Methodology of the present study entitled “Correlates of Body Mass Index and body composition of adults in Kochi” is discussed under the following heads:

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### 3.1 Selection of area and subjects

The state of Kerala is divided into 14 districts. The Ernakulam district includes the largest metropolitan region of the state and is known as the commercial capital of Kerala. Kochi corporation in Ernakulam district was selected for the conduct of the present study. It is the most densely populated corporation in the state. As per 2001 census, it has a population of 5,96,473 of which 58.53 per cent that is, 3,49,116 are adults. Increased percentage of adult population provides the corporation an opportunity to rapidly improve the health and nutritional status of the citizens and to optimally utilize the available human resources.

Kochi corporation is divided into 72 wards comprising Urban, Rural Coastal and Unclassified wards out of which 25 wards (Figure 3.1) were selected as study locations to represent the corporation.
Figure 3.1. Study area in Kochi corporation
Subjects in the age group of 18-60 years were selected. House visits were made in the corporation area to select the households that had at least one person aged between 18-60 years. A total of 2500 subjects (Appendix1) including male and female (non pregnant and nonlactating) who had consented formed the population for the study.

### 3.2 Study design

It was a cross sectional study, carried out by adopting multistage stratified random sampling procedure. Of the 72 wards in the study locale, 25 wards were selected by area sampling technique. To study the Body Mass Index (BMI) pattern of the population, 100 subjects were randomly selected from each of the wards to have a total sample size of 2500. They were screened for height and weight and the BMI of each subject was calculated. BMI classification of WHO (2004), was followed (Table 3.1) to categorise the subjects.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Principal cut-off points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt;18.50</td>
</tr>
<tr>
<td>Severe thinness</td>
<td>&lt;16.00</td>
</tr>
<tr>
<td>Moderate thinness</td>
<td>16.00 - 16.99</td>
</tr>
<tr>
<td>Mild thinness</td>
<td>17.00 - 18.49</td>
</tr>
<tr>
<td>Normal weight</td>
<td>18.50 - 24.99</td>
</tr>
<tr>
<td>Overweight</td>
<td>≥25.00</td>
</tr>
<tr>
<td>Pre-obese</td>
<td>25.00 - 29.99</td>
</tr>
<tr>
<td>Obese</td>
<td>≥30.00</td>
</tr>
<tr>
<td>Obese class I</td>
<td>30.00 - 34.99</td>
</tr>
<tr>
<td>Obese class II</td>
<td>35.00 - 39.99</td>
</tr>
<tr>
<td>Obese class III</td>
<td>≥40.00</td>
</tr>
</tbody>
</table>
For the in-depth study on the energy balance and body composition pattern of adults in relation to different BMI, purposive sampling technique was used. A total of 420 adults were chosen as shown in Table 3.2. with equal representation by gender, age group i.e. early adulthood 18-29 years and late adulthood 30-60 years as classified by ICMR (1990) and BMI categories i.e. <18.5(underweight), 18.5-24.9(Normal weight) and 25 and above (Overweight).

<table>
<thead>
<tr>
<th>Age in years</th>
<th>Underweight BMI</th>
<th>Normal weight BMI</th>
<th>Overweight BMI</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male female</td>
<td>Male female</td>
<td>Male female</td>
<td></td>
</tr>
<tr>
<td>18-29</td>
<td>35 35</td>
<td>35 35</td>
<td>35 35</td>
<td>210</td>
</tr>
<tr>
<td>30-60</td>
<td>35 35</td>
<td>35 35</td>
<td>35 35</td>
<td>210</td>
</tr>
<tr>
<td>Total</td>
<td>70 70</td>
<td>70 70</td>
<td>70 70</td>
<td>420</td>
</tr>
</tbody>
</table>

For classification of the subjects by BMI, the cutoffs recommended by WHO (2004) which defines low BMI<18.5 (underweight), normal BMI 18.5-24.9 (Normal weight) and high BMI 25 and above (Overweight) was followed.

### 3.3 Conduct of the study

Initially for data collection from the 2500 subjects, an interview schedule (Appendix 2) was developed and information on the demographic profile, age, height and weight was collected by the investigator through visits at each household individually and BMI was calculated from the data on height and weight. For the in-depth study, a questionnaire was developed and used to collect information from the 420 adults on socioeconomic status, motivating and demotivating factors on food intake, physical activity, energy intake (24
hour recall) and energy expenditure using 24 hour activity diary (Appendix 3). The questionnaire was prepared in English and also in Malayalam, the regional language of the state. For the 420 adults reselected from the study locale, apart from height and weight, various circumferences at mid upper arm, waist, hip and skinfold thickness at biceps, triceps, subscapula and suprailiac were also taken.

3.4 Techniques employed for anthropometric assessment

Anthropometric assessment of nutritional status can be divided into two main categories; the assessment of physical characteristics and the assessment of body composition (Gibson, 2005). Body composition of the 420 subjects selected was studied based on respective BMI as underweight, normal and overweight using the simple, non invasive methods such as anthropometric parameters as well as bioelectrical impedance analysis (BIA).

3.4.1 Physical characteristics

Physical characteristics comprise of various anthropometric measurements such as height, weight, circumference at mid upper arm, waist and hip and skinfold thickness at triceps, biceps, suprailiac and sub scapular.

a. Body height

The measurement was taken, the subject standing barefooted, erect on a horizontal surface with heels together, the shoulders relaxed and arms at the side. The subject was made to look straight. The point of contact of the head was marked with a scale over the head of the subject applying a slight pressure to reduce the thickness of the hair. The height was measured using fiberglass tape to the nearest 0.2 cm.
b. **Body weight**

Body weight is the most widely used and the simplest reproducible anthropometric measurement for the evaluation of nutritional status. The weight was recorded to the nearest 100 grams. The weight was measured by using standardized portable scale which has a total capacity of 200kg. The balance was calibrated daily and corrected for zero error before taking the measurement of each individual. Weight was measured without footwear and minimum clothing.

c. **Body Mass Index**

The body Mass Index (BMI) is expressed as the ratio of weight in (kg) / Height (m²). It is a simple and useful index of relative weight applied to assess obesity or chronic energy deficiency (Sauvaget *et al.* 2008). Due to its ease of measurement and calculation, it is the most widely used diagnostic tool to identify weight problems within a population.
For a given height BMI is proportional to weight. However, for a given weight BMI is inversely proportional to the square of the height. Body Mass Index was calculated using the equation

\[
BMI = \frac{\text{Weight in Kg}}{(\text{Height in meter})^2}
\]

d. **Waist circumference (WC)**

Waist circumference is the measure of the distance around the abdomen. Waist circumference is a convenient and simple measure which is unrelated to height and correlates closely with Body Mass Index (BMI) and the ratio of waist to hip circumference, is an approximate index of intra-abdominal fat mass and total body fat. Practical considerations appeared to favour the use of waist circumference as an alternative to BMI.

As per WHO STEPS protocol (WHO, 2011) for measuring waist circumference, the measurement is made at the approximate midpoint between the lower margin of the last palpable rib (lowest point) and the top of the iliac

*Adapted from NHLBI Obesity Education Initiative (2000)*
crest (top of the hip bone). The investigator found the midpoint and asked the subject to wrap the tape around them. Special attention was taken to make sure that the subject stood with arms at the sides, feet positioned close together, and weight evenly distributed across the feet. The reading was taken to the nearest 0.1 cm at the end of a normal expiration. According to WHO (2011) there is an increased risk at WC 90 cm for men and WC 80 cm for women and a substantially increased risk of lifestyle diseases for men with WC 102 cm and women 88cm.

e. Hip circumference (HC)

Hip circumference is measured around the widest portion of the buttocks, with the tape parallel to the floor. To measure hip circumference the measuring tape is positioned around the maximum circumference of the buttocks. For women, this is at groin level.

Adapted from NHANES III (1988)

For men it is normally about 2-4 inches below the navel. The subject was asked to stand with their feet together, place their arms at their side with palms of their hands facing inwards and breathe out gently. The
measurements were made to the nearest 0.1 cm with a stretch resistant tape that is wrapped snugly around the subject. Each measurement was repeated to obtain a concordant value.

f. Waist hip ratio (WHR)

Waist hip ratio is widely accepted for body fat measurements. It provides an indication of the predominance of fat storage in the abdominal region. To calculate waist hip ratio the measurements of the waist circumference is divided by the hip circumference. Same unit of measurement was used for each measure.

\[
\text{Waist to hip ratio (WHR)} = \frac{\text{WC}}{\text{HC}}
\]

where

\[
\text{WC} = \text{waist circumference.}
\]

\[
\text{HC} = \text{hip circumference.}
\]

World Health Organization’s (WHO, 2011) cut-off points were used to identify subjects at risk i.e. Waist hip ratio ≥ 0.90 cm for men ≥ 0.85 cm for women.

According to WHO (2011) waist circumference and waist to hip ratio (as measures of abdominal obesity) are correlated with BMI, but the level of association varies, suggesting that these measures may provide different information and thus may not be interchangeable.

g. Mid upper arm circumference (MUAC)

Mid upper arm circumference is recognized to identify malnutrition and to indicate the status of muscle development. The MUAC measurement reflects adult nutritional status as defined by BMI (Collins, 1996). For measurement of mid upper arm circumference, the midpoint of the subject’s left upper arm was calculated by first locating the tip of the
subject’s shoulder with investigator’s finger tips. The elbow was bent to make a right angle. The midpoint between the shoulder and the elbow was calculated and marked with a marker pen. The arm was left hanging freely and the fiber glass tape was gently but firmly placed at the midpoint embracing the arm without exerting too much pressure on the soft tissues. The reading was taken to the nearest 0.1 centimeter with the fiberglass tape still in position.

h. **Skinfold thickness**

The skinfold thickness is defined as a measure of the double thickness of the epidermis, underlying fascia and subcutaneous adipose tissue. The skinfold thickness was taken to the nearest 0.1 mm on different trunk sites (subscapular and suprailiac) and on extremities (triceps and biceps) using Harpender’s skin calipers. According to Bamji et al. (2003) a systematic advantage has been demonstrated for using averages of biceps and triceps skin fold rather than a single skinfold thickness to assess the percentage of body fat in adult women and men.

i. **Fatfold at triceps**

The measurement is made on the dorsal side at the same mid point where mid upper arm circumference is measured. The skinfold is picked up between the thumb and fore finger about one centimeter above the mid point between acromion (bone over the shoulder blade) and olecranon (bony prominence of the elbow) taking care not to include underlying muscle.
ii. **Fatfold at biceps**

With the left arm of the subject hanging loosely in a relaxed state, the biceps skinfold was measured as the thickness of the vertical fold in the front of the upper arm approximately over the middle of the biceps muscle, directly above the centre of the cubital fossa and the reading was noted directly to the nearest 0.1mm.
iii. **Fatfold at subscapula**

The sub (under) scapular (the wing bone) fatfold was measured just below and lateral to the angle of the left scapular by picking it up with the thumb and forefinger in a line running approximately 45° to the spine in the natural line of skin cleavage.

![Fatfold at Subscapula](image)

Adapted from [http://www.pponline.co.uk/encyc/body-composition-1105](http://www.pponline.co.uk/encyc/body-composition-1105)

iv. **Fatfold at suprailiac**

A slightly diagonal fold is measured on the crest of the ilium (The ilium is the largest of the three innominate bones of the pelvis.) at the anterior axillary line (a vertical line along anterior axillary fold). To locate hip bone the subject bent laterally to the left with right hand the investigator pressed on the skin from the under last rib to the hip bone. When the bony area is located, placed the thumb on the hipbone and had the subject turned to the upright position, the fold is taken by the fingers and the thickness was noted down.
3.5 Tools and techniques used in the computation of energy balance

The balance between energy intake (calories consumed) and energy expenditure (calories burned) determines body energy stores. Major part of the excess energy is stored in the body as fat. It is therefore, the balance between energy intake and energy expenditure that primarily determines whether body fat and hence, the body weight is gained or lost. Energy balance can be calculated using the formula:

\[
\text{Energy balance} = \text{Energy intake} - \text{Energy expenditure}
\]

If the energy intake is higher than the expenditure, then it is called positive energy balance. If the intake is less than the expenditure, then it is called negative energy balance. Both lower and higher energy balances are associated with health hazards.

3.5.1 Energy intake

Energy for the metabolic and physiological functions of human body is derived from the chemical energy bound in food and its macronutrient constituents such as carbohydrates, protein and fat. After food is ingested its chemical energy is released and converted into thermal, mechanical and other forms of energy.
Energy intake was calculated by using 24 hour dietary recall method. It was interpreted using nutritive value of Indian foods (ICMR, 1989). A set of standardized cups and spoons suited to local conditions were used. All the adult subjects were familiarized to standardized cups and spoons which helped them to recall the food intake for 24 hours. Considering the fact that physical activity and eating habits may vary on some days of the week, a period of two working days and one holiday was used while collecting information on energy intake and expenditure.

3.5.2 Energy expenditure

Energy expenditure can be divided into three categories

a) Energy to support basal metabolism (Basal Metabolic Rate)

b) Energy to digest and metabolise food (Thermic Effect of Food)

c) Energy expenditure on physical activity (EEPA)

a. Basal Metabolic Rate (BMR): - Basal Metabolic Rate is the energy invested in the internal activities of the body. Basal Metabolic Rate constitutes nearly half or more of the total energy expenditure. It was calculated using predictive equations based on body weight.

i. Computation of BMR of the selected subjects based on BMI

The BMR predictive equations were used for the first time by the 1985 Joint FAO/WHO/UNU expert group and have gained considerable popularity since then. A comparison of this equation with the actual measured BMR in a large number of well nourished Indians has indicated that it is five per cent lower than the FAO/WHO/UNU equation. Therefore a modified equation applicable to Indians was derived by ICMR (1990) as given in Table 3.3 was used for predicting BMR (Kcal/24hr) in the present study.
ii. Comparative analysis of BMR by predictive equations

Measuring BMR is time consuming and requires specialized equipment that is generally unavailable in the clinical setting, and even if available, would be impractical to use in large-scale dietary survey work. Instead of measuring BMR directly, the main approach adopted involves the BMR factorial method, endorsed by the FAO/WHO/UNU (2004) which predicts BMR from equations based on previous measures, which are then used to estimate daily energy requirements. There have been several prediction equations generated over the past century, dating back to the seminal work of Harris and Benedict in the year 1919.

<table>
<thead>
<tr>
<th>Equations</th>
<th>Subjects</th>
<th>Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) ICMR(1990)</td>
<td>Male 18-29 yrs 30-60 yrs</td>
<td>14.5 x B.W (kg) + 645</td>
</tr>
<tr>
<td></td>
<td>Female 18-29 yrs 30-60 yrs</td>
<td>10.9 x B.W (kg) + 833</td>
</tr>
<tr>
<td>(b) FAO/WHO/UNU (2004)</td>
<td>Male 18-29 yrs 30-60 yrs</td>
<td>14.0 x B.W (kg) + 471</td>
</tr>
<tr>
<td></td>
<td>Female 18-29 yrs 30-60 yrs</td>
<td>8.3 x B.W (kg) + 788</td>
</tr>
<tr>
<td>(c) Kurian’s (2005)</td>
<td>Male 18-60yrs</td>
<td>15.3 x B.W (Kg) + 679</td>
</tr>
<tr>
<td></td>
<td>Female 18-60yrs</td>
<td>11.6 x B.W (Kg) + 879</td>
</tr>
<tr>
<td><strong>Underweight</strong></td>
<td>Male 18-60yrs</td>
<td>14.7 x B.W (Kg) + 496</td>
</tr>
<tr>
<td></td>
<td>Female 18-60yrs</td>
<td>8.7 x B.W (Kg) + 829</td>
</tr>
<tr>
<td><strong>Normal weight</strong></td>
<td>Male 18-60yrs</td>
<td>23.931 x B.W(Kg) + 145.08</td>
</tr>
<tr>
<td></td>
<td>Female 18-60yrs</td>
<td>21.968 x B.W (Kg) + 139.81</td>
</tr>
<tr>
<td><strong>Overweight</strong></td>
<td>Male 18-60yrs</td>
<td>22.626 x B.W(Kg) + 94.092</td>
</tr>
<tr>
<td></td>
<td>Female 18-60yrs</td>
<td>12.517 x B.W(Kg) + 491.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.6299 x B.W(Kg) + 842.89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13.386 x B.W(Kg) + 476.03</td>
</tr>
</tbody>
</table>
FAO/WHO/UNU (2004) Expert consultation has provided equations for predicting the BMR from body weights based on world wide data on BMR which is applicable to different population groups but also recommended that BMR predictive equations are to be revisited, reviewed and reformulated. Kurian et al. (2005) observed that there were significant differences in the BMR among the three BMI groups with underweight and normal weight subjects having a significantly lower BMR compared to overweight subjects. Therefore they derived BMR predictive equations for Indian male and female subjects belonging to different BMI groups and recommended that these equations to be used on increased sample size from different population groups. An attempt was made to compare the BMR calculated using equations (Table 3.3) proposed by ICMR for Indian population and FAO/WHO/UNU predictive equation for International use both for general adult population against those proposed by Kurian et al. (2005) for Indian adults with different BMI.

b. **Thermic effect of food**

Regulatory thermogenesis which is categorized into obligatory and facultative included the metabolic responses to the food ingested i.e., the use of energy in digesting, absorbing, storing and disposing of ingested nutrients. For all practical purposes the component of energy expenditure related to regulatory thermogenesis are known to merge into measurements related to the cost of physical activity. Consequently the new simplified approach has only two principal components of energy expenditure, that are BMR and physical activity (ICMR, 1990) and in the present study also computation of energy expenditure was done based on BMR and physical activity.
Methodology

c. Energy expenditure on physical activity (EEPA)

The third component of energy metabolism is the energy spent on voluntary physical activity. This accounts for an average of about 30 per cent of the total calorie expenditure while thermic effect of food accounts for ten per cent and BMR accounts for 60 per cent.

Energy expenditure on physical activity was determined from physical activity level (PAL) where, the PAL was determined by a questionnaire containing daily activity record. For this, the number of minutes spent by the subject on each activity was recorded for a period of 24 hours. The PAL can be calculated by assigning physical activity ratios (PAR) given by FAO/WHO/UNU expert group (FAO/WHO/UNU, 2004) to these activities (Appendix 9). PAR is the ratio that expresses the energy cost of an individual activity per min, as multiples of BMR.

\[
PAL = \left( \sum PAR \times \frac{T_i}{24} \right)
\]

Where

- \( PAR \) = Physical activity ratio for each activity
- \( T_i \) = Time spent (hours in each activity)

d. Total daily energy expenditure (TDEE)

TDEE can be determined as the product of the BMR and the physical activity level (PAL). While the BMR can either be measured or be predicted from body weight (ICMR, 1990) the PAL can be determined by the time spent on each physical activity for 24 hours (mean of 3 days) as obtained from the physical activity diary. Multiplication of the PAL value with BMR will give an estimate value for the energy expenditure for each day and hence the formula FAO/WHO/ UNU (2004):
TDEE = (PAL) x BMR

The measurement of total daily energy expenditure is an important aspect of the assessment of human health and nutrition and it has gained further importance for field application, with the joint consultation of the FAO/WHO/UNU (2004).

3.6 Assessment of body composition

The measurement of body composition is an important consideration for everyone who promotes good health. These measurements provide an indication of both nutritional status and physical fitness. Simple anthropometric indices are frequently used to assess the body composition of selected populations.

Anthropometry is one of the most basic tools for assessing body composition even though a variety of other methods are also available for accurate measurements such as underwater weighing, dual energy X-ray absorptiometry (DXA), total body water, total body electrical conductivity, total body potassium, and computerized tomography. However, the use of most of these methods is limited to research settings because of their complexity and cost.

Anthropometric methods used to assess body composition are based on a model in which the body consists of two chemically distinct compartments fat and fat free mass. Proportion of fat mass and fat free mass can be used to study as to how much muscle and fat exist in humans with different BMI. In the current study both body fat and fat free mass were assessed using various measures.
3.6.1 Determination of fat free mass

Fat free mass was determined only through anthropometry.

a. **Mid upper arm area (MUAA)**

Mid upper arm area is an estimation of the area of the upper arm. It is derived from the MUAC using the formula (Frisancho, 1981):

\[
MUAA = \frac{(MUAC)^2}{4\pi}
\]

b. **Mid upper arm muscle circumference (MUAMC)**

It is an estimation of the circumference of the bone and muscle portions of the upper arm. It is derived from MUAC and the triceps skinfold (TSF) by accounting for the thickness of the subcutaneous fat that surrounds the muscle, using the formula (Jelliffe, 1966):

\[
MUAMC = MUAC - \left(\pi \times \frac{TSF}{10}\right)
\]

Where

- **MUAC** = Mid upper arm circumference (cm) and
- **TSF** = Triceps skinfold (mm)

c. **Mid upper arm muscle area (MUAMA)**

It is an estimation of the area of the bone and muscle portions of the upper arm. A simple approach in assessing nutritional status and muscle mass, is the determination of upper arm muscle area which is widely used in adults and calculated by using mid upper arm circumference and triceps skinfold thickness (Boye *et al.*, 2002). It is derived from the MUAMC using the formula (Frisancho, 1981):

\[
MUAMA = \frac{(MUAMC)^2}{4\pi}
\]
d. Corrected mid upper arm muscle area (CMUAMA)

Mid upper arm muscle area estimates lean body mass. It is an estimation of the area of the muscle portions of the upper arm, attempting to eliminate the area due to bone. It is derived from the MUAMC using the formulae (Heymsfield et al., 1982), with the MUAC and TSF values in centimeters.

For men: CMUAMA = \[
\frac{\left[ MUAC - \left( \frac{\pi X \frac{TSF}{10}}{10} \right)^2 \right]}{4\pi} - 10
\]

For women: CMUAMA = \[
\frac{\left[ MUAC - \left( \frac{\pi X \frac{TSF}{10}}{10} \right)^2 \right]}{4\pi} - 6.5
\]

3.6.2. Determination of body fat mass

The fat content of the body has physiological and medical importance. It may influence morbidity or mortality.

a. The mid upper arm fat area (MUFA)

The mid upper fat area (MUFA) is an estimation of the area of the fat portions of the upper arm and is simply the difference between the MUAA and the MUAMA and was calculated by the formula (Frisancho, 1990):

\[
MUFA = MUAA - MUAMA
\]

b. Arm fat index (AFI)

It is the percentage of fat in the arm and is derived as a percentage from MUFA and MUAA by the formula (Frisancho 1990):

\[
AFI = 100 \times \frac{MUFA}{MUAA}
\]
c. **Per cent body fat (%BF)**

A moderately satisfactory estimate of the body fat content can be obtained from height and weight. Bhat *et al.* (2005) recommend that future studies of body fat ('adiposity') in Indians should measure multiple skinfolds or use a specifically calibrated bioelectrical impedance machine rather than rely solely on BMI cut-points of obesity. So far no study has compared the estimates of per cent body fat of adults of different BMI in Kerala. Therefore, an attempt has been made to investigate the association between per cent body fat of adults of different BMI in Kochi. In the present study following methods were used:

i) Per cent body fat from sum of skinfold measurements (Durnin and Womersley equation, 1974).

ii) Body fat per cent from body density (Siri’s equation, 1961)

iii) Body fat per cent from predictive equation from body mass index (Deurenberg *et al.* 1991)

iv) Body fat per cent from predictive equation for Indians (Goel *et al.*, 2008)

v) Body fat per cent from Bioelectrical Impedance Analysis (BIA)

**i) Per cent body fat from sum of skinfold measurement (Durnin and Womersley equation 1974) of the selected adults as per BMI.**

Taking skinfold measurements is a common method for determining body fat composition. Perhaps one of the most frequently used equations is the equation of Durnin and Womersley (1974). This test estimates the percentage of body fat by measuring skinfold thickness (subcutaneous adipose tissue) at specific locations on the body as indicated in page numbers 62-65.
Skinfold thickness was measured to the nearest mm. These readings were made at four sites on all subjects, i.e. biceps, triceps, subscapular and suprailiac areas. Body fat equivalent to sum of skinfold thickness was calculated by Durnin and Womersley table (1974) (Appendix 4).

ii) **Body fat per cent from body density (Siri’s equation 1961) of the selected adults as per BMI**

This calculation of body fat per cent involves measuring four skinfold sites, triceps, biceps, subscapular and suprailiac, and substitute the log of their sum into the following linear regression equation,

\[
\text{Body density} = C - M \times \log(\Sigma S)
\]

Where C and M stands for standard age and sex-specific coefficients (Appendix 5) and \(\Sigma S\) = Sum of all four skinfold measurements (mm)

Once the body density is determined, per cent body fat (%BF) can be calculated using the Siri’s Equation (1961) as given below:

\[
\text{Per cent Body Fat} = \left(\frac{495}{\text{Body density}}\right) - 450
\]

iii) **Body fat per cent from predictive equation from body mass index (Deurenberg et al. 1991)**

Body fat can be estimated from body mass index (BMI). The BMI is calculated from an individual's weight divided by the square of the height is expressed in kg/m². The body fat is estimated from the body mass index using Deurenberg formula. Deurenberg formula for adults is:

\[
\text{Adult body fat per cent} = (1.20 \times \text{BMI}) + (0.23 \times \text{Age (yrs)}) - (10.8 \times \text{gender}) - 5.4
\]

Where male gender = 1 and female = 0.
iv) **Body fat per cent from predictive equation for Indians (Goel et al., 2008)**

Goel et al. (2008) derived predictive equations of body fat for Indians as functions of simple anthropometric measures such as triceps skinfold, waist circumference, weight and height.

\[
\text{Per cent Body fat} = 42.42 + 0.003 \times \text{age (years)} + 7.04 \times \text{gender (male =1, female = 2)} + 0.42 \times \text{triceps skinfold (mm)} + 0.29 \times \text{waist circumference (cm)} + 0.22 \times \text{weight (Kg)} - 0.42 \times \text{height (cm)}
\]

v) **Bioelectrical impedance analysis (BIA)**

Bioelectrical impedance analysis (BIA) is a widely used method for estimating body composition. The technology is relatively simple, quick, and non-invasive. BIA is currently used in diverse settings. Despite a general public perception that BIA measures “body fat,” the technology actually determines the electrical impedance of body tissues, which provides an estimate of total body water (TBW). The general principle behind BIA is that two conductors are attached to a person’s body and a small electric current is sent through the body. The resistance between the two conductors will provide the measure of body fat. In the present study, ankle was placed on the electrodes and the readings were directly noted down from the digital display on the equipment.

d. **Fat mass and fat free mass**

In two compartmental model of body composition, human body is basically divided into two components, fat and fat free mass (Venkataramana, 2011). In the present study fat mass and fat free mass were determined by the following formulae (Gibson, 2005);
Fat mass (Kg) = Body weight (BW Kg) X Per cent body fat (%BF)
Fat free mass (Kg) = Body weight (BW Kg) – Fat mass (FM Kg)

3.7 Development of a computer based intervention tool

During the course of the present study, it was felt that there is a need to have novel public health strategies such as computer based health education remedial measures, about life style changes and dietary modification in order to promote a healthy lifestyle among the population under study. According to IAMAI (2011) the growth of telecommunication industry in India is evident and widely appreciated while Internet usage within the adult segment including women continues to gauge constant stability. The newer generation dominates the usage.

New technologies have shown promise as effective, accessible, and inexpensive solutions. In addition, the use of the Internet to communicate information to individuals may allow population health interventions to be delivered and widely disseminated, at relatively low cost. To date, several Internet-based interventions have demonstrated reductions in weight through a combination of self-monitoring, education, and motivational messaging (Anhoj and Jensen, 2004)

The diffusion of the Internet in Kerala is likely to be a function of the economic and social conditions. Currently, Kerala ranks first among Indian states and union territories in the density of telephone connections. Kerala has the third highest rate of mobile phone usage in the country (Davidson et al. 2002).

Therefore it was felt that it would be appropriate to formulate and develop a computer based software package as a ready reckoner for BMI, physical
activity level, BMR energy intake, energy expenditure and overall energy balance to motivate adult population for self monitoring, appropriate lifestyle transition and attainment of overall health. Steps involved in the development of the software package as waterfall model is shown in Figure 3.2

![Figure 3.2. Steps in the development of nutrition software “Calebor”](image)

**Step 1. Background**

According to Das et al. (2005) there is an urgent need to have public health remedial measures such as health education about life style changes and dietary modification. The available evidence does show that computer based nutrition programmes may be a promising tool and strategy to encourage people to adopt healthier diets (Brug et al., 2005). Therefore, it was thought
of interest to develop a user friendly software package to give health awareness and motivate adult population to follow a healthy lifestyle.

**Step 2. Conceptualisation and design**

The important task in creating a software package is the conceptualization. After having a thorough understanding of the need for new software, the next step was to decide the end result from the programme. In this step, content (nutritive value of ethnic foods and PAR of physical activities) from authorized agencies i.e. ICMR, FAO/WHO/UNU are incorporated into the software. In addition, nutritive value of standardized food products from lab and publications were also translated into the computer language. The name of the software was selected carefully to sound the right function to the target users. It was named “Calebor” based on an amalgam, by taking parts of the relevant words and putting them together (cal/orie and e/nergy b/alance or/ganiser). The name is relevant, positive, memorable, reasonably short, not too generic, and not too similar to a competing name.

Based on the required end result, as given in Figure 3.3 the following specifications were decided. The designing of the software was undertaken by skilled and experienced professionals.
Step 3: Establishing reliability

Evaluating software is operating the software under controlled conditions, to verify that it behaves "as specified", to detect errors, and to validate that what has been specified, is what the user actually wanted. Verification is the checking or testing of items, for conformance and consistency by evaluating the results against pre-specified requirements. Validation looks at the system correctness – i.e. the process of checking that what has been specified is what the user actually wanted. Validation checks to see if we are building what the customer wants/needs, and verification checks to see if we are building the system correctly. Both verification and validation are necessary, but are different components of any testing activity. Reliability refers to the consistency of a measure. A test is considered reliable if we get the same result repeatedly.
Chapter 3

a) Test–retest method

While there are several methods for estimating test reliability, one of the most useful types is test-retest method. To estimate test-retest reliability, energy balance test is administered with the new software twice. If the researcher obtains the same results on the two administrations of the instrument, then the reliability coefficient will be 1.00.

b) Parallel Method

It is to ensure that the processing of new application is consistent with the processing of previous application version. It is used to clarify the uncertainty regarding correctness of processing of new application where the new and old versions are similar. In this parallel method of testing new application results obtained from Calebor were compared against manual computation regarding BMI, energy intake, expenditure and energy balance using the same questionnaires filled up by 15 adults.

Step 4: Establishing validity (Evaluation by experts and field test)

Validity refers to the degree in which our test or other measuring device is truly measuring what we intended it to measure. Construct validity determines whether the programme measured the intended attribute. Validity in software engineering addresses various issues that are:

a) Usefulness - Is it doing what is needed? b) Embodying important required characteristics – Is it doing it in an acceptable or appropriate way? and c) Correctness of functionality – Is it doing what it is supposed to do?

For the establishment of validity in the present study, the methods given below were used.
Methodology

a) Evaluation by panel or experts

Validity is established by performance test done on the new software package “Calebor” by experts in nutrition and dietetics, those who have post graduate degree in nutrition and working experience for at least five years in this field. The software was evaluated with the checklist (Appendix 6) using Likert scale. It contains simple statements to which the respondent is asked to evaluate the level of agreement or disagreement as measured. Five ordered response levels with score as furnished below was used.

1. Strongly disagree = -2
2. Disagree = -1
3. Neither agree nor disagree = 0
4. Agree = +1
5. Strongly agree = +2

It is considered symmetric or "balanced" because there are equal amounts of positive and negative positions. A manual (Appendix X) was also prepared to help the users.

b) Evaluation by field test

Validity was established by field test also. After it was found agreeable by nutritionist/dietitians, it was further validated by 20 consumers at the field level. The target users i.e. male and female adults of 18-29 years and 30-60 years evaluated the software using the same checklist used by the experts.

Step 5: Packaging

The software thus designed along with the manual is given in (Appendix 10). The software compact disc (CD) and package had pictures representing the concept, thus motivating the users.
3.8 Data analysis and interpretation

Multistage sampling was adopted for the present study. Data were entered and statistically analysed using SPSS version 17. All the entries were double checked for any possible key board error. For both anthropometric and body composition parameters, the distribution was confirmed for mean and standard deviation. Chi square test was applied to find the relationship between BMI and the demographic factors. The Z-test comparison of proportions is used to test differences between groups. The Z-test assumes that each observation falls into one of two mutually exclusive categories. All observations are independent. For comparing difference in the means of various parameters across the three groups as stratified by BMI, analysis of variance (ANOVA) followed by multiple range test was used. There is significant difference between the mean values of the various parameters at one per cent significance level, because the P value obtained is <0.01. A forward stepwise multiple analysis of Pearson’s correlation coefficient, linear regression and R-square change was performed to determine the relation between BMI and anthropometric parameters, energy balance and body composition indices. The data thus obtained were tabulated, analyzed and interpreted.
Figure 3.4: Research Design