3.1 Research Design

Research design plays a very significant role in making any research successful and reliable as it decides the fate of proposal and its outcome. The design of the study depends upon purpose of the research, the findings of the data collection and the other needs of the research. The present study was cross sectional in nature.

3.1.1 Sample Selection

Sample

A total of 2167 normal healthy individuals from both sexes, aged 6-25 years were selected purposively from Amritsar, Punjab. The power of the study was 90%, \( \alpha = 0.05 \). Total four groups were considered as sample, viz. pre-adolescents, adolescents, post-adolescents and young adults. To estimate the handgrip strength of pre-adolescents (n=545) of 6-10 years age group and adolescents (n= 566) of age group 11-15 years, samples were selected from different schools of Amritsar. Post-adolescents (n=548) of age group 16-20 years were selected from different schools and colleges of Amritsar. Young adults (n = 508), aged 21-25 years were selected from different colleges and Guru Nanak Dev University of Amritsar, Punjab. Of these 2167 subjects, 53 individuals (45 male and 8 female students) were recorded as left hand dominant. Rest of the subjects were right hand dominant. Apart from these, 114 volleyball players and 113 softball players aged 18-25 years were also considered as samples. These samples were taken from state and inter-university level competitions organized in and around Amritsar, Punjab, India. An equal number of controls were also taken.

Sample size determination

The appropriate sample size for a population based study is determined generally by three factors:

1. Estimated prevalence of variable of interest- handgrip strength in this study.
2. The desired level of confidence and precision.
3. The acceptable margin of error.
Sample size was calculated by the following formula:

\[
    n = \frac{t^2 \cdot p(1-p)}{m^2}
\]

where \(n\) = required sample size
\(t\) = confidence interval at 95% (standard value of 1.96)
\(p\) = estimated prevalence of handgrip strength in this study
\(m\) = margin of error

**Inclusion criteria**
Following were the inclusion criteria of the subjects:
1. Individuals aged 6–25 years were selected.
2. Children able to understand what study entails were chosen.
3. Both males and females were selected.
4. Healthy subjects free from any illness were selected.
5. Players of inter-university level were selected.

**Exclusion criteria**
Following were the exclusion criteria of the subjects:
1. Recent injury.
2. Systemic or mechanical pain
3. Involvement in any other study.

**Place of study**
Study was conducted at various schools, colleges and Guru Nanak Dev University, Amritsar, Punjab, India between 2009-2012.
TABLE 3.1
Distribution of the subjects

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>n</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Absolute No.</td>
<td>percent</td>
</tr>
<tr>
<td>6</td>
<td>104</td>
<td>53</td>
<td>50.96</td>
</tr>
<tr>
<td>7</td>
<td>109</td>
<td>55</td>
<td>50.46</td>
</tr>
<tr>
<td>8</td>
<td>101</td>
<td>51</td>
<td>50.50</td>
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<tr>
<td>9</td>
<td>115</td>
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</tr>
<tr>
<td>25</td>
<td>101</td>
<td>51</td>
<td>50.50</td>
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<tr>
<td>Total</td>
<td>2167</td>
<td>1101</td>
<td>50.81</td>
</tr>
</tbody>
</table>

3.2 Methods
For any scientific investigation to be valid and reliable, correct methodology should be adopted that accounts for the success or failure of research work. Methodology is an essential part of every project, therefore, it must be carefully planned
to get authentic results and conclusions.

3.2.1 Tools for data collection

1. Handgrip dynamometer
2. Harpenden skinfold caliper
3. Sliding caliper
4. Anthropometer (Biocraft # 3AN-1)
5. Measuring tape
6. Weighing machine
7. Data collecting Perfora

3.2.2 Parameters measured

1. Dominant handgrip strength
2. Non-dominant handgrip strength
3. Height
4. Body weight
5. Body Mass Index
6. Hand length
7. Hand breadth
8. Second digit length
9. Fourth digit length
10. 2D/4D ratio
11. Upper arm circumference
12. Hip circumference
13. Biceps skinfold
14. Triceps skinfold
15. Subscapular skinfold
16. Suprailiac skinfold
17. Calf skinfold
18. Humerus biepicondylar diameter
19. Femur biepicondylar diameter
20. Upper arm length
21. Forearm length
22. Total arm length
23. Arm muscle area
24. Arm area
25. Arm fat area
26. Arm fat index
27. Percent body fat
28. Percent lean body mass

3.2.3 Procedure of data collection

Age of the subjects was estimated from their respective schools, colleges and university registers. The study was approved by the Institutional ethical committee. The subjects were informed about the purpose of the trial and had to give their signed informed consent before being enrolled. All the anthropometric measurements were taken on each subject by following standard technique given by Lohman et al. (1988). All the measurements were taken on the right side of the subjects except handgrip strength which was measured on both the sides.

a. Handgrip strength measurement (Dominant and non-dominant)

The handgrip strength was measured using a standard adjustable digital handgrip dynamometer (Takei Scientific Instruments Co., LTD, Japan) at standing position with shoulder adducted and neutrally rotated and elbow in full extension. The dynamometer was held freely without support, not touching the subject’s trunk. The subjects were asked to exert maximum force on the dynamometer thrice from their hand. The maximum value in kilograms was recorded. Anthropometric equipment and handgrip dynamometer were calibrated before each assessment. All subjects were tested after 3 minutes of independent warm-up. Thirty seconds time interval was maintained between each handgrip strength testing.

b. Anthropometric measurements

The following anthropometric measurements were taken:

1. Height

Instrument used: Anthropometer.
Materials and Methods

It measured the vertical distance from the vertex to floor. Vertex is the highest point on the head. The subject was asked to stand erect and the head was in Frankfort horizontal plane. The unit of height was measured in cm.

Procedure

The subject was asked to stand erect on a horizontal surface stretching the body as much as possible. The heels of the subject were touching each other and head was on Frankfort horizontal plane. The anthropometer was placed on mid sagittal plane of the subject. The moving cross bar of the anthropometer was allowed to touch the vertex of the subject lightly and results were recorded from the reading scale of the vertically placed anthropometer in centimeters.

2. Body Weight

Instrument used: Weighing machine.

It measured the total body weight of the subject with minimum clothes, when the bowel was empty.

Procedure

The subject was asked to stand erect on the weighing machine with bare feet and the reading was taken from the reading scale on the machine in kg.

3. Body Mass Index

Procedure

Body mass index was calculated by dividing weight in kilograms by square of height of the subject in metres. Hence it is represented by:

\[ \text{BMI} = \frac{\text{Body mass (kg)}}{\text{Height (m)}}^2 \]

4. Hand Length

Instrument used: Sliding caliper.

It measured the straight distance between the mid point of a line joining the styliion and dactyliion of the middle finger.

Procedure

The subject was asked to place his/her hand on the table to its maximum stretch. The fixed cross bar was allowed to touch the styliion and the moving cross bar on the dactyliion lightly. The results were recorded in cm.
5. **Hand Breadth**
   Instrument used: Sliding caliper.
   It measured the straight distance between metacarpal radiale and metacarpal ulnare.

   **Procedure**
   The subject was asked to place his/her hand on the table to its maximum stretch. One arm of the sliding caliper was allowed to touch on the metacarpal radiale and the other arm to the metacarpal ulnare of the subject. Results were recorded from the reading scale of the sliding caliper in centimeter.

6. **Second digit length**
   Instrument used: Sliding caliper.

   **Procedure**
   The length of index finger was measured from the dactylion to the crease of metacarpal.

7. **Fourth digit length**
   Instrument used: Sliding caliper.

   **Procedure**
   The length of ring finger was measured from dactylion to the crease of metacarpal.

8. **2D/4D Ratio**
   It measured the length ratio of second and fourth digits.

9. **Upper arm Circumference**
   Instrument used: Steel tape.
   It measured the maximum circumference of the upper arm.

   **Procedure**
   The subject was asked to stand erect hanging the arm freely by the side. The measurement was taken at right angle to the axis of hanging arm where the biceps muscle was most developed. Results were recorded in cm.

10. **Hip circumference**
    Instrument used: Steel tape.
It measured the maximum circumference of the hip.

**Procedure**

The subject was asked to stand erect on a horizontal plane keeping his/her feet close to each other. The steel tape was applied around the hip of the subject. Results were recorded in cm.

11. **Biceps skinfold**

   Instrument used: Harpenden skinfold caliper.

   It measured the skinfold thickness on the mid upper arm over the biceps muscle.

**Procedure**

The subject was asked to stand erect hanging the arms freely by the side. On the right arm, skin and subcutaneous tissue fold over the biceps muscle was picked up and the jaws of the caliper applied on the fold. Results were recorded from the circular reading scale of the skinfold caliper in millimeter.

12. **Triceps skinfold**

   Instrument used: Harpenden skinfold caliper.

   It measured the skinfold thickness on the mid upper arm over the triceps muscle.

**Procedure**

The subject was asked to stand erect hanging the arms freely by the side. On the right arm, skin and subcutaneous fold over the triceps muscle was picked up and the jaws of the caliper applied on the fold. Results were recorded from the circular reading scale of the skinfold caliper in millimeter.

13. **Subscapular skinfold**

   Instrument used: Harpenden skinfold caliper.

   It measured the skinfold thickness below the inferior angle of scapula.

**Procedure**

The subject was asked to stand erect hanging the arms freely by the side. The subscapular skinfold was picked below the inferior angle of scapula and the jaws of the caliper applied on the fold. Results were recorded from the circular reading scale of the skinfold caliper in millimeter.

14. **Suprailiac skinfold**

   Instrument used: Harpenden skinfold caliper.
It measured the skinfold thickness about 1 cm above and 2 cm medial to anterior superior iliac spine.

**Procedure**

The subject was asked to stand erect. The suprailliac skinfold on the anterior superior iliac spine was picked up and the jaws of the caliper applied on the fold. Results were recorded from the circular reading scale of the skinfold caliper in millimeter.

15. **Calf skinfold**

   Instrument used: Harpenden skinfold caliper.

   It measured the skinfold thickness on the medial side of the calf muscle where it was developed its maximum.

**Procedure**

The subject was asked to sit on a horizontal surface bending knees at right angle with the lower legs hanging freely. Skinfold on the medial calf muscle was picked up and the jaws of the skinfold caliper were applied to the site. Results were recorded from the circular reading scale of the skinfold caliper in millimeter.

16. **Humerus biepicondylar diameter**

   Instrument used: Sliding caliper.

   It measured the straight distance between the two outermost points on the condyles of lower end of humerus.

**Procedure**

The subject was asked to sit on a horizontal surface in erect posture with the arms bending at right angle. The two blunt arms of sliding caliper were allowed to touch across the outermost points on the condyles of the distal end of humerus. Results were recorded from the reading scale of the sliding caliper in cm.

17. **Femur biepicondylar diameter**

   Instrument used: Sliding caliper.

   It measured the straight distance between the two outermost points of the condyles on lower end of femur.

**Procedure**

The subject was asked to sit on a horizontal surface preferably on a flat stool, with knees bent at right angle. The two blunt arms of sliding caliper were allowed to touch
across the outermost points on the condyles of the distal end of femur. Results were recorded from the reading scale of the sliding caliper in cm.

18. **Upper arm length**

   Instrument used: Anthropometer.

   It measured the vertical distance between acromion (the most lateral point on the lateral margin of the acromion process) and radiale (the highest point on the upper margin of the radiale capitulum).

   **Procedure**

   The subject was asked to stand erect on a horizontal surface stretching the body as much as possible and arms hanging by the side. The fixed cross bar of the anthropometer was allowed to touch the acromion and the moving cross bar to the radiale point lightly. Results were recorded on the reading scale of the anthropometer in cm.

19. **Forearm length**

   Instrument used: Anthropometer.

   It measured the vertical distance between radiale and stylion (the deepest point on the styloid process of radius while the arm is hanging by the side).

   **Procedure**

   The subject was asked to stand erect on the horizontal surface stretching as much as possible with arms hanging by the side. The fixed cross bar of anthropometer was allowed to touch the radiale and the moving cross bar to the radial stylion lightly. Results were recorded in cm from the reading scale of the anthropometer rod.

20. **Total arm length**

   Instrument used: Anthropometer.

   It measured the vertical distance between acromion and dactylion (the lowest point on the anterior margin of the middle finger with the arm hanging by the side).

   **Procedure**

   The subject was asked to stand erect on the horizontal surface stretching as much as possible with arms hanging by the side and fingers stretched. The fixed cross bar was allowed to touch the acromion and the moving cross bar to the dactylion position lightly. Results were recorded from the anthropometer rod in cm.
21. **Arm muscle area (calculated)**
   Procedure manually: Arm muscle area (cm\(^2\)) = \[G_{\text{arm}} - (\pi Sf_{\text{tri}}) \] / 4\pi

22. **Arm area (calculated)**
   Procedure manually: Arm area (cm\(^2\)) = \((G_{\text{arm}})^2/4\pi\)

23. **Arm fat area (calculated)**
   Procedure manually: Arm fat area (cm\(^2\)) = arm area - arm muscle area

24. **Arm fat index (calculated)**
   Procedure manually: Arm fat index = arm fat area / arm area

25. **Percent body fat** (Siri, 1956)
   Procedure manually: Percent body fat = \{(4.95/Body density)-4.5\} \times 100
   Body density (Durnin and Womersley, 1974)
   - Body density for men = 1.1610 - 0.0632 log\(\sum 4\)
   - Body density for women = 1.1581 - 0.0720 log\(\sum 4\)
   - Body density for boys = 1.1533 - 0.0643 log\(\sum 4\)
   - Body density for girls = 1.1369 - 0.0598 log\(\sum 4\)

26. **Percent lean body mass**
   Procedure: percent lean body mass = 100 - percent body fat

3.3 **Statistical Analysis**

Data was analyzed using SPSS (Statistical Package for Social Science) version 17.0. Student’s t test was applied for the comparison of all the variables between different sets of populations, and ANOVA was also applied. Pearson correlation coefficients, linear correlations and multiple regression analyses were carried out with handgrip strength (separately) as a dependent variable and rest of the anthropometric variables as independent. A 5% level of probability was used to indicate statistical significance.

1. **Arithmetic Mean** (\(\overline{X}\))

   Arithmetic mean gives the average of the whole range of the data given by adding together all the items and by dividing this total by number of items, and is given by the following formula:

   \[
   \overline{X} = \frac{\sum X}{N}
   \]
Where

\[ \bar{X} = \text{arithmetic mean} \]
\[ \sum X = \text{sum of all variables} \]
\[ N = \text{total number of all variables} \]

2. Standard Error (S.E.)

It enables the measurements of magnitude of the sampling error. It is calculated by the following formula:

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

Where

\[ \text{S.D.} = \text{Standard deviation} \]
\[ N = \text{Total number of variables} \]

3. Standard Deviation (SD)

It gives the degree of deviation or dispersion of the recorded data from the mean. It is given by the formula:

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

Where

\[ \text{S.D.} = \text{Standard deviation} \]
\[ X = \text{Individual variables} \]
\[ \bar{X} = \text{Mean of variables} \]

4. Students t-test

It gives the difference between the two independent random samples of size \( N_1 \) and \( N_2 \) with mean \( X_1 \) and \( X_2 \) and S.E. of \( X_1 \) and S.E. of \( X_2 \). It is calculated by the following formula:

\[ t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{(\text{S.E.}_1)^2 + (\text{S.E.}_2)^2}} \]
Where
\[ t = \text{t test} \]
\[ \bar{X}_1 = \text{Mean of 1st variable} \]
\[ \bar{X}_2 = \text{Mean of variable} \]
\[ \text{S.E.}_1 = \text{Standard error of 1st variable} \]
\[ \text{S.E.}_2 = \text{Standard error of 2nd variable} \]

5. **One-way ANOVA TEST**

One-way ANOVA for different subject design is used to compare results from 3 or more conditions, with different, unmatched subject groups in each condition. It only tells, if there are general non-specified differences in the results from the 3 conditions.

The following table is formed:

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Squares</th>
<th>'f' ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Conditions</td>
<td>SS&lt;sub&gt;bet&lt;/sub&gt;</td>
<td>df&lt;sub&gt;bet&lt;/sub&gt;</td>
<td>MS&lt;sub&gt;bet&lt;/sub&gt;</td>
<td>F&lt;sub&gt;bet&lt;/sub&gt;</td>
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<td>Total</td>
<td>SS&lt;sub&gt;tot&lt;/sub&gt;</td>
<td>df&lt;sub&gt;tot&lt;/sub&gt;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. **Correlation**

To understand the dimension of relationship of handgrip strength as dependent variable with set of anthropometric variables, Karl Pearson’s product moment correlation coefficients were calculated. The correlation coefficient is denoted by ‘r’ and is expressed as follows:

\[ r = \frac{N\sum (A \times B) - \sum A \times \sum B}{\sqrt{[N\sum A^2 - (\sum A)^2][N\sum B^2 - (\sum B)^2]}} \]

\[ \sum A = \text{Sum of variables A} \]
\[ \sum B = \text{Sum of variables B} \]
\[ \text{DF} = N-2 \]

The p value for the corresponding r value was seen in the table using the degree of freedom. Level of significance was p < 0.05.
Interpretation of $r$

A value close to +1 indicates a perfect or near perfect positive relationship between two quantitative variables and a value closer to -1 indicates perfect negative relationship between them. A value close to zero indicates that the two quantitative variables are not linearly related.

7. Regression analysis

To quantify the association between dependent variables (dominant and non-dominant handgrip strength) and sets of independent anthropometric variables, regression analysis was done.

Linear regression

More precisely, if $x$ and $y$ are two related variables, then linear regression analysis helps us to predict the value of $y$ for a given value of $x$ or vice versa. By linear regression, we mean models with just one independent and one dependent variable. The variable whose value is to be predicted is known as dependent variable and the one whose known value is used for prediction is known as independent variable. Mathematically, the equation for straight line is:

$$y = a + bx$$

Where, $y$ is the value of the dependent variables (dominant and non-dominant handgrip strength) and $x$ is the value of independent (anthropometric) variables, ‘b’ is the slope of the line and ‘a’ is the point where the line intercepts the vertical axis. The slope is called the regression coefficient. The difference between the observed value of the dependent variable $y$ and its expected value by the regression model is called the residual. For the data points falling above the regression, the residual will be positive and for those falling below the line, the residual will be negative. The expression of the slope ($b$) and intercept ($a$) are obtained as:

$$b = \frac{\text{sum of } xy - (\text{sum } x)(\text{sum } y)n}{\text{sum } x^2 - (\text{sum } x)^2/n}$$

$$a = \frac{(\text{sum } y)/n - [b (\text{sum } x)/n]}$$

Multiple linear regression

It was also studied how dominant and non-dominant handgrip strength were affected by height, body weight, hand length, hand breadth etc. together. This
relationship is called as multiple regression. In this set up, the number of independent variables is more than one. Therefore, in this analysis the regression of dependent variables (dominant and non-dominant handgrip strength) on a set of independent variables ($x_1, x_2, \ldots, x_n$ like height + body weight + hand length + hand breadth + ...) was studied. This analysis helped in finding out whether the different anthropometric variables were related to the dominant and non-dominant handgrip strength or not and if related, then which all of them were significantly related indicating the order of their importance. Furthermore, this analysis also helped to predict the dependent variable (dominant and non-dominant handgrip strength) based on the significantly contributing independent anthropometric variables indicating the error observed in the prediction.

In the multivariate linear regression analysis, the model is

$$y = a + b_1x_1 + b_2x_2 \ldots + b_nx_n$$

where, $x_1, x_2, \ldots, x_n$ are the independent variables; $b_1, b_2, \ldots, b_n$ are the regression coefficients of $x_1, x_2, \ldots, x_n$ respectively. $x_1, x_2, \ldots, x_n$ are also called as predictor variables and $y$ is also referred to as explained or predicted variables.