	0.501	-5.776	22.844	0.634	-5.057	-0.001	0.338	153.470
29	118.304	1.954	0.495	21.643	0.573	-8.059	16.865	0.893	-7.797	0.000	0.382	156.790
32	117.983	0.570	-0.184	21.838	0.565	-8.604	30.777	0.495	-4.265	0.005	0.285	170.540
40	114.329	2.460	0.524	37.937	0.991	-9.200	0.049	-5.212	-10.911	0.000	0.704	152.270
45	114.419	2.031	0.500	28.018	1.088	-10.490	12.219	0.641	-8.153	-0.001	0.684	154.650
46	107.160	1.977	0.498	35.755	0.822	-8.264	11.392	0.084	-0.160	0.000	0.410	152.690
47	102.381	1.952	0.489	42.617	0.610	-5.098	9.952	1.383	-12.754	0.000	0.395	154.950
48	111.531	1.776	0.499	22.640	0.405	-5.453	17.808	1.509	-13.734	-0.013	0.435	151.860
49	113.282	1.953	0.490	35.976	0.564	-8.007	14.576	1.297	-11.750	0.000	0.363	163.780
50	106.934	1.903	0.499	23.975	0.559	-8.566	32.594	0.499	-4.260	0.014	0.389	163.440
56	119.286	2.187	0.526	26.293	0.588	-7.284	13.053	0.997	-9.451	0.002	0.451	158.62
58	100.344	3.599	0.330	41.964	0.535	-5.551	9.544	1.100	-10.675	-0.001	0.289	151.84
60	101.941	1.981	0.496	30.940	0.383	-4.496	23.284	0.647	-5.963	0.000	0.106	156.06
61	91.658	1.880	0.490	43.430	0.142	-2.523	28.066	0.496	-4.391	-0.001	0.488	154.61
63	107.925	7.608	1.094	34.439	0.478	-5.620	14.232	0.805	-7.078	-0.001	0.268	156.56
64	114.470	1.898	0.494	19.817	0.679	-10.732	22.534	1.034	-9.276	0.000	0.393	156.800
65	118.047	1.931	0.493	12.063	0.908	-13.306	22.970	1.230	-11.041	0.000	0.237	153.080
69	122.179	3.110	0.506	26.522	0.854	-11.786	9.597	2.509	-22.720	0.000	0.376	158.300
73	121.821	1.976	0.497	11.476	1.720	-24.769	22.972	1.128	-10.535	0.000	0.400	156.270
76	114.888	2.010	0.500	40.711	0.367	-3.877	6.809	2.915	-25.993	-0.004	0.278	162.290
78	112.213	1.913	0.483	38.493	0.869	-9.077	1.550	0.980	-16.351	0.000	0.495	152.260
79	107.035	1.999	0.500	37.545	0.504	-6.196	7.035	0.881	-8.669	-0.007	0.501	151.600
81	104.896	1.984	0.498	30.582	0.342	-4.782	23.498	0.546	-5.498	0.000	0.491	158.540
Mean	**109.570**	**2.135**	**0.488**	**31.372**	**0.641**	**-7.940**	**16.118**	**0.946**	**-10.484**	**0.001**	**0.413**	**156.530**

Table A3: Biological Parameters of Boys Stature (using BTT Model)

Sub	**AMCM (yr)**	**VMCM (cm/yr)**	**HMCM (cm)**	**ATO (yr)**	**VTO (cm/yr)**	**HTO (cm)**	**APHV (yr)**	**PHV (cm/yr)**	**HPHV (cm)**	**FS (cm)**

1	10.50	5.40	144.00	14.50	4.00	162.50	15.60	5.65	168.00	179.65
2	8.50	5.15	130.00	10.70	5.00	142.00	13.20	6.90	155.00	170.96
4	8.00	5.00	126.00	10.70	4.40	138.00	13.30	6.85	150.00	165.24
5	8.30	6.20	128.00	9.80	2.45	134.50	13.50	5.50	150.00	165.88
10	7.20	5.25	126.00	10.00	3.95	138.00	13.30	4.45	152.00	170.49
17	9.30	3.70	123.50	10.40	3.25	128.00	13.50	6.00	147.50	168.19
30	7.50	7.00	126.00	10.50	3.55	145.50	14.00	4.80	158.00	175.35
35	9.00	4.55	135.00	12.60	4.45	144.00	16.00	6.85	159.50	176.39
43	7.80	6.80	123.00	10.50	3.85	138.00	14.00	5.20	153.00	171.90
51	8.60	6.35	124.00	10.60	4.45	138.50	13.40	6.60	157.00	181.86
54	7.40	5.65	120.50	10.50	4.40	134.50	14.50	6.80	156.00	176.59
55	8.30	4.75	112.00	10.30	3.85	122.50	15.40	7.10	150.00	174.33
59	9.60	5.50	128.00	12.00	5.20	140.50	13.50	5.30	150.00	163.39
62	7.00	5.95	114.50	11.00	4.05	134.00	14.40	7.00	152.00	169.17
67	8.50	5.80	125.50	12.00	4.30	142.00	13.50	4.40	149.00	165.67
68	9.00	6.00	123.00	10.50	3.35	130.00	13.50	7.00	150.00	170.40
72	8.50	4.35	126.00	10.40	4.25	136.00	14.20	5.25	154.00	172.61
83	7.50	6.90	119.50	9.20	4.30	130.00	13.20	6.90	149.00	175.54
89	7.00	7.40	111.50	8.50	3.80	122.00	13.20	6.40	142.50	161.67
Mean	**8.29**	**5.67**	**124.53**	**10.77**	**4.04**	**136.87**	**13.96**	**6.05**	**152.76**	**171.33**

Table A4: Biological Parameters of girls using BTT Model

Sub	**AMCM (yr)**	**VMCM (cm/yr)**	**HMCM (cm)**	**ATO (yr)**	**VTO (cm/yr)**	**HTO (cm)**	**APHV (yr)**	**PHV (cm/yr)**	**HPHV (cm)**	**FS (cm)**
6	8.50	6.50	131.25	10.50	3.90	147.00	13.70	4.40	155.00	167.16
7	7.50	6.00	118.00	11.25	3.80	141.50	13.00	3.95	139.50	153.66
13	8.20	5.05	123.50	11.40	3.75	138.00	13.60	5.10	146.00	156.33
19	9.30	7.30	132.00	11.20	2.05	138.00	13.00	3.30	146.50	154.69
23	10.20	7.10	140.00	14.50	0.70	157.00	16.20	0.95	158.00	159.89
24	8.00	7.20	117.50	10.30	3.55	129.00	13.50	5.20	142.50	160.23
49	9.40	6.70	125.00	10.60	4.55	146.25	13.50	4.65	146.25	163.78
64	8.20	6.50	126.00	12.30	2.30	139.00	15.40	3.10	147.00	156.80
65	9.30	7.60	129.50	11.60	1.90	146.50	14.50	2.55	147.00	153.08
69	9.20	7.10	126.25	10.80	2.50	134.50	13.50	5.10	146.25	158.30
73	9.60	6.90	132.50	11.80	2.00	144.50	13.40	4.55	150.00	156.27
Mean	**8.85**	**6.72**	**127.41**	**11.48**	**2.82**	**141.93**	**13.94**	**3.90**	**147.64**	**158.20**