ISSN 1683-5603

International Journal of Statistical Sciences Vol. 3 (Special Issue), 2004, pp 269–280 © 2004 Dept. of Statistics, Univ. of Rajshahi, Banqladesh

# Stepwise Regression for Predicting Final Stature of Japanese Children

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[Received March 17, 2004; Accepted July 29, 2004]

#### Abstract

Stepwise regression approach was used to predict the final stature of Japanese children. A sample of 509 boys and 311 girls was considered. After removing the outliers and influential data points, regression equations (highly cross validated) to predict final stature have been proposed for Japanese boys and girls, separately.

**Keywords and Phrases:** Final Stature, Stepwise Regression, Outlier, Influential Point, Mid-growth Spurt.

AMS Classification: 62-07, 62F15, 62F10, 62J02, 62J07, 92B10.

# 1 Introduction

Accurate predictions of final stature are important for children growing or maturing at unusual rates and for children with diseases, such as hypothyroidism, that can alter their potentials for growth in stature. Therefore, it might have been a great concern not only to pediatricians but, also parents having a child with short stature. Many researchers have tried to estimate the final stature through different methods (Ali and Ohtsuki, 2001; Bayley and Pinneau,1952; Khamis and Guo, 1993; Khamis and Roche, 1994; Onat, 1975; Roche et al., 1975a,b; Wainer et al., 1978;). Most of the above researchers predicted the final stature through skeletal age. Recently, Ali and Ohtsuki (2001) proposed some predicting equations based on growth parameters, e.g., stature at peak height velocity, and stature at take off. Thus, to predict one's final stature using Ali and Ohtsuki's equations, those two growth parameters are required. Whereas, to have those parameters one should need a longitudinal data of stature to fit the model. Also, it can be possible to predict the final stature after finding the relationship of the final stature with statures at different ages drawn from the well-fitted distance curve.

To get well-fitted distance curve with greater precision, researchers are dealing with different models (Ali et al., ND; Bock et al., 1973; Berkey and Reed, 1987; Count, 1943; Jenss and Bayley, 1937; Jolicoeur et al., 1988, 1992; Karlberg, 1989; Preece and Baines, 1978 etc.). However, for a good prediction, it is necessary to select a good model. Jolicoeur et al., 1992 declared that, till then, JPA-2 had the best fit compared with other structural growth models. Recently, Ali et al. (ND) pointed out through an unpublished data that the average root mean square error of the estimate for triphasic generalized logistic model (BTT model) were smaller than that for JPA-2 model, and added that JPA-2 model can't estimate the mid-growth spurt whereas the BTT model can.

Significant correlation between final stature and predicted stature at different statures from age 2 to 13 have been reported by Ali (2000). This should be a strong clue to find out some relationships (equations) between final stature and the statures at different ages from 2 to 13 years.

The purpose of the present study is to apply the BTT model to longitudinal data of stature of Japanese boys and girls to predict the distance curve, and then find out some equations to predict the final stature of the Japanese based on statures at different ages drawn from the distance curve.

# 2 Data and Methods

## 2.1 Data

Longitudinal data of 820 Japanese children and youths (509 boys and 311 girls), ranging in age from 0 to 20 years and born from 1967 to 1977, were collected from their personal records. Several universities from the Kanto District were selected and all students of some classes of those selected universities were included except those who had incomplete information (Here "incomplete" indicates that the lack of information, i.e., missing of variables). Though the database includes serial data for many variables, including stature, weight, sitting height, and chest circumference, only stature was analyzed in this study. For a brief discussion of the data, see Ali and Ohtsuki (2001).

#### 2.2 Methods

To estimate statures at different ages, the BTT model was applied on the individual longitudinal data of stature to get the distance curve as previously described by Ali et al. (ND). Stature at age *i* (denoted by  $S_i$ ),  $i = 2, 3, \dots, 13$ , drawn from the predicted distance curve for each individual were then considered for further analysis to predict the final stature of the Japanese. According to the Bock et al. (1994), predicted final stature (PFS) has been considered in this study as  $S_{25}$  (i.e., stature at age 25 years) for each individual. However, the definition of age at final stature is different by the researchers (Kato et al., 1998).

Final stature of individuals followed by their growth pattern as well as different statures at their previous ages. The function of stature on age of every individual is monotonically increasing over the period of birth to young age. To understand the pattern, either linear or nonlinear, between the final stature and stature at one's previous ages can be easily shown from the correlation matrix plot. Very often, the relationship between predicted final stature (PFS) and stature at different previous ages are found to be as linear (Figs. 1 and 2).

Considering that we have to predict the final stature with respect to statures at different ages from 2 to 13 years. As Fig. 1 and 2 show the relationship between PFS and statures at different previous ages are linear, we can consider multiple linear regression of PFS on stature at previous ages. How many stature-variables are essential to explain the maximum percentage of variation (Here, the maximum percentage of variation explained by the regression is referred to as maximum  $R^2$ ) can be determined by the forward stepwise regression analysis method (Draper and Smith, 1966, pp.169-171) as also previously described by Ali and Ohtsuki (2001). The STATISTICA software was used.

Like Ali and Ohtsuki (2001), a regression equation without an intercept (intercept forced to zero, regression through the origin) is applicable in this study, too. Because one can not think predicted final stature (PFS) if stature at any previous age considered in this study is zero. In such a situation, inclusion of intercept term result low value of  $R^2$ .

Since multiple regression is a mathematical maximization procedure, it can be very sensitive to data points within "split off" or are different from the rest of the points, that is, to outliers. Just 1 or 2 such points can affect the interpretation of the results, and it is certainly debatable as to whether 1 or 2 points should be permitted to have such a profound influence.



Figure 1: Correlation matrix plot between PFS and stature at different ages for Japanese boys.



Figure 2: Correlation matrix plot between PFS and stature at different ages for Japanese girls.

#### Ali, et al.: Predicting Final Stature of Japanese Children

Therefore, it is important to be able to detect outliers and influential points. There is a distinction between the two because a point that is an outlier (either on y or for the predictors) will not necessarily be influential in affecting the regression equation. There are various statistics for identifying outliers on y and on the set of predictors, as well as for identifying influential data points. Mahalonobis distance (Stevens, 1996, pp.111-115) to detect outlier and Cook's distance (Cook, 1977; Cook and Weisberg, 1982) to detect influential data points were applied in the present study as also previously described by Ali and Ohtsuki (2001). Cook and Weisberg (1982) have indicated that a Cook distance > 1 would generally be considered large, implying an influential point.

Multiple regression estimates (the B coefficients) are not very stable particularly if the size of the sample is very small (less than 100). In other words, single extreme observations can greatly influence the final estimates. Therefore, it is always necessary to review these statistics, and to repeat crucial analyses after discarding any outliers and influential data points. Finally, inference should be drawn with the data set that is free from any outlier and influential point.

To know how well the regression equations will predict on independent samples of the population individuals, cross-validated correlation, a model validation technique, is considered (Khan and Ali, 2003; Stevens, 1996; p. 96). The cross validity predictive power, denoted by  $\rho_{cv}^2$ , is defined as:

$$\rho_{cv}^2 = 1 - \frac{(n-1)(n-2)(n+1)}{n(n-k-1)(n-k-2)}(1-R^2);$$

where n is the sample size, k is the number of predictors in the regression equation and the cross-validated R is the correlation between observed and predicted values of the dependent variable. Using the above statistic, it can be concluded that if the prediction equation is applied to many other samples from the same population, then  $(\rho_{cv}^2 \times 100)\%$  of the variance on the predicted variable would be explained by the regression equation (Stevens, 1996; p. 100).

## 3 Results

BTT model was run on the individual longitudinal data of stature to find out the distance curve for each individual. The predicted statures from the distance curve considered in this study were: stature at age  $2(S_2)$ , stature at age  $3(S_3)$ , stature at age  $4(S_4)$ , stature at age  $5(S_5)$ , stature at age  $6(S_6)$ , stature at age  $7(S_7)$ , stature at age  $8(S_8)$ , stature at age  $9(S_9)$ , stature at age  $10(S_{10})$ , stature at age  $11(S_{11})$ , stature at age  $12(S_{12})$ , stature at age  $13(S_{13})$ , and predicted final stature (PFS).

Using forward stepwise regression, it was found that only three stature-variables can able to explain the maximum percentage of variation by the regression equation (i.e.,  $R^2$ ). The model is as follows:

$$PFS = \beta_1 S_i + \beta_2 S_j + \beta_3 S_k + \epsilon$$

#### 274 International Journal of Statistical Sciences, Vol. 3 (Special), 2004

where  $\beta_1$ ,  $\beta_2$  and  $\beta_3$  are the partial regression coefficients, and  $\epsilon$  is the random error term assumed to be distributed as normally with mean zero and variance unity;  $S_i, S_j$ , and  $S_k$  are the stature-variables defined at age i, j, and k, respectively, i, j, k = $2, 3, \dots, 13; i \neq j \neq k$ . The set i, j, k is different for different cases (case 1, case 2, and case 3). The case 1, case 2, and case 3 refer to analysis based on whole sample individuals, individuals who have the mid-growth spurt, and individuals who don't have the mid-growth spurt, respectively. A summary of the forward stepwise regression of the dependent variable PFS for different cases was found and shown in Table 1.

Table 1: Summary of the stepwise regression for the dependent variable PFS (Predicted final stature)

Cases	Sample	Variable	Step	Coefficient	Standard	F – to	p-level	$R^2$	Variables	
	size		+in		error	enter/remove	-		included	
	Boys									
Case 1	410	$S_9$	1	1.270660	0.096113	377603.7	0.000000	0.99892	1	
		$S_3$	2	0.638750	0.079237	54.2	0.000000	0.99905	2	
		S <sub>12</sub>	3	-0.377094	0.072787	26.8	0.000000	0.99910	3	
Case 2	012	g	1	1 091520	0.152105	225484.0	0.000000	0.00006	1	
Case 2	213	59	1	0.402674	0.155105	223464.9	0.000000	0.99900	1	
		53	2	0.493074	0.097118	21.5	0.000000	0.99917	2	
		S <sub>12</sub>	3	-0.296906	0.114832	6.7	0.010398	0.99920	3	
Case 3	191	$S_5$	1	-0.304324	0.345247	139935.2	0.000000	0.99864	1	
		$S_9$	2	1.080969	0.212497	10.8	0.001185	0.99872	2	
		$S_2$	3	0.730981	0.172769	17.9	0.000036	0.99883	3	
					Girls					
Case 1	262	$S_{13}$	1	3.20074	0.143402	393773.6	0.000000	0.99934	1	
		S <sub>12</sub>	2	-3.29566	0.280664	196.9	0.000000	0.99962	2	
		S <sub>11</sub>	3	1.11848	0.155298	51.9	0.000000	0.99969	3	
Case 2	96	S12	1	3.09039	0.109926	216090.1	0.000000	0.99956	1	
		S12	2	-3.23795	0.230637	194.4	0.000000	0.99986	2	
		$S_{11}^{12}$	3	1.16692	0.142226	67.3	0.000000	0.99992	3	
Case 3	134	S <sub>13</sub>	1	3.18652	0.197888	243768.8	0.000000	0.99946	1	
		S <sub>12</sub>	2	-3.03767	0.368247	129.1	0.000000	0.99972	2	
		S <sub>11</sub>	3	0.86965	0.192203	20.5	0.000013	0.99976	3	

Case 1, Case 2 and Case 3 refers to the analysis based on whole sample, individuals who have the mid-growth spurt and who without the mid-growth spurt, respectively. The classification of Case 2 and Case 3 is considered here for each individual on the results of BTT model on AUXAL. The sample sizes among three cases are not consistent due to omitting the outliers.

Table 1 shows that the regression coefficients are highly significant at 100p% level (p-values are given in Table 1). Moreover, standard errors of the estimate attain smaller amount. This table also exhibits that for three-variable regression equation, maximum  $R^2$  is attained in case 2 (As  $R^2$  for the predicted equation is the same as in step 3 here.). Also, the average standard errors of the predicted equation in case 2 are smaller than those in case 3 for both sexes (Table 2).

It should be noted that, though, the present study has been started with a sample of 820 individuals (509 boys and 311 girls), but the result (Table 1) shows a contradiction (why?). Because, the present study have lost some sample individuals in two steps. First, some sample individuals, when they were run on BTT model through the software AUXAL (Bock et al., 1994), were not convergent because of having extreme



Figure 3: At 5% level critical value of Mahalanobis Distance  $(D^2)$  when the number of predictor, k, is 3. This figure is made using the tabulated value given in Stevens, 1996, p. 115.

outliers or missing observations in the raw data. Second, some individuals have been lost when it was intended to predict final stature and to repeat the crucial analyses to discard any outliers and influential data points. The well-known statistical software STATISTICA 6.0 was used to find the calculated value of Mahalanobis Distance  $(D^2)$ and Cook's Distance. It was then compared with tabulated value given in Figure 3. The sample observation for which the calculated value of  $D^2$  was greater than its corresponding tabulated value was considered as the outlier. Also, the sample observation for which the Cook's Distance was greater than 1 was considered as the influential data point. Both outliers and influential data points were discarded from the analysis. Thus, the final predicted equations from the stepwise regression methods presented here are free from the problem of inclusion of outlier and influential data points.

# 4 Discussion

According to Ali and Ohtsuki (2001) the predictions of final stature, on average, were underestimated approximately by 0.03 cm in case 1, over-estimated by 0.26 cm in case 3, but asymptotically unbiased in case 2 for boys. For girls, these predictions, on average, underestimated by 0.03 cm in both case 1 and case 3, but it was underestimated by only 0.002 cm in case 2. On the other hand, the present study shows that the prediction is, on average, underestimated approximately by 0.11 cm in case 1, 0.13 cm in case 2, but over-estimated by 0.21 cm in case 3 for boys; and under-estimated by

#### 276 International Journal of Statistical Sciences, Vol. 3 (Special), 2004

0.03 cm in case 1, and 0.02 cm in case 2 and 3 for Japanese girls. Also, the standard errors of the prediction are smaller in case 2 compared to case 3 for both in the present result and those of Ali and Ohtsuki (2001). This implies, in average, the prediction of adult stature is rather better in those individuals who have the mid-growth spurt than those individuals who don't have this spurt. Thus, the present study fully support the Ali and Ohtsuki's postulation (2001) - "The BTT model gives the asymptotically unbiased estimate of the growth parameters for those individuals who have the mid-growth spurt, and gives biased estimate (although the biased is small) of the growth parameters for individuals who don't have the mid-growth spurt; the reason may be the triphasic function itself".

Analyses of residual for individual cases were considered to understand the precision of the prediction for final stature. Average values of observed final stature, predicted final stature, residuals, 90% confidence bounds for residuals, and standard error of the prediction were calculated and shown together with those of Ali and Ohtsuki (2001) in Table 2. Table 2 shows that the average absolute residuals in case 2 are smaller than those in case 3 for Japanese boys.

Comparing with Ali and Ohtsuki (2001), the present study shows that the prediction of adult stature based on growth parameters are better than based on statures at different ages. But the residual and the standard error of the prediction are also small in the present study. Therefore, the present prediction equations are also useful for the Japanese population. On the other hand, the present prediction equations are easy to calculate and need stature-value at only three age points, and need not to fit any model with longitudinal data from birth to maturity.

To predict final stature from the study of Ali and Ohtsuki (2001), it is necessary to get STO and SPHV that is possible if a longitudinal data of stature is available to fit the growth model. Also, many researchers have been used skeletal age to predict the final stature (Bayley and Pinneau,1952; Khamis and Guo, 1993; Onat, 1975, 1983; Roche et al., 1975a,b; Wainer et al., 1978). The present prediction method need not any curve fitting or skeletal age from the x-ray exposure of the subject, however, it is essential to estimate the skeletal age for the clinical purpose or the pediatric treatment for a short stature. Also, predicting final stature without skeletal age is applicable, for example, not only for the purpose of sports talent detection and selection based on their predicted final stature, but also for giving advice for choosing more suitable sport event and position from the viewpoint of predicted final stature.

The mean residual of the predicted final stature of the present study (Table 2) are smaller compared with that of others (Bayley and Pinneau,1952; Khamis and Guo, 1993; Khamis and Roche, 1994; Roche et al., 1975a,b; Wainer et al., 1978). Average prediction failure, i.e., residual>4.0 cm, was reported by Khamis and Guo (1993) as about 10% for boys and 8% for girls. In the present study, 12% failure occurred for boys (for case 3), but only7% for case 1, 2% for case 2, 6% for case 3 occurred for the data of girls. Case 3 and a part of case 1, that is, sample without mid-growth spurt, are affected with the triphasic BTT model itself. Standard errors of the predicting

Table 2: Averages of the observed, predicted, residual, 90% confidence bounds of residuals and standard error (SE) of predicted equations of final stature based on stature-variable for different cases together with the results (shown in parenthesis), based on biological variables, of Ali and Ohtsuki (2001).

Cases	Sample	Observed	Predicted	Residual		90% Confid. Bound		SE of	
	Size	Stature	Stature	$(\mathrm{cm})$		of Residual (cm)		Prediction	
		(cm)	(cm)	Mean	SD	Lower	Upper	(cm)	
Boys									
Case 1	410	172.34	172.23	0.113	5.17	-6.024	7.497	0.42	
	(415)	(172.40)	(172.37)	(0.026)	(2.70)	(-1.896)	(3.530)	(0.18)	
Case2	213	171.68	171.55	0.133	4.89	-4.982	6.150	0.54	
	(213)	(171.72)	(171.72)	(0.002)	(0.84)	(-0.830)	(0.874)	(0.08)	
Case3	191	173.01	173.22	-0.213	5.94	-6.739	8.990	0.68	
	(197)	(173.10)	(173.37)	(-0.264)	(2.71)	(-2.618)	(4.342)	(0.31)	
Girls									
Case1	262	159.00	159.19	0.027	2.80	-2.652	3.512	0.29	
	(234)	(159.05)	(159.02)	(0.030)	(2.92)	(-2.651)	(4.449)	(0.26)	
Case2	96	157.86	157.84	0.018	1.45	-1.717	1.708	0.25	
	(96)	(157.86)	(157.84)	(0.022)	(1.94)	(-1.855)	(2.054)	(0.27)	
Case3	134	159.74	159.72	0.020	2.48	-2.421	3.389	0.36	
	(136)	(159.82)	(159.79)	(0.034)	(3.25)	(-3.304)	(4.987)	(0.38)	

Categories of Cases 1-3 are the same as in Table 1. The sample sizes among three cases are not consistent due to omitting the outliers.

final stature of the present study (Table 2) are smaller than those of some others (Onat, 1975, 1983), and about the same as those of Ali and Ohtsuki (2001) for girls but larger than those for boys. Comparing with 90% confidence bounds for residuals, the present study for girls (Table 2) shows better prediction than those of some others (Ali and Ohtsuki, 2001; Khamis and Roche, 1994; Roche et al., 1975a; Wainer et al., 1978).

Finally, the proposed equations of predicting final stature for the Japanese are as follows:

For Boys (average)

$$PFS = 1.27066S_9 + 0.63875S_3 - 0.377094S_{12}$$

For Boys (who have mid-growth spurt)

 $PFS = 1.281532S_9 + 0.493674S_3 - 0.296906S_{12}$ 

For Boys (who don't have mid-growth spurt)

$$PFS = 1.080969S_9 + 0.730981S_2 - 0.304324S_5$$

For Girls (average)

 $PFS = 3.20074S_{13} - 3.29566S_{12} + 1.11848S_{11}$ 

For Girls (who have mid-growth spurt)

$$PFS = 3.09039S_{13} - 3.23795S_{12} + 1.16692S_{11}$$

and For Girls (who don't have mid-growth spurt)

 $PFS = 3.18652S_{13} - 3.03767S_{12} + 0.86965S_{11}$ 

The proposed predicted equations to predict the final stature of Japanese boys and girls are cross validated by the cross validity predictive power as described in method section.

Estimated cross validity predictive power,  $\rho_{cv}^2$ , of the predicted equations for different cases of Japanese boys and girls are shown in Table 3. This table indicates that for any independent sample of the Japanese population more than 99% of the variance on the predicted variable, PFS, would be explained by the proposed equations. In other words, the expected amounts of shrinkage of  $R^2$  are very small for all cases of boys and girls, implying a highly cross validated. It should be noted that the predictor variables are affected with *near multicollinearity* problem but it did not affect much the stepwise regression results as the  $R^2$  values of all three cases of boys and girls are very high in step 1 (see Table 1).

Table 3: Estimated cross validity predictive power,  $\rho_{cv}^2$ , of the predicted equations based on stature-variables for different cases of Japanese boys and girls

	Cases	n	k	$R^2$	$ ho_{cv}^2$
Boys					
	Case $1$	410	3	0.99910	0.99908
	Case $2$	213	3	0.99920	0.99917
	Case $3$	191	3	0.99883	0.99879
Girls					
	Case $1$	262	3	0.99969	0.99968
	Case $2$	96	3	0.99992	0.99991
	Case 3	134	3	0.99976	0.99975

Categories of Cases 1, 2 and 3 are the same as in Table 1.

### Acknowledgement

We are grateful to Prof. Bikas K Sinha, Editor-in-Chief, Prof. M.A. Basher Mian, Executive Editor, and the anonymous reviewers for their cooperation, comments and suggestions on an earlier version of the manuscript. We are also grateful to the Japan Society for the Promotion of Science (JSPS) for their financial support during this study.

## References

- Ali, M. A. (2000). Secular trends in growth of Japanese and prediction of their adult stature. Doctoral Dissertation, Tokyo Metropolitan University, Tokyo, Japan.
- [2] Ali, M. A. and Ohtsuki, F. (2001). Prediction of adult stature for Japanese population: A stepwise regression approach. Am. J. Hum. Biol. 13: 316-322.
- [3] Ali, M. A., Rahman J.A.M.S., Ashizawa, K. and Ohtsuki, F. (ND). Human growth in Japanese children: An application of triphasic generalized logistic model. *Int.* J. Stat. Sc. (submitted for publication).
- [4] Bayley, N. and Pinneau, S.R. (1952). Tables for predicting adult height from skeletal age: Revised for use with Greulich-Pyle hand standards. J. Pediatr., 40: 423-441.
- [5] Berkey, C.S. and Reed, R.B. (1987). A model for describing normal and abnormal growth in early childhood. *Hum. Biol.*, 49: 973-987.
- [6] Bock, R.D., Wainer, H., Petersen, A., Thissen, D., Murray, J. and Roche, A.F. (1973). A parameterization for individual human growth curves. *Hum. Biol.*, 45: 63-80.
- [7] Bock, R.D., du Toit, S.H.C. and Thissen, D. (1994). AUXAL: Auxological analysis of longitudinal measurements of human stature. Chicago: *SSI*.
- [8] Cook, R.D. (1977). Detection of influential observations in linear regression. *Technometrics*, 19: 15–18.
- [9] Cook, R.D. and Weisberg, S. (1982). Residuals and influence in regression. *Chapman and Hall.* New York.
- [10] Count, E.W. (1943). Growth patterns of human physique: an approach to kinetic anthropometry. *Hum. Biol.*, 15: 1-32.
- [11] Draper, N.R. and Smith, H. (1966). Applied regression analysis. John Wiley & Sons, Inc. New York.
- [12] Jenss, R.M. and Bayley, N. (1937). A mathematical model for studying the growth of a child. *Hum. Biol.*, 9: 556-563.
- [13] Jolicoeur, P., Pontier, J., Pernin, M-O. and Sempe, M. (1988). A lifetime asymptotic growth curve for human height. *Biometrics*. 44: 995-1003.
- [14] Jolicoeur, P., Pontier, J., and Abidi, H. (1992). Asymptotic models for the longitudinal growth of human stature. Am. J. Hum. Biol. 4: 461-468.

#### 280 International Journal of Statistical Sciences, Vol. 3 (Special), 2004

- [15] Kato, S., Ashizawa, K. and Satoh, K. (1998). An examination of the definition 'final height' for practical use. *Ann. Hum. Biol.* 25: 263-270.
- [16] Karlberg, J. (1989). A biologically-oriented mathematical model (ICP) for human growth. Acta. Paediatr. Suppl. 350: 70-94.
- [17] Khamis, H.J. and Guo, S. (1993). Improvement in the Roche-Wainer-Thissen stature prediction model: A comparative study. Am. J. Hum. Biol. 5: 669-679.
- [18] Khamis, H. and Roche, A.F. (1994). Predicting adult stature without using skeletal age: The Khamis-Roche method. *Pediatrics*, 94: 504-507.
- [19] Khan, M.A.R. and Ali, M.A. (2003). Restricted cross validity predictive power. Pak. J. Statist. 19(2): 199-202.
- [20] Onat, T. (1975). Prediction of adult height of girls based on the percentage of adult height at onset of secondary sexual characteristics, at chronological age, and skeletal age. *Hum. Biol.* 47: 117-130.
- [21] Onat, T. (1983). Multifactorial prediction of adult height of girls during early adolescence allowing for genetic potential, skeletal and sexual maturity. *Hum. Biol.* 55: 443-461.
- [22] Preece, M.A. and Baines, M.J. (1978). A new family of mathematical models describing the human growth curve. Ann. Hum. Biol., 5: 1-24.
- [23] Roche, A.F., Wainer, H., and Thissen, D. (1975a). The RWT method for the prediction of adult stature. *Pediatrics*. 56: 1026-1033.
- [24] Roche, A.F., Wainer, H., and Thissen, D. (1975b). Predicting adult stature for individuals. *Monograph in Paediatrics*. 3: Karger, Basel.
- [25] Stevens, J. (1996). Applied multivariate statistics for the social sciences. Third Edition. Lawrence Erlbaum Associates, Inc., Publishers, New Jersey.
- [26] Wainer, H. Roche. A.F., and Bell, S. (1978). Predicting adult stature without skeletal age and without paternal data. *Pediatrics*. 61: 569-572.