MATERIAL AND METHODS

In the present investigation, an attempt has been made to study the Morphological Characteristics of elite Indian Track and Field Athletes mainly preparing for 2010 Common Wealth Games. 2010 Common Wealth games are special as for which, India is the host country. The results of the present study are based on the data of Track and Field athletes collected from Coaching Camps held at SAI NS NIS, Patiala. Event wise distribution of the athletes is given below:-

1. Runners
   - Sprinters (100,200&400 m)
   - Middle Distance (800,1500 m)
   - Long Distance (3000,5000 & 10,000 m)
   - 20km Walkers

2. Jumpers
   - Long
   - Triple
   - High

3. Throwers
   - Javelin
   - Hammer
   - Discus
   - Shot Put

4. Other Categories
   - Decathlon
   - Heptathlon
   - Pole Vault
The number of athletes studied in each group and sub group is mentioned below in the Table 1

<table>
<thead>
<tr>
<th>Event</th>
<th>No. of Subject Studied</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>W</td>
</tr>
<tr>
<td>1. Runners</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Sprinters</td>
<td>45</td>
<td>26</td>
</tr>
<tr>
<td>ii) Middle Distance</td>
<td>16</td>
<td>06</td>
</tr>
<tr>
<td>iii) Long Distance</td>
<td>06</td>
<td>09</td>
</tr>
<tr>
<td>iv) 20Km Walker</td>
<td>10</td>
<td>04</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>77</td>
<td>45</td>
</tr>
<tr>
<td>2. Jumpers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Long</td>
<td>10</td>
<td>02</td>
</tr>
<tr>
<td>ii) Triple</td>
<td>04</td>
<td>02</td>
</tr>
<tr>
<td>iii) High</td>
<td>06</td>
<td>01</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20</td>
<td>05</td>
</tr>
<tr>
<td>3. Throwers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Javelin</td>
<td>16</td>
<td>03</td>
</tr>
<tr>
<td>ii) Hammer</td>
<td>13</td>
<td>05</td>
</tr>
<tr>
<td>iii) Discus</td>
<td>13</td>
<td>07</td>
</tr>
<tr>
<td>iv) Shot Put</td>
<td>12</td>
<td>04</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>54</td>
<td>19</td>
</tr>
<tr>
<td>4. Other Categories</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Decathlon</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>ii) Heptathlon</td>
<td>-</td>
<td>02</td>
</tr>
<tr>
<td>iii) Pole Vault</td>
<td>03</td>
<td>02</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>15</td>
<td>04</td>
</tr>
<tr>
<td>Grand Total</td>
<td>166</td>
<td>73</td>
</tr>
</tbody>
</table>
As mentioned earlier, the above athletes have been the part of National Camps being held at NS NIS, Patiala for preparation of 2010 Common Wealth Games. Patiala has a long tradition in the field of sports. The Indian Olympic Games were held here in 1944 and 1956 in the Yadvindra Stadium – first Cinder – Track Stadium for Athletics and Cycling in India, built by late Maharaja Yadvindra Singh. Patiala has rightly been called the cradle of Indian Sports and two of its Rulers, Maharaja Yadavinder Singh and his illustrious father Maharaja Bhupinder Singh have popularly been called the first sporting citizen of this country. They took a great interest in sports and built a fine Stadium to popularize sports. It has produced renowned players in Athletics, Volleyball, Wrestling, Cricket and Polo (Bajwa, 1969). Since then the Netaji Subhas National Institute of Sports which is situated in this city is playing the pivotal role in sports in India. This is for this reason that out of 17 identified sports disciplines, marked for 2010 Common Wealth Games, Coaching Camps for 8 sports disciplines are being held in this Institute.

Track and Field is a sport consisting of 22 Olympic events (not counting Relays) that involves Running, Walking, Jumping, Vaulting, Hurdling and Throwing. Although, analysis of data pertaining to other field for so great a number of diverse events is difficult yet morphological findings are remarkably consistent in athletes of different events. In order to study Morphological Characteristics of Indian 2010 Common Wealth Probable of Track and Field,
The following 30 anthropometric measurements were taken on each athlete by using standardized techniques and instruments (Weiner & Laurie, 1969, Rose et al., 1980).

<table>
<thead>
<tr>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Body Weight (Kg)</td>
</tr>
<tr>
<td>2. Stature (cm)</td>
</tr>
<tr>
<td>3. Sitting height (cm)</td>
</tr>
<tr>
<td>4. Height illio-spinale (cm)</td>
</tr>
<tr>
<td>5. Upper arm length (cm)</td>
</tr>
<tr>
<td>6. Forearm length (cm)</td>
</tr>
<tr>
<td>7. Hand length (cm)</td>
</tr>
<tr>
<td>8. Hand breadth (cm)</td>
</tr>
<tr>
<td>9. Hand Span (cm)</td>
</tr>
<tr>
<td>11. Hip width (cm)</td>
</tr>
<tr>
<td>12. Foot Length (cm)</td>
</tr>
<tr>
<td>13. Biacromial diameter (cm)</td>
</tr>
<tr>
<td>14. Billiocristale diameter (cm)</td>
</tr>
<tr>
<td>15. Femur bicondylar diameter (cm)</td>
</tr>
<tr>
<td>16. Humerus bicondylar Diameter (cm)</td>
</tr>
<tr>
<td>17. Wrist diameter (cm)</td>
</tr>
<tr>
<td>18. Ankle Diameter (cm)</td>
</tr>
<tr>
<td>19. Upper arm Circumference</td>
</tr>
<tr>
<td>a) Flexed (cm)</td>
</tr>
<tr>
<td>b) Normal (cm)</td>
</tr>
<tr>
<td>20. Fore-arm Circumference (cm)</td>
</tr>
<tr>
<td>21. Thigh Circumference (cm)</td>
</tr>
<tr>
<td>22. Calf Circumference (cm)</td>
</tr>
</tbody>
</table>
23. Biceps Skinfolds (mm)  
24. Triceps Skinfolds (mm)  
25. Fore-arm Skinfolds (mm)  
26. Sub scapular Skinfolds (mm)  
27. Suprailliac Skinfolds (mm)  
28. Supraspinale Skinfolds (mm)  
29. Thigh Skinfolds (mm)  
30. Calf Skinfolds (mm)

All the unilateral measurements were taken on the left hand side of the athlete. The measurements pertaining to somatotype calculations were taken from left as well as right sides of the body.

Body weight was measured with Avery Weighing Machine. The circumferences were taken with a thin steel tape. Harpenden Skin fold Caliper was used for estimating the skin fold thicknesses. The other measurements were taken with the help of an anthropometer rod anthropometer compass and the sliding caliper. The methodology of each measurement is described as follows:-

**Body Weight**

The subject, wearing minimal clothing, stood erect in the centre of the scaled platform of a portable weighing machine and the weight was recorded. The zero of the scale was checked before taking each measurement.

**Stature**

It is the vertical distance from the vertex to the horizontal floor. The stature was measured with an
anthropometric rod. The measurement was taken with the individual standing straight against an upright wall, touching it with heels, buttocks and back. The head was oriented in the Frankfort plane (the upper border of the ear opening and the lower border of the eye socket on the horizontal line), and the heels were together. The subject was stretched upwards by a gentle traction on the mastoid region, taking care that the heels were kept to the ground. The anthropometric rod was held vertically in front of the subject in mid-sagittal plane and the horizontal movable bar was brought down to touch the point vertex.

**Sitting Height**

It is the vertical distance from the point vertex to the sitting plane. The subject was asked to sit erect on a table with her feet unsupported, the hands rested on the thighs. The head was oriented in the Frankfort Plane gentle upward traction was exerted on the mastoid region and the distance between the vertex and the table was measured with an anthropometric rod, touching the back of the individual at the sacral and inter scapular regions in the mid sagittal plane.

**Height Iliospinale**

The distance between the anterior superior iliac spine and the standing surface was measured with the anthropometric rod with the subject in the same position as that for stature.
**Upper arm length**

The straight distance between the points acromiale and radiale was measured with the anthropometer segment when the subject stood erect with her arms hanging down freely.

**Forearm length**

The distance between the point’s radiale and stylion was measured with the anthropometer segment while the individual stood erect with his arms hanging down freely.

**Hand length**

The straight distance between the points stylion and dactylion was measured with a sliding caliper.

**Foot length**

With the subject sitting with equal pressure on both the feet the distance between the most posterior point of the heel (akropodian) and the tip of the longest toe (pternion) was measured with the anthropometer segment.

**Biacromial diameter**

With the individual standing in a relaxed position and arms hanging down freely, the distance between the most lateral points of the acromion processes was measured with the anthropometer segment by standing behind the subject.

**Humerus bicondylar diameter**

The width between the medial and lateral epicondyles of the humerus was measured with the upper arm horizontal and forming a right angle with the forearm. The caliper was applied at an angle approximately bisecting the angle of the elbow. Slight pressure was placed on the crossbars in order to compress the subcutaneous tissue.
**Femur bicondylar diameter**

With the individual seated and the knee bent at a right angle, the greatest distance between the lateral and medial epicondyles of the femur was measured with the sliding calipers with slight pressure on the cross bars.

**Hand breadth**

With the arm lying straight on the table and the fingers together, the distance between the distal tips of metacarpals II-V (which may be oblique) was measured with the sliding calipers.

**Upper arm circumference**

With the arm extended and hanging loosely at the side of the subject, the circumference was measured with a flexible steel tape at the level halfway between the tip of acromion and olecranon.

**Forearm circumference**

Maximal circumference of forearm was measured with a flexible steel tape.

**Calf circumference**

The maximum circumference of calf was measured, when the subject was sitting with her feet slightly apart and her weight equally distributed on both legs.

**Biceps Skinfold**

This skinfold was picked up on the front of the arm about 1 cm above the level marked on the skin for the arm circumference and directly in line with the centre of the cubital fossa.
**Triceps Skinfold**

With the subjects arm hanging loosely, a fold was picked up at the back of the arm, directly in line with the point of the elbow, at the same level as that for the biceps skinfold.

**Forearm**

This skinfold was measured on the lateral side of the forearm at the marked level where the forearm, circumference was recorded.

**Subscapular**

The subscapular skinfold was picked up just beneath the inferior angle of the scapula in a direction which was obliquely downwards and outwards at 45°.

**Suprailiac**

The fold was picked up approximately 1 cm above and 2 cm medial to the anterior superior iliac spine on a diagonal line going downwards and inwards at 45°.

**Calf**

A vertical skinfold was picked up on the medial side of the lower leg, at the level of the maximum girth of the calf.

The following parameters have been observed on each athlete:-

1. Height (cm)
2. Sitting Height (cm)
3. Height Trochanterion (cm)
4. Weight (kg)
5. Height-Weight Ratio
6. Ponderal Index
7. **Body Fat (%, kg)**
8. **Lean Body Mass (%, kg)**
9. **Muscle Mass (%, kg)**
10. **Bone Mass (%, kg)**
11. **Somatotype**
   a. **Endomorphy**
   b. **Mesomorphy**
   c. **Ectomorphy**

**Calculation of Percent Body Fat**

After obtaining the four skinfold thicknesses i.e. biceps, triceps, subscapular and suprailiac, the body density was computed by following the technique described by Durnin and Womersley (1974). This involved the following steps:

   a) Addition of four skinfolds values to get total skinfold value.

   b) Calculation of body density by using Durning and Womersley (1974) formulae appropriate to the age and sex category of the subject. The formulae are given below:

**For Males:**

i) $\text{Body Density} = 1.1620 - 0.0630 \log (\text{Biceps+Triceps})$ (for 17-19 yrs) + Subscapular + Suprailiac Skinfold)

ii) $\text{Body Density} = 1.1631 - 0.0632 \log (\text{Biceps+Triceps})$ (for 20-29 yrs) + Subscapular + Suprailiac Skinfolds)

iii) $\text{Body Density} = 1.1422 - 0.0544 \log (\text{Biceps+Triceps})$ (for 30-39 yrs) + Subscapular + Suprailiac Skinfolds)
For Females:

i) Body Density = 1.1549–0.678Log (Biceps + Triceps (for 16-19 yrs)+ Subscapular + Suprailiac Skinfolds)

ii) Body Density = 1.1599–0.0717Log(Biceps + Triceps (for 20-29 yrs)+ Subscapular + Suprailiac Skinfolds)

iii) Body Density = 1.1423–0.0326Log(Biceps + Triceps (for 30-39 yrs)+ Subscapular + Suprailiac Skinfolds)

Body density calculated with the help of above mentioned equations was converted to percent body fat by using the formula devised by Brozek et al. (1963):

\[
\text{Percent Body Fat} = \left(\frac{4.570}{\text{Body Density}} - 4.12\right) \times 100
\]

Calculation of Body Fat (in Kgs) or Total Body Fat:

Total Body Fat Decimal Fraction of % body fat x body weight

Lean Body Fat (in percent and kilograms):

a) Percent Lean Body Mass: The formulae to calculate percent lean body mass of the subject is as follows:

\[
\text{Percent Lean Body Mass} = 100 \times - \% \text{ fat.}
\]

b) Lean Body Mass (in kg): This was calculated by subtracting the current fat mass (in kg) from the current body mass or weight (in kg) and was represented by the following equations:

\[
\text{Lean Body Mass (kg)} = \text{Body Mass (kg)} - \text{Fat Mass (kg)}
\]
**Somatotype:**
Heath and Carter (1967) and Carter (1975) have defined somatotypes as follows:
“A somatotype is a description of the present morphological conformation. It is expressed in a three numeral rating, consisting of numeral represents the evaluation of three primary components of physique which describe individual variations in human morphology and composition”.

**First Component (or Endomorphy):** refers to relative fatness in individual physiques; it also refers to relative leanness. That is first component ratings are evaluations of degrees of fatness which lie on a continuum from the lowest recorded values to the highest recorded values.

**Second Component (or Mesomorphy):** refers to relative musculo-skeletal development per unit of height. Second component ratings are evaluations of musculo-skeletal development which lie on a continuum from lowest to highest degrees recorded. The second component is thought of as “Lean Body Mass Relative to Height”.

**Third Component (or Ectomorphy):** refers to relative linearity of individual physiques. Third component ratings are based largely, but not entirely, on height/cube root of weight ratios. Ectomorphy ratings evaluate the form and degree of longitudinal distribution of the first and the second component.

“The Heath-Carter Anthropometric Somatotype Method”: was used for estimating the somatotype. The ten anthropometric measurements needed for obtaining the
somatotype were: Height, Weight, Triceps Skinfold, Subscapular Skinfold, Supra-Spinale Skinfold, Calf Skinfold, Humerus Biepicondylar Diameter, Femur Biepicondylar Diameter, Biceps Girth and Calf Girth.

**First Component or Endomorphy Rating:** The measurements required for endomorphy ratings are skinfolds at triceps, subscapular (as already described above) and supraspinale.

**Supraspinale (R):** For taking the supraspinale (R) measurement, the fold was raised 5 to 7 cm above the anterior superior iliac spine on a line to the anterior axillary border and on a diagonal line going downward and inward at 45°.

The exact decimal rating of endomorphy was assigned from the measurements directly using the following equation of Carter (1980).

\[
\text{Endomorphy} = 0.7182 + 0.1451 \times x - 0.00068 \times x^2 + 0.0000014 \times x^3
\]

Where \( x \) is the sum of triceps, subscapular and supraspinale, skinfolds. For obtaining height corrected endomorphy, \( x \) is multiplied by \((170.18/\text{height in cm})\).

**Second component or Mesomorphy Rating:** The measurements required for mesomorphy ratings are humerus biepicondylar, femur biepicondylar, upper arm circumference, calf circumference and calf skinfolds.

**Humerus Biepicondylar (in cm) (R):** The width between the medial and lateral epicondyles of the humerus
was recorded keeping the upper arm horizontal and forming a right angle with the forearm.

The sliding caliper was applied at an angle approximately bisecting the angle of elbow and slight pressure was applied on the cross bars in order to compress the subcutaneous tissues. It was measured across the styloid processes of radius and ulna. The reading was recorded with a sliding caliper by applying pressure to compress the subcutaneous tissues.

**Femur Bi-condylar (R):** The subject was seated on the chair with knee bent at the right angle. The maximum distance between lateral and medial epicondyles of the femur was measured with the help of sliding caliper. The nods of the caliper were placed on the medial and lateral points of femur at an angle of 45° approximately.

**Upper Arm Circumference (flexed) (L & R):** The measurement was taken at the greatest girth of the upper arm when subject flexed the upper arm fully.

**Calf Circumference (R):** It is the maximum circumference of the calf. The subject was asked to stand erect by keeping feet apart with equal weight on both the feet. The steel tape was wrapped around the most developed gastrocinemius muscle of the right lower leg. The measurement was taken in centimeters.

**Calf Skinfold (R) (mm):** The skinfold was measured vertically on the medial side of the lower leg, where the maximum development of calf muscle was found out. The subject was seated on the chair with knee bent at 90°
With the following equation of Carter (1980) exact decimal rating of mesomorphy was obtained from the measurements directly.

**Mesomorphy** = (0.858 humerus width + 0.601 femur width + 0.188 corrected arm girth + 0.161 corrected calf girth) – (height x 0.131) + 4.50

Corrected Arm Girth can be obtained as:

Corrected Arm Girth = Upper Arm (Flexed) Circumference (cm) – (Sum of Biceps + Triceps).

The values of Biceps and Triceps were in mm and they had to convert into centimeters.

Corrected Arm Girth = Upper Arm (Flexed) Circumference (cm) - \frac{\text{Biceps (cm)} + \text{Triceps (cm)}}{2}

**Calculation of corrected Calf Girth:**

Corrected Calf Girth = Calf Circumference (cm) – Calf Skin fold (in cm).

The value of calf skin fold was in mm and was converted into cm by dividing it with 10.

**Third Component or Ectomorphy Rating:**

The third component was directly calculated from height – weight ratio (HWR) by using the equations of Carter (1980).

\[ \text{Height – Weight Ratio (HWR)} = \frac{\text{Height (cm)}}{3\sqrt{\text{Body weight (kg)}}} \]

The equation of Carter (1980) is as follows:

Ectomorphy = HWR x 0.732 – 28.58

If HWR < 40.75 but > 38.25, then
Ectomorphy = HWR x 0.463 – 17.63

If HWR ≥ 38.25, then a rating of 0.1 is assigned.

**Ponderal Index:**

$$\sqrt[3]{\frac{\text{Weight (Kg)}}{\text{Height (cm)}}} \times 10$$

**STATISTICAL COMPUTATIONS**

The following statistical methods have been applied for the computation of results from the raw data:

1. **Arithmetic Mean ($\bar{X}$):** It is calculated to measure the central tendency of parameter which is the ‘typical value’ in the distribution of particular parameter. All the individual values of the variables are added and then the sum is divided by the total number of individuals:

$$\bar{X} = \frac{\sum X}{N}$$

Where $X$ = Mean value

$\sum x$ = Sum of all the individual values.

$N$ = Number of individuals.

2. **Standard Deviation (S.D):**

Standard deviation is a measure of the variation and is universally used to show the scatter of individual measurements around the mean of all the measurements in a given distribution. By definition, it
is the square root of the average of the scattered deviations of the measurements from their mean. It is calculated as follows:

\[
S.D = \sqrt{\frac{\sum X^2 - (\sum X)^2}{n}}
\]

\[
\quad \frac{n - 1}{n}
\]

Where \( \sum X^2 \) = Sum of the squares of the individual value.

\( (\sum X)^2 \) = the square of the sum of the individual values.

3. **Standard Error of Mean (S.E.M):**

The standard error of mean indicates the magnitude of sampling error. It is useful in estimating the average dispersion of arithmetic mean around the true mean and is calculated as follows:

\[
S.E.M = \frac{S.D.}{\sqrt{N}}
\]

Where S.D = Standard Deviation

N = Number of Observations.

It is ratio of the standard deviation to the square root of the number of observations.

4. **Test of Significance (t):**

The ‘t’ test is applied to know whether the difference between the means of two samples is significant or not at any particular level of significance.
The value ‘t’ is obtained by applying the following formula:

\[ t = \sqrt{\frac{1}{n_1} + \frac{1}{n_2} \left\{ \frac{(n_1-1) SD_1^2 + (n_2-1) SD_2^2}{n_1 + n_2 - 2} \right\}} \]

Where SD_1 and SD_2 represent the standard deviations. \( \bar{X}_1 \) and \( X_2 \) are the means. \( n_1 \) and \( n_2 \) the number of subjects for the respective groups.

5. **Analysis of Variance (ANOVA) (One Way):**

It is used to test the significance of the differences among the sample means when the number of samples is more than two. The process of computing ANOVA is as follows:

i) Sum of all the observations of various samples:

\[ \sum X_1 + \sum X_2 + \sum X_3 \ldots \sum X_n = G.T. \]

Where \( \sum X_1, \sum X_2, \sum X_3 \ldots \sum X_n \) are the summation of the different samples.

\[ (G.T)^2 \]

ii) Correction factor (C.F.) = \( \frac{(G.T)^2}{N} \)

Where G.T. = \( \sum X_1 + \sum X_2 + \sum X_3 \ldots \sum X_n \)

N = Total number of observations in all the groups.

iii) The total sum of squares (T.S.S) :

\[ \frac{(G.T)^2}{N} \]

\[ = \sum X_1^2 + \sum X_2^2 + \sum X_3^2 \ldots \sum X_n^2 \]
iv) Sum of squares between the samples (S.S.B) :
\[(\sum X_1)^2 + (\sum X_2)^2 + (\sum X_3)^2 \ldots \sum X\]

where \(n_1n_2\) are the number of observations of respective groups.

v) Sum of squares within the sample (SSW) :
\[SSW = TSS - SSB.\]

## ANOVA

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares S.S.</th>
<th>Mean Sum of Squares M.S.S.</th>
<th>F.Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Sample</td>
<td>C-1</td>
<td>SSB</td>
<td>*MSSB=SSB/C-1</td>
<td>-</td>
</tr>
<tr>
<td>Within the samples</td>
<td>N-C</td>
<td>SSW</td>
<td>MSSW=SSW/N-C</td>
<td>MSSB/MSSW</td>
</tr>
<tr>
<td>Total</td>
<td>N-1</td>
<td>TSS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Here:

SSB : Sum of square between samples
SSW : Sum of square within samples
MSSB : Mean sum of square between samples
MSSW : Mean sum of square within samples

To calculate the test of significance as:

\[F=MSSB/MSSW\] this F is with d.f. as (C-1, N-C)

The level of significance is taken as 0.05 and 0.01.
Post-hoc Test:

Wherever ANOVA shows the significant difference among the sample means, Post-hoc Test (Multiple range was applied to see the differences in difference pairs.

The Post-hoc t-test for this was –

\[ t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\text{MSSW} \times \left( \frac{n_1 + n_2}{n_1 \times n_2} \right)}} \]