Literature available from developed and some developing nations suggests that birth weight bears an association with body fat particularly, abdominal fat. A number of factors such as – postnatal growth, socioeconomic status, breastfeeding and introduction of complementary foods can possibly mediate this relationship. In addition to body fat, birth weight may also bear a close association with the cognitive development. Both, prenatal and postnatal growth appears to significantly influence the brain development and growth. Postnatal catch-up growth as well as environmental stimulation may play a crucial role in recovering from the nutritional insult and preventing cognitive impairment.

The present study was designed to study the association between birth weight and (i) nutritional status and body fat measures in 2 to 4 year old children, (ii) selected cognitive functions in children aged between 3 to 4 years.

3.1 Research Questions

In order to gain a better and in-depth understanding of this area, the following research questions were formulated –

1. What is the prevalence of low birth weight in the study group?
2. What is the prevalence of undernutrition and overnutrition in the children aged 2 to 4 years?
3. What are the factors that influence the nutritional status of the children?
4. Is there any association between birth weight and the current anthropometric measurements in children aged 2 to 4 years?
5. Is there any relationship between birth weight and body fat (\%), waist circumference, waist-to-height ratio (WHtR) and subscapular to triceps ratio (SSF: TSF) in young children?
6. Is there any difference in the anthropometric measurements, body fat (%), waist circumference, WHtR and SSF: TSF across the categories of birth weight and rate of weight gain (change in weight SD)?

7. Is there any difference in the anthropometric measurements, body fat (%), waist circumference, waist-to-height ratio and SSF: TSF across the categories of birth weight and current HAZ?

8. Whether the independent variables - birth weight, current HAZ or change in weight SD are associated with body fat (%), waist circumference, WHtR and SSF: TSF at the age of 2 to 4 years?

9. Are there any differences in the cognitive test scores between the following groups – normal birth weight non-stunted, normal birth weight stunted, low birth weight stunted and low birth weight non-stunted?

### 3.2 Ethical Approval

The present study was a cross-sectional study conducted among 1205 children aged 2 to 4 years of age. The study was approved by the Independent Ethics Committee, Navi Mumbai (IEC no 09122) (Appendix I).

### 3.3 Estimation of Sample Size

The sample size was estimated using the formula $n = \frac{4pq}{L^2}$

Where $n$ is the number of samples

$p = \text{population proportion}$

$q = 100 - p$

$L = \text{percentage error allowed of the population proportion}$
Based on the available literature, the population proportion (p) born with undernutrition among 3 to 5 year old children was found to vary between 25 to as much as 45%. For the purpose of estimation of sample size, the population proportion was considered to be 25%.

\[ q = 100 - p = 100 - 25 = 75 \]

L was presumed to be 10% of p giving a power of \((1 - L)\) i.e. 90% to the study. On this basis, a sample size of 1200 children aged 2 to 4 years of age was estimated. All the children were recruited for the study from *anganwadis* situated in Mumbai city.

### 3.4 Selection of Anganwadis

With the consent of the Deputy Commissioner of Integrated Child Development Service (ICDS), Konkan Region the study was carried out in the *anganwadis*. The city of Mumbai is divided into two zones – city and suburbs. The ‘city’ zone is constituted of five projects (areas) while the ‘suburbs’ are made up of 28 projects. Of these, the Child Development Project Officers (CDPOs) of the following projects were willing to participate in the study –

- Wadala – Sewri (city)
- Andheri -1 (suburbs)
- Andheri -2 (suburbs)
- Andheri -3 (suburbs)
- Mankhurd (suburbs)

In the suburbs, each project had approximately 140 to 160 *anganwadis* each. A list of all the *anganwadis* with their serial numbers was obtained from the respective CDPOs. From this list, one *anganwadi* was randomly selected. Thereafter, every sixth *anganwadi* was selected by simple random sampling. Thus, in each project approximately 25 *anganwadis* were selected to be included in the study. Wadala – Sewri project had approximately 260 *anganwadis*. However, a substantial part of the Wadala - Sewri area was under
redevelopment. Therefore, the officials allotted 24 *anganwadis* where the study was conducted. Thus, 100 *anganwadis* were selected in the suburbs and 24 in the city.

3.5 Study Design: This cross-sectional study was divided into two parts –

(i) Nutritional Assessment - Detailed anthropometric measurements, medical history, morbidity data and general information about the family were collected for all the 1205 children aged 2 to 4 years of age.

(ii) Cognitive Assessment – Cognitive assessment was carried out for children aged 3 to 4 years only. Of the 655 children aged 3 to 4 years, a sub sample of 20% i.e. 120 children was drawn for the cognitive assessment.

3.6 Phase I: Assessment of Nutritional Status

3.6.1 Selection of Subjects for Assessment of Nutritional Status

Inclusion criteria: Children were included in the study if –

- They had authentic birth weight records such as the discharge card of the hospital where the child was born or the *anganwadi* register.
- Their age was between 24 to 48 months on the day of the survey. Age was calculated from the date of birth. The date of birth was obtained from either the *anganwadi* records or the birth certificate or the immunization card or the discharge card given to mother after the child’s birth from the hospital.

Exclusion criteria: Any child with the following criteria was excluded from the study -

- Suffering from any chronic illness that influences the nutritional status
- Born with congenital anomalies.
- Born extremely premature (< 28 weeks of gestational age)

In each *anganwadi*, every child who satisfied the inclusion criteria was considered for the study. The parents and/or the primary caregiver of the child were informed about the study in the local language. The ‘Information Sheet for Parents/Primary Caregivers’ has
been provided in the Appendix II. The children were finally included in the study only after obtaining a written informed consent from them. The signature of the parents/primary caregiver was obtained on the consent form. In case the parents/primary caregiver were unable to sign then, his/her thumb impression was obtained along with the signature of a witness. Thus, 972 children from the suburbs and 233 from the city were included in the study (Figure 3.1).

FIGURE 3.1: SELECTION OF ANGANWADIS FOR NUTRITIONAL ASSESSMENT
3.6.2 Pilot Study

A pilot study was conducted at two *anganwadis* (which were not included in the main study) situated in Andheri (East) on 40 children aged between 2 to 4 years. Birth weight and age was obtained from the *anganwadi* records. Details about the family, child’s feeding history, medical history and morbidity was gathered from the parent or guardian. Anthropometric measurements – weight, height, mid-upper arm circumference, head circumference, waist circumference and skinfold thickness (biceps, triceps, subscapular and supraileac) were taken. All the measurements were taken in triplicates.

3.6.3 Data Collection

Data was collected from the mother or the primary caregiver by personal interview in the local language. In every locality of the selected areas, the mothers or the primary caregivers were contacted through the *anganwadi* worker posted in that locality. The *anganwadi* worker was explained about the purpose and procedure of conducting the study. A prior appointment was taken for collecting the data as per the convenience of the *anganwadi* worker, the parent or the primary caregiver and the eligible children. All the interviews were conducted during the working hours of the *anganwadi* i.e. between 11:00 to 14:00 hours. Each interview with the parent or the primary caregiver lasted for around 15 to 20 minutes. The interview was followed by the measurement of the various anthropometric parameters which lasted for around 20 minutes or slightly more. The structured interview schedule is given in Appendix IV. Information collected during the interview is described as follows –

*General Information*

Information about the child’s family and the mother were collected from the parent or the primary caregiver by a structured interview schedule.
Family details – Family details included – the total number of family members (including the children), their education, occupation and income. The income of all the family members was added up to calculate the total family income. The per capita income was calculated by dividing the total family income by the total number of family members.

Details about the mother – The mother’s current age was recorded. Based on her current age and the index child’s date of birth, the mother’s age at the time of index child’s birth was calculated. The total number of children the mother has and the index child’s birth order was also recorded. Information regarding the index child’s birth i.e. preterm or full-term was required. However, this information was not available in the anganwadi records. Some mothers had the hospital discharge card where the gestational age was mentioned. Mothers, who did not have any records, were asked if the index child was born after or prior to the completion of nine months of pregnancy. Those born after the completion of nine months were classified as full-term and those born prior to the completion of nine months were classified as preterm.

Child’s Feeding History – Information about breastfeeding i.e. the total duration of breastfeeding (TBF), whether the child was exclusively breastfed, duration of exclusive breastfeeding (EBF) and the age at which complementary feeding (CF) was initiated, was obtained from either of the child’s parent or primary caregiver. Wherever required, the parent/primary caregiver were probed further to elicit information.

Child’s Medical History - The parent or the primary caregiver was asked if the child was ever hospitalized. If yes, details regarding number of times he/she was hospitalized, the cause for the same, age at the time of hospitalization and the duration were also collected. In addition to this, if the child suffered from tuberculosis or undernutrition or any other chronic illness in the past was also asked.

Child’s Morbidity - Information was sought about the child’s morbidity in the last 15 days. The parent or the guardian was asked if the child suffered from any of the following
illness in the past 15 days – diarrhea, cold, cough, typhoid, malaria, jaundice, dengue, viral fever or any other. Details of the duration of the illnesses were also recorded.

**Anthropometric measurements**

Birth weight of the children was retrospectively collected from the *anganwadi* records or the hospital discharge card. In addition to this, the current anthropometric measurements that were measured are listed below. All the measurements were taken by the researcher in the presence of the *anganwadi* workers. All the equipments used were calibrated before data collection began.

- **Weight** – Children were weighed with minimal clothing on an electronic digital weighing scale (Dr Gene Wellness; Model MS8270) with an accuracy of 0.1 kg. The child was made to stand on the centre of the platform with the body weight evenly distributed on both the feet without touching anything else. (Fidanza & Keller, 1991)

- **Height** – A non-extensible, flexible and accurate measuring tape was used to measure the height of the children. The tape was calibrated against a stadiometer in the laboratory (GPM; Swiss Mada). The child was made to stand on a horizontal surface without shoes or shocks with the heels together and back straight. The Frankfort Plane i.e. the line joining the left tragion and the lowest point of the inferior margin of the left orbit was kept horizontal. A ruler or scale was used to mark the highest point of the child’s head. Height was measured to the nearest 0.1 cm. (Fidanza & Keller, 1991)

- **Mid-Upper Arm Circumference (MUAC)** – The validated non-extensible, flexible and accurate measuring tape was used to measure the MUAC of the children. The mid-point between the acromion and olecranon processes was marked with the
child’s arm flexed at 90º angle. The child was then made to relax the hand in such a way that it hangs just away from the side of the body. (Heymsfield, 1991)

- Waist circumference – Waist circumference was measured midway between the lowest rib margin (costal margin) and superior anterior iliac crest with a validated non-extensible, flexible and accurate tape-measure (Seidell, 1991).

- Head circumference – Head circumference was measured at the largest circumference around the mid-forehead or the occipitofrontal area with a validated non-stretchable, flexible and accurate tape-measure to the nearest 0.1 cm. The measurement was taken thrice and the largest reading was considered as the final one. (Fidanza & Keller, 1991).

- Skinfold thickness – Skinfold was formed by placing the thumb and the index finger on the skin about 4 to 8 cms apart and were then brought together in a defined axis about one centimeter above the marked site. The jaws of the skinfold caliper were applied at the midpoint of the fold. The fold was held and maintained during the measurement. The fold was released after the measurement was taken. The same procedure was repeated again after a pause to prevent sustained compression at the site of the fold. Harpendens caliper (Baty International; RH15 9LB, England) was used to measure the skinfold thicknesses at four sites –
  
  - Triceps – The measurement was taken at the midpoint of the back of the upper arm between the tips of the olecranon and acromial processes that was determined when the arm was kept flexed at 90º angle. With the arm hanging freely at the side, the calipers were applied vertically above the olecranon at the marked level.
- Biceps – The fold was measured over the belly of the bicep muscle at the same level as triceps, with the arms hanging freely and palm facing outwards.

- Supraileac – The measurement was taken just above the iliac crest, in the mid-axillary line with the arm slightly abducted.

- Subscapular – The fold was measured just below the inferior angle of the scapula at 45° angle to the vertical along the natural cleavage lines of the skin. (Norgan, Fidanza, & Sarchielli, 1991)

All the anthropometric measurements were taken in triplicates and the mean value (except for head circumference) was used for further analysis. Intra-observer variability was tested for all the anthropometric measurements. The intraclass correlation coefficients (ICC) was 1.000 (95% CI: 0.999 – 1.000) for weight, height and MUAC each. ICC for head circumference and waist circumference were 0.997 (95% CI: 0.993 – 0.999) and 0.999 (95% CI: 0.998 – 1.000) respectively. ICC for skinfold thicknesses were as follows: biceps – 0.988 (95% CI: 0.962 – 0.996), triceps – 0.944 (95% CI: 0.863 – 0.977), subscapular – 0.946 (95% CI: 0.878 – 0.955) and supraileac – 0.947 (95% CI: 0.852 – 0.980).

### 3.6.4 Interpretation of Data and Cut Offs Used

*Birth Weight* – Birth weight was classified as follows –

- < 2.5 kg – low birth weight (LBW)
- 2.5 to 4.0 kg – normal birth weight (NBW)
- > 4.0 kg – high birth weight (HBW)

(Oldroyd et al, 2011; Loazia & Atalah, 2012; UNICEF, 2014)
**Body Mass Index (BMI)** - BMI was calculated using the formula –

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

**Z – scores** - WHOAnthro version 3.2.2 was used to calculate the z scores for the following indices – weight-for-age (WAZ), height-for-age (HAZ), weight-for-height (WHZ), BMI-for-age (BAZ), MUAC-for-age (MUACZ), head circumference-for-age (HCZ), triceps-for-age (TSZ) and subscapular-for-age (SCZ). The cut-offs and corresponding interpretation of these indicators are given in Table 3.1a and b.

**Table 3.1a: Cut-offs and Interpretation of WAZ, HAZ, WHZ and BAZ**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Cut-offs</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight-for-age Z score (WAZ)</td>
<td>&gt; -1.99 SD</td>
<td>Normal WAZ</td>
</tr>
<tr>
<td></td>
<td>-2.0 to -2.99 SD</td>
<td>Moderately Underweight</td>
</tr>
<tr>
<td></td>
<td>&lt; -3.0 SD</td>
<td>Severely Underweight</td>
</tr>
<tr>
<td>Height-for-age Z score (HAZ)</td>
<td>&gt; -1.99 SD</td>
<td>Normal HAZ</td>
</tr>
<tr>
<td></td>
<td>-2.0 to -2.99 SD</td>
<td>Moderate Stunting</td>
</tr>
<tr>
<td></td>
<td>&lt; -3.0 SD</td>
<td>Severe Stunting</td>
</tr>
<tr>
<td>Weight-for-height Z score (WHZ)</td>
<td>&gt; -1.99 SD</td>
<td>Normal WHZ</td>
</tr>
<tr>
<td></td>
<td>-2.0 to -2.99 SD</td>
<td>Moderate Wasting</td>
</tr>
<tr>
<td></td>
<td>&lt; -3.0 SD</td>
<td>Severe Wasting</td>
</tr>
<tr>
<td></td>
<td>&gt; +2 SD</td>
<td>Overweight</td>
</tr>
<tr>
<td>BMI-for-age Z score (BAZ)</td>
<td>&gt; +2.0 SD</td>
<td>Obese</td>
</tr>
<tr>
<td></td>
<td>1.0 to 1.99 SD</td>
<td>Overweight</td>
</tr>
<tr>
<td></td>
<td>-1.99 to 0.99 SD</td>
<td>Normal BAZ</td>
</tr>
<tr>
<td></td>
<td>-2.0 to -2.99 SD</td>
<td>Moderate Thinness</td>
</tr>
<tr>
<td></td>
<td>&lt; -3.0 SD</td>
<td>Severe Thinness</td>
</tr>
</tbody>
</table>

(WHO, 2006; WHO, 2007)
Table 3.1b: Cut-offs and Interpretation of the MUACZ, HCZ, TSFZ and SSFZ

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Cut-offs</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUAC-for-age Z score (MUACZ)</td>
<td>&gt;-1.99 SD</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>-2.0 to -2.99 SD</td>
<td>Moderate wasting</td>
</tr>
<tr>
<td></td>
<td>&lt;3.0 SD</td>
<td>Severe wasting</td>
</tr>
<tr>
<td>Head Circumference-for-age Z score (HCZ)</td>
<td>&gt;-1.99 SD</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>-2.0 to -2.99 SD</td>
<td>Moderate microcephaly</td>
</tr>
<tr>
<td></td>
<td>&lt;3.0 SD</td>
<td>Severe microcephaly</td>
</tr>
<tr>
<td>Triceps-for-age Z score (TSFZ) and Subscapular-for-age Z score (SSFZ)</td>
<td>&gt;-1.99 SD</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>-2.0 to -2.99 SD</td>
<td>Moderately low</td>
</tr>
<tr>
<td></td>
<td>&lt;3.0 SD</td>
<td>Severely low</td>
</tr>
</tbody>
</table>

(WHO, 2006; WHO, 2007; Cheong et al, 2008; Mullin et al, 2014)

Calculation of Body Fat (%) - A number prediction equations have been put forth for calculating body fat based on the skinfold measurements. Hussain et al (2014) correlated the DEXA measurements with some of the prediction equations – Slaughter, Goran and Denezberg in school-going children in Pakistan. The results revealed that Slaughter’s equation predicted body fat (%) with high accuracy (95%), minimal bias and good precision with DEXA. More than 75% of the values were within 5% of the estimated DEXA values.

Body fat (%) was calculated using the equation given by Slaughter et al (1988). This equation is used for children who have their tricep and subscapular skinfold measurement < 35 mm. The equation for boys and girls is as follows-

Boys: % body fat = 1.21 (sum of 2 skinfolds) – 0.008 (sum of 2 skinfolds²) -1.7

Girls: % body fat = 1.33 (sum of 2 skinfolds) – 0.013 (sum of 2 skinfolds²) – 2.5
**Measures of Central Adiposity** – The following indicators for central adiposity were used:

a) Waist Circumference Percentiles – The mean waist circumference of the children were classified as per the waist circumference percentiles given by Khadilkar et al (2014). Khadilkar et al (2014) developed age- and sex-specific percentiles for Indian children aged 2 to 18 years from the data collected from children belonging to affluent households from five major cities – Delhi, Chennai, Kolkata, Pune and Raipur.

b) Waist-to-height ratio (WHtR) – Waist-to-height ratio was calculated as waist circumference (cm)/ height (cm). WHtR of > 0.5 is indicative of excess upper body fat accumulation (Kuriyan et al, 2011).

c) Subscapular-to-triceps ratio (SSF: TSF) – The ratio of subscapular to tricep skinfold thickness (SSF: TSF) was calculated. Subscapular skinfold has been used as a measure of truncal fat while subscapular: tricep ratio has been used as an indicator of truncal: peripheral adiposity (Rogers et al, 2003). SSF: TSF correlates with central fat distribution as measured by DEXA (r = 0.66) (Daniels et al, 2000). Currently, there are no standards or cut-offs for SSF: TSF. A higher ratio is indicative of central adiposity.

**Rate of Weight Gain** – In order to determine if the child experienced catch-up growth or catch-down growth or had maintained the growth rate, the change in weight standard deviation (SD) was calculated as follows -

\[
\text{Change in Weight SD} = \text{Present WAZ} - \text{WAZ at birth}
\]

If this value was > 0.67 SD then, it was considered that the child showed catch-up growth. On the other hand, if the SD scores decreased by 0.67 then, it was considered as significant catch-down growth (Ong et al, 2000).
3.7 Phase II: Assessment of Cognitive Functions

The phase II of this study was to assess selected cognitive function in a subsample. The following research question was addressed.

Research Question

Is there any difference in the cognitive functions of the children across the four groups namely - normal birth weight non-stunted (NBWNS), normal birth weight stunted (NBWS) and low birth weight non-stunted (LBWNS)?

3.7.1 Hypotheses

The following hypothesis and sub-hypotheses were formulated based on the objective of the study.

Children in the low birth weight stunted (LBWS) group perform poorly in the cognitive tests in comparison with others.

1. The performance IQ of LBWS children is lowest as compared that of the other groups namely – NBWNS, NBWS and LBWNS.

Seguin Form Board Test (SFBT) was used to measure the performance intelligence of the children. The performance in the test was dependent on a range of cognitive functions - motor dexterity, visuo motor skills, spatial organization and speed of performance (Desai and Kothare, 2009).

Investigators have studied the relationship of these functions with birth weight at different ages. Veena et al (2010) found that at nine years, visuospatial ability increased by 0.1 SD for every 1 SD increase in birth weight. Ostgard et al (2014) found that SGA-born adolescents had significantly lower visuo-motor and visuo-spatial functions as assessed by Trail Making Test (p < 0.01). In a meta-analysis, Geldof et al (2012) found that children born with very low birth weight (< 1.5 kg at birth) had deficits in visuo-spatial abilities and visuo-motor integration.
Lira et al (2009) observed that normal birth weight children scored higher in performance IQ than the LBW children at eight years of age (p = 0.04). Hutchinson et al (2013) observed that preterm (< 28 weeks of gestation)/extremely low birth weight (< 1000 g) children had 0.8 SD lower mean IQ scores than their term normal birth weight counterparts at eight years of age (t = -8.2, p < 0.001). In particular, these children had lower processing speed than the normal birth weight children (t = -4.3, p < 0.001). Similar trends have been seen in adolescents as well (Lohangen et al, 2010; Chaudari et al, 2013).

Apart from fetal growth restriction, some researchers have also studied the impact of stunting or chronic undernutrition on the cognitive functions. Delayed somatic growth has been associated with deficit of energy and micronutrients in the brain which can potentially impede neurodevelopment (Sokovolic et al, 2014). Longitudinal studies have shown that stunting at two years of age can influence cognitive and psychosocial outcomes well into adolescence. Stunted children scored poorly in the domains of visuospatial function and overall cognition than the well nourished controls at the ages 5 to 10 years (Kar et al, 2008; Sokovolic et al, 2014). In contrast, no differences were seen among the two groups in motor speed (Kar et al, 2008; Sokovolic et al, 2014).

Medial temporal lobe, parietal lobe, retrosplenial cortex, parietal-occipital sulcus and hippocampus are believed to play an important role in visuospatial function (Burgess, 2008). Frontal cortex plays a crucial role in visuo motor functions (Kar et al, 2008). SGA children have been reported to have lower total cerebral volume (p = 0.002), cortical surface area (p = 0.0001) and hippocampal volume (p = 0.034) than the AGA controls at 4 to 7 years of age (Bie et al, 2011). Similar anatomical abnormalities have been seen at 13.5 and 15 years (Isaac et al, 2000; Raznahan et al, 2012). Further, SGA children who experienced catch-up growth continued to have significantly lower volumes in the above mentioned brain areas.
as compared to AGA controls but higher than the SGA children without catch-up growth (Bie et al, 2011).

2. The memory performance of LBWS children is lowest as compared that of the other groups namely – NBWNS, NBWS and LBWNS.

A number of researchers have studied relationship of birth weight with memory function in children and adolescents. Geva et al (2006) found that IUGR born children at nine years had significantly lower digit span (p < 0.001), immediate recall (p < 0.024) and delayed recall (p < 0.002) than the control. Hutchinson et al (2013) reported that at the age of eight years children born very low birth weight (VLBW) had poor working memory as compared to those born normal birth weight (t = -5.5, p < 0.001). In another study, preterm VLBW adolescents showed a deficit of 0.4 to 0.6 SD in working memory at the age of 16 years (Luu et al, 2011). Ostgard et al (2014) found that adolescents born SGA had significantly lower scores on Weschler memory scale and auditory immediate memory scale (p < 0.01) than their non-SGA counterparts at 19–20 years of age. In comparison to the non-SGA, SGA adolescents were at higher risk of obtaining < -1.5 SD scores on memory domain (OR: 13.3, 95% CI: 1.57 – 112.47).

In addition to fetal environment, postnatal nutritional status also appears to play a pivotal role in shaping the memory function. Stunting in childhood (5 to 6 years) has been associated with poor short term memory and retrieval ability (Kar et al, 2008; Sokovolic et al, 2014).

The structures of the brain that are related to memory are – cerebellum, hippocampus, amygdala and the cerebral cortex (Thompson, 1986). SGA children have been reported to have lower total cerebral volume (p = 0.002), cortical
surface area ($p = 0.0001$), while matter volume of cerebellum ($p < 0.0001$) and hippocampal volume ($p = 0.034$) than the AGA controls at 4 to 7 years of age (De Bie et al, 2011). Similar anatomical abnormalities have been seen at 13.5 and 15 years (Isaac et al, 2000; Raznahan et al, 2012). Further, SGA children who experienced catch-up growth continued to have significantly lower volumes the total cortical volume ($p = 0.008$), cortical surface area ($p = 0.001$), cerebrallar white matter ($p = 0.002$) and hippocampus ($p = 0.01$) as compared to AGA controls but higher than the SGA children without catch-up growth (De Bie et al, 2011).

In addition to birth weight and postnatal growth, in a study conducted among children aged 5 to 17 years, SES was significantly associated with the volume of hippocampus ($R^2$ change = 0.124, $p < 0.001$) and amygdala ($R^2$ change = 0.071, $p < 0.001$) (Noble et al, 2012).

3. **The planning performance of LBWS children is lowest as compared that of the other groups namely – NBWNS, NBWS and LBWNS.**

Planning is a cognitive process that is a part of a broader set of cognitive function known as executive functions. Not many studies have evaluated the planning performance in children born low birth weight or those who are stunted in childhood. Nevertheless, some studies have examined the executive function in these groups of children. Geva et al (2006) found that IUGR children scored lower in certain executive functions – visual attention ($p < 0.001$), form fluency ($p < 0.001$) and Tower of London ($p < 0.014$) than the controls at nine years of age. Aarnoundre-Moens et al (2009) carried out a meta-analysis which highlighted that preterm and very low birth weight children had poorer executive functions than the control. Ostgard et al (2014) found that SGA-born adolescents scored lower in the executive function domain than the non-SGA participants at 19 – 20 years of
age (p < 0.01). Further, Kar et al (2008) observed that stunted children aged 5 to 10 years had significantly lower executive functions (verbal fluency, design fluency) than the well-nourished controls (p < 0.01).

The prefrontal cortex is believed to play a crucial role in planning behavior. The prefrontal cortex is highly interconnected with other cortical and subcortical areas (Unterrainer and Owen, 2006). De Bie et al (2011) observed that SGA children had smaller cortical surface area (p < 0.0001) and white matter volume of cerebral and cerebellar hemispheres (p < 0.0001). Further, SGA children who experienced catch-up growth continued to have significantly lower volumes the total cortical volume (p = 0.008), cortical surface area (p = 0.001) and cerebellar white matter (p = 0.002) as compared to AGA controls but higher than the SGA children without catch-up growth.

4. There is no difference between the four groups namely – NBWNS, NBWS, LBWS and LBWNS in thinking.

Not much literature is available with regards to concept formation or concept identification. Waber et al (2014) compared the neuropsychological profile of adults who had experienced protein-energy malnutrition (PEM) in the first year of life with that of a healthy group. The PEM group had compromised concept formation after adjusting for the standard of living in childhood and adolescence as also the current intellectual ability.

3.7.2 Selection of the Sub-sample

The cognitive functions were assessed for children aged 3 to 4 years. A sub-sample of 20% of the total sample aged 3 to 4 years was drawn from the 1205 children who were assessed for nutritional status. Four groups were made based on the children’s birth weight and the current height-for-age Z score (HAZ) – (i) normal birth weight and non-
stunted (NBWNS), (ii) normal birth weight and stunted (NBWS), (iii) low birth weight and stunted (LBWS) and (iv) low birth weight and non-stunted (LBWNS). The inclusion criteria for selection of the participants are given in Table 3.2.

**Table 3.2: Criteria for Selection of Children for Cognitive Assessment**

<table>
<thead>
<tr>
<th>No</th>
<th>Description</th>
<th>Birth weight (kg)</th>
<th>HAZ (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal Birth Weight and Non-Stunted (NBWNS)</td>
<td>≥ 2.7</td>
<td>≥ -1.50</td>
</tr>
<tr>
<td>2</td>
<td>Normal Birth Weight and Stunted (NBWS)</td>
<td>≥ 2.7</td>
<td>≤ -2.00</td>
</tr>
<tr>
<td>3</td>
<td>Low Birth Weight and Stunted (LBWS)</td>
<td>&lt; 2.5</td>
<td>≤ -2.00</td>
</tr>
<tr>
<td>4</td>
<td>Low Birth Weight and Non-Stunted (LBWNS)</td>
<td>&lt; 2.5</td>
<td>≥ -1.50</td>
</tr>
</tbody>
</table>

In each group, a list of participants who met the inclusion criteria was prepared. From this list, 45 participants were selected in the NBWNS, NBWS and LBWS group each by simple random sampling. In the LBWNS group, 43 participants met the inclusion criteria. So, all the LBWNS children were selected for the assessment. The selection of the children for cognitive assessment is given in Figure 3.2. In all, 122 children completed all the cognitive tests.
FIGURE 3.2: SELECTION OF CHILDREN FOR COGNITIVE ASSESSMENT
3.7.3 Tools

*Seguin Form Board* – Seguin Form Board Test (SFBT) is one of the oldest performance tests developed by a French physician, Seguin. The test aims at measuring global non-verbal intelligence of children aged three to ten years. The tasks in the test indicate the children’s motor dexterity, visuo motor skills, spatial organization and speed of performance (Desai and Kothare, 2009). SFBT significantly correlated with other tests for intelligence such as – Draw-A-Man test \( r = 0.47 \), Coloured Progressive Matrices \( r = 0.34 \), Peabody Picture Vocabulary Test \( r = 0.31 \) and Stanford-Binet Test \( r = 0.38 \). SFBT is a valid and a reliable speed test of intelligence at lower age levels for Indian children with minimal influence of extraneous variables such as sex or education levels (Venkatesan, 1998; Basavarajappa et al, 2009). Recently, Basavarajappa et al (2009) presented revalidated norms of SFBT for Indian children aged 36 – 120 months from rural and urban areas belonging to different socioeconomic sections.

The board has ten wooden blocks of different shapes. Before administering the test, the blocks were taken out by the psychologist and stacked in a particular order as described in the manual. The child was instructed to place the varied shaped blocks in their corresponding recesses on the board as fast as possible. This entire exercise was repeated thrice. The time taken (seconds) to complete the task was recorded by the psychologist using a stopwatch. The shortest time taken to complete the task was considered to arrive at the mental age of the child using the norms for SFBT.

*Porteus Maze Test* - The Porteus maze test was designed to examine the child’s ability to ‘use planning capacity, prudence and mental alertness in a new situation of a concrete nature’. In addition to this, as impulsiveness, irresolution, suggestibility, nervousness and excitability interfere with the individual’s success; this test is believed to examine temperamental capacities as well. The test consists of a series of mazes graded in
difficulty and standardized for use for children aged three to 14 years of age. The test was first described in 1914 and revised in 1919. The reliability of the test was found to be 0.95. The maze test has good internal consistency with Cronbach’s alpha value of 0.81 (Krikorian and Bartok, 1998).

The procedure of the maze test is such that each individual is given an opportunity to realize his own errors by repeated trials. This allows the individual to learn from his errors/experience and re-adapt his methods. This unique characteristic feature of the maze test distinguishes it from the other performance tests. The tests were conducted and scored as per the standard procedure described in the manual (Porteus, 1924). The children were given a pencil and instructed to draw between the two black lines, without touching them. The psychologist illustrated the same by drawing an inch along the path from the starting (S) point in the direction of the arrow. In certain cases, the psychologist held the child’s hand to guide him/her till the first turn in the path. If the child made a mistake then, he/she was stopped immediately and was given a new sheet to begin. For tests of each year two trials were allowed. The number of errors allowed for every year has been given in the manual. The testing was continued until failure in the tests for two successive years occurred. The scoring pattern of the test is described in Table 3.3.
### TABLE 3.3: SCORING PATTERN OF THE PORTEUS MAZE TEST

<table>
<thead>
<tr>
<th>Test Year</th>
<th>Trials Allowed</th>
<th>Errors Permitted</th>
<th>Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>2</td>
<td>3</td>
<td>If on either trial there are not more than three errors in running off the path, III-year credit is given. Any attempt of following the outline of the test is given II-year credit.</td>
</tr>
<tr>
<td>IV</td>
<td>2</td>
<td>2</td>
<td>If on either trial there are not more than two errors in crossing the lines, IV-year credit is given.</td>
</tr>
</tbody>
</table>
| V         | 2              | 2               | a) Goes out from the first open road = full credit (1 yr)  
            |                 |                 | b) Goes out from second open road in the first trial and in the second trial goes out from the correct opening = full credit  
            |                 |                 | c) Goes out of second opening in both trials = half credit  
            |                 |                 | d) Goes in to a blocked road in the first and correct one in the second = half credit  
            |                 |                 | e) Goes in to a blocked road in the first and second opening in the second trial = no credit  
            |                 |                 | f) Goes in to blocked road in both the trials = failure |
| VI        | 2              | 2               | If child passes the test in first trial = one-year credit; passes in second trial = half credit |

**Recognition** - A set of 40 cards containing pictures of items used in day-to-day life that the children would be familiar with were selected. The picture cards were numbered consecutively from one to forty. The psychologist showed the first 20 cards one after the other giving sufficient time for the child to identify the picture. After this, the first 20 cards were randomly mixed with the remaining cards (i.e. card number 21 to 40). After mixing the two set of cards, the child was again shown all the forty cards one by one. For
every card, the child was asked to recognize if the psychologist had shown him/her the picture card earlier in the first set. The child’s response was noted down as follows –

(i) If the child correctly said that he was shown the card earlier then the response was recorded as ‘hit’.

(ii) If the child gives a wrong response by saying that he was not shown the card earlier (whereas the card was shown to him), his reply will be recorded as ‘miss’.

(iii) If the child correctly said that he was not shown the card earlier then the response was recorded as ‘correct rejection’.

(iv) If the child gives a wrong response by saying that he was shown the card earlier (whereas the card was not shown to him), his reply will be recorded as ‘false alarm’.

Recall - A set of 15 cards with pictures familiar to the child were selected. Care was taken so that the pictures used in ‘Recognition’ were not repeated for ‘Recall’. The psychologist showed all the 15 cards one after the other giving sufficient time for the child to identify each picture. Before showing the picture cards, the child was instructed to carefully look at each card and remember it. After showing all the cards, the child was asked to recall the names of the pictures shown to him/her. All the names that the child was able to recollect were noted down. If the child named any object which was not shown to him then, those responses were recorded as ‘false response’. All the names that the child could correctly recall were labeled as ‘true response’.
Hanfmann and Kasanin Concept Formation Test – This test was developed by Hanfmann and Kasanin in 1937. The test box contains 22 blocks differing in colour, shapes, size and height as given below –

- Colour – white, yellow, orange, green and blue
- Shape – square, rectangle, triangle, circle and quadrilateral
- Size – large and small
- Height – tall and flat

Each block has one of the four printed names at its bottom –

- Lag = large and tall
- Mur = small and tall
- Bik = large and flat
- Cev = small and flat

All the blocks were mixed together. The blocks were kept such that the printed names were not visible to the child. The child was told that the 22 blocks are actually of four different kinds of groups. Each group has the name printed at the bottom. The child was expected to examine the name and sort the blocks into the four groups. These groups were to be made on the basis of the concept of size and height. This test was modified to suit the young participants of this study.

The child was asked to sort the 22 blocks and place the similar looking blocks together. Once the child completed sorting, the psychologist asked him/her on what basis did he/she sort the blocks. The child was then asked to sort the blocks again. There were two possibilities –

(i) If the child used the same concept then, he/she was asked to explore any other way of sorting the same set of blocks. If the child used a new concept then, he
was asked to repeat the same again. However, if the child was unable to use any new concept then, the test was stopped.

(ii) If the child used a new concept then, the psychologist asked about the basis for sorting and was asked to repeat again. The child was asked to think of new ways to categorize the blocks. The test was stopped when the child was unable to think of new ways to do so.

The psychologist made a note of the different concepts that the child used while sorting.

3.7.4 Variables

**Independent Variables** -

- Normal Birth Weight and Non-Stunted (NBWNS)
- Normal Birth Weight and Stunted (NBWS)
- Low Birth Weight and Stunted (LBWS)
- Low Birth Weight and Non-Stunted (LBWNS)

**Dependent Variables** -

- Performance IQ
- Planning performance
- Memory performance
- Thinking

**Operational Definition** –

Independent Variables -

- Normal Birth Weight and Non-Stunted (NBWNS) – Normal birth weight (NBW) was defined as a weight ≥ 2.7 kg at birth. Children who presently had height-for-
age Z score (HAZ) of $\geq 1.5$ SD were regarded as non-stunted. So children with a birth weight $\geq 2.7$ and HAZ $\geq 1.5$ SD were considered as NBWNS.

- Normal Birth Weight and Stunted (NBWS) – Children born with a birth weight of $\geq 2.7$ kg and were presently stunted i.e HAZ $\leq -2.0$ SD were regarded as NBWS.

- Low Birth Weight and Stunted (LBWS) - Low birth weight (LBW) was defined as a weight $< 2.5$ kg at birth. Children with a birth weight $< 2.5$ kg and present HAZ $\leq -2.0$ SD were referred to as LBWS.

- Low Birth Weight and Non-Stunted (LBWNS) - Children born with a birth weight of $< 2.5$ kg and were presently non-stunted i.e HAZ $\geq 1.5$ SD were regarded as LBWNS.

Dependent Variables -

- Performance IQ – The shortest time (seconds) required to successfully complete SFBT and the total time (seconds) taken to complete the three trials of the test were considered as an indicator of performance IQ.

- Planning – Mental age (years) obtained on the Porteus Maze test reflected the planning performance of the children.

- Memory – Recall and recognition were used to assess memory performance. The number of correct responses in recall and recognition were indicative of memory performance.

- Thinking –Thinking was defined as the number of concepts (colour/shape/size) the children used to sort the blocks correctly.

3.7.5 Pilot Study

The pilot study was conducted on eight children from the above mentioned groups who were not included as a part of the main study. The tests were administered by two trained psychologists in the local language. The tests were administered individually to the child
in the premises of the anganwadi during their functioning hours. The tests administered were – Hanfmann and Kasanin Concept Formation test, Porteus Maze test, SFBT, recall, and recognition. Of these, the Hanfmann and Kasanin Concept Formation test and Porteus Maze test were modified to suit the young children. The modifications have been discussed below.

Porteus Maze test - Most of the children could understand the instructions and perform the test. However, during the pilot study, two children were unable to hold the pencil properly. The children were accustomed to writing on the slate using a pencil chalk. Therefore, for those children who could not hold the pencil, the mazes were drawn on the slate and the children were asked to perform the test on the slate instead of the paper. The children who were unable to hold the pencil, were able to hold the pencil chalk properly and perform the test.

Hanfmann and Kasanin Concept Formation Test - During the pilot study, some children were unable to understand what was meant by ‘sorting’ or arranging the blocks in ‘similar groups’. Therefore, the psychologists gave them an example of how to arrange items in similar groups by using items such as – pens, erasers and clips. The psychologist would jumble up the pens, erasers and clips and ask the child to separate the pens and so on. Care was taken that none of the concepts that the child could use while performing the actual test (color, shape or size) were used during the example. After doing this exercise, the children were able to understand the instructions for the test and perform accordingly.

3.7.6 Procedure

A detailed list of the children who met the inclusion criteria from the initial group of children who participated in the Phase I i.e. Nutritional Assessment was prepared. From this list, 45 children were selected in each of the groups by simple random sampling. An
area-wise as also *anganwadi*-wise lists were prepared of the children selected for the cognitive assessment.

The permission to conduct nutritional assessment as well as cognitive functions assessment was obtained before beginning the Phase I. However, the area supervisor was contacted again and briefed about the purpose of this part of the study and the study procedure. With the consent of the supervisor, the respective *anganwadi* workers were contacted. The purpose of the study along with the detailed procedure of the tests were explained to each *anganwadi* worker in the local language. Each one of them was also given the list of children who were selected for the tests. Some of the children also attended regular school in addition to the *anganwadi*. Therefore, a suitable date and time was fixed based the convenience of the *anganwadi* worker and the concerned children. All the tests were administered during the regular timings of the *anganwadi* (11:00 to 13:30 hours).

On the day of the tests, the parents/primary caregiver of each of the child was explained about the purpose and procedure of the study in Hindi/Marathi. A written informed consent was obtained from them (Appendix III). All the anthropometric measurements were taken again for each child.

The tests were administered in the *anganwadi* premises or a neighboring house. Most often, the rooms very small and would become congested if all the *anganwadi* children were seated. Therefore, the *anganwadi* worker would initially distribute the supplementary food to all the children and let the ones who were not selected go home slightly early.

All the tests were administered by two trained psychologists. Before beginning with the tests, the psychologists spent some time in building a rapport with the child. The parents and/or the *anganwadi* worker were also involved during this stage as the children were more familiar with them. Rapport was established by either having a casual conversation
with the child and/or playing games with them and/or by making them draw anything for their choice.

Some children were scared and cried. The *anganwadi* workers and/or parents were made to console them. A few cried inconsolably. They were not included in the study. Also, those who were ill at the time of the assessment were excluded from the study. Some children were woken up from the sleep and brought to the *anganwadi*. Such children were sleepy and were therefore asked to come on another day after completing their sleep. Those children who had to leave for school, they completed all the tests in two – three sessions on subsequent days.

Each psychologist administered the tests to one child at a time. Thus, two children could undergo simultaneous assessment. The two pairs of the psychologist and subject were made to sit at a comfortable distance from each other within the same room so that there was minimal disturbance or distraction. The parents (if present; many left immediately for work) and the *anganwadi* worker were requested to avoid giving any form of hints or clue to help the child.

The children were administered the tests in the following sequence – Hanfmann and Kasanin Concept Formation test, Recall, Porteus Maze test, Segiun Form Board test and Recognition. Special care was taken to keep sufficient time gap between Recall and Recognition to avoid any confusion among the children. The Cognitive Functions Record Sheet is provided in Appendix V.

### 3.8 Statistical Analysis:

The data were analyzed using Statistical Package for Social Sciences (SPSS) version 20.0. Data were analyzed separately for the two phases.
3.8.1 Assessment of Nutritional Status

The Z scores for all the anthropometric measurements were computed using WHO Anthro version 3.2.2. Descriptive statistics for all the anthropometric variables were presented as mean ± SD along with 95% confidence intervals (CI). Intra-observer variability in the measurement of anthropometric parameters were analysed by computing the intraclass correlation co-efficients (ICC). ICC were computed for weight, height, MUAC, head circumference, waist circumference and the four skinfold measurements.

Frequency distributions were carried out to determine the nutritional status of the children. Chi-square tests were done to examine the factors influencing the nutritional status of the children.

Karl Pearson’s correlation co-efficient was computed to study the association between birth weight and the other anthropometric indices and body fat measures. One-way analysis of variance (ANOVA) was carried out to see the difference in the anthropometric parameters, body fat (%), waist circumference, WHtR and SSF: TSF between the birth weight categories. One-way analysis of covariance (ANCOVA) was carried out to find out the difference in the anthropometric parameters, body fat (%), waist circumference, WHtR and SSF: TSF between the birth weight categories after adjusting for confounding variables - age, sex, family size, mother’s education, parity, birth order, preterm birth, duration of exclusive breastfeeding, per capita income and change in weight SD.

The children born as LBW, NBW and HBW were further classified on the basis of their change in weight SD in the following categories - catch-down growth, no change in weight SD and catch-up growth. One-way ANOVA was performed to study the differences in the anthropometric parameters, body fat (%), waist circumference, WHtR and SSF: TSF of LBW CDG, LBW no change in weight SD, LBW CUG, NBW CDG, NBW no change in weight SD, NBW CUG and HBW CDG children. Further, LBW, and
NBW children were grouped according to their HAZ status – stunted (S) and non-stunted (NS). One-way ANOVA was carried out to see the differences in the anthropometric parameters, body fat (%), waist circumference, WHtR and SSF: TSF in LBWS, LBWNS, NBWS and NBWNS children. HBW children were not included in this analysis as the number of HBW who were stunted and non-stunted was less.

Linear regression was carried out to examine the association of birth weight, current HAZ and change in weight SD with BMI and different measures of body fat in LBW and NBWs children separately. The dependent variables were – BMI, body fat (%), waist circumference, WHtR and SSF: TSF. The regression models were adjusted for sex, age and the duration of exclusive breastfeeding.

3.8.2 Cognitive Assessment

Kolmogorov-Smirnov and Shapiro-Wilk tests were used to test normality. The scores of the cognitive tests were not distributed normally (p value for both the test > 0.05). Therefore, non-parametric test, Kruskal Wallis test was used to compare the mean ranks of the scores obtained in the SFBT, recognition, recall and Porteus Maze test by the children in the four groups - NBWNS, NBWS, LBWS and LBWNS. Chi-square test was carried out to compare the frequency of the concepts used by children in the four groups. Chi-square test was also used to determine the differences in the sociodemographic characteristics of the four groups.