Chapter IV

ANALYSIS OF DATA AND RESULTS OF THE STUDY

The analysis of data, collected on 100 male students (swimming beginners) representing various schools of Greater Gwalior, is presented in this chapter. Complete data was analysed with the help of Personal Computer XT, IBM Competable, available in the Statistics Division of Lakshmibai National College of Physical Education, Gwalior.

To find out the relationship of dependent variable (swimming learning scores) to each of the independent variables (anthropometric, behavioural and physiological factors) the data was examined by Pearson's Product Moment Correlation\(^1\) and separate Correlation Matrices were prepared. To examine the combined effect of anthropometric and physiological variables on swimming learning, Multiple correlation was computed separately

for these two categories. Multiple correlation was also computed between all the anthropometric, behavioural and physiological variables together to assess their combined effect on the learning of crawl stroke swimming.

Step down regression method was used for identifying the most contributing anthropometric and physiological variables towards the learning of crawl stroke swimming. Multiple regression\textsuperscript{2} was developed in order to predict the swimming learning ability on the basis of most contributing anthropometric, physiological and all combined variables.

The level of significance to check the relationship obtained by Pearson's Product Moment Correlation and Multiple Correlation was set at .05 which was considered appropriate because the research process adopted did not involve highly sophisticated equipments demanding the application of more stringent levels of significance. In using the Product moment correlation a value of .197 was required for significance at the .05 level of confidence.

for 98 degree of freedom.  

Findings

Relationship of Anthropometric, Behavioural and Physiological Variables to Learning of Crawl Stroke Swimming

The scores of each of the independent variables of anthropometric, behavioural and physiological variables were correlated with crawl stroke swimming learning scores (criterion measure), in order to find out the relationship between the dependent and independent variables, which are represented in Tables 2, 3 and 4. Separate correlation matrices were prepared for the anthropometric, behavioural and physiological variables which are shown in Tables 5, 6 and 7 respectively.

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3 Clarke and Clarke, Research Process in Physical Education, Recreation and Health, p.231.
<table>
<thead>
<tr>
<th>Variables Correlated</th>
<th>Correlation Co-efficient (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.530*</td>
</tr>
<tr>
<td>Standing height</td>
<td>0.485*</td>
</tr>
<tr>
<td>Foot length</td>
<td>0.541*</td>
</tr>
<tr>
<td>Foreleg length</td>
<td>0.269*</td>
</tr>
<tr>
<td>Thigh length</td>
<td>0.613*</td>
</tr>
<tr>
<td>Leg length</td>
<td>0.509*</td>
</tr>
<tr>
<td>Trunk length</td>
<td>0.354*</td>
</tr>
<tr>
<td>Forearm length</td>
<td>0.448*</td>
</tr>
<tr>
<td>Upperarm length</td>
<td>0.414*</td>
</tr>
<tr>
<td>Arm length</td>
<td>0.458*</td>
</tr>
<tr>
<td>Head circumference</td>
<td>-0.025</td>
</tr>
<tr>
<td>Shoulder width</td>
<td>0.376*</td>
</tr>
<tr>
<td>Upperarm girth</td>
<td>0.180</td>
</tr>
<tr>
<td>Thigh girth</td>
<td>0.495*</td>
</tr>
<tr>
<td>Calf girth</td>
<td>0.496*</td>
</tr>
<tr>
<td>Leg length/Trunk length</td>
<td>0.121</td>
</tr>
</tbody>
</table>
TABLE 2 (Contd.)

<table>
<thead>
<tr>
<th>Variables Correlated</th>
<th>Correlation Co-efficient (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreleg length/Thigh length</td>
<td>-0.430*</td>
</tr>
<tr>
<td>Forearm length/Upperarm length</td>
<td>-0.066</td>
</tr>
</tbody>
</table>

\[ N = 100 \]

*Significant at .05 level of confidence.

\[ r_{.05} (98) = .197. \]

Table 2 reveals that the crawl stroke swimming learning is significantly related to weight, standing height, foot length, foreleg length, thigh length, leg length, trunk length, forearm length, upperarm length, arm length, shoulder width, thigh girth, calf girth and foreleg length/thigh length, whereas no significant relationship is obtained between head circumference, upperarm girth, leg length/trunk length and forearm length/upperarm length, and swimming learning. Therefore, it is evident that weight, standing height, foot length, foreleg length, thigh length, leg length, trunk length, forearm length, upperarm length, arm length, shoulder
width, thigh girth, calf girth and foreleg length/thigh length contribute to the learning of crawl stroke swimming as shown in Figures 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15 and 17 and remaining anthropometric variables do not significantly contribute to the learning of crawl stroke swimming (Fig. 11, 13, 16 and 18).
Fig. 1  Relationship between Weight and Swimming Learning.
Fig. 2 Relationship between Standing Height and Swimming Learning.
Fig. 3 Relationship between Foot Length and Swimming Learning
Fig. 4  Relationship between Foreleg Length and Swimming Learning.
Fig. 5 Relationship between Thigh Length and Swimming Learning.
Fig. 6  Relationship between Leg Length and Swimming Learning.
Fig. 7 Relationship between Trunk Length and Swimming Learning
Fig. 8 Relationship between Forearm Length and Swimming Learning
Fig. 9 Relationship between Upperarm Length and Swimming Learning
Fig. 10  Relationship between Arm Length and Swimming Learning.
Fig. 11 Relationship between Head Circumference and Swimming Learning.
Fig. 12 Relationship between Shoulder width and Swimming Learning.
Fig. 13 Relationship between Upperarm Girth and Swimming Learning.
Thigh Girth

Fig. 14 Relationship between Thigh Girth and Swimming Learning.
Fig. 15  Relationship between Calf Girth and Swimming Learning.
Fig. 16  Relationship between Leg Length/Trunk Length and Swimming Learning.
Fig. 17 Relationship between Foreleg Length / Thigh Length and Swimming Learning.
Fig. 18 Relationship between Forearm Length/Upperarm Length and Swimming Learning
TABLE 3

RELATIONSHIP OF BEHAVIOURAL VARIABLES TO SWIMMING LEARNING SCORES

<table>
<thead>
<tr>
<th>Variables Correlated</th>
<th>Correlation Co-efficient (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of aspiration</td>
<td>0.085</td>
</tr>
<tr>
<td>Intelligence</td>
<td>0.681*</td>
</tr>
<tr>
<td>Concentration</td>
<td>0.188</td>
</tr>
</tbody>
</table>

N = 100

*Significant at .05 level of confidence.

$r_{.05} (98) = .197$

Table 3 indicates that the crawl stroke swimming learning is significantly related to intelligence whereas, no significant relationship is obtained between level of aspiration and concentration, and swimming learning. Therefore, it is evident that intelligence contribute to the learning of crawl stroke swimming, as shown in Figure 20. Level of aspiration and concentration do not significantly contribute to quicker learning of swimming (Fig. 19 and 21).
Fig. 19  Relationship between Level of Aspiration and Swimming Learning
Fig. 20 Relationship between Intelligence and Swimming Learning
Fig. 21 Relationship between Concentration and Swimming Learning.
### TABLE 4

**RELATIONSHIP OF PHYSIOLOGICAL VARIABLES TO SWIMMING LEARNING SCORES**

<table>
<thead>
<tr>
<th>Variables Correlated</th>
<th>Correlation Co-efficient (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of body fat</td>
<td>0.401*</td>
</tr>
<tr>
<td>Body density</td>
<td>-0.406*</td>
</tr>
<tr>
<td>Vital capacity</td>
<td>0.705*</td>
</tr>
<tr>
<td>Aerobic capacity</td>
<td>0.498*</td>
</tr>
<tr>
<td>Power</td>
<td>0.670*</td>
</tr>
<tr>
<td>Arm and shoulder strength</td>
<td>0.622*</td>
</tr>
<tr>
<td>Abdomen strength</td>
<td>0.388*</td>
</tr>
<tr>
<td>Leg strength</td>
<td>0.674*</td>
</tr>
<tr>
<td>Average ankle flexibility</td>
<td>0.139</td>
</tr>
<tr>
<td>Trunk-hip flexibility</td>
<td>0.186</td>
</tr>
<tr>
<td>Shoulder flexibility</td>
<td>0.057</td>
</tr>
</tbody>
</table>

N = 100

*Significant at .05 level of confidence.

$r_{.05} (98) = .197$
Table 4 shows that the learning of crawl stroke swimming is significantly related to body fat percentage, body density, vital capacity, aerobic capacity, power, arm and shoulder strength, abdomen strength, and leg strength, whereas no significant relationship is obtained between average ankle flexibility, trunk-hip flexibility and shoulder flexibility, and swimming learning. Therefore, it is evident that body fat percentage, body density, vital capacity, aerobic capacity, power, arm and shoulder strength, abdomen strength and leg strength contribute to the learning of crawl stroke swimming as shown in Fig. 22, 23, 24, 25, 26, 27, 28 and 29. Average ankle flexibility, trunk-hip flexibility and shoulder flexibility do not significantly contribute to the learning of crawl stroke swimming (Fig. 30, 31 and 32).
Fig. 22 Relationship between Percentage of Body Fat and Swimming Learning.
Fig. 23 Relationship between Body Density and Swimming Learning.
Fig. 24 Relationship between Vital Capacity and Swimming Learning.
Fig. 25  Relationship between Aerobic Capacity and Swimming Learning.
Fig. 26 Relationship between Power and Swimming Learning.
Fig. 27 Relationship between Arm and Shoulder Strength and Swimming Learning.
Fig. 28 Relationship between Abdomen Strength and Swimming Learning
Fig. 29 Relationship between Leg Strength and Swimming Learning.
Average Ankle Flexibility

Fig. 30 Relationship between Average Ankle Flexibility and Swimming Learning.
Fig. 31 Relationship between Trunk-Hip Flexibility and Swimming Learning.
Fig. 32  Relationship between Shoulder Flexibility and Swimming Learning
### Table B

**Correlation Matrix on Anthropometric Variables**

|   | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $X_{14}$ | $X_{15}$ | $X_{16}$ | $X_{17}$ | $X_{18}$ | $Y$ |
| $X_1$ | 0.836 | 0.654 | 0.694 | 0.767 | 0.824 | 0.621 | 0.749 | 0.715 | 0.749 | 0.538 | 0.498 | 0.319 | 0.687 | 0.733 | 0.095 | -0.172 | -0.170 | 0.530 |
| $X_2$ | 0.735 | 0.860 | 0.829 | 0.952 | 0.751 | 0.914 | 0.800 | 0.880 | 0.403 | 0.610 | 0.249 | 0.618 | 0.645 | 0.065 | -0.079 | -0.118 | 0.485 |
| $X_3$ | 0.621 | 0.682 | 0.739 | 0.459 | 0.699 | 0.607 | 0.656 | 0.236 | 0.470 | 0.336 | 0.523 | 0.524 | 0.225 | -0.155 | -0.092 | 0.541 |
| $X_4$ | 0.578 | 0.863 | 0.624 | 0.820 | 0.730 | 0.803 | 0.305 | 0.518 | 0.230 | 0.501 | 0.595 | 0.144 | 0.344 | -0.126 | 0.269 |
| $X_5$ | 0.909 | 0.571 | 0.794 | 0.668 | 0.786 | 0.299 | 0.555 | 0.246 | 0.638 | 0.611 | 0.256 | -0.550 | -0.081 | 0.613 |
| $X_6$ | 0.678 | 0.913 | 0.796 | 0.895 | 0.337 | 0.606 | 0.267 | 0.643 | 0.676 | 0.222 | -0.164 | -0.110 | 0.509 |
| $X_7$ | 0.655 | 0.697 | 0.675 | 0.342 | 0.518 | 0.154 | 0.443 | 0.480 | 0.550 | -0.015 | -0.253 | 0.354 |
| $X_8$ | 0.679 | 0.881 | 0.329 | 0.596 | 0.264 | 0.543 | 0.565 | 0.255 | -0.088 | 0.131 | 0.440 |
| $X_9$ | 0.847 | 0.335 | 0.503 | 0.144 | 0.537 | 0.510 | 0.029 | -0.040 | -0.632 | 0.414 |
| $X_{10}$ | 0.312 | 0.551 | 0.221 | 0.567 | 0.547 | 0.112 | -0.083 | -0.215 | 0.458 |
| $X_{11}$ | 0.290 | 0.198 | 0.461 | 0.317 | 0.078 | -0.060 | -0.099 | -0.025 |
| $X_{12}$ | 0.208 | 0.389 | 0.380 | 0.032 | -0.118 | -0.046 | 0.376 |
| $X_{13}$ | 0.257 | 0.273 | 0.064 | -0.052 | 0.087 | 0.180 |
| $X_{14}$ | 0.668 | 0.126 | 0.210 | -0.147 | 0.495 |
| $X_{15}$ | 0.615 | -0.098 | -0.085 | 0.496 |
| $X_{16}$ | -0.154 | 0.212 | 0.121 |
| $X_{17}$ | -0.047 | -0.430 |
| $X_{18}$ | -0.066 |

| Key: | $X_1$ = Weight | $X_2$ = Standing height | $X_3$ = Foot length | $X_4$ = Forearm length | $X_5$ = Thigh length | $X_6$ = Leg length | $X_7$ = Trunk length | $X_8$ = Forearm length | $X_9$ = Upper arm length | $X_{10}$ = Arm length | $X_{11}$ = Head circumference | $X_{12}$ = Shoulder width | $X_{13}$ = Upper arm girth | $X_{14}$ = Thigh girth | $X_{15}$ = Calf girth | $X_{16}$ = Leg length/Trunk length | $X_{17}$ = Forearm length/Thigh length | $X_{18}$ = Forearm length/Upper arm length | $Y$ = Swimming learning |
TABLE 6

CORRELATION MATRIX ON BEHAVIOURAL VARIABLES

<table>
<thead>
<tr>
<th></th>
<th>$X_2$</th>
<th>$X_3$</th>
<th>$Y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$</td>
<td>0.024</td>
<td>0.171</td>
<td>0.085</td>
</tr>
<tr>
<td>$X_2$</td>
<td></td>
<td>0.074</td>
<td>0.681</td>
</tr>
<tr>
<td>$X_3$</td>
<td></td>
<td></td>
<td>0.188</td>
</tr>
</tbody>
</table>

Key: $X_1$ = Level of aspiration

$X_2$ = Intelligence

$X_3$ = Concentration

$Y$ = Swimming learning.
### CORRELATION MATRIX ON PHYSIOLOGICAL VARIABLES

<table>
<thead>
<tr>
<th></th>
<th>X2</th>
<th>X3</th>
<th>X4</th>
<th>X5</th>
<th>X6</th>
<th>X7</th>
<th>X8</th>
<th>X9</th>
<th>X10</th>
<th>X11</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>0.997</td>
<td>0.384</td>
<td>0.184</td>
<td>0.273</td>
<td>0.248</td>
<td>0.221</td>
<td>0.395</td>
<td>0.044</td>
<td>-0.211</td>
<td>0.068</td>
<td>0.401</td>
</tr>
<tr>
<td>X2</td>
<td>-0.384</td>
<td>-0.188</td>
<td>-0.273</td>
<td>-0.247</td>
<td>-0.232</td>
<td>-0.394</td>
<td>-0.048</td>
<td>0.212</td>
<td>-0.055</td>
<td>-0.406</td>
<td></td>
</tr>
<tr>
<td>X3</td>
<td>0.554</td>
<td>0.710</td>
<td>0.452</td>
<td>0.364</td>
<td>0.659</td>
<td>0.106</td>
<td>0.263</td>
<td>0.029</td>
<td>0.705</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X4</td>
<td>0.558</td>
<td>0.408</td>
<td>0.395</td>
<td>0.495</td>
<td>0.223</td>
<td>0.361</td>
<td>-0.131</td>
<td>0.498</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X5</td>
<td>0.521</td>
<td>0.331</td>
<td>0.573</td>
<td>0.083</td>
<td>0.235</td>
<td>0.029</td>
<td>0.670</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X6</td>
<td>0.551</td>
<td>0.531</td>
<td>0.175</td>
<td>0.259</td>
<td>-0.075</td>
<td>0.622</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X7</td>
<td>0.366</td>
<td>0.034</td>
<td>0.099</td>
<td>-0.024</td>
<td>0.388</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X8</td>
<td>0.097</td>
<td>0.231</td>
<td>0.093</td>
<td>0.674</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X9</td>
<td>0.109</td>
<td>0.058</td>
<td>0.139</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X10</td>
<td>0.099</td>
<td>0.186</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X11</td>
<td>0.057</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Key:**
- $X_1$ = Percentage of body fat
- $X_2$ = Body density
- $X_3$ = Vital capacity
- $X_4$ = Aerobic capacity
- $X_5$ = Power
- $X_6$ = Arm and shoulder strength
- $X_7$ = Abdomen strength
- $X_8$ = Leg strength
- $X_9$ = Average ankle flexibility
- $X_{10}$ = Trunk-hip flexibility
- $X_{11}$ = Shoulder flexibility
- Y = Swimming learning
Multiple Correlation of Anthropometric, Physiological and All Combined Variables to Learning of Crawl Stroke Swimming

To examine the combined effect of anthropometric and physiological variables on swimming learning, multiple correlation was computed separately for these two categories. Multiple correlation was also computed between all the anthropometric, behavioural and physiological variables together to assess their combined effect on the learning of crawl stroke swimming.

The variables considered, their co-efficient of determination ($R^2$), multiple correlation ($R$) and efficiency of prediction ($E$) are presented in tables 8, 9 and 10 respectively. [Multiple correlation was not computed for behavioural variables since only one variable (intelligence) was found significantly related to swimming learning out of the three selected variables].
### TABLE 8

**MULTIPLE CORRELATION OF ANTHROPOMETRIC VARIABLES TO CRAWL STROKE SWIMMING LEARNING**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Variables Considered</th>
<th>Co-efficient of Determination (R²)</th>
<th>Multiple Correlation (R)</th>
<th>Efficiency in Percentage (E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. All eighteen variables included</td>
<td>0.5474</td>
<td>0.7398</td>
<td>32.724</td>
<td></td>
</tr>
<tr>
<td>2. Excluding Variables X₂</td>
<td>0.5473</td>
<td>0.7397</td>
<td>32.717</td>
<td></td>
</tr>
<tr>
<td>3. Excluding variables X₂, X₁₇</td>
<td>0.5472</td>
<td>0.7397</td>
<td>32.709</td>
<td></td>
</tr>
<tr>
<td>4. Excluding variables X₂, X₁₇, X₁₂</td>
<td>0.5464</td>
<td>0.7391</td>
<td>32.650</td>
<td></td>
</tr>
<tr>
<td>5. Excluding variables X₂, X₁₇, X₁₂, X₁₃</td>
<td>0.5446</td>
<td>0.7379</td>
<td>32.516</td>
<td></td>
</tr>
<tr>
<td>6. Excluding variables X₂, X₁₇, X₁₂, X₁₃, X₁₄</td>
<td>0.5419</td>
<td>0.7361</td>
<td>32.316</td>
<td></td>
</tr>
<tr>
<td>7. Excluding variables X₂, X₁₇, X₁₂, X₁₃, X₁₄, X₁</td>
<td>0.5414</td>
<td>0.7357</td>
<td>32.279</td>
<td></td>
</tr>
<tr>
<td>8. Excluding variables X₂, X₁₇, X₁₂, X₁₃, X₁₄, X₁, X₁₀</td>
<td>0.5378</td>
<td>0.7333</td>
<td>32.014</td>
<td></td>
</tr>
<tr>
<td>9. Excluding variables X₂, X₁₇, X₁₂, X₁₃, X₁₄, X₁, X₁₀, X₁₆</td>
<td>0.5331</td>
<td>0.7301</td>
<td>31.699</td>
<td></td>
</tr>
<tr>
<td>S.No.</td>
<td>Variables Considered</td>
<td>Co-efficient of Determination $(R^2)$</td>
<td>Multiple Correlation $(R)$</td>
<td>Efficiency in Prediction in Percentage $(E)$</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------</td>
<td>----------------------------------------</td>
<td>----------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>10.</td>
<td>Excluding variables $X_2$, $X_1$, $X_4$, $X_6$, $X_7$</td>
<td>0.5302</td>
<td>0.7281</td>
<td>31.458</td>
</tr>
<tr>
<td>11.</td>
<td>Excluding variables $X_2$, $X_1$, $X_4$, $X_6$, $X_7$, $X_8$</td>
<td>0.5229</td>
<td>0.7231</td>
<td>30.927</td>
</tr>
<tr>
<td>12.</td>
<td>Excluding variables $X_2$, $X_1$, $X_3$, $X_4$, $X_6$, $X_7$, $X_8$, $X_{11}$</td>
<td>0.5114</td>
<td>0.7151</td>
<td>30.100</td>
</tr>
<tr>
<td>13.</td>
<td>Excluding variables $X_2$, $X_1$, $X_3$, $X_4$, $X_6$, $X_7$, $X_8$, $X_{11}$, $X_{12}$</td>
<td>0.4963</td>
<td>0.7044</td>
<td>29.028</td>
</tr>
<tr>
<td>14.</td>
<td>Excluding variables $X_2$, $X_1$, $X_3$, $X_4$, $X_6$, $X_7$, $X_8$, $X_{11}$, $X_{12}$, $X_{18}$</td>
<td>0.4863</td>
<td>0.6973</td>
<td>28.327</td>
</tr>
</tbody>
</table>
15. Excluding variables $X_2$,
   $X_{17}$, $X_{12}$, $X_{13}$, $X_{14}$, $X_1$,
   $X_{10}$, $X_{16}$, $X_7$, $X_4$, $X_{11}$,
   $X_8$, $X_{18}$, $X_9$

   \[
   \begin{array}{ccc}
   \text{S. No.} & \text{Variables Considered} & \text{Co-efficient of Determination} (R^2) & \text{Multiple Correlation (R)} & \text{Efficiency of Prediction in Percentage (E)} \\
   \hline
   15. & & 0.4819 & 0.6941^* & 28.020 \\
   \end{array}
   \]

   $N = 100$

   *Significant at .05 level of confidence.

   $R_{.05} (95) = .308$

   Key: $X_2$ = Standing height
   $X_{17}$ = Foreleg length/Thigh length
   $X_{12}$ = Shoulder width
   $X_{13}$ = Upperarm girth
   $X_{14}$ = Thigh girth
   $X_1$ = Weight
   $X_{10}$ = Arm length
   $X_{16}$ = Leg length/Trunk length
   $X_7$ = Trunk length
   $X_4$ = Foreleg length
   $X_{11}$ = Head circumference
   $X_8$ = Forearm length
   $X_{18}$ = Forearm length/Upperarm length
   $X_9$ = Upperarm length
The analysis of data presented in Table 8 shows that the combined contribution of all the eighteen anthropometric variables taken together, is very highly correlated to swimming learning with a co-efficient value of .739 and an efficiency of 32.724 percent of prediction.

Thereafter, the step down regression method started deleting the variables one by one, which were least contributing to the learning of crawl stroke swimming. The last step, where the step down process was terminated, shows that the combined contribution of the retained variables of foot length, thigh length, leg length, and calf girth taken together, correlated significantly to crawl stroke swimming learning ability as the computed value .694 for multiple correlation co-efficient was more than the tabulated value of .308 required to be significant at .05 level of confidence with 95 degrees of freedom.\textsuperscript{4} The value of .694 for multiple correlation denoted an efficiency of 28.02 percent of prediction.

From the obtained value of multiple correlation it can be inferred that foot length, thigh length, leg length

\textsuperscript{4}Tbid.
and calf girth when taken together, contribute significantly to crawl stroke swimming learning ability and it is much higher as compared to the relationship of each independent variable of anthropometric measures.

The graphical representation of multiple correlation obtained between crawl stroke swimming learning ability and these four anthropometric variables taken together, is depicted in Fig. 33.
### Table 9

**Multiple Correlation of Physiological Variables to Crawl Stroke Swimming Learning**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Variables Considered</th>
<th>Co-efficient of Determination ($R^2$)</th>
<th>Multiple Correlation (R)</th>
<th>Efficiency of Prediction in Percentage (E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>All eleven variables included</td>
<td>0.6937</td>
<td>0.8328</td>
<td>44.655</td>
</tr>
<tr>
<td>2.</td>
<td>Excluding variable $X_9$</td>
<td>0.6934</td>
<td>0.8327</td>
<td>44.628</td>
</tr>
<tr>
<td>3.</td>
<td>Excluding variables $X_9$, $X_{10}$</td>
<td>0.6930</td>
<td>0.8324</td>
<td>44.592</td>
</tr>
<tr>
<td>4.</td>
<td>Excluding variables $X_9$, $X_{10}$, $X_7$</td>
<td>0.6920</td>
<td>0.8318</td>
<td>44.502</td>
</tr>
<tr>
<td>5.</td>
<td>Excluding variables $X_9$, $X_{10}$, $X_7$, $X_{11}$</td>
<td>0.6913</td>
<td>0.8314</td>
<td>44.439</td>
</tr>
<tr>
<td>6.</td>
<td>Excluding variables $X_9$, $X_{10}$, $X_7$, $X_{11}$, $X_4$</td>
<td>0.6890</td>
<td>0.8300*</td>
<td>44.232</td>
</tr>
</tbody>
</table>

$N = 100$

*Significant at .05 level of confidence.

R .05 (93) = .353

**Key:**
- $X_9$ = Average ankle flexibility
- $X_{10}$ = Trunk-hip flexibility
- $X_7$ = Abdomen strength
- $X_{11}$ = Shoulder flexibility
- $X_4$ = Aerobic capacity
The analysis of data presented in Table 9 indicates that the combined contribution of all the 11 physiological variables taken together, is very highly correlated to crawl stroke swimming learning with the co-efficient value of .832 and an efficiency of 44.655 percent of prediction.

Thereafter, the step down regression method started deleting the variables one by one, which were least contributing to the learning of crawl stroke swimming. The last step, where the step down process was terminated, indicates that the combined contribution of the retained variables of body fat percentage, body density, vital capacity, power, arm and shoulder strength, and leg strength taken together, correlated significantly to crawl stroke swimming learning ability as the computed value of .830 for multiple correlation co-efficient was more than the tabulated value of .353 required to be significant at .05 level of confidence with 93 degrees of freedom. The value of .830 for multiple correlation denoted an efficiency of 44.232 percent of prediction.

From the obtained value of multiple correlation it can be deduced that percentage of body fat, body density,

5 Ibid.
vital capacity, power, arm and shoulder strength, and leg strength taken together, contribute significantly to crawl stroke learning ability and it is much higher as compared to the relationship of each independent variable of physiological measures.

The graphical representation of multiple correlation obtained between crawl stroke swimming learning ability and these six physiological variables taken together, is shown in Fig. 34.
## Table 10

**Multiple Correlation of Anthropometric, Behavioural and Physiological Variables (All Combined) to Crawl Stroke Swimming Learning**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Variables Considered</th>
<th>Co-efficient of Determination ($R^2$)</th>
<th>Multiple Correlation (R)</th>
<th>Efficiency of Prediction in Percentage (E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>All 32 variables</td>
<td>0.8520</td>
<td>0.9230</td>
<td>61.530</td>
</tr>
<tr>
<td>2.</td>
<td>Twenty six variables excluding $X_{32}$, $X_5$, $X_{31}$, $X_{14}$, $X_{25}$, $X_{26}$</td>
<td>0.8475</td>
<td>0.9205</td>
<td>60.948</td>
</tr>
<tr>
<td>3.</td>
<td>Excluding variables $X_{32}$, $X_5$, $X_{31}$, $X_{14}$, $X_{25}$, $X_{26}$, $X_2$</td>
<td>0.8467</td>
<td>0.9201</td>
<td>60.846</td>
</tr>
<tr>
<td>4.</td>
<td>Excluding variables $X_{32}$, $X_5$, $X_{31}$, $X_{14}$, $X_{25}$, $X_{26}$, $X_2$, $X_1$</td>
<td>0.8463</td>
<td>0.9199</td>
<td>60.795</td>
</tr>
<tr>
<td>5.</td>
<td>Excluding variables $X_{32}$, $X_5$, $X_{31}$, $X_{14}$, $X_{25}$, $X_{26}$, $X_2$, $X_1$, $X_{16}$</td>
<td>0.8457</td>
<td>0.9196</td>
<td>60.718</td>
</tr>
<tr>
<td>6.</td>
<td>Excluding variables $X_{32}$, $X_5$, $X_{31}$, $X_{14}$, $X_{25}$, $X_{26}$, $X_2$, $X_1$, $X_{16}$, $X_{21}$</td>
<td>0.8450</td>
<td>0.9192</td>
<td>60.629</td>
</tr>
<tr>
<td>7.</td>
<td>Excluding variables $X_{32}$, $X_5$, $X_{31}$, $X_{14}$, $X_{25}$, $X_{26}$, $X_2$, $X_1$, $X_{16}$, $X_{21}$, $X_{19}$</td>
<td>0.8438</td>
<td>0.9185</td>
<td>60.477</td>
</tr>
<tr>
<td>S.No.</td>
<td>Variables Considered</td>
<td>Co-efficient of Determination ($R^2$)</td>
<td>Multiple Correlation (R)</td>
<td>Efficiency in Percentage (E)</td>
</tr>
<tr>
<td>------</td>
<td>---------------------</td>
<td>----------------------------------------</td>
<td>--------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>8.</td>
<td>Excluding variables $X_{32}$, $X_5$, $X_{31}$, $X_{14}$, $X_{25}$, $X_{26}$, $X_2$, $X_1$, $X_{16}$, $X_{21}$, $X_{19}$, $X_7$, $X_{15}$</td>
<td>0.8425</td>
<td>0.9178</td>
<td>60.313</td>
</tr>
<tr>
<td>9.</td>
<td>Excluding variables $X_{32}$, $X_5$, $X_{31}$, $X_{14}$, $X_{25}$, $X_{26}$, $X_2$, $X_1$, $X_{16}$, $X_{21}$, $X_{19}$, $X_7$, $X_{15}$</td>
<td>0.8411</td>
<td>0.9171</td>
<td>60.137</td>
</tr>
<tr>
<td>10.</td>
<td>Excluding variables $X_{32}$, $X_5$, $X_{31}$, $X_{14}$, $X_{25}$, $X_{26}$, $X_2$, $X_1$, $X_{16}$, $X_{21}$, $X_{19}$, $X_7$, $X_{15}$, $X_{29}$</td>
<td>0.8384</td>
<td>0.9156</td>
<td>59.800</td>
</tr>
<tr>
<td>11.</td>
<td>Excluding variables $X_{32}$, $X_5$, $X_{31}$, $X_{14}$, $X_{25}$, $X_{26}$, $X_2$, $X_1$, $X_{16}$, $X_{21}$, $X_{19}$, $X_7$, $X_{15}$, $X_{29}$, $X_{10}$</td>
<td>0.8350</td>
<td>0.9137</td>
<td>59.379</td>
</tr>
<tr>
<td>12.</td>
<td>Excluding variables $X_{32}$, $X_5$, $X_{31}$, $X_{14}$, $X_{25}$, $X_{26}$, $X_2$, $X_1$, $X_{16}$, $X_{21}$, $X_{19}$, $X_7$, $X_{15}$, $X_{29}$, $X_{10}$, $X_{13}$</td>
<td>0.8311</td>
<td>0.9116</td>
<td>58.502</td>
</tr>
<tr>
<td>S.No.</td>
<td>Variables Considered</td>
<td>Co-efficient of Determination ($R^2$)</td>
<td>Multiple Correlation (R)</td>
<td>Efficiency of Prediction in Percentage (E)</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------</td>
<td>---------------------------------------</td>
<td>---------------------------</td>
<td>------------------------------------------</td>
</tr>
</tbody>
</table>
| 13.   | Excluding variables $X_{32'}$  
$X_5'$, $X_{31}'$, $X_{14}'$, $X_{25}'$, $X_{26}'$  
$X_2'$, $X_1'$, $X_{16}'$, $X_{21}'$, $X_{19}'$  
$X_7'$, $X_{15}'$, $X_{29}'$, $X_{10}'$, $X_{13}'$  
$X_{30}$  
$X_{28}$ | 0.8240             | 0.9077                                 | 58.047                    |
| 14.   | Excluding variables $X_{32'}$  
$X_5'$, $X_{31}'$, $X_{14}'$, $X_{25}'$, $X_{26}'$  
$X_2'$, $X_1'$, $X_{16}'$, $X_{21}'$, $X_{19}'$  
$X_7'$, $X_{15}'$, $X_{29}'$, $X_{10}'$, $X_{13}'$  
$X_{30}$, $X_{28}$ | 0.8158             | 0.9032                                 | 57.081                    |
| 15.   | Excluding variables $X_{32'}$  
$X_5'$, $X_{31}'$, $X_{14}'$, $X_{25}'$, $X_{26}'$  
$X_2'$, $X_1'$, $X_{16}'$, $X_{21}'$, $X_{19}'$  
$X_7'$, $X_{15}'$, $X_{29}'$, $X_{10}'$, $X_{13}'$  
$X_{30}$, $X_{28}$, $X_{11}$ | 0.8084             | 0.8991                                 | 56.227                    |

Key:  
$X_{32}$ = Shoulder flexibility  
$X_5$ = Thigh length  
$X_{31}$ = Trunk-hip flexibility  
$X_{14}$ = Thigh girth  
$X_{25}$ = Aerobic capacity
\[ X_{26} = \text{Power} \]
\[ X_2 = \text{Standing height} \]
\[ X_1 = \text{Weight} \]
\[ X_{16} = \text{Leg length/Trunk length} \]
\[ X_{21} = \text{Concentration} \]
\[ X_{19} = \text{Level of aspiration} \]
\[ X_7 = \text{Trunk length} \]
\[ X_{15} = \text{Calf girth} \]
\[ X_{29} = \text{Leg strength} \]
\[ X_{10} = \text{Arm length} \]
\[ X_{13} = \text{Upperarm girth} \]
\[ X_{30} = \text{Average ankle flexibility} \]
\[ X_{28} = \text{Abdomen strength} \]
\[ X_{11} = \text{Head circumference} \]

The analysis of data presented in Table 10 indicates that the combined contribution of all the anthropometric, behavioural and physiological variables taken together is very highly correlated to swimming learning ability with a co-efficient value of .923 and an efficiency of 61.530 percent of prediction.

Thereafter, the step down regression method started deleting the variables one by one, which were least contributing to the learning of crawl stroke swimming. The last
step, where the step down process was terminated, identified a total of thirteen variables. These remaining variables of (anthropometric, behavioural and physiological variables combined together) foot length, foreleg length, leg length, forearm length, upperarm length, shoulder width, foreleg length/thigh length, forearm length/upper-arm length, intelligence, percentage of body fat, body density, vital capacity, and arm and shoulder strength taken together, showed a very high combined contribution to crawl stroke swimming learning with a computed value of .899 for multiple correlation co-efficient and an efficiency of 56.227 percent of prediction.

From the obtained value of multiple correlation it can be inferred that foot length, foreleg length, leg length, forearm length, upperarm length, shoulder width, foreleg length/thigh length, forearm length/upperarm length, intelligence, percentage of body fat, body density, vital capacity, and arm and shoulder strength when all combined together, are found highly contributing to crawl stroke swimming learning ability as compared to the relationship of each independent variable of anthropometric, behavioural and physiological measures. Further, the prediction efficiency of 56.227 percent showed much
higher contribution when all variables were combined together as compared to the efficiency of prediction by separate multiple correlations of anthropometric (28.02%) and physiological (44.23%) variables.

The graphical representation of multiple correlation obtained between crawl stroke swimming learning ability and these 13 variables taken together, is depicted in Fig. 35.

**Multiple Regression Analysis**

Step down regression method was used with the help of Personal Computer XT, for identifying the most contributing anthropometric and physiological variables towards the learning of crawl stroke swimming. The method was also used for identifying the most contributing variables from all the anthropometric, behavioural and physiological variable combined together.

**Regression Equation of Anthropometric Variables on Swimming Learning**

Table 8 shows four anthropometric variables which were retained by the step down procedure for preparing regression line on swimming learning scores. Regressions co-efficients of these four selected variables and their t-values are given in Table 11.
Foot Length, Foreleg Length, Leg Length, Forearm Length, Upperarm Length, Shoulder width, Foreleg Length / Thigh Length, Forearm Length / Upperarm Length, Intelligence, Percentage of body fat, Body Density, Vital capacity, Arm and shoulder strength.

Fig. 35 Relationship between Foot Length, Foreleg Length, Leg Length, Forearm Length, Upperarm Length, Shoulder width, Foreleg Length / Thigh Length, Forearm Length / Upperarm Length, Intelligence, Percentage of body fat, Body Density, Vital capacity, Arm and shoulder strength.
TABLE 11

REGRESSION CO-EFFICIENTS OF ANTHROPOMETRIC VARIABLES FOR MULTIPLE LINEAR EQUATION ON SWIMMING LEARNING SCORES

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Variables</th>
<th>Beta Weight</th>
<th>Regression Co-efficient</th>
<th>t Value</th>
<th>t Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Foot length</td>
<td>0.3299</td>
<td>0.2660</td>
<td>3.0014</td>
<td>0.0032</td>
</tr>
<tr>
<td>2.</td>
<td>Thigh length</td>
<td>0.8514</td>
<td>0.3226</td>
<td>4.7961</td>
<td>0.0000</td>
</tr>
<tr>
<td>3.</td>
<td>Leg length</td>
<td>-0.6922</td>
<td>-0.1621</td>
<td>3.3970</td>
<td>0.0009</td>
</tr>
<tr>
<td>4.</td>
<td>Calf girth</td>
<td>0.2714</td>
<td>0.1690</td>
<td>2.7033</td>
<td>0.0078</td>
</tr>
</tbody>
</table>

Table 11 shows that t values for testing the significance of four regression co-efficients are significant at very low levels. The significance level for each variable is shown under the column 't-probability'. The following regression equation of the anthropometric variables on front crawl stroke swimming learning has been prepared by using the above regression co-efficients.

\[ Y = 88.6137 + 0.2660X_3 + 0.3226X_5 - 0.1621X_6 + 0.1690X_{15} \]

Where:

\[ Y \] = The standard score of predicted swimming learning ability.
\[ x_3 = \text{Foot length} \]
\[ x_5 = \text{Thigh length} \]
\[ x_6 = \text{Leg length} \]
\[ x_{15} = \text{Calf girth}. \]

Regression Equation of Physiological Variables on Swimming Learning

Table 9 indicates six physiological variables which were retained by the step down procedure for preparing regression line on swimming learning scores. Regression co-efficients of these four selected variables and their \( t \) values are given in Table 12.

**TABLE 12**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Variables</th>
<th>Beta Weight</th>
<th>Regression Co-efficient</th>
<th>( t ) Value</th>
<th>( t ) Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Percent body fat</td>
<td>-2.055</td>
<td>-1.9323</td>
<td>2.558</td>
<td>0.0121</td>
</tr>
<tr>
<td>2.</td>
<td>Body density</td>
<td>-2.158</td>
<td>-867.6179</td>
<td>2.685</td>
<td>0.0085</td>
</tr>
<tr>
<td>3.</td>
<td>Vital capacity</td>
<td>0.276</td>
<td>0.0011</td>
<td>2.997</td>
<td>0.0030</td>
</tr>
<tr>
<td>4.</td>
<td>Power</td>
<td>0.211</td>
<td>0.0712</td>
<td>2.410</td>
<td>0.0174</td>
</tr>
<tr>
<td>5.</td>
<td>Arm and shoulder strength</td>
<td>0.201</td>
<td>0.1892</td>
<td>2.652</td>
<td>0.0096</td>
</tr>
<tr>
<td>6.</td>
<td>Leg strength</td>
<td>0.228</td>
<td>0.0179</td>
<td>2.721</td>
<td>0.0075</td>
</tr>
</tbody>
</table>
Table 12 shows that t values for testing the significance of four regression coefficients are significant at very low levels. The significance level for each variable is shown under the column 't probability'. The following regression equation of the physiological variables on front crawl stroke swimming learning has been prepared by using the above regression coefficients:

\[ Y = 1046.3776 - 1.9323 X_1 - 867.6179 X_2 + 0.0011 X_3 \\
+ 0.0712 X_5 + 0.1892 X_6 + 0.0179 X_8 \]

Where:

- **Y** = The standard score of predicted swimming learning ability
- **X_1** = Percentage of body fat
- **X_2** = Body density
- **X_3** = Vital capacity
- **X_5** = Power
- **X_6** = Arm and shoulder strength
- **X_8** = Leg strength

**Regression Equation of Anthropometric, Behavioural and Physiological Variables (All Combined) to Crawl Stroke Swimming Learning**

Table 10 identifies 13 anthropometric, behavioural and physiological factors which were retained by the step down procedure for preparing regression line on swimming
learning scores. Regression co-efficients of these selected variables and their t values are given in Table 13.

**TABLE 13**

REGRESSION CO-EFFICIENTS OF ANTHROPOMETRIC, BEHAVIOURAL AND PHYSIOLOGICAL VARIABLES (ALL COMBINED) FOR MULTIPLE LINEAR EQUATION ON SWIMMING LEARNING SCORES

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Variables</th>
<th>Beta Weight</th>
<th>Regression Co-efficient</th>
<th>t Value</th>
<th>t Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Foot length</td>
<td>0.2009</td>
<td>0.1621</td>
<td>2.7293</td>
<td>0.0073</td>
</tr>
<tr>
<td>2.</td>
<td>Foreleg length</td>
<td>1.1547</td>
<td>0.5333</td>
<td>2.4204</td>
<td>0.0169</td>
</tr>
<tr>
<td>3.</td>
<td>Leg length</td>
<td>-1.4101</td>
<td>-0.3301</td>
<td>2.9871</td>
<td>0.0034</td>
</tr>
<tr>
<td>4.</td>
<td>Forearm length</td>
<td>-1.0905</td>
<td>-0.6102</td>
<td>2.3856</td>
<td>0.0185</td>
</tr>
<tr>
<td>5.</td>
<td>Upperarm length</td>
<td>1.4920</td>
<td>1.0121</td>
<td>2.5307</td>
<td>0.0126</td>
</tr>
<tr>
<td>6.</td>
<td>Shoulder width</td>
<td>0.1973</td>
<td>0.0746</td>
<td>3.116</td>
<td>0.0023</td>
</tr>
<tr>
<td>7.</td>
<td>Foreleg length/Thigh length</td>
<td>-0.6065</td>
<td>-13.3082</td>
<td>2.6076</td>
<td>0.0103</td>
</tr>
<tr>
<td>8.</td>
<td>Forearm length/Upperarm length</td>
<td>1.1019</td>
<td>16.7649</td>
<td>2.5716</td>
<td>0.0113</td>
</tr>
<tr>
<td>9.</td>
<td>Intelligence</td>
<td>0.3455</td>
<td>0.0399</td>
<td>5.5262</td>
<td>0.0000</td>
</tr>
<tr>
<td>10.</td>
<td>Percentage of body fat</td>
<td>-2.4701</td>
<td>-2.3231</td>
<td>3.1433</td>
<td>0.0021</td>
</tr>
<tr>
<td>11.</td>
<td>Body density</td>
<td>-2.5700</td>
<td>-1033.3692</td>
<td>3.2702</td>
<td>0.0014</td>
</tr>
<tr>
<td>12.</td>
<td>Vital capacity</td>
<td>0.3746</td>
<td>0.0014</td>
<td>4.8005</td>
<td>0.0000</td>
</tr>
<tr>
<td>13.</td>
<td>Arm and shoulder strength</td>
<td>0.2210</td>
<td>0.2083</td>
<td>3.6991</td>
<td>0.0003</td>
</tr>
</tbody>
</table>
The level of significance for each of the thirteen retained variables, as shown in Table 13 under the heading 't-probabilities', indicates that all the thirteen variables are significantly correlated to the learning of crawl stroke swimming at very very low levels. This was one of the reasons for terminating the step down process at this stage. If the process of step down would have continued for further deleting the variables, there would have been a loss of accuracy in preparing the regression line and the efficiency of prediction also would have further gone down.

The following regression equation of all combined variables on front crawl stroke swimming learning has been prepared by using the regression co-efficients given in Table 13:

\[ Y = 1214.1202 + 0.1621 \, x_3 + 0.5333 \, x_4 - 0.3301 \, x_6 \\
- 0.6102 \, x_8 + 1.0121 \, x_9 + 0.0746 \, x_{12} \\
- 13.3082 \, x_{17} + 16.7649 \, x_{18} + 0.0399 \, x_{20} \\
- 2.3231 \, x_{22} - 1033.3692 \, x_{23} + 0.0014 \, x_{24} \\
+ 0.2083 \, x_{27} \]

Where:

\[ Y = \text{The standard score of predicted swimming learning ability.} \]
$X_3$ = Foot length
$X_4$ = Foreleg length
$X_6$ = Leg length
$X_8$ = Forearm length
$X_9$ = Upperarm length
$X_{12}$ = Shoulder width
$X_{17}$ = Foreleg length/Thigh length
$X_{18}$ = Forearm length/Upperarm length
$X_{20}$ = Intelligence
$X_{22}$ = Percentage of body fat
$X_{23}$ = Body density
$X_{24}$ = Vital capacity
$X_{27}$ = Arm and shoulder strength

**Discussion of Findings**

**Relationship of Anthropometric, Behavioural and Physiological Variables to Learning of Crawl Stroke Swimming**

**Anthropometric Variables**

The statistical analysis of data revealed that learning of crawl stroke swimming is significantly related to weight, standing height, foot length, foreleg length, thigh length, leg length, trunk length, forearm length,
upperarm length, arm length, shoulder width, thigh girth, calf girth and foreleg length/thigh length, whereas no significant relationship is obtained between head circumference, upperarm girth, leg length/trunk length and forearm length/upperarm length, and swimming learning.

This may be attributed to the fact that the physical size and shape of a performer has a direct relationship to the nature of the movement produced for any skill. The body size and limb segment length relate to differences in body and limb mass which is unique for each individual and therefore, each performer's pattern of movement for a specific skill is unique.6

In the present study, the learning of crawl stroke swimming involved both skill and speed. While analysing the process of swimming it should be remembered that the movement of the body through the water primarily depends upon the buoyancy, water resistance, and the propulsive forces.7 The resistance of the


7 Ibid., p.98.
water is overcome by moving the arms and legs in a particular fashion and the swimmer receives his propulsive forces from his arms and legs to pull him through the water. His speed of swimming is a resultant of the amount and speed of water pulled or pushed backwards. More water can be pulled or pushed simply by increasing the pulling surface, the frequency of pulling and kicking. The pulling surface is fully dependent upon the length and size of the limbs. Longer the limbs, more the amount of water pulled or pushed, and better the speed. The size of the hands, feet, lengths of forearm, upperarm, thigh and lower leg in turn depend largely upon the height and weight of the swimmer. More the height, longer the limb segments. Stronger and thicker muscles of the thigh (thigh girth) and calf (calf girth) should contribute to stronger kicking by the legs and thereby producing better speed of swimming. Yacher, Larsen and Bear⁹


⁹Yacher, Larsen and Bear, Swimming Technique 19; 16-18.
mention that efficient young swimmers improve their swimming speed primarily by growing taller. The body build of Johnny Weismuller, the man who dominated the world in free style swimming (crawl technique) in 1920's, was considered the ideal: wide shoulders, 6 feet 2 inches in height, slim hips, and large feet.\textsuperscript{10}

The trunk length normally varies with the standing height whereas, the shoulder width with both height and weight in the grown up individual.\textsuperscript{11} In the correlation matrix (Table 5) also the trunk length and shoulder width have shown high correlations with the standing height and weight. That might be the reason for a significant relationship of trunk length and shoulder width to the learning of crawl stroke swimming.

The head circumference showed a negative and very low correlation (-0.025) to the learning of crawl stroke swimming which may be attributed to the fact that frontal resistance to forward progress is created by


the water immediately in front of the swimmer. Larger the head, more will be the water resistance. Moreover, the head does not produce any propulsive movements and therefore, it does not significantly contribute to the learning of crawl stroke swimming.

The present study revealed significant relationship of weight, height, foot length, foreleg length, thigh length, leg length, forearm length, upperarm length, arm length, thigh girth and calf girth to the learning of crawl stroke swimming, thus supporting the findings of Adams, Brace, and Carlin. It also supports the mechanical analysis of the swimming process by Higgins and Counselman.

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12 Counselman, The Science of Swimming, p.3.
13 Adams, Research Quarterly 5: 95-100.
16 Higgins, Human Movement-An Integrated Approach.
17 Counselman, The Science of Swimming.
Behavioural Variables

The statistical analysis of the data revealed that learning of crawl stroke swimming is significantly related to intelligence. Level of aspiration showed no relationship (.085) whereas concentration indicated a low correlation (.188) to the learning of crawl stroke swimming.

The findings may be attributed to the fact that motor learning involves both mental and physical coordinations. The learning of sport skills require thinking, action, feedback, evaluation and repeated action. Intelligence is exercised in the analysis of a skilled movement. The more complex and more interpretive the movement, greater the amount of intelligence necessary to comprehend it. If a student does well on intelligence tests, he should be expected to learn motor activities more quickly and proficiently than those students who obtain lower intelligence ratings.  

18 Oxendine, Psychology of Motor Learning, pp. 7-13.
19 Singer, Motor Learning and Human Performance, pp. 89-90.
20 Cratty, Movement Behaviour and Motor Learning, pp. 249-251.
however, clarifies that the influence of intelligence as a factor on sport skill acquisition depends on the level and the type of skill under consideration, as well as, on whether comparisons are made during the initial, middle, or final stages of skill learning. Greatest individual differences in skill learning due to intellectual variation occur during the initial stages of skill acquisition. Among superior athletes, it is often found that a minimal I.Q. level is necessary to achieve superiority. These interpretations and the finding of the present study are supported by Harmon and Oxendine,21 Kulcinski,22 Carr23 and Woodruff.24

Before performing a skill, the individual typically formulates a hypothesis about his chances for success. He makes some estimate of his expected attainment on the basis of his past experience of success or

21Harmon and Oxendine, Research Quarterly 32:184.


23Carr, Research Quarterly 16:178.

failure when performing similar and identical tasks. This estimation (Level of aspiration) reflects his optimism or lack of it when faced with the challenge. Singer\textsuperscript{25} and Oxendine\textsuperscript{26} have advocated that this level of aspiration can be used to improve his performance since higher aspiration may act as an incentive, something for which to strive. This statement was, however, contradicted by Worell\textsuperscript{27} who found that students, who did not wish to achieve much, received the highest college grades and students with higher aspirations were generally unsuccessful. The study by Dabas and Singh\textsuperscript{28} on the relationship of aspiration level to performance in selected swimming events of Indian inter-varsity swimmers, also revealed that there was no significant relationship between aspiration level and performance in swimming.

\textsuperscript{25}Singer, \textit{Motor Learning and Human Performance}, p.119.

\textsuperscript{26}Oxendine, \textit{Psychology of Motor Learning}, p.196.

\textsuperscript{27}Leonard Worell, "Level of Aspiration and Academic Success," \textit{Journal of Educational Psychology} 50: 47-54.

The present study also indicated no relationship between level of aspiration and learning of crawl stroke swimming which may be attributed to the fact that sometimes the individuals expressing higher level of aspiration maintain some hope for success while repeatedly experiencing failure and that those with low aspirations, who experienced failure, overtly withdraw failure producing situations. Moreover, some individuals usually set a higher level of aspiration in public than in private, simply because they try to avoid the loss of self esteem in front of others and wish to put themselves in a high category. The results of the present study are supported by the findings of Smith,\textsuperscript{29} Svec\textsuperscript{30} and Chaloupka.\textsuperscript{31}

The non-significance of concentration to the learning of crawl stroke swimming may be attributed

\textsuperscript{29} Smith, \textit{Research Quarterly} 20:196-209.


\textsuperscript{31} Chaloupka, \textit{Dissertation Abstracts International} 30:1418-A.
to the fact that the presence of some disturbing or inhibiting emotional complications disturb the concentration and emotional stability, such as, fear of the water in learning to swim. Such factors also disturb the neuromuscular coordination in varying degrees which in turn disturb the training and rhythm of the technique. 32, 33

Physiological Variables

The statistical analysis of the data revealed that the learning of crawl stroke swimming is significantly related to body fat percentage, body density, vital capacity, aerobic capacity, power, arm and shoulder strength, abdomen strength, and leg strength, whereas no significant relationship is obtained between average ankle flexibility, trunk-hip flexibility and shoulder flexibility, and learning of crawl stroke swimming.

This may be attributed to the fact that physiological readiness is a prerequisite to the learning of

33 Behrman, Research Quarterly 38:165.
motor skills. Motor skills are not developed until the child's neuromuscular system is sufficiently ready. Different levels of physiological maturity are essential for the learning of different motor skills and are specific to each child. A student cannot learn a routine on the parallel bars without first developing a degree of arm and shoulder strength. Agility and skill in footwork are essential for successful participation in handball.\(^{34}\)

Strength, endurance, lung capacities and power are the indications of physiological maturity which underlies all motor performance. These factors seem to play an important role for success in swimming also.\(^{35}\) Walker\(^{36}\) found that a group ranking high in motor fitness learned to perform swimming skills nearly twice as fast as a group which ranked low on motor fitness.

\(^{34}\)Gendine, *Psychology of Motor Learning*, p.147.


To swim fast a swimmer receives his propulsion from his arms and legs, thus, strength in arms, shoulders and legs should be a determining factor to success in swimming. The flutter leg kick originates from the hip joint involving the abdominal muscles too. Furthermore, Councilman\(^{37}\) states that speed swimming on short distances needs more power as compared to long distance events. McCloy\(^{38}\) supported the idea by saying that power is one of the most important factor in many activities especially where the force comes directly through striking with the hands as in boxing, wrestling and swimming and where the speed is involved.

Strength, muscular endurance and aerobic capacity permit the individual to prolong the performance of an act. The performer will be able to perform at length without fatigue and any drop in quality of the skill. A weakness in any of these factors will limit the coordination and effort needed for the performance of


that skill. These interpretations and the findings of the present study are supported by Wright, Brace, Yacher, Larsen and Bear, Vincent, Donovan and Manly. The findings of the study on flexibility are supported by Greer, Albrecht and Rosson.

39 Singer, Motor Learning and Human Performance, p.57.
40 Wright, Dissertation Abstracts International 34:7032-A.
42 Yacher, Larsen and Bear, Swimming Technique 19:17.
43 Vincent, Research Quarterly 38:502.
44 Donovan, Dissertation Abstracts International 40:4956-A.
45 Manly, Dissertation Abstracts International 37: 2057-A.
46 Greer Jr., Dissertation Abstracts International 30:1845-A.
47 Albrecht, Completed Research in Health, Physical Education and Recreation 1 :56.
48 Rosson, Swimming World 11:5.
The statistical significance of crawl stroke swimming learning to percentage of body fat (\( .401 \)) and body density (\( -.406 \)) may be attributed to the fact that an individual's ability to float is largely affected by: (1) The ratio of fat to fat free body mass; (2) the ratio of volume to weight or density; and (3) the relative volume of the lungs. The lesser the density of the body composition, the more buoyant the performer. The size of lung volumes (residual volume as well as total lung volume), forming a bellows inside the chest, obviously affects buoyancy as more air makes the trunk float much easier.\(^ {49,50} \) This buoyancy is an important factor which contributes to ease and efficiency in the learning of swimming skills. Individuals with a low degree of buoyancy experience considerable difficulty in keeping the body horizontal in the water. Much of the force exerted by the legs may be utilized in plaining the body which may affect the rate of learning and efficiency of performance. Lane and Mitchem,\(^ {51} \) and


\(^ {50} \)Higgins, *Human Movement-An Integrated Approach*, p.98.

Brace\textsuperscript{52} also felt that non-buoyant persons may be handicapped in learning to swim.

The findings of the study are supported by Robins,\textsuperscript{53} Kaye,\textsuperscript{54} Rork,\textsuperscript{55} and Manly.\textsuperscript{56}

Combined Contribution of Anthropometric, Behavioural and Physiological Variables to Learning of Crawl Stroke Swimming

**Anthropometric Variables**

The findings of the study revealed that the anthropometric variables of the lower extremity (foot length, thigh length, leg length and calf girth), when combined together, contribute better to crawl stroke swimming learning as compared to the relationship of each of independent variables of anthropometric measures

\textsuperscript{52}Brace, *Research Quarterly* 12:181-185.

\textsuperscript{53}Robins, *Dissertation Abstracts International* 39:4125-A.


\textsuperscript{55}Rork, *Research Quarterly* 8:19-27.

\textsuperscript{56}Manly, *Dissertation Abstracts International* 37:2057-A.
to the dependent variable. This may be attributed to the fact that the leg kick in crawl stroke serves as a stabilizer and means of keeping the hips and legs high in a streamlined position, which will otherwise create unwanted resistance, disturb the body alignment and stroke rhythm. Correct and streamlined body position is more essential in the initial stages of stroke development. 57

Physiological Variables

It is evident from the results that the physiological variables (percentage of body fat, body density, vital capacity, power, arm and shoulder strength, and leg strength), when combined together, contribute better to the learning of crawl stroke swimming as compared to the contribution of each physiological variable separately. This may be attributed to the fact that crawl stroke swimming largely depends on lung capacities, power and strength. Physiological maturity is essential for quicker learning and better performance in swimming.

The swimmer receives his propulsion from his arms and legs and thus, strength and power in arms, shoulders and legs should be the determining factor to success in swimming.\textsuperscript{58,59} Better lung volumes will enhance cardio-vascular endurance and floatability which in turn contribute to ease and efficiency in the learning of swimming skills. The lesser the density of the body composition, the more buoyant the performer.\textsuperscript{60,61}

\textbf{All Combined Anthropometric, Behavioural and Physiological Variables}

The findings of the study revealed that when all the anthropometric, behavioural and physiological variables are combined together (foot length, foreleg length, leg length, forearm length, upperarm length, shoulder width, 

\textsuperscript{58}Counselman, \textit{Competitive Swimming Manual for Coaches and Swimmers}, p.29.

\textsuperscript{59}McCloy, \textit{Research Quarterly} 11:29.

\textsuperscript{60}Ghesquiere, \textit{Swimming II}.

\textsuperscript{61}Higgins, \textit{Human Movement-An Integrated Approach}. 
foreleg length/thigh length, forearm length/upperarm length, intelligence, percentage of body fat, body density, vital capacity, and arm and shoulder strength), they contribute much better (.899) to crawl stroke swimming learning as compared to the contribution of each anthropometric, behavioural and physiological variables separately. The anthropometric variables seem to dominate the behavioural and physiological variables in the learning of crawl stroke swimming. It has also been noticed that some of the variables, which did not show significant contribution in their own category, have shown their relationship to swimming learning when combined with the factors of other two categories (foreleg length, forearm length, upperarm length, shoulder width, foreleg length/thigh length and forearm length/upperarm length). Similarly, some factors have not shown significant relationship when combined with all other variables, which they had shown in their own categories (thigh length, calf girth, power and leg strength). This may be attributed to the fact that such variables are interrelated with some other variables and exhibit their positive or negative contribution either in presence or in absence of these variables.
Multiple Regression Analysis

Results of the multiple regression analysis presented in the preceding sections of this chapter indicated that it is possible to make predictions regarding crawl stroke swimming learning ability on the basis of anthropometric, physiological and all combined anthropometric, behavioural and physiological variables with a reasonable degree of accuracy under the limitations of the study.

Anthropometric Variables

Thigh length has greater loading value in the regression equation followed by foot length and calf girth. Leg length has also been found to be of value in the regression equation but, in a negative direction. Though, the swimmer receives his propulsion from arms and legs to pull him through the water but, the lower extremity proportions (stronger leg kick), initially help him in stabilizing and streamlining the body position which is very essential during the stroke learning. ⁶²

Physiological Variables

Body density has the greatest negative loading value in the regression equation followed by body fat percentage. Among positive values, arm and shoulder strength has greater value followed by power, leg strength and vital capacity. This may be attributed to the fact that while swimming most of the propulsive forces are produced by the arms and less by the legs.\textsuperscript{63,64} Power too is an important factor especially where the force comes directly through striking with the hands as in swimming.\textsuperscript{65} Better vital capacity and the least body density will enhance the ease and efficiency in the learning of swimming skills.

All Combined Anthropometric, Behavioural and Physiological Variables

The relative measurement of forearm length/upperarm length has greater positive loading value

\textsuperscript{63} Ibid.


\textsuperscript{65} McCloy, \textit{Research Quarterly} 11:28.
followed by upperarm length, foreleg length, arm and shoulder strength, foot length, shoulder width, intelligence and vital capacity. Among negative values body density has the greatest loading value followed by foreleg length/thigh length, body fat percentage, forearm length and leg length.

**Discussion of Hypotheses**

The hypotheses stated earlier in Chapter I have been accepted in the case of some of the selected variables and rejected in case of others. The discussions of hypotheses are as follows:

1. The hypothesis that there would be significant relationship between anthropometric variables and learning scores in front crawl stroke swimming has been partially rejected. It has been accepted with regard to body weight, standing height foot length, foreleg length, thigh length, leg length, trunk length, forearm length, upperarm length, arm length, shoulder width, thigh girth, calf girth and foreleg length/thigh length. This hypothesis has been rejected with regard to head circumference, upperarm girth, leg length/trunk length and forearm length/upperarm length.
2. The hypothesis that there will be significant relationship between behavioural variables and learning scores in front crawl stroke swimming has been partially accepted. It has been accepted with regard to intelligence and rejected in case of level of aspiration and concentration.

3. The hypothesis that the physiological variables recorded before commencing instructions in swimming will have significant relationship to learning scores in front crawl stroke swimming has been partially rejected. It has been accepted in case of body fat percentage, body density, vital capacity, aerobic capacity, power, arm and shoulder strength, abdomen strength and leg strength. The hypothesis has been rejected in case of average ankle flexibility, trunk-hip flexibility and shoulder flexibility.