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# Body Index and Ratio Determinants of Performance Potentials of the Bangladeshi Adolescent Male Jumper Athletes

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**Abstract**

The purpose of the present study was to investigate the body index and ratio determinants of the performance potentials (PP) of the Bangladeshi adolescent male jumper athletes. Primary data of size 117 were collected using multi-stage sampling on PP and relevant anthropometric measurements. Body index and ratios: Body Mass Index (BMI), Rohrer's Index (RI), Sitting Height Index of Build (SHIB), Cormic Index (CI), Ape Index (ApeI), Waist to Height Ratio (WsHtR) and Waist to Hip Ratio (WsHpR) were then calculated accordingly. Forward stepwise ridge regression was followed to find out the most important determinants of PP of the athletes. Satisfying all the test and validity conditions, it was found that BMI was the most important determinant among the considered body index and ratios. Other determinants of PP were found to be RI and SHIB. The proposed equation can be followed for enhancing the PP of the adolescent male jumper athletes by the relevant sport authorities.

***Keywords:*** *Performance potentials, Body mass index, Rohrer's index, Sitting height index of build, Cormic index, Ape index, Waist to height ratio, Waist to hip ratio, Adolescent male athletes, Stepwise ridge regression, Cross validity predictive power, and Model building*

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এই অধ্যয়নের উদ্দেশ্য ছিল বাংলাদেশী কিশোর বালক লাফবিদ অ্যাথলেটদের কৃতিত্ব-সম্ভাব্যতার নির্ধারক হিসেবে দেহসূচক ও অনুপাত নিয়ে অনুসন্ধান করা। কৃতিত্ব-সম্ভাব্যতা এবং সংশ্লিষ্ট দেহ সংক্রান্ত পরিমাপের উপর বহু-স্তরবিশিষ্ট নমুনায়ন প্রয়োগ করে ১১৭ আকারের প্রাথমিক উপাত্ত সংগ্রহ করা হয়েছে। তারপর দেহসূচক ও অনুপাত: দেহ-ভর সূচক (BMI), রোহরার-এর সূচক (RI), বসা-উচ্চতার গড়ন সূচক (SHIB), করমিক সূচক (CI), গরিলা সূচক (ApeI), কোমর-উচ্চতা অনুপাত (WsHtR) ও কোমর-নিতম্ব অনুপাত (WsHpR) যথাযথভাবে নির্ণয় করা হয়েছে। অ্যাথলেটদের কৃতিত্ব-সম্ভাব্যতার সর্বাপেক্ষা গুরুত্বপূর্ণ নির্ধারক নিরূপণের জন্য অগ্রগামী ধাপযুক্ত রিজ নির্ভরণ পদ্ধতিটি অনুসৃত হয়েছে। পরীক্ষণ ও বৈধতার সব শর্তপূরণ করে পাওয়া গেছে যে, BMI হচ্ছে বিবেচিত দেহসূচক ও অনুপাতসমূহের মধ্যে সর্বাপেক্ষা গুরুত্বপূর্ণ। RI ও SHIB কৃতিত্ব-সম্ভাব্যতার অন্যান্য নির্ধারক হিসেবে প্রতীয়মান হয়েছে। প্রস্তাবিত সমীকরণটি কিশোর বালক লাফবিদ অ্যাথলেটদের কৃতিত্ব-সম্ভাব্যতা প্রবলতর করার নিমিত্তে সংশ্লিষ্ট ক্রীড়া কর্তৃপক্ষসমূহ অনুসরণ করতে পারে।

## 1. Introduction

The performance of sportsmen has become a matter of national importance, prestige and prosperity. The selection and development of talent in sports has been gaining greater emphasis in the recent years, which involves integral approach of different sports personnel and science specialties. It is needed to pay attention to the sports in childhood and adolescences, since it has been observed that best performance in many sports is reached only if appropriate training is started at early age.

It is difficult to predict potentially talented athletes. There are number of factors which affect the performance of athletes, such as physiological, biochemical, biomechanical, genetic, anthropological and psychological factors. Performance in sports and games are affected by various factors like physique, training, skill, age, motivation etc. also, physique being the most fundamental of all of them. Generally, for any particular sport or event, the athletes are recognized and selected on the basis of the characteristics of their body. It is apparently true that human being begins life with a morphological and functional potential, which sets body shapes and composition, lung and visceral organs, bone structure, size and condition of heart *i.e.*, overall health and physical fitness. The total number of muscles and nerve cells within the human body are fixed at birth, which indicates that some persons are born with a high potential for physical fitness and work performance while others are not. It cannot be denied that the morphological or physical characteristics are determined by heredity, though it is difficult to assess the role of heredity and environmental factors that affect physical variations. Specific training and the physical exercise can improve the performance of an athlete only up to certain limit that is set by his/her genotypes [1].

“The athletes are both, born and made. The basic structure must be present for the possibility of athlete to arise. Lack of proper physique may not help athletes to achieve a desired level of performance. This basic structure or physique of an athlete is likely to depend on one's heredity or family line trends” [2]. Correlation between sports capabilities and anthropometric measurements like body structure, physical characteristics have been observed by many researchers. Sports physicians utilize this knowledge to evaluate and predict performance potentials of the athletes on the basis of observed physical characteristics and specific requirements of the game. “An individual's choice of athletic event might be due to the characteristics probably inborn”[3]. Every sport requires a particular type of body. Various researchers recommended that suitable physique plays a major role for success in sports [4-13]. Their studies play significant roles for the purpose of selection of sportsmen as well as talent hunt for a particular game or sport.

Reviewing the literatures, it is revealed that body indices and ratios may be very important predictor of athletes' performance potentials. But it has never been heard or seen that such type of research were conducted in Bangladesh or on Bangladeshi athletes. Furthermore, all the research works mentioned above are of some descriptive findings or based on simple test of hypothesis. Therefore, an attempt is needed to be taken to build model for Performance Potentials (PP) of the athletes, particularly the adolescent male jumper athletes, of Bangladesh so that their PP would be improved through the improvement of its determinants. Thus, the objective of the present study is to find out the determinants of PP through model building.

## 2. Data and Methodology

Different anthropometric measurements from a sample covering 25 Upazilas of 11 Districts under 4 Divisions of Bangladesh were collected through multi-stage random sampling. After getting the relevant ethical clearance from the proper authority, a total of 414 athletes were interviewed and examined from all over the countries among which 117 were mainly jumpers *i.e.*, best performance of each of whom was in jumping events and this study is based on them. For the test of consistency, results of descriptive statistics along with their standard errors and biases from *Bootstrap Sampling* might be compared.

### 2.1 Body indices and ratios

Measuring body indices and ratios require systematic approaches and accurate tools. Typically, anthropometric measures such as height, limb lengths, and circumferences of various body parts were taken. These were then used to calculate indices and ratios. To measure these accurately, a few tools are commonly used. These include anthropometric tape for measuring circumferences, weighing scale for measuring body mass, and stadiometer for measuring height. It's crucial to follow standardized techniques for measurement to ensure accuracy and repeatability. All the related anthropometric measurements were taken by using recommended and appropriate instruments and methods [14], and then some of the indices and ratios of our interests were calculated as follows:

Body Mass Index, $BMI = \frac{Weight}{(Height)^2} kg/m^2$;

Rohrer's Index (or Corpulence Index), $RI = \frac{Weight}{(Height)^3} kg/m^3$;

Sitting-Height Index of Build, $SHIB = \frac{Weight}{(Sitting\ Height)^3} kg/m^3$;

Cormic Index, $CI = \frac{Sitting\ Height}{Height} \times 100$;

Ape Index, $ApeI = \frac{Arm\ Span}{Height}$;

Waist to Height Ratio, $WsHtR = \frac{Waist\ Girth}{Height}$;

Waist to Hip Ratio, $WsHpR = \frac{Waist\ Girth}{Hip\ Girth}$

**2.2 Model building**: For the purpose of model building the dependent variable is taken to be the Performance Potentials (PP) of the athletes [15], which is an ordinal variable with the values 1-18 (1 being the school level 3rd to 18 being the international level 1st). The levels of competitions in ascending orders are: school, upazila, district, division, national, and international.

To build model, we must check the normality and linearity assumptions of the dependent variable. Accordingly, we can select the linear or non-linear model to fit. The noisy-irregular pattern can be removed by using smoothing method. The well-known and most popular valid method is *4253H, Twice Resistant Smoothing* method [16, 17]. The most popular method for screening the most important determinants is *Forward Stepwise* regression method [18]. If the explanatory variables are inter-correlated, then *Forward Stepwise Ridge Regression* might be useful [19]. To validate the fittings, normal probability plot of the residuals, half-normal probability plot of the residuals, and residuals vs. deleted residuals plot might be studied, *adj.*$R^2$ and cross-validity predictive power $\rho_{cv}^2$ might be applied [20, 21].

## 3. Results and Discussion

Descriptive statistics (location and scale parameters) and shape characteristics of the anthropometric variables together with their results from resistant smoothing (within parentheses) are shown in Table-1. It is seen from the table that all the estimates obtained from the sample (of size 117) are almost similar *i.e.*, biases are very negligible as compared to the estimates obtained from the re-sampling, which are equivalent to estimates obtained from 1,000 Bootstrap sample of size 117. Thus, the sample can be regarded as highly valid, reliable and consistent. On average, height, weight, sitting height, arm span, waist girth, and hip girth of the Bangladeshi adolescent male jumper athletes were $162.63 \pm 0.849$ cm, $48.10 \pm 0.797$ kg, $84.81 \pm 0.468$ cm, $167.81 \pm 0.862$ cm, $64.47 \pm 0.501$ cm and $81.48 \pm 0.500$ cm, respectively. A study on Indian male students of 16 year revealed that height, weight, and sitting height were $165.18 \pm 4.65$ cm, $50.54 \pm 6.24$ kg and $86.58 \pm 2.55$ cm respectively [22], which indicates that on average Bangladeshi male adolescents were shorter and lighter than the Indian male adolescents. School Boys of 14 years of age were of height, weight, and sitting height 161.62±6.93 cm, 49.13±10.50 kg and 84.15±4.00 cm, respectively [23] shows that Bangladeshi male adolescents were taller but lighter than Indian male adolescents. Mean height and weight of higher secondary boys in rural India were observed as 165.38 cm and 51.64 kg, respectively [24], which was much higher than the findings of this study. According to a study [25], 16 years aged non-tribal Bengalee Indian boy of Tripura were slightly taller (163.5±2.8 cm), but much lighter (46.3±2.4 kg) as compared to the Bangladeshi adolescent male jumper athletes. Burdwani Bengalee adolescent male athletes were of average height of 163.4±5.978 cm and weight of 45.8±7.223 [26], that means our adolescent male jumper athletes were shorter but heavier than them.

**Table 1.** Descriptive statistics of the anthropometric measurements together with them from resistant smoothing (within parentheses) and their comparison with bootstrap sampling

| **Anthropometric Measurement (*n = 117*)** | **Descriptive Statistics** | **Estimate** | **S.E.** | **Re-sampling Estimate (Based on 1,000 Bootstrap Samples)** | | | |
|---|---|---|---|---|---|---|---|
| | | | | **Bias** | **S.E.** | **95% C.I.** | |
| | | | | | | **Lower** | **Upper** |
| Height (in cm) | Mean | 162.63 (164.76) | 0.849 (0.381) | 0.007 (-0.007) | 0.885 (0.374) | 160.82 (163.98) | 164.28 (165.44) |
| | S.D. | 9.186 (4.124) | --- | -0.083 (-0.009) | 0.696 (0.358) | 7.692 (3.487) | 10.503 (4.876) |
| Minimum = 135.7 (149.7) | Skewness | -0.961 (-0.562) | 0.224 (0.224) | 0.010 (0.065) | 0.161 (0.381) | -1.270 (-1.150) | -0.635 (0.324) |
| Maximum = 178.4 (173.3) | Kurtosis | 0.683 (1.679) | 0.444 (0.444) | 0.018 (-0.272) | 0.535 (0.977) | -0.216 (-0.765) | 1.838 (3.038) |
| Weight (in kg) | Mean | 48.10 (50.51) | 0.797 (0.435) | -0.011 (-0.012) | 0.830 (0.415) | 46.42 (49.69) | 49.72 (51.31) |
| | S.D. | 8.619 (4.707) | --- | -0.078 (-0.016) | 0.475 (0.334) | 7.571 (4.073) | 9.453 (5.369) |
| Minimum = 27.7 (37.2) | Skewness | -0.315 (-0.037) | 0.224 (0.224) | 0.001 (-0.004) | 0.160 (0.282) | -0.629 (-0.592) | 0.004 (0.495) |
| Maximum = 66.8 (64.9) | Kurtosis | -0.513 (0.438) | 0.444 (0.444) | 0.017 (-0.070) | 0.233 (0.459) | -0.900 (-0.519) | 0.023 (1.319) |
| Sitting Height (in cm) | Mean | 84.81 (86.16) | 0.468 (0.193) | 0.004 (0.000) | 0.478 (0.190) | 83.82 (85.78) | 85.72 (86.52) |
| | S.D. | 5.064 (2.091) | --- | -0.044 (-0.010) | 0.348 (0.242) | 4.333 (1.628) | 5.675 (2.570) |
| Minimum = 70.5 (77.0) | Skewness | -0.828 (-1.463) | 0.224 (0.224) | 0.002 (0.130) | 0.167 (0.484) | -1.160 (-2.047) | -0.519 (-0.162) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Maximum = 94.2 (90.0) | Kurtosis | 0.152<br>(4.535) | 0.444<br>(0.444) | 0.024<br>(-0.687) | 0.471<br>(1.914) | -0.621<br>(-0.403) | 1.317<br>(7.137) |
| Arm Span<br>(in cm) | Mean | 167.81<br>(169.87) | 0.862<br>(0.405) | 0.004<br>(-0.010) | 0.899<br>(0.396) | 165.94<br>(169.04) | 169.48<br>(170.58) |
| | S.D. | 9.319<br>(4.382) | --- | -0.088<br>(-0.007) | 0.701<br>(0.351) | 7.811<br>(3.731) | 10.702<br>(5.118) |
| Minimum = 140.4 (154.6) | Skewness | -0.918<br>(-0.408) | 0.224<br>(0.224) | 0.012<br>(0.046) | 0.160<br>(0.339) | -1.232<br>(-0.968) | -0.605<br>(0.350) |
| Maximum = 183.7 (179.5) | Kurtosis | 0.652<br>(1.137) | 0.444<br>(0.444) | 0.013<br>(-0.197) | 0.519<br>(0.787) | -0.245<br>(-0.785) | 1.753<br>(2.331) |
| Waist Girth<br>(in cm) | Mean | 64.47<br>(65.94) | 0.501<br>(0.289) | -0.012<br>(-0.007) | 0.513<br>(0.280) | 63.47<br>(65.40) | 65.47<br>(66.50) |
| | S.D. | 5.419<br>(3.127) | --- | -0.049<br>(-0.010) | 0.380<br>(0.212) | 4.678<br>(2.711) | 6.161<br>(3.530) |
| Minimum = 53.1 (58.5) | Skewness | 0.385<br>(0.099) | 0.224<br>(0.224) | -0.036<br>(-0.008) | 0.297<br>(0.215) | -0.208<br>(-0.341) | 0.923<br>(0.488) |
| Maximum = 84.1 (74.9) | Kurtosis | 0.394<br>(0.198) | 0.444<br>(0.444) | -0.137<br>(-0.029) | 0.801<br>(0.332) | -0.980<br>(-0.407) | 1.759<br>(0.928) |
| Hip Girth<br>(in cm) | Mean | 81.48<br>(83.00) | 0.500<br>(0.271) | -0.007<br>(-0.007) | 0.520<br>(0.258) | 80.42<br>(82.49) | 82.50<br>(83.50) |
| | S.D. | 5.405<br>(2.928) | --- | -0.048<br>(-0.009) | 0.300<br>(0.208) | 4.745<br>(2.533) | 5.924<br>(3.340) |
| Minimum = 68.5 (74.6) | Skewness | -0.357<br>(-0.087) | 0.224<br>(0.224) | 0.002<br>(0.000) | 0.159<br>(0.283) | -0.672<br>(-0.636) | -0.038<br>(0.449) |
| Maximum = 92.9 (91.8) | Kurtosis | -0.501<br>(0.459) | 0.444<br>(0.444) | 0.017<br>(-0.070) | 0.242<br>(0.460) | -0.889<br>(-0.513) | 0.073<br>(1.308) |

Body index and ratio variables were measured accordingly. Table-2 shows that biases of the estimates in all the cases are very negligible. Hence, it can be said that sampling was biased-free. Mean of BMI got the value of 18.57 $kg/m^2$, that of RI, SHIB, CI, ApeI, WsHtR and WsHpR was 11.27 $kg/m^3$, 78.79 $kg/m^3$, 52.30, 1.031, 0.400 and 0.794, respectively. A study found that BMI of Indian male students of 16 years was 18.49$\pm$1.91 [22], which indicated that Bangladeshi male adolescent jumper athletes were of slightly higher BMI than that of Indian adolescents [27] found that BMI of the school boys of age 13-14 of West Bengal, India as 18.04$\pm$4.38 *i.e.*, lower than Bangladeshi adolescent male jumper athletes' average BMI. A study [23] suggested that mean BMI of the studied Bangladeshi male adolescent jumpers were of lower BMI (18.72$\pm$3.38) than Indian male adolescents of 14 years. Calculated mean BMI [24] of higher secondary boys of rural India (18.86 $kg/m^2$) is much higher than the mean BMI of Bangladeshi male adolescents.

The very low value of S.E. indicates the consistent results in the population might be addressed. This is in accord with the results of 1000 Bootstrap samples. The low length of confidence interval of average indices and ratios implied insignificant sampling fluctuations. So, our results indicated highly robustness in the index and ratio variables estimates.

**Table 2.** Descriptive statistics of the calculated body index and ratio variables of the athletes

| **Body Index and Ratio (*n = 117*)** | **Descriptive Statistics** | **Estimate** | **S.E.** | **Re-sampling Estimate (Based on 1,000 Bootstrap Samples)** | | | |
|---|---|---|---|---|---|---|---|
| | | | | **Bias** | **S.E.** | **95% C.I.** | |
| | | | | | | **Lower** | **Upper** |
| Body Mass Index (BMI) | Mean | 18.57 | 0.105 | -0.003 | 0.100 | 18.37 | 18.77 |
| | S.D. | 1.139 | --- | -0.005 | 0.074 | 0.996 | 1.283 |
| Minimum = 16.1 | Skewness | 0.108 | 0.224 | -0.009 | 0.194 | -0.293 | 0.447 |
| Maximum = 21.7 | Kurtosis | -0.096 | 0.444 | -0.027 | 0.305 | -0.696 | 0.538 |
| Rohrer's Index (RI) | Mean | 11.27 | 0.058 | -0.001 | 0.056 | 11.16 | 11.38 |
| | S.D. | 0.626 | --- | -0.002 | 0.038 | 0.549 | 0.698 |
| | Skewness | 0.066 | 0.224 | -0.003 | 0.188 | -0.269 | 0.477 |
| Minimum = 9.8 Maximum = 13.0 | Kurtosis | -0.302 | 0.444 | -0.021 | 0.314 | -0.854 | 0.379 |
| Sitting Height Index of Build (SHIB) | Mean | 78.79 | 0.373 | -0.020 | 0.355 | 78.09 | 79.47 |
| | S.D. | 4.038 | --- | -0.047 | 0.355 | 3.346 | 4.739 |
| Minimum = 65.8 | Skewness | 0.459 | 0.224 | -0.045 | 0.410 | -0.398 | 1.169 |
| Maximum = 94.2 | Kurtosis | 1.720 | 0.444 | -0.299 | 0.998 | -0.370 | 3.376 |
| Cormic Index (CI) | Mean | 52.30 | 0.066 | 0.002 | 0.063 | 52.18 | 52.43 |
| | S.D. | 0.712 | --- | -0.004 | 0.044 | 0.620 | 0.794 |
| Minimum = 50.29 | Skewness | -0.081 | 0.224 | 0.005 | 0.190 | -0.465 | 0.297 |
| Maximum = 54.13 | Kurtosis | -0.164 | 0.444 | -0.050 | 0.342 | -0.801 | 0.584 |
| Ape Index (ApeI) | Mean | 1.0310 | 0.000 | -0.000 | 0.000 | 1.0304 | 1.0316 |
| | S.D. | 0.004 | --- | -0.000 | 0.000 | 0.003 | 0.004 |
| Minimum = 1.022 | Skewness | -0.028 | 0.224 | 0.005 | 0.151 | -0.318 | 0.278 |
| Maximum = 1.039 | Kurtosis | -0.590 | 0.444 | -0.002 | 0.239 | -1.004 | -0.059 |
| Waist to Height Ratio (WsHtR) | Mean | 0.400 | 0.001 | 0.000 | 0.001 | 0.397 | 0.403 |
| | S.D. | 0.016 | --- | -0.000 | 0.001 | 0.014 | 0.018 |
| Minimum = 0.36 | Skewness | 0.179 | 0.224 | -0.001 | 0.151 | -0.118 | 0.473 |
| Maximum = 0.44 | Kurtosis | -0.176 | 0.444 | 0.003 | 0.274 | -0.644 | 0.420 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Waist to Hip Ratio (WsHpR) | Mean | 0.794 | 0.002 | 0.000 | 0.002 | 0.791 | 0.798 |
| | S.D. | 0.017 | --- | -0.000 | 0.001 | 0.015 | 0.020 |
| Minimum = 0.75 | Skewness | 0.288 | 0.224 | -0.019 | 0.198 | -0.105 | 0.653 |
| Maximum = 0.84 | Kurtosis | 0.263 | 0.444 | -0.039 | 0.384 | -0.431 | 1.076 |

The primary necessity for any higher statistical analysis is the normality assumption of the dependent variable. Figure-1 shows that the distribution of PP is approximately normal. Therefore, next attempts can be made.

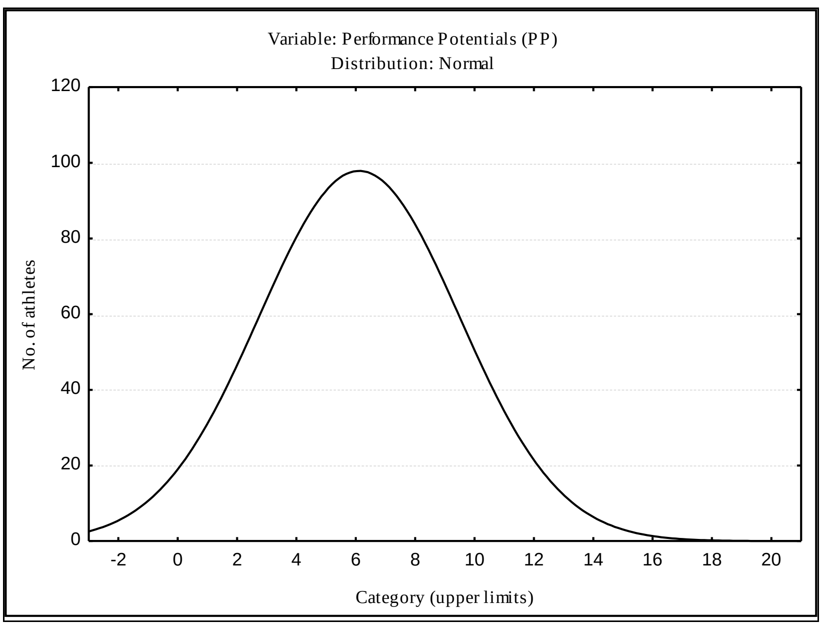


**Figure 1.** Shape of the distribution of the Performance Potentials (PP) of the athletes.

Note: This figure is reused with the permission of the authors [15].

Next step is to study the correlation with the type and significance. Whenever, correlation exists and is found to be significant the investigation is needed to explore the linearity of the relationship among the variables.

Table-3 shows that PP is highly significantly correlated with all the calculated body index and ratios except ApeI. Therefore, a regression model of PP can be fitted on body index and ratios for the improvement of PP of the adolescent male jumper athletes. Furthermore, all the considered body index and ratios are also significantly correlated among themselves. It means that a severe multi co-linearity problem is present there. So, we should select a regression technique which can provide us a valid regression model by overcoming the prevailing multi co-linearity problem. Figure-2, scatterplot matrix of PP and body index and ratios, exhibits the type of relationship among the variables. The types of some of the relationship are linear and some other can be regarded as approximately linear. Hence, we must select a technique in which linearity assumption is a must and which is capable of providing a valid regression model by eliminating multi co-linearity problem. We know that stepwise regression is a method which iteratively examines the statistical significance of each of the predictors in a linear regression model. We also know that forward stepwise regression is a stepwise regression approach that starts from the null model and adds a variable that improves the model the most, one at a time, until the stopping criteria is met. When the independent variables are highly intercorrelated, stable estimates for the regression coefficients cannot be obtained via ordinary least squares (OLS) methods [28, 29]. In the presence of multicollinearity, ridge regression technique result in estimated coefficients that are biased but have smaller variance than OLS estimators and may, therefore, have a smaller mean square error [19]. Since, ridge regression artificially decreases the correlation coefficients so that more stable estimates can be computed, therefore, *Forward Stepwise Ridge Regression* can be supposed to be the most appropriate here.

**Table 3.** Correlation matrix of PP, Body Index and Ratios

| | PP | BMI | RI | SHIB | ApeI | CI | WsHtR | WsHpR |
|---|---|---|---|---|---|---|---|---|
| **PP** | 1.000 | | | | | | | |
| **BMI** | 0.394*** | 1.000 | | | | | | |
| **RI** | 0.388*** | 0.926*** | 1.000 | | | | | |
| **SHIB** | 0.342*** | 0.766*** | 0.758*** | 1.000 | | | | |
| **ApeI** | -0.029 | -0.221*** | -0.243*** | 0.234*** | 1.000 | | | |
| **CI** | 0.138** | 0.359*** | 0.480*** | -0.205*** | -0.694*** | 1.000 | | |
| **WsHtR** | 0.369*** | 0.880*** | 0.934*** | 0.698*** | -0.245*** | 0.467*** | 1.000 | |
| **WsHpR** | 0.293*** | 0.660*** | 0.753*** | 0.538*** | -0.187*** | 0.416*** | 0.893*** | 1.000 |

where, ** $p < 0.01$, *** $p < 0.001$

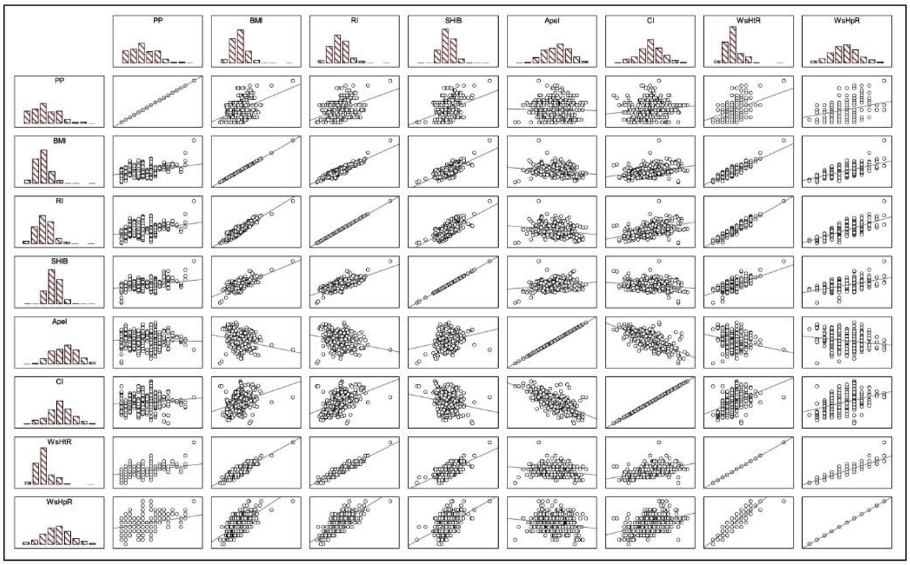


**Figure 2.** Scatterplot matrix of PP and Body Index and Ratios

**Forward Ridge Regression Model of PP on Body Index and Ratios:**

$$PP = \underset{(0.014)}{0.116} * BMI + \underset{(0.016)}{0.186} * RI + \underset{(0.021)}{0.026} * SHIB$$

$n = 117,\ adj.R^2 = 0.7569,\ \rho^2_{cv} = 0.7416,\ Overall\ fitting\ significant\ (p < 0.0001).$

The above equation includes only 3 out of the considered 7 body index and ratios: Body mass index, Rohrer's index and Sitting height index of build. The fitted model of PP shows that all the regression coefficients are positive and highly significant. It implies that if the effects of remaining 2 indices can be kept fixed, then the value of PP will be increased by 0.116 units if BMI is increased by 1 unit. Under the similar conditions, PP will be increased by 18.6% and 2.6% of 1 unit if RI and SHIB will be increased by 1 unit, respectively. The values of *adj.* $R^2$ and $\rho^2_{cv}$ were very close to each other, therefore, the fitted model is highly cross-valid. Since, almost 76% of the variation in response is explained by the predictors, hence, we can also say that fitting of the model of PP on body index and ratios of the adolescent male jumper athletes is moderately good. Both the normal probability plot of residuals (Figure-3a) and half-normal probability plot of residuals (Figure-3b) indicated that the distribution of residuals was approximately normal. Scatterplot of residuals and deleted residuals (Figure-3c) justified that the fit of the equation was good and free from outliers.

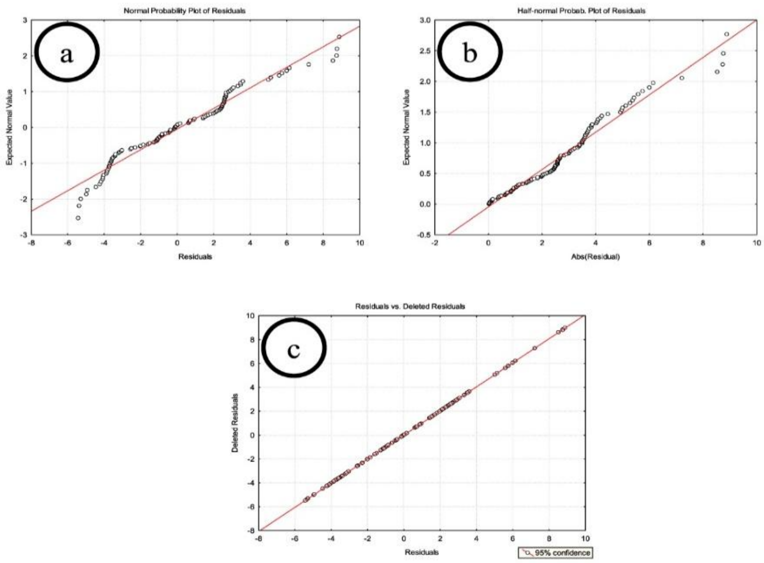


**Figure 3.** a) Normal Probability Plot of Residuals; b) Half-normal Probability Plot of Residuals; and c) Residuals vs. Deleted Residuals Plot.

A study [15] proposed the equation for determining PP on somatotype components. Their proposed equation is:

$$PP = 0.434 * Endomorphy + 0.413 * Mesomorphy$$

($p = 0.000$) ($p = 0.000$)

$n = 414$, *adj.* $R^2 = 0.7427$, $\rho^2_{cv} = 0.7396$, $F = 598.52$ ($p = 0.000$)

Another study [30] proposed the following equation for determining PP on body indices and ratios.

$$PP = 0.235 * BMI + 0.226 * RI + 0.206 * SHIB + 0.196 * WsHtR$$

($p = 0.000$) ($p = 0.001$) ($p = 0.002$) ($p = 0.003$)

$n = 414$, *adj.* $R^2 = 0.7618$, $\rho^2_{cv} = 0.7565$, $F = 332.06$ ($p = 0.000$).

Comparing the proposed equation of Performance Potentials (PP) with the proposed equations in the first study [15], which was based on the somatotype components, and with the second study [30], which was based on the body indices and ratios, we can point out the following: i) from the view point of the values of *adj.* $R^2$ and cross-validity predictive power, $\rho^2_{cv}$, the proposed equation of this study is almost similar with each of those 2; ii) number of determinants in this equation is 3, whereas that in the first study [15] was only 2 and in the second study [30] was 4, which is the indication of less flexibility of explaining variations of PP than the later and more flexibility of explaining the same than the earlier; iii) the calculation of the body indices and ratios were very simple as compared to the calculation of somatotype components where a total of 10 anthropometric measurements were needed (namely: height, weight, humerus breadth, femur breadth, arm girth, calf girth, triceps skinfold, subscapular skinfold, supraspinale skinfold, and medial-calf skinfold) and highly technical and conditional equations were applied, which indicates that the equation of this study involves much fewer labour than the equation proposed by the first study [15]. Therefore, it can be said that the proposed equation in this study, as easy to build and less time might be consumed, is much easier and efficient. Furthermore, this equation is specifically for the jumper athletes, whereas the reviewed 2 were for all athletes, and hence it is suggested or recommended to use exclusively for enhancing the adolescent male jumper athletes' performance.

## 4. Conclusion

Primary data on Performance Potentials (PP) and anthropometric measurements were collected and several body index and ratios were calculated accordingly. On average, height, weight, sitting height, arm span, waist girth, and hip girth of the Bangladeshi adolescent male jumper athletes were found to be 162.63 cm, 48.10 kg, 84.81 cm, 167.81 cm, 64.47 cm and 81.48 cm, respectively. Mean of BMI, RI, SHIB, CI, ApeI, WsHtR and WsHpR got the values of 18.57 $kg/m^2$, 11.27 $kg/m^3$, 78.79 $kg/m^3$, 52.30, 1.031, 0.400 and 0.794, respectively. The very low value of S.E. indicated that the consistent results in the population might be addressed, which is in accord with the results of 1000 Bootstrap samples. The low length of confidence interval (CI) of body index and ratios implied insignificant sampling fluctuations. So, the results indicated highly robustness in the calculated body index and ratios. The stepwise Ridge regression suggested that 3 body index and ratios are enough to explain the performance potentials (PP) of the adolescent male jumper athletes of Bangladesh, and the valid equation is-

$$PP = 0.116 * BMI + 0.186 * RI + 0.026 * SHIB$$

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