Over the past two decades, researchers and policy makers have emphasized on the significance of the first 1000 days of life. Growth in fetal life and during the first two years of postnatal life is now believed to hold the key for health outcomes in immediate future and later life. In the short-term, low birth weight and chronic childhood undernutrition are independently associated with high morbidity, growth faltering and developmental delay. On the other hand, early undernutrition followed by rapid weight gain in infancy and childhood has been linked to obesity and adverse metabolic outcomes in adult life. This dichotomy has lead to growing interest in the nutritional status, body composition and cognition in early years of life.

The present study was thus conducted firstly, to study the relationship between birth weight, current nutritional status and body composition of children aged 2 to 4 years. Secondly, to examine if birth weight and current nutritional status influenced selected cognitive functions in a sub-sample of children aged 3 to 4 years.

This study was approved by the Independent Ethics Committee, Navi Mumbai. The Child Development Project Officers (CDPOs) of five areas in Mumbai city volunteered to participate in the study. One thousand two hundred and five children aged between 2 to 4 years were recruited from 80 anganwadis spread across the five areas. A written informed consent was obtained from the parent or primary caregiver. Information regarding the family background, breastfeeding duration, age of introduction of complementary foods and child’s morbidity was collected from the parent or the primary caregiver. Nutritional status of all the children was assessed using anthropometric measurements. Weight, height, MUAC, waist circumference and head circumference were measured. Body fat was estimated using skinfold thicknesses and prediction equation. BMI, waist-to-height ratio (WHtR) and ratio of subscapular to triceps skinfold (SSF: TSF) were calculated.
From the 1205 children, cognitive functions were assessed for 122 children aged 3 to 4 years. 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 measures of cognitive functions assessed included – intelligence, planning ability, memory and concept formation. Segiun Form Board test, Porteus Maze test, Recognition, Recall, and Hanfmann, and Kasanin Concept Formation test were administered to the children by two trained psychologists.

Of the 1205 children, there were 624 (51.8%) boys and 581 (48.2%) girls. There were 550 (45.6%) children aged 2 to 3 years and 655 (54.4%) aged 3 to 4 years. The children mostly belonged to families where the parents had completed schooling. About one-third of the fathers and one-fourth of the mothers had completed schooling while about 13% parents had completed higher secondary schooling and 6% were graduates. Most of the mothers were housewives. The rest either worked as domestic help or were employed in service industry as nurses or salesperson. Forty percent of the fathers were employed in the service industry. About one-fourth (28.3%) of the fathers were semi-skilled workers while 17.1% were drivers and 11.7% were involved in small-scale businesses. The mean total family income was Rs 13,625 ± 9933.7 every month with the mean per capita income per month being Rs 2518.75 ± 1613.19. In most of the families, the main earning members received daily wages or did not have any permanent employment. As a result of this, they did not have steady monthly income.

The key findings of the study have been summarized below -

The mean birth weight of the children was 2.74 ± 0.5 kg. In all, 20.5% (247) had LBW, 78.6% (947) had NBW and 0.9% (11) had HBW. As reported by the parent or primary caregiver, 98% of the children were born full-term while the rest were born pre-term. The
morbidity data and feeding history of the children is associated with their nutritional status. Almost 28% of the children had been hospitalized at least once in their postnatal life. Thirty nine percent children had fallen ill in the previous 15 days. Most common illnesses were cough, cold and fever. Further, 30.3% children (n = 335) were exclusively breastfed for the first six months of life. The mean duration of exclusive breastfeeding (EBF) was 3.78 ± 2.2 months while the mean total duration of breastfeeding (TBF) was 20.75 ± 10.3 months. Complementary foods were introduced at a mean age of 7.65 ± 4.0 months which is higher than the WHO recommendation.

In addition to the above, the rate of postnatal weight gain also influences nutritional status of children. Children were categorized based on the change in weight SD. The change in weight standard deviation (SD) was calculated as the difference between the current weight-for-age Z score (WAZ) and WAZ at birth. If this value was > 0.67 SD then, it was considered that the child showed catch-up growth (CUG). On the other hand, if the SD scores decreased by 0.67 then, it was considered as significant catch-down growth (CDG) (Ong et al, 2000). There were 40% children who experienced CDG while 23% had CUG and 37% children had no change in weight SD. More than half of the LBW children (60%) experienced CUG, one-third (31.6%) had no change in weight SD and 8.9% had CDG. On the other hand, nearly half the children (48%) born NBW experienced CDG while 13.7% experienced catch-up growth. About 40% of the NBW children showed no change in their weight SD. Thus, higher percentage of LBW children exhibited CUG while majority of the NBW children experienced CDG. This growth trajectory can influence their nutritional status in the childhood.

The current nutritional status of the children was examined. According to WHO Growth Standards (2006), 36.1% children were underweight (WAZ < -2.0 SD), 35.2% were stunted (HAZ < -2.0 SD) while 16.7% were wasted (WHZ < -2.0 SD). The prevalence of underweight and stunting was higher in children particularly girls aged 3 to 4 years than those aged 2 to 3 years indicating presence of chronic undernutrition. According to BAZ,
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. There were no differences in the prevalence of thinness and overweight in the two age groups. According to MUAC, none of the children were severely wasted (< 11.5 cm). As per the MUACZ scores, 8.5% children were wasted (MUACZ < -2.0 SD). Based on head circumference Z scores 16.7% children had microcephaly (HCZ < 2.0 SD). There were no differences in the percentage of children who had MUACZ and HCZ scores < 2.0 SD in the two age groups. Majority of the children (> 80%) who had catch-up growth had normal WAZ, HAZ, WHZ, BAZ, MUACZ and HCZ. Various factors influenced the nutritional status of the children. Higher prevalence of underweight, stunting and low MUACZ (< -2 SD) were associated with lower per capita income, lower levels of maternal education and having more than two children in the family. Children who were underweight or stunted received EBF for less than three months.

Skinfold thickness was measured at four sites – triceps (TSF), biceps (BSF), subscapular (SSF) and suprailiac (SuSF). According to WHO Growth Standards (2006), about 96% children had normal TSFZ (> -2.0 SD) while 86% had normal SSFZ scores (> -2.0 SD). Slaughters equation (1988) was used to calculate body fat (%). The mean body fat (%) was 12.35 ± 2.3. Girls aged 3 to 4 years had higher mean body fat (%) than the boys (F = 5.00, p < 0.05). As seen earlier, about 66% of the children were normally nourished as per WAZ and HAZ while greater percentage had normal TSFZ and SSFZ scores. In addition to total body fat, waist circumference was measured and indices for central adiposity were calculated. The overall mean waist circumference of the children was 45.36 ± 9.6 cm. Children were classified in to waist circumference percentiles developed for 2 to 18 years old Indian children (Khadilkar et al, 2014). Forty-four percent children had waist circumference between 15 – 50th percentile while, 30.4% were between 50 – 75th percentile. About 12% children were found to have > 75th percentiles for waist circumference. No differences were found in the percentage of boys and girls in the
different waist circumference percentile categories. Khadilkar et al (2014) suggested that waist circumferences above 70th percentile as a cut-off for identifying children with risk of metabolic syndrome. Accordingly, in this study, 17% (202) children were at-risk for metabolic syndrome although only 3.8% were overweight/obese as per BAZ scores. The mean WHtR for all the children was 0.50 ± 0.1. The value of 0.5 is used as a cut-off for both children as well as adults (Kuriyan et al, 2011). Nearly 70% (842) children had WHtR > 0.5 while 30.1% (363) had a ratio < 0.5. Higher proportion of girls in the 3 to 4 year age group had WHtR > 0.5 than the boys. 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.

The rate of weight gain influenced the body fat (%) and the measures of central adiposity. Greater percentage of children who experienced catch-up growth had body fat in the highest quartile and waist circumference > 75th percentile than the ‘no change in weight SD’ and CDG groups.

In this study, almost one-third of the children were chronically undernourished as indicated by WAZ and HAZ scores. However, over 85% of them had normal TSFZ and SSFZ scores. This trend is suggestive of a tendency of conserving body fat and abdominal fat. Nearly, 17% of the children had waist circumference > 70th percentile and 70% had WHtR > 0.5 thus indicating metabolic risk at a young age.

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).

After adjusting for the covariates - age, sex, family size, mother’s education, parity, birth order, preterm birth, per capita income, duration of exclusive breastfeeding and change in weight SD, the LBW children were found to have significantly lower WAZ, HAZ, WHZ,
BAZ, MUACZ and HCZ than both, the NBW and HBW children. Greater proportion of the children born LBW were underweight, stunted, wasted and thin than the NBW and HBW ones. More number of children born with LBW had MUACZ < -2.0 SD and microcephaly. This suggests that children born LBW may continue to remain undernourished in their postnatal life too.

**Birth Weight and Body Fat (%), Central Adiposity** – 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). After adjusting for the covariates, the mean TSFZ, SSFZ and body fat (%) were significantly lower in the LBW children than the NBW and HBW children. However, more than 94% and 80% of the all children irrespective of their birth weight had normal TSFZ and SSFZ scores respectively.

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). After adjusting for the covariates, the mean waist circumference was significantly lower in the LBW children than the NBW and HBW children. As compared to the LBW children, more NBW and HBW children had waist circumference percentiles > 50th percentile. In all, 6.5% of the LBW, 13.3% of NBW and 9.1% of HBW children were found to have > 70th percentile. Over 60% of the LBW, NBW and HBW children had WHtR > 0.5, indicating metabolic risk.

**Birth Weight, Rate of Weight Gain, Current Anthropometric Indices and Body Fat** - Along with birth weight, the rate weight gain from birth to early childhood may also influence the nutritional status and fat measures. In terms of anthropometric measurements, the LBW children who attained catch-up growth were found to be at par with the NBW children who maintained their rate of weight gain (no change in weight SD). The LBW children with CUG and NBW no change in weight SD had similar mean body fat (%) but lower than the NBW CUG. Further, the LBW CUG, NBW CDG and
NBW no change in weight SD had similar mean 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 particularly, abdominal fat in spite of having lower body fat as compared to the NBW CUG group.

**Birth Weight, Childhood Stunting, Current Anthropometric Indices and Body Fat** – The NBWS children had significantly lower mean values than the NBWNS group for all the anthropometric parameters except BMI and BAZ. In spite of having lower anthropometric measurements, the NBWS children had similar mean body fat (%), waist circumference and SSF: TSF as that of the NBWNS ones. The mean WHtR of the NBWS was significantly higher than that of NBWNS group. Thus, in spite of being stunted, the NBW children had a tendency to conserve total body fat and truncal fat. The LBWNS children had most anthropometric indices similar to that of NBWNS ones. But, the mean body fat (%) of the LBWNS group was significantly lower than the NBWNS group. The mean waist circumference and SSF: TSF of LBWNS was similar as that of NBWNS children. The LBWNS in spite of having lower total body fat than NBWNS, tended to accumulate fat in the abdomen region.

Thus, in LBW and NBW children, birth weight and change in weight SD were positively associated with both, BMI and body fat (%). In NBW, birth weight and change in weight SD were also positively associated with waist circumference, WHtR and ratio of SSF to TSF. On the other hand, in LBW group, only change in weight SD was positively associated with ratio of SSF to TSF. Further, in both LBW and NBW children, HAZ scores were inversely associated with BMI and body fat (%).

**Birth Weight, Nutritional Status and Cognition** – Seguin Form Board Test (SFBT) 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. The Porteus maze test examines the child’s ability to ‘use planning capacity, prudence and mental alertness in a new situation of a concrete nature’. Recognition and recall assess the memory function while Hanfmann, and Kasanin Concept Formation test examines the child’s ability to form concepts and identify them. Overall, there were no statistical differences in the scores for all the above mentioned cognitive tests across the four groups of children. However, the stunted children (NBWS and LBWS) performed poorly than the non-stunted ones (NBWNS and LBWNS). A number of factors may be responsible for these findings. Greater proportion of the NBWS children had lower per capita income than the others ($\chi^2 = 12.811, p = 0.046$) while, 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.

**Based on these findings, the following conclusions can be drawn –**

1. Almost one-third of the children were underweight and an equal number were stunted in the study sample from urban slums which compared well with NFHS-3.

2. LBW children who exhibited CUG were almost at par with the NBW children who maintained their growth rate (no change in weight SD) in terms of their anthropometric indices. However, catch-up growth in LBW children is likely to be associated with accumulation of total body fat and abdominal fat. Thus, it is important to promote catch-up growth in LBW infants but at the same time, excessive accumulation of body fat should be prevented.

3. In NBW children, CUG is associated with higher body fat and abdominal fat. However, NBW children who experience CDG are likely to have lower anthropometric indices but possess a tendency to conserve abdominal fat.
4. In both LBW and NBW children, increase in HAZ was associated with lower body fat and WHtR. Thus chronic undernutrition appears to be associated with higher body fat (%).

5. In this study, birth weight was not associated with the selected cognitive functions. Stunted children irrespective of their birth weight had slightly lower cognitive scores. The LBWNS group who were at par with the NBWNS in term of anthropometric measurements had slightly better cognitive scores than the latter. This could be because, these children had much more exposure to formal education and higher per capita income as compared to others. Thus, besides nutritional status, environmental factors do play a crucial role in the child’s development.

**Limitation of the Study:**

1. Skinfold thicknesses were used to estimate the body fat (%). No measure for lean body mass was included.

2. Information regarding exclusive breastfeeding and complementary feeding was collected retrospectively. Therefore, details of the same could not be collected as the mothers did not remember accurately.

3. The details of the current dietary intake were not collected.

4. For the young age group of 3 to 4 years, there were very few culture-free cognitive tests which could be used for the study group.

5. The children belonged to a socioeconomically disadvantaged section of the society. As a result, the children were unfamiliar with certain objects used in the tests as compared to their peers from better socioeconomic backgrounds. Due to this, the children took slightly longer time to get acquainted with the novel situations and perform.
**Recommendations**

Prospective, longitudinal studies should be conducted to study the influence of birth weight, postnatal weight gain and linear growth on body composition from early childhood to adolescence. In view of the existing nutrition transition, the influence of dietary factors on the postnatal weight gain, linear growth and body composition should also be studied.

India has a high prevalence of low birth weight therefore adequate measures need to be taken to reduce the incidence of low birth weight. For this, focus should be laid on the health and nutritional status of adolescent girls and expectant women. In neonates born with low birth weight, healthy catch-up growth should be promoted to ensure optimal growth and development during the critical period of growth.

India also has high prevalence of chronic undernutrition in children below five years. Adequate measures should be taken to prevent postnatal growth faltering and ensure optimal growth and development. Care should be taken that in the process of promoting growth, disproportionate fat accumulation should be prevented.

*Anganwadis*, child-care centres and community workers must have intensive education programmes for the mother and the rest of the family to promote -

- Exclusive breastfeeding for six months
- Timely introduction of complementary foods
- Use of indigenous foods and traditional preparations in the daily diet.
- Importance of early childhood education so that the parents send their children regularly to the *anganwadi* or school.
- Environmental stimulation for the growing child by encouraging mother-child interaction, use of toys, learning games and books.
- Encourage physical activity, exercise and sports

In this study, LBW children did show catch-up in terms of weight, height and head circumference but, accumulated fat mass. LBW children who had achieved desirable linear growth also performed better in the cognitive tests as compared to others. This
means that LBW infants have the potential for catch-up in anthropometry and cognition. On the other, a significant proportion of NBW children experienced growth faltering and scored poorly in the cognitive tests. They were seen to be at risk for conserving body fat. Mothers and the rest of the family should be made aware of the window of opportunity available in the first two years of life to promote growth and prevent undernutrition. They should be educated and encouraged to adopt infant and young child feeding practices (IYCF). Along with this, families should be sensitized to provide adequate care, attention and stimulation for overall growth and development of the child born LBW.