Chapter 4

ANALYSIS OF DATA

The aim of the investigation was to evolve a method for classification of secondary school boys into homogeneous groups based upon measures of age, height and weight, by computing the coefficient of determination of these factors and various combinations thereof, as related to the performance criterion. The coefficients of determination of the factors of age, height and weight were computed by Regression Analysis Technique. The factors were grouped into following categories for purpose of computations.

**Category 1**— Age, height and weight individually (as single factor variable) in relation to performance.

**Category 2**— Body build indices based on height and weight in relation to performance.

(a) Weight – height ratio \( \left( \frac{w}{h} \right) \)

(b) Quatelet’s Index \( \left( \frac{w}{h^2} \right) \)

(c) Inverse Ponderal Index \( \frac{h}{\sqrt{w}} \)

(d) Tuxford Index \( \frac{w}{h} \times \frac{3.08 - m}{235} \)

Where \( w = \) weight (kgs), \( h = \) height (cms) and \( m = \) age (months)
**Category 3**— Body build indices multiplies age in relation to performance.

(a) \( \text{Age} \times \frac{w}{h} \)

(b) \( \text{Age} \times \frac{w}{h^2} \)

(c) \( \text{Age} \times \frac{h}{\sqrt{w}} \)

(d) \( \text{Age} \times \frac{\sqrt[3]{w}}{h} \)

**Category 4**— Two factor combinations out of age, height and weight (other than the body build indices) as single variables in relation to performance.

(a) \( \text{Age} \times \text{Height} \)

(b) \( \text{Age} \times \text{Weight} \)

(c) \( \text{Height} \times \text{Weight} \)

(d) \( 1.5 \text{ Height} + \text{Weight} \)

(e) \( \text{Height} \div \text{Age} \)

(f) \( \text{Weight} \div \text{Age} \)

**Category 5**— Three factor combinations involving age, height and weight as single variables in relation to performance.

(a) \( \text{Age} \times \text{Weight} \times \text{Height} \)

(b) \( \text{Age} + \text{Height} + \text{Weight} \)

(c) \( \text{Age} (1.5 \text{ Height} + \text{Weight}) \)

(d) \( \text{Age} \times 1.5 \text{ Height} \times \text{Weight} \)

(e) \( \text{Weight} + \text{Height} \times \text{Age} = \left( \frac{\text{Weight}}{\text{Height} \times \text{Age}} \right) \)
Category 6—Contributions of age, height and weight severally in the following combinations in relation to performance.

(a) Age + Weight + Height (Trivariate Regression)

(b) Weight + Height (Bivariate Regression)

In all the above combinations, age was considered in months, height in centimeters and weight in kilograms.

Pattern of Analysis

I. Linear Regression Model was adopted to compute the coefficient of determination ($R^2$) of the factors as they occur in combinations stated in categories 1 to 5 above.

Under the Linear Regression Model, the coefficient of determination ($R^2$) was computed by using the following formula\(^1\), treating the factors of age, weight and height individually or in combination as independent variables.

$$R^2 = \frac{\sum xy}{\sum y^2} \quad \ldots(1)$$

And $b$ is calculated by using the formula\(^2\)

$$b = \frac{\sum xy}{\sum x^2} \quad \ldots(2)$$


\(^2\)Ibid., p.63.
Where $R^2 = \text{Coefficient of determination (squared multiple correlation coefficient)}$

$$\Sigma xy = \text{Sum of the product of the corrected values of dependent and the independent variable.}$$

$$\Sigma y^2 = \text{Sum of squares of the variable (correlated)}$$

$$\Sigma x^2 = \text{Sum of squared of the variable (correlated)}$$

$$b = \text{Regression coefficient of } y \text{ on } x$$

$xy$ in the above formula is derived by substituting the values in the following formula$^3$

$$xy = \frac{\Sigma xy}{N}$$

where

$X = \text{Sum of the values of independent variable (factor or factors)}$

$Y = \text{Sum of the values of dependent variable (performance)}$

and $N = \text{Number of observations}.$

$\Sigma y^2$ in formula (1) above is derived by using the following formula$^4$

$$\Sigma y^2 = \Sigma y^2 - \frac{(\Sigma y)^2}{N}$$

where

$y$ is the value of the dependent variable and $N = \text{Number of observations}.$

---


$^4$Ibid.
Σx² in formula (2) is derived by using the following formula\(^5\):

\[
\sum x^2 = Sx^2 \sum x^2 - \frac{(\Sigma y)^2}{N} \quad \ldots \ (5)
\]

Where \(x\) is the value of the independent variable and \(N\) is the number of observations.

The significance of the relationship of the dependent and independent variables was tested statistically by the application of Fisher's Test (F-test), which is a test of statistic for overall regression, using the following formula\(^6\):

\[
F = \frac{R^2}{K-1} + \frac{1-R^2}{N-K}
\]

Where

\(R^2 = \text{Coefficient of determination (squared multiple correlation coefficient)}\)

\(K = P + 1\)

\(N = \text{Number of observations}\)

\(P = \text{Number of independent variables}\)

\(^5\)Ibid.

The 't' ration value of the relationship was obtained by taking the square root of the F value\(^7\) (obtained by formula 6).

\[ t^2 = F \]

The level of significance chosen for F and t test was .01.

II. Multiple Regression Model was adopted to compute the coefficients of determination (R\(^2\)) of the factors of age, height and weight as in combinations stated under category 6.

Under the multiple regression mode, the coefficient of determination (R\(^2\)) was computed by using the following formula\(^8\), treating the performance as the dependent variable and the factors of age, height and weight as the independent variables.

\[ R^2 = \frac{b_1 \Sigma x_1 y + b_2 \Sigma x_2 y + b_3 \Sigma x_3 y}{\Sigma y^2} \]

Where

\[ R^2 = \text{Coefficient of determination (squared multiple correlation coefficient)} \]

\[ b_1, b_2, b_3 = \text{Paratiael Regression Coefficients of } y \text{ on } x_1, x_2 \text{ and } x_3. \]

\[ \Sigma x_i y \text{ (} i = 1, 2, 3 \text{) = Sum of the product of the corrected values of dependent variable on independent variables (} i = 1, 2, 3 \text{)} \]

---

\(^7\)Ibid., p.155

\(^8\)Ibid., p.73
\[ \Sigma x_i y \] is derived by substituting the appropriate values in the following formula\(^9\):

\[ \Sigma x_i y = Sx_i y - \frac{\sum x_i y}{N} \quad (i = 1, 2, 3) \quad \ldots (9) \]

Where

\[ \Sigma x_i = \text{Sum of the independent variables} \quad (I = 1, 2, 3) \]

\[ \Sigma y = \text{Sum of the dependent variables} \]

and \( N = \text{Number of observations} \)

\[ \Sigma y^2 = \text{Sum of squares of performance (corrected)} \]

The significance of the relationship of dependent and the independent variables was tested statistically by the application of Fisher’s test (the F test) by using the following method.\(^10\)

\[ \frac{SS_R}{SS_E/df} \quad \text{or} \quad \frac{MSS_R}{MSS_E} \quad \ldots (10) \]

where

\[ SS_R = \text{Sum of squares due to regression} \]

\[ SS_E = \text{Residual Sum of Squares} \]

\[ df = \text{Degree of Freedom} \]

\[ MSS_R = \text{Mean Sum of Squares the to Regression} \quad (SS_R/df) \]

\[ MSS_E = \text{Mean Residual Sum of Squares} \quad (SS_E/df) \]


\(^{10}\)Ibid., p.138.
The ‘t’ test to test the significance of individual coefficient was computed by using the following formulae\(^{11}\).

\[
t_1 = \frac{b_1}{\sqrt{c_{11}}} \quad \cdots \text{(11)}
\]

\[
t_2 = \frac{b_2}{\sqrt{c_{22}}} \quad \cdots \text{(12)}
\]

\[
t_3 = \frac{b_3}{\sqrt{c_{33}}} \quad \cdots \text{(13)}
\]

and ‘s’ is computed by the following method:

\[
s^2 = \frac{SS_E}{(n-p-1)} \quad \cdots \text{(14)}
\]

Hence

\[
s = \sqrt{\frac{SS_E}{(N-P-1)}}
\]

Where \(b_1, b_2, b_3\) = Partial Regression Coefficients of Independent Variables.

\(c_{11}, c_{22}, c_{33}\) = Diagonal Elements of the Matrix Inverse of \(x^T x\),

\[
x^T x = \begin{bmatrix}
\Sigma x_1^2 & \Sigma x_1 x_2 & \Sigma x_1 x_3 \\
\Sigma x_2 x_1 & \Sigma x_2^2 & \Sigma x_2 x_3 \\
\Sigma x_3 x_1 & \Sigma x_3 x_2 & \Sigma x_3^2
\end{bmatrix}
\]

\(^{11}\text{Ibid. pp. 107, 142}\)
\[ SS_E = \text{Residual Sum of Squares} \]
\[ n = \text{Number of Observations} \]
\[ p = \text{Number of variables} \]
\[ s^2 = \text{Mean of Residual Sum of Squares} \]

The coefficients of the determination (\( R^2 \)) of the independent variables under the linear regression model and the multiple regression model were obtained by computerization of data, availing computer model HP – 2100A (HEWLETT – PACKARD 2100A) at M/S Kirloskar Electric Company. The flow chart\(^{12}\) of the model is shown as figure 5. The computer values have been approximated to three places of decimal

**FINDINGS**

I. Age Height, Weight as single factor predictors of performance

The computed values of coefficient of determination (\( R^2 \)) of age, height and weight, the regression coefficient values (b) which provide the information on the weightages of these factors in prediction, the coefficient of zero order correlation (r), the calculated ‘F’ and ‘t’ values obtained on application of the test of significance to \( R^2 \) values have been presented in Table 1 below. (For computed values vide appendices E.1 to E.3)

Input Values of Independent and Dependent Variables

Determine Average Values of Independent and Dependent Variables

Set Up Normal Equation

Solve for Coefficients $A_j$

$J = 1, 2, \ldots, M$

Solve for $A_0$

Compute $Y_1 = 1, 2, \ldots, N$

Perform Tests

STOP

Fig.t: Computer Flow Chart for Multiple Linear Regression Analysis
Table 1. Coefficient of Determination ($R^2$), Coefficient of Zero Order Correlation ($r$), Regression Coefficient ($b$) of Age, Height and Weight and the ‘F’ and the ‘t’ values of Significance

<table>
<thead>
<tr>
<th>Variables</th>
<th>$R^2$</th>
<th>$r$</th>
<th>$b$</th>
<th>F value</th>
<th>‘t’ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Age</td>
<td>$5.8159722 \times 10^{-2}$</td>
<td>.241</td>
<td>$2.2003658 \times 10^{-1}$</td>
<td>32.14$^*$</td>
<td>5.67$^*$</td>
</tr>
<tr>
<td>b) Height</td>
<td>$1.86149508 \times 10^{-1}$</td>
<td>.431</td>
<td>$7.67405987 \times 10^{-1}$</td>
<td>119.36$^*$</td>
<td>10.93$^*$</td>
</tr>
<tr>
<td>c) Weight</td>
<td>$1.49648041 \times 10^{-1}$</td>
<td>.387</td>
<td>$7.65925169 \times 10^{-1}$</td>
<td>91.83$^*$</td>
<td>9.58$^*$</td>
</tr>
</tbody>
</table>

($F_{0.01(1,522)} = 6.69; t_{0.01} = 1.59$)

* Significance at .01 level

Table 1 reveals that the coefficient of determination ($R^2$) which provides information on the percentage of contribution in the prediction of the performance is observed to be highest with respect to height (.186) while the weight and the age occur next in order with the values of .150 and .058 respectively. This is supported by the values of the zero order correlation ($r$) that the factors have with the performance. The height shows a correlation of .241, the weight .387 and age, .241. The F values and the t values
obtained by the test of significance of the relationship of these factors with performance have also been found to be significant at 01 level. Since the values of coefficient of determination \((R^2)\) and the ‘F’ and ‘t’ values of significance are observed to be highest with respect to height, height can be considered for single factor classification for secondary school girls. The investigator’s hypothesis that height may provide a basis for suggesting a single factor classification was held tenable to the extent that it correlated highest with the performance criterion.

II. The body build indices viz. weight:height ratio \((\frac{w}{h})\), Quetelet’s Index \((\frac{w}{h^2})\), Inverse Ponderal Index \((\frac{h}{\sqrt{w}})\), Tuxford Index \((\frac{w}{h} \cdot \frac{3.8-m}{235})\) as predictors of performance.

The computed values of Coefficients of determination \((R^2)\) of \(\frac{w}{h}, \frac{w}{h^2}, \frac{h}{\sqrt{w}}, \frac{w}{h} \cdot \frac{308-m}{225}\) the coefficient of correlation \((R)\), the regression coefficient values \((b)\) which provide the information on the weightages of these factors in prediction, the calculated ‘F’ and ‘t’ values obtained on application of the test of significance to \(R^2\) values have been provided in Table 2. (For computed values vide Appendices E.4 to 3.7).
Table 2. Coefficient of Determination ($R^2$) of $\frac{w}{h}$, $\frac{w}{h^2}$, $\frac{h}{\sqrt{w}}$, $\frac{w}{h} \frac{308-m}{225}$ Coefficient of Correlation ($R$), Regression Coefficient ($b$), and ‘F’ and ‘t’ values of Significance

<table>
<thead>
<tr>
<th></th>
<th>$R^2$</th>
<th>$R(t)$</th>
<th>$b$</th>
<th>$F$</th>
<th>$t$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Weight</td>
<td>9.37051773 x 10^2</td>
<td>1.08638641 x 10^2</td>
<td>54.0*</td>
<td>7.35*</td>
<td></td>
</tr>
<tr>
<td>height ratio</td>
<td>(0.0937051773)</td>
<td>(108.638641)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>= .094</td>
<td>= .306</td>
<td>= 1.8.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Quetelet’s</td>
<td>2.64418945 x 12^-2</td>
<td>9.28200586 x 10^3</td>
<td>14.15*</td>
<td>3.76*</td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>(.0264418945)</td>
<td>(.9282.00586)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>= .026</td>
<td>= .163</td>
<td>= 9282</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Inverse</td>
<td>1.44763966 x 10^-4</td>
<td>-8.6206336 x 10^-2</td>
<td>0.08</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>Ponderal</td>
<td>(.00014476366 x 10^-4)</td>
<td>(.00014476366 x 10^-4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>= .0001</td>
<td>= .012</td>
<td>= -.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) Tuxford</td>
<td>1.44763966 x 10^-2</td>
<td>6.15410995 x 10^1</td>
<td>6.71*</td>
<td>2.60*</td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>(.0127475727)</td>
<td>(.61.5410995)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>= .013</td>
<td>= .113</td>
<td>= 61.54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$F_{.01} (1, 522) = 6.69; \ t_{.01} = 2.59$

*Significant at .01 level

Table 2 indicates that the weight-height ratio $\left(\frac{w}{h}\right)$ has the greater $R^2$ value indicating that its percentage of contribution is highest among the various body build indices. The Quetelet’s index $\left(\frac{w}{h^2}\right)$ and the Tuxford Index $\frac{w}{h} \frac{308-m}{235}$ have the percentages of
contribution next in order. These three indices have been found to be significant at 01 level both by the ‘F’ test and the ‘t’ test. But the amount of regression of these indices have been found to be very low. With respect to Inverse Ponderal Index \( \left( \frac{h}{\sqrt[w]{w}} \right) \), the coefficient of determination \( R^2 \) has been found to be least and also not statistically significant. Hence any of the body build indices do not appear to provide a valid basis for suggesting any classification index. The investigator’s hypothesis that some of the body build indices may provide a basis for classification, index was not supported.

An attempt was made to find if any of the body build indices considered along with age could provide a valid basis for suggesting a classification procedure. Hence the combinations (a) Age x weight -Height Ratio \( \frac{w}{h} \), (b) Age x Quetelet’s Index \( \frac{w}{h^2} \), (c) Age x Inverse Ponderal Index \( \left( \frac{h}{\sqrt[w]{w}} \right) \), (d) Age x ponderal Index \( \frac{\sqrt[w]{w}}{h} \) were taken as independent variables and their coefficients of determination in relation to performance criterion were computed. The computed values of coefficients of determinations \( R^2 \) of (Age x \( \frac{w}{h} \)), (Age x \( \frac{w}{h^2} \)), (Age x \( \frac{h}{\sqrt[w]{h}} \)), (Age x \( \frac{\sqrt[w]{w}}{h} \)), the coefficient of correlation \( r \), the regression coefficient values \( b \) which provide the information on the weightages of these factors in prediction the calculated ‘F’ and ‘t’ values obtained on application of the test of significance to \( R^2 \) values have been provided in Table 3. (For computed values vide Appendices E.S to E.11)
Table 3 Coefficient of Determination ($R^2$), Coefficient of Correlation ($r$), the Regression Coefficient ($b$) of factors of Age $\times \frac{w}{h}$, Age $\times \frac{w}{h^2}$ Age $\times \frac{h}{\sqrt{w}}$, Age $\times \frac{3\sqrt{w}}{h}$ and the ‘F’ and ‘t’ Values of Significance

<table>
<thead>
<tr>
<th>Variables</th>
<th>$R^2$</th>
<th>$R(r)$</th>
<th>$b$</th>
<th>$F$</th>
<th>$t$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Age $\times \frac{w}{h}$</td>
<td>$1.23695359 \times 10^{-1}$</td>
<td>$.124$</td>
<td>$.352$</td>
<td>$73.92^*$</td>
<td>$8.58^*$</td>
</tr>
<tr>
<td></td>
<td>$(.123695329)$</td>
<td>(.570070267)</td>
<td>$.57$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Ages $\times \frac{w}{h^2}$</td>
<td>$6.06338605 \times 10^{-2}$</td>
<td>$.061$</td>
<td>$.246$</td>
<td>$33.67^*$</td>
<td>$5.80^*$</td>
</tr>
<tr>
<td></td>
<td>$(.0606338605)$</td>
<td>$(.63.914.549)$</td>
<td>$.63.91$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Age $\times \frac{h}{\sqrt{w}}$</td>
<td>$4.64771390 \times 10^{-2}$</td>
<td>$.046$</td>
<td>$.216$</td>
<td>$25.40^*$</td>
<td>$5.04$</td>
</tr>
<tr>
<td></td>
<td>$(.0464771390)$</td>
<td>$(.00408610236)$</td>
<td>$.004$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) Age $\times \frac{3\sqrt{w}}{h}$</td>
<td>$4.22319993 \times 10^{-2}$</td>
<td>$.042$</td>
<td>$.206$</td>
<td>$23.00^*$</td>
<td>$4.80^*$</td>
</tr>
<tr>
<td></td>
<td>$(.0422319993)$</td>
<td></td>
<td>$.701$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

($F_{.01} (1,522) = 6.69; t_{.01} = 2.59$)

*Significant at .01 level

A reference to table 3 reveals that the coefficient of determination ($R^2$) of weight-height ratio ($\frac{w}{h}$) combined with age is found to be highest. The ‘F’ and ‘t’ values of the relationship of all the variables with the performance have been found to be significant, but it may be observed that the percentage of information given by the variables (body build indices in combination
with age) has not shown any considerable improvement. Tuxford Index was not considered here as age factor is included in the index itself. None of these combinations was considered convincing enough for suggesting any classification index.

Each of these combinations of age, height and weight has been considered as a single variable (independent) in relation to performance (dependent variable). Hence the extent of contribution of each of these variables of age, height and weight in predicting the performance is not available.

III (a). Two factors combinations among factors of age, height and weight treated as a single variable in relation to performance. The following combinations were considered as a single variable to compute the coefficients of determination ($R^2$).

(a) Age $\times$ Height

(b) Age $\times$ Weight

(c) Height $\times$ Weight

(d) 1.5 Height + Weight

(e) Height $\div$ Age

(f) Weight $\div$ Age

The computed values of coefficients of determination ($R^2$) of (a) Age x height, (b) Age x Weight, (c) Height x Weight (d) 1.5 Height + Weight (e) Height $\div$ Age, (f) Weight $\div$ Age, the coefficient of correlation (r), the regression coefficient values (b) which
provide the information on the weightages of these factors in prediction, the calculated ‘F’ and ‘t’ values obtained on application of the test of significance to $R^2$ values have been presented in Table 4. (For computed values vide Appendices E.12 to E.17). Table 4 Coefficient of Determination ($R^2$) of Age x Height, Age x Weight, Height x Weight, 1.5 Height $\div$ Weight, Height $\div$ Age, Weight $\div$ Age, Coefficient of Correlation ($r$), Regression Coefficient ($b$) and ‘F’ and ‘t’ Values of Significance

<table>
<thead>
<tr>
<th>Variable</th>
<th>$R^2$</th>
<th>$R (r)$</th>
<th>$b$</th>
<th>$F$</th>
<th>$t$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Age $\times$ Height</td>
<td>$1.54588163 \times 10^{-1}$</td>
<td>$1.90970697 \times 10^{-3}$</td>
<td>$= .154$</td>
<td>$95.39^*$</td>
<td>$9.77^*$</td>
</tr>
<tr>
<td>b) Age $\times$ Weight</td>
<td>$1.71659052 \times 10^{-1}$</td>
<td>$3.90764792 \times 10^{-3}$</td>
<td>$= .172$</td>
<td>$108.13^*$</td>
<td>$10.40^*$</td>
</tr>
<tr>
<td>c) Height $\times$ Weight</td>
<td>$1.79017276 \times 10^{-1}$</td>
<td>$4.5258826 \times 10^{-3}$</td>
<td>$= .209$</td>
<td>$113.81^*$</td>
<td>$10.67^*$</td>
</tr>
<tr>
<td>d) 1.5 Height $+$ Weight</td>
<td>$2.08959401 \times 10^{-1}$</td>
<td>$73.73650789 \times 10^{-1}$</td>
<td>$= .209$</td>
<td>$137.84^*$</td>
<td>$11.74^*$</td>
</tr>
<tr>
<td>e) Height $\div$ Age</td>
<td>$8.48969794 \times 10^{-5}$</td>
<td>$1.61086917$</td>
<td>$= .001$</td>
<td>$0.44$</td>
<td>$0.210$</td>
</tr>
<tr>
<td>f) Weight $\div$ Age</td>
<td>$7.0104852 \times 10^{-2}$</td>
<td>$8.92035980 \times 10^1$</td>
<td>$= .07$</td>
<td>$39.35^*$</td>
<td>$6.27^*$</td>
</tr>
</tbody>
</table>

$(F_{.01} (1, 522) = 6.67) \; ; \; t_{.01} = 2.59)$

*Significant Level .01
It can be seen from the above table that the coefficient of determination $R^2$ of “1.5 Height + Weight” is of the order .2.9 being the highest among the variables. The combination of Height $\times$ Weight, Age $\times$ Weight have almost the same percentage of contribution .179 and .171 respectively. The combination of Age $\times$ Height comes next in order with the percentage of contribution of .154. The above combinations are statistically significant at .01 level, when their relationship with performance was evaluated by the “F test and the ‘t’ test. The combinations of Height $\div$ Age and Weight $\div$ Age, however, were found to have a least percentage of contribution .00008 and .0701 respectively. Their relationship with performance of Weight $\div$ Age was found to be significant while that of height $\div$ Age was not significant (.01 level). Considering the above facts, the following single variable combinations of two factors may be taken as the basis for suggesting classification indices.

(1) 1.5 Height $\div$ Weight

(2) Height $\times$ Weight

Since the above combinations are treated as single variables, the contribution of each variable in the performance cannot be decided.

III. (b). Combinations of three factors of age, height and weight as a single variable in relation to performance. The
following combinations were considered as a single variable to compute the coefficients of determination ($R^2$)

(a) Age $\times$ Height $\times$ Weight

(b) Age $\div$ Height $\div$ Weight

(c) Age $(1.5 \text{ Height} \div \text{ Weight})$

(d) Age $\times$ 1.5 Height $\times$ Weight

(e) Weight $\div$ Height Age

The computed values of coefficients of determination ($R^2$) of Age $\times$ Height $\times$ Weight; Age $\div$ Height $\div$ Weight; Age $(1.5 \text{ Height} \div \text{ Weight})$, Age $\times$ 1.5 Height $\times$ Weight; Weight $\div$ Height Age, the coefficient of correlation ($r$), the regression coefficients values ($b$) which provide the information on the weightages of these factors in prediction, the calculated ‘F’ and ‘t’ values obtained on application of the test of significance of $R^2$ values have been presented in Table 5. (For computed values vide Appendices E.18 to E.22).
Table 5 Coefficient of Determination $R^2$, the Coefficients of Correlation (r) Regression Coefficients (b) of the Factors in Combination of Age $\times$ Height $\times$ Weight, Age $\div$ Height $\div$ Weight, Age (1.5 Height $\div$ Weight), Age $\times$ 1.5 Height $\times$ Weight, Weight $\div$ Height $\div$ Age, and the ‘F’ and ‘t’ Values of Significance

<table>
<thead>
<tr>
<th>Variables</th>
<th>$R^2$</th>
<th>$R$ (r)</th>
<th>b</th>
<th>F value</th>
<th>$t$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Age $\times$ Height $\times$ Weight</td>
<td>$1.98309511 \times 10^{-1}$</td>
<td>$2.37791792 \times 10^{-5}$</td>
<td>$.198$</td>
<td>129.12*</td>
<td>11.36*</td>
</tr>
<tr>
<td>× Height</td>
<td>$0.000237791792$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>× Weight</td>
<td>$.445$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Age $\div$ Height $\div$ Weight</td>
<td>$1.88127756 \times 10^{-1}$</td>
<td>$2.68271685 \times 10^{-1}$</td>
<td>$.188$</td>
<td>120.94*</td>
<td>11.00*</td>
</tr>
<tr>
<td>Height</td>
<td>($1.88127756$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>÷ Weight</td>
<td>$.434$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Age (1.5 Height $\div$ Weight)</td>
<td>$1.75488155 \times 10^{-1}$</td>
<td>$1.06129865 \times 10^{-3}$</td>
<td>$.175$</td>
<td>111.03*</td>
<td>10.54*</td>
</tr>
<tr>
<td>(1.5 Height $\div$ Weight)</td>
<td>($0.0106129865$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>÷ Weight</td>
<td>$.419$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) Age $\times$ 1.5 Height $\times$ Weight Age</td>
<td>$2.38468274 \times 10^{-2}$</td>
<td>$8.95462891 \times 10^{-3}$</td>
<td>$.0238468274$</td>
<td>12.73*</td>
<td>3.57*</td>
</tr>
<tr>
<td>1.5 Height $\times$ Weight Age</td>
<td>($8954.62891$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$*Significant$ at .01 level

Among the single variable combinations of three factors of age, height and weight, (a) age $\times$ height $\times$ weight and (b) age $\times$ 1.5 height $\times$ weight show equal percentage of contribution ($R^2$) of
.198 which is the highest among the variables. The remaining combinations have varying contributions which are lower as noted below:

(1) Age ÷ Height ÷ Weight = .188
(2) Age (1.5 Height ÷ Weight) = .175
(3) Weight ÷ Height × Age = .024

The relationship of all the three variables (three factor combinations with performance) are shown to be significant at .01 level by the application of 'F' and 't' tests. Of the various combinations (a) Age × Height × Weight and (b) Age × 1.5 Height × Weight, which have the same R² value (.198) would appear to suggest themselves to be considered for computing a classification index. But since each of these combinations has been considered as a single variable, the information on the extent of contribution of each of the factors of age, height and weight in the combinations cannot be made out in the regression.

In order to find out the extent of contribution of each of the factors of age, height and weight to performance the multiple regression analysis was adopted by the Matrix Inversion Method as described. (Page No. 380)

The values of Inverse Matrix were computed by the Computer Programming. The Matrices thus obtained may be seen in the Computer Printouts (vide Appendix B.1 pages 95 – 96).
The computed values of the Coefficient of Determination ($R^2$) of the three variables age, height and weight in relation to performance is .228355 (= .228). The multiple correlation coefficient ($R$) was arrived at by taking the square root of $R^2$.

$$R = \sqrt{R^2} \text{ which is } .477854 (= .478)$$

To test the significance for the relationship of the three variables age, height and weight for predicting the performance F test was applied. The sum of squares due to regression, the deviation from regression (Residual Sum of Squares) the Mean sum of squares, the Degree of Freedom and the $F$ value are presented in Table 6.

Table 6 ‘F’ Test of Significance of Multiple Regression of Three Variables (age, height, weight) on Performance

<table>
<thead>
<tr>
<th>Computations</th>
<th>Sum of Squares (SS)</th>
<th>Degree of Freedom (df)</th>
<th>Mean Sum of Squares (MSS)</th>
<th>$F$ - Ration $(MSS_R + MSS_E)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Regression</td>
<td>24276.25.63</td>
<td>(p)</td>
<td>8125.4166 (MSS_R)</td>
<td>51.295112*</td>
</tr>
<tr>
<td>b) Deviation from Regression</td>
<td>8237.075</td>
<td>520 (n-p-1)</td>
<td>158.4028 (MSS_E)</td>
<td></td>
</tr>
</tbody>
</table>

Total Sum of Squares = 106747.0009  $F_{.01} (3, 520) = 3.82$

$P = \text{Number of Variables}$

$N = \text{Number of Observations}$

$MSS_R = \text{Mean Squares of Regression}$

$MSS_E = \text{Mean Squares of Deviation from Regression}$

* Significant at .01 level
Further ‘t’ test was applied to test the significance of partial regression coefficients of the three variables age, weight and height by using the formulae (11, 12, 13, 14). The partial regression coefficients ($b_1, b_2, b_3$) the values of $c_{11}, c_{22}, c_{33}$) and the value of $s$ is presented in Table 7. The calculations of the ‘t’ values may be found in Appendix. G.1

Table 7 ‘t’ Test of Significance for the Partial Regression Coefficients ($b_1, b_2, b_3$)

<table>
<thead>
<tr>
<th>Variables</th>
<th>SS_E</th>
<th>s</th>
<th>b</th>
<th>c</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>82370.75</td>
<td>12.85915</td>
<td>.13138965</td>
<td>$8.3168306 \times 10^{-5}$</td>
<td>3.62*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>= .13</td>
<td>(.000083168306)</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>82370.75</td>
<td>12.585915</td>
<td>.33243823</td>
<td>$.61161234 \times 10^{-4}$</td>
<td>3.88*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>= .33</td>
<td>(.00061161234)</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>82370.75</td>
<td>12.585915</td>
<td>.5310992</td>
<td>$.48604023 \times 10^{-4}$</td>
<td>6.05*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>= .53</td>
<td>(.000048604023)</td>
<td></td>
</tr>
</tbody>
</table>

$t_{0.01} = 2.59$

* Significant at .01 level

All the values are found to be significant at 0.01 level.

By the Matrix Analysis it has been possible to determine the coefficient of regression of each of the factors of age, weight, and height. As could be seen from Table 7, the coefficient of regression ($b$) of the factors of Age = .13, Weight $t = .33$ and
Height = .53. The values show that age contributes to the extent of one tenth of its value, weight contributes one-third of its value and height contributes nearly one half of its value. Hence, it appears to be evident that all the three factors of age, weight and height are of importance in providing information on the motor ability of the secondary school boys.

An attempt was made to find if the coefficient of determination of the two factor combination of height and weight was unaffected by deleting the age factor. Matrix Inversion Method was applied to the two variables combination of Height + Weight. The computed values of the Matrix Inversion have been provided in Appendix F (page 371). The coefficient of determination $R^2$ was found to be .209 and the multiple correlation coefficient ($R$) was .4571656 ($= .457$). To test the significance of the relationship of the two factors of height and weight for predicting the performance, F test of significance was applied and the results are presented in Table 8 below.
Table 8 F Test of Significance of Multiple Regression of Two Variables (Height and Weight) on performance.

<table>
<thead>
<tr>
<th>Computations</th>
<th>Sum of Squares (SS)</th>
<th>Degree of Freedom (df)</th>
<th>Mean Sum of Squares ( (MSS^R + MSS_E) )</th>
<th>F - Ration</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Regression</td>
<td>22302.5103</td>
<td>2 (p)</td>
<td>11151.25515</td>
<td>68.800398*</td>
</tr>
<tr>
<td>b) Deviation from Regression</td>
<td>84444.4897</td>
<td>521(n-p-1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Sum of Squares

\[(y^2) = 106747.0000 \quad F_{.01(2,521)} = 3.82\]

\(p = \) The number of Variables

\(n = \) Number of Observations

\(MSS_R = \) Mean Square of Regression

\(MSS_E = \) Mean Squares of Deviation from Regression

*Significant at. 01 level

The ‘t’ test of significance was applied to test the significance of partial regression coefficient of the two variables height and weight. The values for computing the ‘t’ test are presented in Table 9. The calculation of the ‘t’ values may be found in Appendix. G.2.
Table 9, ‘t’ Test of Significance for the Partial Regression Coefficients (b₁, b₂)

<table>
<thead>
<tr>
<th>Variables</th>
<th>SSE</th>
<th>s Values</th>
<th>b Values</th>
<th>c Values</th>
<th>t values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>8444.4887</td>
<td>12.731125</td>
<td>.38253868 (b₁)</td>
<td>.59959184 × 10⁻⁴</td>
<td>3.88*</td>
</tr>
<tr>
<td>Height</td>
<td>8444.4887</td>
<td>12.731125</td>
<td>.55323541</td>
<td>.48367947 × 10⁻⁴</td>
<td>6.25*</td>
</tr>
</tbody>
</table>

(t₀₁ = 2.59)

*Significant at .01 level

Table 9 reveals that the partial Regression Coefficient Values of Weight (b₁) and Height (b₂) are significant at .01 level.

Selection of the Variables for Classification.

As could be seen from the foregoing analyzing, the factors of age, height and weight individually and in several combinations were tried to assess the coefficients of determination (R²) and the coefficient of multiple correlation (R). The combinations which registered highest R² values from each category were taken for final selection of the best combination on the basis of the R² values. The body build indices and their combinations with age have not been considered as they registered a very low R² values. The R² values of combinations considered for final selection have been presented in Table 10 below.
Table 10 the Coefficient of Determination ($R^2$) of the Factors of Age, Height and Weight in Relation to Performance

<table>
<thead>
<tr>
<th>Variable</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Single Factor Variables</td>
<td></td>
</tr>
<tr>
<td>1. Age</td>
<td>.058</td>
</tr>
<tr>
<td>2. Height</td>
<td>.186</td>
</tr>
<tr>
<td>3. Weight</td>
<td>.150</td>
</tr>
<tr>
<td>B. Single Variable Combination of Two Factors</td>
<td></td>
</tr>
<tr>
<td>1. Height $\times$ Weight</td>
<td>.179</td>
</tr>
<tr>
<td>2. 1.5 Height $\div$ Weight</td>
<td>.209</td>
</tr>
<tr>
<td>C. Single Variable Combination of Three Factors</td>
<td></td>
</tr>
<tr>
<td>1. Age $\times$ Height $\times$ Weight</td>
<td>.198</td>
</tr>
<tr>
<td>2. Age $\times$ 1.5 Height $\times$ Weight</td>
<td>.198</td>
</tr>
<tr>
<td>D. Trivariable Regression</td>
<td></td>
</tr>
<tr>
<td>1. Age $\div$ Height $\div$ Weight</td>
<td>.228</td>
</tr>
<tr>
<td>E. Bivariate Regression</td>
<td></td>
</tr>
<tr>
<td>1. Height $\div$ Weight</td>
<td>.209</td>
</tr>
</tbody>
</table>

As could be read from Table 10, the combination of Age, Height and Weight as a trivariate combination has the highest coefficient of determination ($R^2$) of .228. It would appear that all the three factors of age, height and weight stake their claim for consideration when suggesting a classification index. When partial regression values for each of these factors were computed
(page 96) the classification index with the three factors would be as follows:

Classification Index = .13 Age + .53 Height + .33 Weight

A perusal of this formula reveals that age contributes least and would appear unimportant when compared to height and weight factors.

The Bivariate Regression Analysis of height and weight in the prediction of performance reveals that the coefficient of determination of the combination ($R^2$) is .209. The computed partial regression values of the two factors (page 371) have been found to be .55 for height and .38 for weight. Even when age factor is deleted, it is observed that partial regression coefficients of height and weight do not show much difference. The Bivariate classification formula would run as follows:

Classification Index = .55 Height + .38 Weight

Hence any of the following classification indices may be followed for classification of secondary school girls.

(a) Index I = .13 Age (months) + .53 Height (cms)

+ .33 Weight (kg)

(b) Index II = .55 Height (cms) + .38 Weight (kg)
Construction of Group Classificatory Norms for the Suggested Indices

The group classificatory norms for suggested Index I and II were computed as per the procedure laid down by Johnson and Nelson\(^\text{13}\) by assuming normality of the distribution. Age, Height and Weight data of 312 subjects in addition to 524 subjects of the study were collected (vide Appendix B.2 Pages 98-103) and the mean and the standard deviation of the scores of Index I may be found in the computer output (Page 385) and those of Index II in the computer output on (Page 389).

Three grade (seniors, Intermediates, Juniors) and five grade (A, B, C, D, E) classifications have been provided for each of the indices.

Two standard deviation (σ) intervals have been taken to arrive at the scored ranges under the three grade classification, and 1.2 standard deviation (σ) intervals have been used to arrive at the score ranges for five grade classification.

GROUP CLASSIFICATION

A. Three Grade Classification

<table>
<thead>
<tr>
<th>Score Range</th>
<th>Class</th>
<th>Score Range</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 122</td>
<td>Seniors</td>
<td>Above 105</td>
<td>Seniors</td>
</tr>
<tr>
<td>108-122</td>
<td>Intermediates</td>
<td>90 to 105</td>
<td>Intermediates</td>
</tr>
<tr>
<td>Below 108</td>
<td>Juniors</td>
<td>Below 90</td>
<td>Juniors</td>
</tr>
</tbody>
</table>

B. Five Grade Classification

<table>
<thead>
<tr>
<th>Score Range</th>
<th>Class</th>
<th>Score Range</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 128</td>
<td>A</td>
<td>Above 111</td>
<td>A</td>
</tr>
<tr>
<td>120-128</td>
<td>B</td>
<td>1.3-111</td>
<td>B</td>
</tr>
<tr>
<td>111-119</td>
<td>C</td>
<td>94-102</td>
<td>C</td>
</tr>
<tr>
<td>102-110</td>
<td>D</td>
<td>85-93</td>
<td>D</td>
</tr>
<tr>
<td>Below 102</td>
<td>E</td>
<td>Below 85</td>
<td>E</td>
</tr>
</tbody>
</table>

With respect to classification index II charts shown as figures 6 and 7, based on the formula have been constructed to arrive at the group classification of cases as a ready reckoner device (Three grade and five grade classifications).
DISCUSSION

The findings of the present study indicate that the factors of age, height and weight either individually or in combination bear a significant but low correlation with performance in agreement with the facts reported in the literature (J. Reilly, 1917; Hetherington and Stolz, 1922; McCloy, 1927; Dalaney, 1928; Neilson and Cozens, 1932; Adams, 1934; Gleneross, 1966).

The classification of formula of 1.5 Height ÷ Weight started to be in use as Madras State Formula, has been found to be incomplete, and not supported by the scientific investigations. The findings of the present study reveal that the combination of 1.5 Height ÷ Weight should be multiplied by regression constant of .37 to be valid as a classification device. In its complete form the formula runs as follows:

\[
\text{Classification Index} = .37 \times (1.5 \times \text{Height} \div \text{Weight})
\]

Table below presents a comparison of the classification formulae for reported in the literature as well as the ones arrived in the present study.
<table>
<thead>
<tr>
<th>Classification Formula</th>
<th>Reilly (1917) (a) 1.29 grade ÷ .965 Age ÷ .226 Height + 1.55 Weight*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(b) 2.225 Age + .226 Height + 1.55 Weight*</td>
</tr>
<tr>
<td>Hetherington And stolz (1922)</td>
<td>2 Age + .200 Height + .1375 Weight*</td>
</tr>
<tr>
<td>Delaney (1928) (a) Above 14 years – 10 Age + Height *</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) Below 14 years – 10 Age + Weight*</td>
</tr>
<tr>
<td>Neilson and Cozens (1932) (a) 20 Age + 5.5 Height + 1.1 Weight *</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) 20 Age + 5.55 Height + Weight*</td>
</tr>
<tr>
<td>Present Study (1982) (a) .13 Age + .53 Height + 3.3 Weight**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) 55 Height + .38 Weight**</td>
</tr>
</tbody>
</table>

*Age in completed years; years; height in inches and weight in pounds.

** Age in months, height in centimeters and weight in kilograms.

Strict comparisons of the present study with the earlier ones with respect to girls are not permitted on account of the racial differences of population and differences in performance criteria. The present finding that the age correlates least with performance criterion compared to height and weight, is not in agreement with the finding with respect to Caucasian and Chinese
girls, as age has been found to correlate highest with the performance criterion in them.

With respect to Caucasian girls, age has been found to correlate highest with the performance. Age, height and weight have been found to correlate equally in respect of Chinese Girls.¹⁴

Even though the factors of age, height and weight register a low correlation with performance, any classification index to be suggested should necessarily be based on these factors as they are easily assessable, least time consuming and feasible.

McCloy’s¹⁵ comments with respect to use of age, height, weight in classification indices appear to use be relevant to recall. He states:

“As is of true of any classifying scheme, however, after such preliminary classifications have been made, a number of exceptions will be found. Elements such as speed, information about the event, motor educability, and such character qualities as interest, persistence and courage are entirely unmeasured by these devices and variations in these and other traits will necessitate adjustments after the group has been classified as to size and maturity by the classification index.”

¹⁵Ibid. p.55.