SYNOPSIS

Birth weight is one of the earliest indicators of a newborn’s health. It is a reflection of how well the baby has grown in utero. The size at birth bears consequences for his/her future life. Being small at birth is a risk factor for immediate survival and has long-term implications on health. On the other hand, being large at birth increases the risk for obesity and other metabolic disorders.

The prevalence of low birth weight (< 2500g) has been highest (~ 28%) in south central Asia, particularly in the Indian sub-continent (UNICEF, 2014). Low birth weight (LBW) is considered to be a major risk factor for undernutrition in low and middle-income countries. According to the United Nations (2012), in Asia, 27% of the children under the age of five years were stunted. Similarly, the prevalence of underweight and wasting were 19.3% and 13.7% respectively.

Undernutrition in early life has been associated with poor neurodevelopmental outcomes. The first 1000 days after conception are considered to be critical for brain growth and development. Early undernutrition is believed to cause structural changes in the developing brain of young children (Issac et al, 2000; Tolsa et al, 2004; Lodygensky et al, 2008). Further, undernutrition also restricts the child’s interaction with the environment which is potentially detrimental to his/her cognitive development. Studies from developed countries have found that children born with LBW or very low birth weight or intrauterine growth restriction (IUGR) had lower cognitive scores (Geva et al, 2006; Geva et al, 2009; Lohaugen et al, 2010; Tofail et al, 2012). LBW and stunting both have been independently related to poorer cognitive outcomes in children. However, the influence of both, birth weight and childhood nutritional status needs to be adequately explored as poor cognitive development may lead to lower productivity in the long-term.

The other long-term consequence of being born LBW is adverse metabolic complications. This relationship was first explored by Barker and his colleagues in 1989 who studied the association of birth weight and mortality from coronary heart disease (CHD) and found that the hazard ratio for death from CHD increased with the decrease in the birth weights. Similar trends were observed in studies conducted in Sweden and Finland (Forsen et al, 1997; Leon et al, 1998). In India, Stein et al (1996) pointed that low birth weight, short birth length and small head circumference at birth were associated with higher prevalence of CHD. In addition to CHD, thinness at birth has also been related to insulin resistance and type 2 diabetes mellitus in adult
life (Hales, et al., 1991; Curhan, et al., 1996; Lithell et al, 1996; Phillips, 1996). These findings have led to the development of fetal origins hypothesis.

More recently, studies conducted in children have also supported such findings (Challa et al, 2009; Lemos et al, 2010; Hemachandra et al, 2007). Higher body fat has been implicated in the pathogenesis of metabolic outcomes. India has a high prevalence of undernutrition among young children. However, not much is known about the body fat indices of these children. Also, there is a paucity of literature on the relationship between birth weight and body fat indices in the young children.

In India, many factors such as - poor socioeconomic status, child feeding practices, exposure to infections and nutritional transition may hamper the nutritional status, body fat and cognitive development of the growing children. Optimal nutritional status and cognitive development are essential for higher productivity and better future. In view of this and the sparse literature available in this area, the present study was undertaken.

**Objectives:** The objectives of this study were -

1. To study the nutritional status and the percent body fat of the children in the age group of 2 - 4 years.
2. To examine if the birth weight has any association with –
   a. Present nutritional status
   b. Body Mass Index (BMI)
   c. Waist circumference
   d. Percent body fat
3. To examine if there is any difference in the cognitive functions of children across the four groups namely - normal birth weight non-stunted (NBWNS), normal birth weight stunted (NBWS), low birth weight stunted (LBWS) and low birth weight non-stunted (LBWNS).

**Hypotheses:**

1. Birth weight has a positive association with weight-for-age Z (WAZ), height-for-age Z scores (HAZ) and weight-for-height (WHZ).
2. Birth weight has a positive association with percent body fat.
3. Birth weight has a positive association with BMI
4. Birth weight has inverse relation with waist circumference and waist-to-height ratio (WHtR)

5. Children born with low birth weight (LBW) and are presently stunted perform poorly in the cognitive test in comparison with others.
   a) The performance IQ of LBWS children is lowest as compared that of the other groups namely – NBWNS, NBWS and LBWNS.
   b) The memory performance of LBWS children is lowest as compared that of the other groups namely –NBWNS, NBWS and LBWNS.
   c) The planning performance of LBWS children is lowest as compared that of the other groups namely –NBWNS, NBWS and LBWNS.
   d) There is no difference between the four groups namely – NBWNS, NBWS, LBWS and LBWNS in thinking performance.

**Methodology:**
The present study was a cross-sectional study conducted among 1205 children aged 2 to 4 years of age. All the children were recruited from *anganwadis* situated in Mumbai city. The study was approved by the Independent Ethics Committee, Navi Mumbai (IEC no 09122).

**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 ICDS has divided Mumbai region in to two zones – city and suburbs. The ‘city’ zone constitutes of five projects (areas) while the ‘suburbs’ are made up of 28 projects. Of these, the Child Development Project Officers (CDPOs) of four projects from the suburbs and one from the city volunteered to participate in the study.

The projects that participated in this study were –
- In the ‘Suburbs’, Andheri -1, Andheri -2, Andheri -3 and Mankhurd participated in the study. Each of these projects had approximately 140 to 160 *anganwadis* each. A list of all the *anganwadis* was obtained from the respective CDPOs. From this list, every sixth *anganwadi* was selected by simple random sampling. Thus, in each project approximately, 25 *anganwadis* were selected to be included in the study.
In the ‘City’ zone, Wadala – Sewri participated in the study. This 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.

**Study Design:** The study was conducted in two phases – (i) Nutritional Assessment and (ii) Cognitive Assessment (Figure 1).

**Phase I: Assessment of Nutritional Status**

**Selection of Subjects:** From the selected anganwadis, all the children who met the inclusion criteria were recruited for the study.

Inclusion criteria: Children were included in the study if –

- Their age was between 24 to 48 months on the day of the survey.
They had authentic birth weight records such as the discharge card of the hospital where the child was born or the *anganwadi* register.

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

- Suffering from any chronic illness such as tuberculosis and chronic diarrhea, that may influence the nutritional status
- Born with congenital anomalies.
- Born extremely premature (< 28 weeks of gestational age)

The parents and/or the guardian of the child were informed about the study in the local language. The children were finally included in the study only after obtaining a written informed consent from them. Thus, 972 children from the suburbs and 233 from the city were included in the study.

**Tools/Methods of Data Collection:**

1) Interview Schedule: Information regarding the family members, parent’s education and occupation was collected from the parent or the guardian via personal interview by using a structured interview schedule. The interview schedule included -

   (i) Family details – Family details included – the total number of family member (including the children), their education level, 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.

   (ii) Details about the mother – The mother’s age at the time of subject’s birth was collected along with the total number of children she has and the subject’s birth order. Also, she was asked if the subject was born preterm or full-term.

   (iii) 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.

   (iv) Child’s Medical History - The parent or the guardian 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.

(v) Child’s Morbidity - Information was sought about the child’s morbidity in the last 15 days. Details of the duration of the illnesses were recorded.

II} Age and Birth Weight: 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. Age was calculated from the date of birth. Birth weight of the children was collected from the *anganwadi* records or the hospital discharge card.

III} Anthropometric measurements: The anthropometric measurements listed below were measured.

- Weight – An electronic digital weighing scale (Dr Gene Wellness; Model MS8270) with an accuracy of 0.1 kg was used to weigh the children. Children were weighed with minimal clothing. Each 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 the standard anthropometric kit. 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) – A non-extensible, flexible and accurate measuring tape was used to measure the MUAC. The child was made to stand erect with the arm flexed at a right angle. 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 – A non-extensible, flexible and accurate measuring tape was used to measure the waist circumference. Waist circumference was measured midway between
the lowest rib margin (costal margin) and superior anterior ileac crest with a non-extensible, flexible and accurate tape-measure (Seidell, 1991).

- **Head circumference** – A non-extensible, flexible and accurate measuring tape was used to measure the head circumference. Head circumference was measured at the largest circumference around the mid-forehead or the occipitofrontal area with a non-stretchable, flexible and accurate tape-measure to the nearest 0.1 cm. The measurement was taken thrice and the largest reading was used for further calculations (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 (TSF)** – 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 90° angle. With the arm hanging freely at the side, the calipers were applied vertically above the olecarnon at the marked level.
  - **Biceps (BSF)** – 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 (SuSF)** – The measurement was taken just above the iliac crest, in the mid-axillary line with the arm slightly abducted.
  - **Subscapular (SSF)** – 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 was used for further calculations for all except head circumference where largest measurement was used.
**Data Collection:**
The data collection first begun in Andheri -1 followed by Andheri – 3, Andheri – 2, Wadala-Sewri and Mankhrud. After selecting the *anganwadis*, each CDPO and/or area supervisor was contacted to decide upon a convenient time frame for data collection. Each area supervisor was briefed about the nature of work. After seeking her permission, the *anganwadi* workers of the selected *anganwadis* were approached. They were explained in detail about the purpose of the study and the procedure in the local language. A convenient date and time was decided for data collection so as to avoid any undue disturbance to the regular activities of the *anganwadi* and that of the study participants. The *anganwadi* worker was requested to inform the children and their parents about the date and time of data collection. They were also requested to carry with them records of birth weight and date of birth of their child on the day of data collection.

On the day of data collection, first, the anthropometric measurements of the children were taken so that they could resume their routine activities at the *anganwadi*. Later, the parents/ guardian were interviewed to collect the details about the family and the child. The parents were informed about the nutritional status of their child and were counseled, if required. After completing each project, a detailed report of the nutritional status of all the children surveyed in that project was submitted to the respective CDPO.

**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. Anthropometric measurements – weight, height, mid-upper arm circumference, head circumference, waist circumference and skinfold thickness (biceps, triceps, subscapular and supraileac) were taken. Blood pressure was measured using a digital BP monitoring machine (OMRON HEM 7113) and a pediatric cuff (OMRON HEM 24-CI). However, during measurements, the cuff was found to be larger for many children. As a result of which, blood pressure could not be recorded for those children. In view of this, the variable of blood pressure was excluded from the study.
Calculation of Nutritional/Body Fat Indices:

I) Body Mass Index (BMI) - BMI (kg/m²) = Weight (kg)/Height (m)²

II) Z – scores – WHO Anthro 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 (MAZ), Head circumference-for-age (HCZ), Triceps-for-age (TSFZ) and Subscapular-for-age (SSFZ). The cut-offs and corresponding interpretation of these indicators is given in Table 1.

Table 1: Cut-offs and Interpretation of the Z Scores of Anthropometric Indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Cut-offs</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight-for-age (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 (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 (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>BMI-for-age (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>
<tr>
<td>MUACZ, Head Circumference Z (HCZ), TSFZ, 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>

III) Body Fat (%) - A number of 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 as compared with the results of DEXA. More than 75% of the values were within 5% of the estimated DEXA values. Thus, percent body fat was calculated using the equation given by Slaughter et al (1988). This equation is used for children who have their triceps 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

IV} Waist-to-height ratio (WHtR) and SSF to TSF ratio were calculated.

V} Weight Change SD - Weight change was calculated using the present WAZ and that at the time of birth. Weight change = Present WAZ – 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).

**Phase II: Assessment of Cognitive Functions**

*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 (n = 655) was drawn from children who were assessed for nutritional status. Four groups were made based on the children’s birth weight and the current 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 criteria for including the children in the respective groups are given in Table 2.

**Table 2: Criteria for Selection of Children for Cognitive Assessment**

<table>
<thead>
<tr>
<th>Group 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>

Figure 2 gives the details of the total number of children who completed all the tests in the four groups.
Figure 2: Selection of Children for Assessment of Cognitive Functions

Children aged 3 to 4 years (n = 655)

- **NBWNS** 146 children met the inclusion criteria
  - n = 45 were selected by simple random sampling
    - Of these, two children had shifted their residence; three were out of town and remaining three were ill at the time of assessment
      - n = 37 were available and completed all the tests
- **NBWS** 73 children met the inclusion criteria
  - n = 45 were selected by simple random sampling
    - Of these, five were out of town; three were ill at the time of assessment; three cried inconsolably during assessment and four did not come to the anganwadi for the assessment
      - n = 30 were available and completed all the tests
- **LBWS** 57 children met the inclusion criteria
  - n = 45 were selected by simple random sampling
    - Of these, three were out of town; three could not be contacted; one was ill at the time of assessment; two cried inconsolably during assessment; three did not complete all the tests and three did not come to the anganwadi for the assessment
      - n = 30 were available and completed all the tests
- **LBWNS** 43 children met the inclusion criteria
  - Of these, three were out of town; four were ill at the time of assessment; five cried inconsolably during assessment; four did not complete all the tests and two did not come to the anganwadi for the assessment
      - n = 25 were available and completed all the tests

Total number of children who completed the test = 122
Tools - All the tests given below were administered by two trained psychologists.

I) 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 & 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 test was administered as per the procedure given in the manual (Goel & Bhargava, 1990).

II) 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 (Porteus, 1924). The maze test has good internal consistency with Cronbach’s alpha value of 0.81 (Krikorian & Bartok, 1998). The tests were conducted and scored as per the standard procedure described in the manual (Porteus, 1924).

III) 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. 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 examiner 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 examiner 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 examiner made a note of the different concepts that the child used while sorting.

IV} 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’.

V} 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’.

Variables:
I} Independent Variables - Normal Birth Weight and Non-Stunted (NBWNS), Normal Birth Weight and Stunted (NBWS), Low Birth Weight and Stunted (LBWS) and Low Birth Weight and Non-Stunted (LBWNS).
II} Dependent Variables - Performance IQ, planning performance, thinking performance and memory performance

Operational Definition:
I} 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 ≥ 1.5 SD were regarded as non-stunted. So children with a birth weight ≥ 2.7 and HAZ ≥ 1.5 SD were considered as NBWNS.
- Normal Birth Weight and Stunted (NBWS) – Children born with a birth weight of ≥ 2.7 kg and were presently stunted i.e HAZ ≤ -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 ≤ -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 ≥ 1.5 SD were regarded as LBWNS.

II} Dependent Variables -
- Performance IQ – The shortest test (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 performance – Mental age (years) obtained on the Porteus Maze test reflected the planning performance of the children.
• Thinking performance – Thinking was defined as the number of concepts (colour/ shape/ size) the children used to sort the blocks correctly.

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

**Pilot Study**

The pilot study was conducted on two children from each of 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 every child in the premises of the *anganwadi* during their functioning hours. The tests administered were – Hanfmann Kasanin Concept Formation test, Porteus Maze test, seguin form board, recall, and recognition. Of these, the Hanfmann 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 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.

**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 and procedure of this part of the study. With the consent of the supervisor, the respective anganwadi workers were contacted. The purpose of the study and 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 on the convenience of the anganwadi worker and the children. The anthropometric measurements of the selected children were measured again. 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/guardian of each of the child was explained about the purpose and procedure of the study in Hindi/Marathi and written informed consent was obtained from them. The tests were administered in the anganwadi premises or a neighboring house. 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 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.

**Statistical Analysis:**

The Z scores for all the anthropometric measurements were computed using WHO Anthro version 3.2.2. The data was analyzed using Statistical Package for Social Sciences (SPSS) version 20.0. For the data on nutritional assessment, descriptive statistics for all the anthropometric variables were presented as mean ± SD along with 95% confidence intervals (CI). Frequency distributions were carried out to determine 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.

The scores of the cognitive tests were not distributed normally. 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.

**Results**

**Characteristics of the Sample:**

Of the 1205 children, 51.8% (624) were boys with 46.0% (287) being in the age group of 2 to 3 years while remaining 54.0% (337) were 3 to 4 years old. Of the total 581 girls, 45.3% (263) were 2 – 3 years and 54.7% (318) were 3 – 4 years old.

**Sociodemographic Profile:** About three fourth of the participants were Hindus (n = 898; 74.3%) while 24.6% (297) were Muslims and the remaining 1% were Christians and Jains. The total number of family members ranged from two to 28 with a mean of 5.7 ± 2.5. Forty-two percent (506) children lived in nuclear families while the remaining 58% lived in joint families. Around 13% mothers and 7% fathers were illiterate. About one-third of the fathers and one-fourth of the mothers had completed matriculation. A small proportion of mothers (5%) and fathers (7.1%) had completed graduation. Most of the mothers (82.8%) were housewives and
8.9% mothers worked as a domestic help/cook or as labourers at construction sites while about 6.4% of the mothers were employed in the service industry. Most of the fathers (40.5%) were employed in the service industry, one-fourth (28.3%) were semi-skilled workers who earned daily wages and 17.1% were drivers who either drove auto rickshaws or taxis or trucks. None of them owned these vehicles. Some (11.7%) either had their own small grocery shops or were involved in small-scale businesses. The per capita income ranged from as low as Rs 100 to Rs 15000 per month with the mean being Rs 2518.75 ± 1613.2.

**Birth Weight:** The birth weight of the children ranged from 0.85 to 5.50 kg, with the mean being 2.74 ± 0.5 kg and the median being 2.7 kg. In all, 20.5% (247) had low birth weight (< 2.5 kg), 78.6% (947) had normal birth weight (2.5 – 4.0 kg) and 0.9% (11) had high birth weight (> 4.0 kg).

**History of Hospitalization** – Almost 28% of the children (n = 334) had been hospitalized at least once in the past with the age at the first hospitalized ranging from 0 to 48 months and the mean age being 3.76 ± 8.4 months. The duration of hospitalization ranged from one to 60 days. Most common reasons for hospitalization were diarrhea (23.4%), viral fever (23.4%) followed by respiratory infections (20.4%). Thirty nine percent children (n = 470) had fallen ill in the previous 15 days. Seventy percent children had cold and cough while 44.6% had fever and 7.4% had diarrhea.

**Breastfeeding and Complementary Feeding** – All except 32 children were breastfed. The World Health Organization (WHO) recommends EBF for the first six months of life. Among the breastfed children 30.3% (n = 335) were exclusively breastfed for the first six months of life. The total duration of breastfeeding (TBF) ranged from 0.25 to 48 months with a mean of 20.75 ± 10.3 months. As per the WHO, complementary feeding should be initiated by six months of age. In this study, complementary foods were introduced between one month to 36 months of age with a mean of 7.65 ± 4.0 months. Sixty-one percent participants (736) received complementary foods between the ages of six to eight months while 9.2% received before six months of age.
**Nutritional Status of the Children:**

Nutritional status of the children was assessed using a variety of anthropometric indices. Weight-for-age Z scores (WAZ), height-for-age Z scores (HAZ), weight-for-height Z scores (WHZ), BMI-for-age Z scores (BAZ), MUAC-for-age Z scores (MUACZ) and head circumference-for-age Z scores (HCZ) were computed.

Head circumference is directly associated with the total brain volume (Ivanovic et al, 2004). The mean HCZ score was -1.08 ± 0.9 SD and 16.9% (201) children had microcephaly. MUAC is used as measure to assess wasting in non-emergency situations as it is a strong predictor of mortality (WHO, 1995). The mean MUAC and MUACZ scores were 14.79 ± 1.1 cm and -0.76 ± 0.9 SD respectively. According to MUACZ, 8.5% (102) were undernourished.

The mean WAZ, HAZ and WHZ were -1.60 ± 1.1 SD, -1.55 ± 1.2 and -1.05 ± 1.0 SD respectively. Low weight-for-age is an indicator of underweight while low height-for-age indicates stunting and low weight-for-height reflects wasting. The prevalence of undernutrition and overnutrition are presented in Figure 3. Overall, 36.1% children were underweight, 35.2% were stunted and 16.6% were wasted. Of these, 8.1%, 10.8% and 1.7% children were severely underweight, stunted and wasted respectively.

Figure 3: Prevalence of Undernutrition and Overnutrition among the Participants

BAZ score is used to assess thinness as well as overweight/obesity in children. The mean BAZ score was -0.89 ± 1.0 SD. Overall, 11.2% and 1.4% were found to be thin and severely thin respectively while, 3.2% and 0.6% children were overweight and obese respectively.
Stunting is an indicator of chronic undernutrition while underweight reflects both acute and chronic undernutrition. Wasting, on the other hand, indicates acute undernutrition. In this study, one-third children were underweight and a similar percentage was stunted. The prevalence of wasting was relatively less. Also, prevalence of overnutrition was low in this group. Thus, it can be said that almost one-third children were chronically undernourished.

Various factors influenced the nutritional status of the children. Higher prevalence of underweight (UW) and stunting (S) were associated with lower per capita income (UW: χ² = 19.854, S: χ² = 23.745; p < 0.01) lower levels of maternal education (UW: χ² = 17.013, S: χ² = 35.341; p < 0.01), lesser duration of EBF (UW: χ² = 22.259, S: χ² = 31.188; p < 0.01) and having more than two children in the family (UW: χ² = 15.671, S: χ² = 28.277; p < 0.001). In addition to these, birth weight independently and in association with postnatal growth influenced all the nutritional status indices as discussed below.

**Birth Weight and Anthropometric Indices** – Birth weight showed strong positive correlation with the WAZ (r = 0.303, p = 0.000), HAZ (r = 0.210, p = 0.000), WHZ (r = 0.259, p = 0.000), BAZ (r = 0.225, p = 0.000), MUACZ (r = 0.259, p = 0.000) and HCZ (r = 0.212, p = 0.000).

The influence of birth weight on nutritional status is confounded by certain factors. Therefore, one-way ANCOVA was carried to see the differences between the mean nutritional indices across the birth weight categories after adjusting for the following covariates - age, sex, family size, mother’s education, parity, birth order, preterm birth, per capita income and weight change SD (Table 3).

**Table 3: Adjusted Mean (SE) Anthropometric Indices in Birth Weight Categories**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>LBW (n = 247) Mean (SE)</th>
<th>NBW (n = 947) Mean (SE)</th>
<th>HBW (n = 11) Mean (SE)</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAZ</td>
<td>-2.77 (0.053)a</td>
<td>-1.32 (0.024)b</td>
<td>0.94 (0.226)c</td>
<td>325.685</td>
<td>0.000</td>
</tr>
<tr>
<td>HAZ</td>
<td>-2.57 (0.071)a</td>
<td>-1.32 (0.033)b</td>
<td>0.58 (0.302)c</td>
<td>133.830</td>
<td>0.000</td>
</tr>
<tr>
<td>WHZ</td>
<td>-1.93 (0.061)a</td>
<td>-0.84 (0.028)b</td>
<td>0.85 (0.262)c</td>
<td>134.882</td>
<td>0.000</td>
</tr>
<tr>
<td>BAZ</td>
<td>-1.64 (0.064)a</td>
<td>-0.72 (0.03)b</td>
<td>0.73 (0.280)c</td>
<td>85.712</td>
<td>0.000</td>
</tr>
<tr>
<td>MUACZ</td>
<td>-1.61 (0.055)a</td>
<td>-0.55 (0.025)b</td>
<td>0.98 (0.237)c</td>
<td>154.123</td>
<td>0.000</td>
</tr>
<tr>
<td>HCZ</td>
<td>-1.72 (0.067)a</td>
<td>-0.97 (0.031)b</td>
<td>-0.17 (0.289)c</td>
<td>52.623</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Means adjusted for age, sex, family size, mother’s education, parity, birth order, preterm birth, per capita income and weight change SD. Values with different superscripts are significantly different from each other.
After adjusting for covariates, the LBW children were found to have significantly lower WAZ, HAZ, WHZ, BAZ, MUACZ and HCZ than both, the NBW and HBW children. All the anthropometric indices of the NBW children were significantly greater than the LBW but lower than the HBW children. Thus, birth weight appears to influence the nutritional status of children in their early years.

**Birth Weight, Postnatal Growth and Anthropometric Indices** - The change in the weight SD from birth till 2 to 4 years is an important variable that may influence the growth and nutritional status of the children. In this study, the growth (i.e. weight change SD) of LBW, NBW and HBW children varied considerably. Therefore, the differences between the anthropometric indices in the LBW, NBW and HBW children were examined with respect to their weight change SD categories – catch-down growth, no weight change and catch-up growth (Table 4).

**Table 4: Mean Anthropometric Indices of LBW, NBW and HBW Children in Different Weight Change SD Categories**

<table>
<thead>
<tr>
<th>Z scores</th>
<th>LBW</th>
<th>NBW</th>
<th>HBW</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CDG (22)</td>
<td>No change (78)</td>
<td>CUG (147)</td>
<td>CDG (447)</td>
<td>No change (370)</td>
</tr>
<tr>
<td>WAZ</td>
<td>-3.57 ± 0.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-2.51 ± 0.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-1.58 ± 0.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-2.08 ± 0.8&lt;sup&gt;d&lt;/sup&gt;</td>
<td>-1.26 ± 0.7&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>HAZ</td>
<td>-3.46 ± 0.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-2.18 ± 0.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-1.56 ± 1.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-2.01 ± 1.1&lt;sup&gt;bd&lt;/sup&gt;</td>
<td>-1.25 ± 0.9&lt;sup&gt;ce&lt;/sup&gt;</td>
</tr>
<tr>
<td>WHZ</td>
<td>-2.31 ± 0.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-1.87 ± 0.7&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>-1.03 ± 0.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-1.35 ± 0.8&lt;sup&gt;d&lt;/sup&gt;</td>
<td>-0.81 ± 0.8&lt;sup&gt;ce&lt;/sup&gt;</td>
</tr>
<tr>
<td>BAZ</td>
<td>-1.92 ± 0.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-1.62 ± 0.8&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>-0.87 ± 0.9&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>-1.14 ± 0.9&lt;sup&gt;bed&lt;/sup&gt;</td>
<td>-0.70 ± 0.8&lt;sup&gt;ce&lt;/sup&gt;</td>
</tr>
<tr>
<td>MUACZ</td>
<td>-2.07 ± 0.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-1.49 ± 0.7&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>-0.78 ± 0.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-1.07 ± 0.7&lt;sup&gt;d&lt;/sup&gt;</td>
<td>-0.49 ± 0.7&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>HCZ</td>
<td>-2.40 ± 0.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-1.57 ± 0.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-1.15 ± 0.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-1.29 ± 0.9&lt;sup&gt;bed&lt;/sup&gt;</td>
<td>-0.86 ± 0.8&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

CDG – Catch-down growth, CUG – catch-up growth. Values with different superscripts are significantly different from each other.
The LBW children who attained catch-up growth had significantly higher WAZ, HAZ, WHZ, MUACZ and HCZ than the LBW children who had either catch-down or no weight change. Further, the LBW children with catch-up growth were found to be at par with the NBW children who had no weight change in all the anthropometric indices. The NBW children who experienced catch-down growth had lower WAZ, HAZ, WHZ and MUACZ than the LBW ones who had catch-up growth. The NBW children with catch-up had significantly higher anthropometric indices than all others except HBW ones. This could be because of the smaller number of children in the HBW group. Thus, children who experienced growth faltering in their fetal and/or early postnatal had lower anthropometric indices than the LBW CUG, NBW no change and NBW CUG.

**Body Fat Indices in the Children:**

Skinfold thicknesses were measured at triceps, biceps, subscapular and supraileac. The triceps and subscapular measurements were used to calculate the total percent body fat. The mean body fat indices are given in Table 5.

<table>
<thead>
<tr>
<th>Table 5: Mean Body Fat Indices of the Study Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameter</strong></td>
</tr>
<tr>
<td>TSFZ</td>
</tr>
<tr>
<td>SSFZ</td>
</tr>
<tr>
<td>Body Fat (%)</td>
</tr>
<tr>
<td>Waist Circumference (cm)</td>
</tr>
<tr>
<td>WHtR</td>
</tr>
<tr>
<td>SSF: TSF</td>
</tr>
</tbody>
</table>

The mean TSFZ and SSFZ scores were closer to zero. According to the WHO (2006) classification, about 96% had normal TSFZ while 86% had normal SSFZ scores (Figure 4a).
Figure 4: (a) Distribution of Children according to TSFZ and SSFZ Categories and (b) Waist Circumference Percentiles

Waist circumference is considered to be a good predictor of visceral adipose tissue and metabolic risk (Kuriyan et al, 2011; Messiah et al, 2012; Khadilkar et al, 2014). Children were classified in the different waist circumference percentiles (Figure 4b) developed by Khadilkar et al (2014) for Indian children aged 2 to 18 years. Khadilkar et al (2014) suggested 70th percentile as a cut-off for risk of metabolic syndrome. Accordingly, in the present study, 16.8% (202) children had their waist circumferences above 70th percentile.

Along with waist circumference, WHtR is also indicative of central adiposity and cardiovascular risk. The value of 0.5 is used as a cut-off for both children as well as adults (Kuriyan et al, 2011). In the present study, 69.9% (842) had WHtR > 0.5 while 30.1% (363) had a ratio < 0.5. The ratio of SSF to TSF is also used as an indicator of central adiposity (Bavdekar et al, 1999). The mean ratio was 0.71 ± 0.1. Currently, there are no reference values to classify children on the basis of SSF to TSF ratio. However, higher the ratio, greater the metabolic risk. In the present study, almost 47% children had a ratio above 0.70.

Thus, though over one-third of the children were chronically undernourished, more than 85% of them had normal TSFZ and SSFZ scores and waist circumference > 15th percentile. This suggests that despite of being undernourished, these children exhibited a tendency to accumulate more body fat.
Factors influencing body fat indices were examined. EBF for more than three months was associated with higher body fat ($\chi^2 = 13.372, p = 0.037$) and waist circumferences ($\chi^2 = 16.656, p = 0.011$). Birth weight and postnatal growth also appeared to influence the body fat indices.

**Birth Weight and Body Fat Indices**

Birth weight showed positive correlation with TSFZ ($r = 0.119, p = 0.000$), SSFZ ($r = 0.135, p = 0.000$), percent body fat ($r = 0.123, p = 0.000$). There was no significant correlation of birth weight with waist circumference ($r = 0.076, p = 0.08$), WHtR ($r = 0.034, p = 0.238$) and the ratio of SSF to TSF ($r = 0.027, p = 0.345$). One-way ANCOVA was carried to see the differences between the mean body fat indices across the birth weight categories after adjusting for the following covariates - age, sex, family size, mother’s education, parity, birth order, preterm birth, per capita income and weight change SD (Table 6).

**Table 6: Adjusted Mean Body Fat (SE) Indices in the Birth Weight Categories**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>LBW (n = 247) Mean (SE)</th>
<th>NBW (n = 947) Mean (SE)</th>
<th>HBW (n = 11) Mean (SE)</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSFZ</td>
<td>-0.67 (0.061)a</td>
<td>-0.31 (0.028)b</td>
<td>0.17 (0.260)bc</td>
<td>15.343</td>
<td>0.000</td>
</tr>
<tr>
<td>SSFZ</td>
<td>-1.37 (0.077)a</td>
<td>-0.65 (0.035)b</td>
<td>-0.17 (0.329)bc</td>
<td>30.207</td>
<td>0.000</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>11.36 (0.161)a</td>
<td>12.59 (0.074)b</td>
<td>13.54 (0.689)bc</td>
<td>22.658</td>
<td>0.000</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>42.83 (0.678)a</td>
<td>45.95 (0.312)b</td>
<td>51.33 (2.904)bc</td>
<td>9.330</td>
<td>0.000</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.49 (0.008)</td>
<td>0.50 (0.004)</td>
<td>0.52 (0.034)</td>
<td>0.778</td>
<td>0.460</td>
</tr>
<tr>
<td>SSF: TSF</td>
<td>0.69 (0.008)</td>
<td>0.71 (0.004)</td>
<td>0.66 (0.036)</td>
<td>2.649</td>
<td>0.071</td>
</tr>
</tbody>
</table>

Means adjusted for family size, mother’s education, parity, birth order, preterm birth, per capita income and weight change SD. Values with different superscripts are significantly different from each other.

After adjusting for covariates, the mean TSFZ, SSFZ, body fat (%) and waist circumference were significantly lower in the LBW children than the NBW and HBW children. No differences were seen in the mean TSFZ, SSFZ, body fat (%) and waist circumference between NBW and HBW children. This could be because of the smaller number of children in the HBW group. Also, there were no differences in the mean WHtR and ratio of SSF: TSF between the LBW, NBW and HBW children. Thus, though the LBW children had lower skinfold and total body fat (%) than the NBW ones, they had similar WHtR and ratio of SSF: TSF. This possibly indicates towards a tendency of accumulating abdominal fat at an early age.
### Birth Weight, Postnatal Growth and Body Fat Indices

The rate of postnatal growth seems to influence the body fat in childhood. In view of this, the differences in the body fat indices between the LBW, NBW and HBW children with different growth trajectories were examined (Table 7).

**Table 7: Mean Body Fat Indices of LBW, NBW and HBW Children in Different Weight Change SD Categories**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LBW (CDG 22)</th>
<th>No change (78)</th>
<th>CUG (147)</th>
<th>NBW (CDG 447)</th>
<th>No change (370)</th>
<th>CUG (130)</th>
<th>HBW (CDG 11)</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSFZ</td>
<td>-0.59 ± 0.9</td>
<td>-0.50 ± 0.7</td>
<td>-0.48 ± 0.8</td>
<td>-0.50 ± 0.8</td>
<td>-0.29 ± 0.8</td>
<td>0.00 ± 0.8</td>
<td>-0.20 ± 0.5</td>
<td>7.937</td>
<td>0.000</td>
</tr>
<tr>
<td>SSFZ</td>
<td>-1.59 ± 1.5</td>
<td>-1.14 ± 1.1</td>
<td>-0.85 ± 1.1</td>
<td>-0.98 ± 1.0</td>
<td>-0.62 ± 1.0</td>
<td>-0.16 ± 1.0</td>
<td>-0.97 ± 0.9</td>
<td>15.061</td>
<td>0.000</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>11.67 ± 2.6</td>
<td>11.69 ± 1.9</td>
<td>12.09 ± 2.3</td>
<td>12.07 ± 2.2</td>
<td>12.62 ± 2.2</td>
<td>13.36 ± 2.4</td>
<td>12.12 ± 1.4</td>
<td>8.285</td>
<td>0.000</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>40.22 ± 13.3</td>
<td>44.11 ± 7.5</td>
<td>45.35 ± 9.7</td>
<td>44.78 ± 8.2</td>
<td>45.96 ± 10.1</td>
<td>47.06 ± 12.5</td>
<td>47.92 ± 3.3</td>
<td>2.601</td>
<td>0.000</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.47 ± 0.1</td>
<td>0.50 ± 0.1</td>
<td>0.50 ± 0.1</td>
<td>0.51 ± 0.1</td>
<td>0.51 ± 0.1</td>
<td>0.51 ± 0.1</td>
<td>0.52 ± 0.0</td>
<td>0.379</td>
<td>0.893</td>
</tr>
<tr>
<td>SSF:TSF</td>
<td>0.64 ± 0.1</td>
<td>0.68 ± 0.1</td>
<td>0.71 ± 0.1</td>
<td>0.70 ± 0.1</td>
<td>0.71 ± 0.1</td>
<td>0.73 ± 0.1</td>
<td>0.65 ± 0.1</td>
<td>4.231</td>
<td>0.000</td>
</tr>
</tbody>
</table>

CDG – Catch-down growth, CUG – catch-up growth. Values with different superscripts are significantly different from each other.

The mean TSFZ, SSFZ, body fat (%), WC and ratio of SSF to TSF of the all the LBW children (irrespective of their postnatal growth), the NBW children with catch-down and no change were similar. NBW children with catch-up growth had significantly higher mean TSFZ, SSFZ and body fat than the rest of the groups except HBW children. Further, the mean WC of the NBW children with CUG was higher than the LBW children who experienced catch-down but similar to all the other groups. Likewise, the mean SSF: TSF of the NBW children with CUG was higher than the LBW children who experienced catch-down and no weight change but similar to all the other groups. Thus, in spite of having lower total body fat (%), the LBW children with CUG and
NBW children with CDG and no change exhibited a tendency towards central distribution of body fat.

Overall, the LBW and NBW groups with poor postnatal growth (LBW CDG, LBW no change and NBW CDG) had lower anthropometric measurements than other groups. In spite of having lower nutritional indices, the LBW groups, NBW CDG and NBW no change had similar total body fat but lower than the NBW CUG. Further, the LBW CUG, NBW CDG and NBW no change had similar waist circumference and ratio of SSF: TSF as that of NBW CUG. Thus, the LBW CUG and the NBW CDG children had a tendency of conserving body fat in spite of having lower body mass as compared to the NBW no change and NBW CUG groups. If this tendency of conserving body fat continues then, it may increase the risk of adverse metabolic outcomes later in life.

Besides this, birth weight and early growth can influence the cognitive functions of children and may bear consequences on their academic performance, overall growth, development and work productivity.

**Cognitive Functions of the Children:**

The first 1000 days of life are crucial for the growth and development of the brain. Therefore, in the present study, the influence of birth weight and current nutritional status on the cognitive functions of children was also examined. The cognitive tests that were administered were – seguin form board test (SFBT), recognition, recall, Porteus Maze test (PMT) and Hanfmann Kasanin Concept Formation test.

### Table 8: Mean Ranks of the Performance in the SFBT and PMT by the Four Groups

<table>
<thead>
<tr>
<th></th>
<th>NBWNS</th>
<th>NBWS</th>
<th>LBWS</th>
<th>LBWNS</th>
<th>χ2</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>37</td>
<td>30</td>
<td>30</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SFBT- Shortest Time</td>
<td>57.66</td>
<td>68.25</td>
<td>65.73</td>
<td>54.00</td>
<td>3.085</td>
<td>0.379</td>
</tr>
<tr>
<td>SFBT- Total Time</td>
<td>58.23</td>
<td>68.15</td>
<td>62.83</td>
<td>56.76</td>
<td>1.869</td>
<td>0.600</td>
</tr>
<tr>
<td>Porteus Maze Test</td>
<td>60.59</td>
<td>56.75</td>
<td>61.93</td>
<td>68.02</td>
<td>1.652</td>
<td>0.648</td>
</tr>
</tbody>
</table>
Performance IQ –
SFBT is indicative of a range of cognitive functions - motor dexterity, visuo motor skills, spatial organization and speed of performance (Desai & Kothare, 2009). No significant differences were seen in the time taken to complete the test. However, the mean rank of the time taken by the children in the LBWNS group was the lowest followed by NBWNS, LBWS and NBWS (Table 8). This means that the children in the LBWNS group took the least time to complete followed by NBWNS, LBWS and NBWS. The mean rank of the NBWS was the highest indicating that these children took the maximum time to complete the test in comparison with all the other groups.

Planning Performance –
The Porteus Maze test assessed the planning performance. The scores of the Porteus Maze test are given as mental ages. No significant differences were seen in the mental ages of the groups. But, the mean rank for the mental ages was the highest for LBWNS group followed by LBWS, NBWNS and NBWS. This means that LBWNS children attained higher mental ages for their performance on the maze test. The mean rank of the mental ages of LBWS (61.93) and NBWNS (60.59) were close to each other. NBWS children had the lowest mean rank which means that they performed poorly as compared to the other groups.

Thinking Performance –
The performance of the children was assessed using Hanfmann Kasanin Concept Formation test. The number of concepts used by children was compared across the four groups using Chi-square test (Figure 5). There was no difference in the performance of the children in the four groups ($\chi^2 = 12.702, p = 0.177$). However, of those who used a single concept, maximum children (70.3%) belonged to the NBWNS group followed by NBWS (66.7%), LBWS (60%) and LBWNS (60%). Equal proportion (~ 30%) of children from NBWNS and LBWS used two concepts to sort the blocks. Four (13.3%) and three (10%) children from NBWS and LBWS respectively were unable to apply any concept. One child from the LBWNS group also was unable to apply any concept to sort the blocks. Only one child from the LBWNS group was able to use three concepts. Thus, all the children in the NBWNS group managed to sort the blocks using either one or two concepts.
Memory Tests –

The children were administered two tests – recognition and recall to assess their memory performance. No significant differences were seen in the memory performance of the groups. However, in the recognition test, the mean rank of the correct responses was the highest in the LBWNS group and was closely followed by the NBWNS group. The NBWS group had the lowest mean rank that means they gave the least number of correct responses.

Table 9: Mean Ranks of the Memory Performance by the Four Groups

<table>
<thead>
<tr>
<th></th>
<th>NBWNS</th>
<th>NBWS</th>
<th>LBWS</th>
<th>LBWNS</th>
<th>(\chi^2)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>37</td>
<td>30</td>
<td>30</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognition – Correct Responses</td>
<td>67.03</td>
<td>51.23</td>
<td>60.20</td>
<td>67.20</td>
<td>4.140</td>
<td>0.247</td>
</tr>
<tr>
<td>Recognition – Incorrect Responses</td>
<td>55.97</td>
<td>71.77</td>
<td>62.80</td>
<td>55.80</td>
<td>4.140</td>
<td>0.247</td>
</tr>
<tr>
<td>Recall – Correct Responses</td>
<td>56.22</td>
<td>65.17</td>
<td>55.38</td>
<td>72.26</td>
<td>4.469</td>
<td>0.215</td>
</tr>
</tbody>
</table>
The LBWNS children had the highest mean rank for correct recall responses. This means that amongst the four groups, LBWNS children could recall maximum number of items correctly. They were followed by NBWS, NBWNS and LBWS groups.

Overall, though there were no statistical differences in the cognitive test scores of the four groups of children but, the stunted children (NBWS and LBWS) performed poorly than the non-stunted ones (NBWNS and LBWNS). Among the stunted children, LBWS scored better than the NBWS. Also, the LBWNS performed better than the NBWNS children. A number of factors may be responsible for these findings. Greater proportion of the NBWS children had lower per capita income than the others ($\chi^2 = 12.811$, $p = 0.046$). On the other hand, more children from the LBWNS group had higher per capita income than the other groups. Also, more than half of the NBWS children attended the anganwadi alone while almost 80% of the LBWNS children attended the formal school in addition to the anganwadis ($\chi^2 = 16.510$, $p = 0.057$). These socioeconomic factors seem to have influenced the performance of the children in the various tests. Besides these, the small sample size could also be responsible for the lack of significance in the statistical tests.

**Discussion:**
Findings from this study suggest that both, birth weight and postnatal growth play a vital role in determining nutritional status and body fat. Children who experienced either fetal or postnatal growth restriction had poorer nutritional status as compared to those who were never experienced growth restriction. During growth restriction, the body adapts to the state of energy deficit by decreasing thermogenesis and improving metabolic efficiency. Also, due to the decrease in metabolic rate, the body attempts to increase the de novo lipogenesis and storage. As a result of these mechanisms, in spite of having poorer nutritional status, all the LBW children (CDG, no change and CUG) and the NBW CDG children had similar body fat as NBW no change children. Further, these children showed a tendency towards central accumulation of fat. Thus, early growth restriction (fetal and/or postnatal) appears to promote conservation of body fat particularly, central adipose tissue.

In this study, birth weight did not appear to influence the cognitive functions. This does not mean that birth weight has no relation with cognition. Literature suggests that the effects are seen in
cases of very low birth weight or very preterm children. None of the children in the present study were either very low birth weight or very preterm children. The present study indicated that chronic undernutrition can influence the cognitive functions of young children.

In addition to this, socioeconomic factors such as per capita income influence both, the nutritional status as well as the cognition. Increased consumption and easy accessibility of energy-dense foods in lower socioeconomic areas may further accelerate adiposity. Physical activity especially games and sports help prevent adiposity and boost the cognitive development. The foundation of healthy future is laid during the early years of life. If this trend of poor nutritional status coupled with a predisposition to adiposity and lower cognitive performance continues in to adolescence and adulthood then, it is likely to adversely affect the health and productivity of the individual. To prevent such an adversity, measures should be taken to reduce the prevalence of LBW, prevent growth faltering especially in the early childhood and provide early child care and education.
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