CHAPTER - II

REVIEW OF LITERATURE
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Malnutrition and Cognitive Abilities

Some of the important and significant studies on malnutrition and its late effects on cognitive abilities of children are presented in this section.

Cabak and Najdanvic (1965) tested a group of 36 previously malnourished children with the Stevanovic adaptation of the Binet Simon Scale. One-half of the children were below the limit of normal intelligence and none showed an IQ greater than 110.

In 1967, the researchers in Indonesia, tested 117 of five to twelve-year-old children whose nutritional status in the late fifties had been recorded in another study. All these 117 children under study were from the same low-socio-economic class. The investigators found that the children's intellectual as well as physical development could be predicted fairly accurately on the basis of their nutritional status during the preschool years (Liang et.al., 1967). Cravioto and his collaborators (1965, 1966) measured the performances of numerous preschool children suffering from severe degrees of protein-calorie malnutrition by Gesell's psychological test and found that all of them showed lower scores and deficits in adaptive, motor-language, personal, and social behaviour as compared to matched controls of the same ethnic groups. Such deficits continued to be present after rehabilitation, especially in those children who suffered from malnutrition during the period of their first six months. These workers found significantly lower
intersensory performance of malnourished children. Not only did they suffer from physical growth retardation resulting in very short statures, but they were handicapped mentally as well.

Stoch and Smythe (1967) presented a paper, at the International Conference on Malnutrition, Learning and Behaviour held at Cambridge, Massachusetts in 1967, on the results of 11 years of study of psychological and intellectual performance on a group of 20 infants who were severely malnourished during infancy. Matched controls were provided to the local population. The learning ability of these malnourished children in the formal education setup was extremely poor, and lagged much behind the average of all other children of that area. In a test of cognition the group which was malnourished showed a markedly poor grasp of the concept of time.

Monckeberg (1968) described detailed observations on 14 severely marasmic children who had been malnourished since the first month of their life due to certain social and economic conditions. These children were fully treated and rehabilitated in the hospital, and their health progress was followed up closely for a period of about six years. A well balanced diet after discharge from the hospital was assured as far as possible by free supplies of milk to families as well as by frequent visits and physical examinations. At the time of testing these children (3-6 years) for intelligence, they showed all the signs of normal weights and clinical recovery. The results showed that the average IQ scores of these children was 62, which is lower than the average of the area even for the lowest socio-economic groups, and none of them scored higher than 76. These results
were fairly conclusive in showing that brain damage in infancy due to severe degree of malnutrition is permanent at least up to the six years of life, despite improving nutritional conditions.

An Indian longitudinal study on Kwashiorkor and mental development done by Champakam et al. (1968) on a group of children malnourished between 18 and 36 months, along with their matched controls, revealed significant differences between groups, not only in intelligence but also in the level of intersensory adequacy.

Zimmerman and Strobell (1969) studied a group of monkeys and children who were malnourished and found that monkeys showed retarded curiosity, manipulation, and social motivation while severely malnourished children lost all the normal curiosity and desire for exploration that is natural in young child.

A study done by Srikantia and Sastri (1971) on children who had treated five to eight years earlier for PCM, showed their mental performance to be inferior to that of matched control children. The attack of PCM in these children had occurred at about the age of three years when most of the development and maturation of the brain should have been completed (the human brain attains 50% of its adult size at the age of six months, 70% at one year and 90% at the third year).

Guillen-Alvarez (1971) in El Salvador, central America, was able to locate 14, 10-12-year old children who had been treated for marasmus at ages between
3 and 9 months. The psychological test performance of these children was compared with the performance of a group of 25 rural children of similar age and socio-economic condition, but without antecedents of severe malnutrition. Intelligence quotients were obtained from a battery of tests, which included Ravens Progressive Matrices, Koch Test and Goodenough Test. The results of the psychometric evaluation showed significant differences in intellectual performance between the marasmus and control children. Thus, while 3 of the 25 controls had IQs below 70, 12 of the 14 nutritional rehabilitated children scored that low. At the other end of the scale while 14 out of 25 controls had IQs at or above 91, only one child with antecedents of marasmus reached that level.

Rajlaxmi and Ramkrishnan (1972) compared 24 children (2 cases of marasmus and 22 cases of kwashiorkor) suffering from severe malnutrition with 20 children, who were grossly under weight, chronically undernourished and belong to the same socio-economic status as the severely malnourished control ones. Among the two groups, the latter children showed prominent signs of apathy, seven children of the first group showed a median IQ of 54, 15 others, whose condition was not as severe, showed median IQ of 71, whereas the two marasmusic cases had an average IQ of 82. When these scores were compared with those of the chronically undernourished controls, they were quite significant. The 20 control cases showed a median IQ of 99.

Hoorweg and Stanfield (1972) conducted a study on a group of children who suffered before they were 27 months with PEM and controls, aged 11-17 years, were matched in Baganda on the variables of age, sex, educational level,
and guardians' education. Psychological test performance was assessed in terms of general intelligence, verbal abilities, visual memory, short-term memory, and learning abilities. Significant differences were found in memory tests of malnourished children, who suffered at early age than the matched controls.

McLaren and his co-workers (1973) re-examined a group of children of 3-4 years, after being discharged from the hospital, with two more control groups in order to compare the mental performance of the stimulated and unstimulated children with their healthy young siblings and with a healthy control or unrelated children belonging to the same low socio-economic class. Mental performances were assessed by standard Binet Intelligence Tests. The children rehabilitated from malnutrition showed significantly lower intellectual quotients than both sibs and unrelated healthy controls.

Cravioto and DeLicardie (1973) studied a group of children in Mexico who suffered from malnutrition before their 30th month. Along with their controls, a number of tests including the Wechsler intelligence scale, recognition of geometric forms, analysis of forms, and auditory-visual integrative ability were administered. It was concluded that it is not only general environmental deprivation but also factors which are closely related to the event of early severe malnutrition that are contributing to a further depression of intellectual performance and learning.

In a study done by Udani, Bhat, and Shah (1976) of mental development of 252 children consisting of 60 children in normal control group coming from the poor socio-economic and cultural communities, 136 children admitted in the
hospital for PCM, children with short-term follow-up, 22 with long-term follow-up and 22 siblings of kwashiorkor cases. It was concluded that during the stage of active malnutrition children have very low IQ and AQ (Adaptive Quotient). During the short-term follow-up of 1-12 months of above children and 5 to 10 years of 22 children it was revealed that the IQ remained significantly low, even though there was marked improvement in the behaviour during recovery. In contrast to PCM grade 3 and 4, and kwashiorkor cases of all types, the control children from the same socio-economic and cultural group, revealed normal or superior IQ. The observations in the siblings of kwashiorkor cases emphasized that there are better IQ values with better nutrition inspite of the same family surroundings. It was also emphasized that low maternal IQ may also have an adverse effect on children.

Studies done by Hurowitz and his associates (1976) on intelligence tests performed on children from malnourished and control groups, and found significant deficits in test performance in the malnourished children, when compared with controls.

The findings on memory tests indicated that nutrition had significant effect on immediate and delayed memory, however it was of a marginal degree. Nwuga (1977) in his study on a group of school children who were hospitalized for kwashiorkor at the age of 1-3 years, has reported that short-term memory was affected in undernourished children.

Oski and Honig (1978) conducted a study on a group of children whose diets were deficient in iron. They found that the incidence of iron deficiency is
highest among the children of the lower socio-economic groups. They also concluded that iron deficiency in infancy may produce long lasting consequences to emotional behaviour. Emotional behaviour or attention span could produce impairment in cognitive development. These investigators in their experiment found that children treated with iron showed a significant increase in their scores on mental development.

Cravioto (1979) studied the IQ of a group of children who had been malnourished when they were under 3 years of age and had 2 years or more of recovery, with their siblings who had not been malnourished and found twice as many of these children with IQ's below 70, only 4 of the previously malnourished children had IQ's of 90 or more as compared to 10 of their well-nourished controls.

Grantham-McGregor, Stewart, and Schofield (1980) studied the effect of adding psychosocial stimulation to the treatment of severely malnourished children by comparing the development levels (DQs) of the children with those of two other groups of children, an adequately nourished group and second malnourished group who received standard hospital care only. The intervention children underwent structural play session daily in hospital. The non-intervention malnourished group showed a marked deficit in DQ compared with the adequately nourished group throughout the study period. The intervention group made significant improvements in DQ in hospital and continued to do so after discharge. By 6 months they were significantly ahead of the non-intervention malnourished group and were no longer significantly behind the adequately nourished group.
In an experiment done by Evans, Bowie, Hansen, Moodie, and Vander Spuy (1980) on newborn children selected from 14 families in which kwashiorkor had occurred. Undernutrition in this test group was prevented for the first years of life by the provision of supplementary feeding. Controls who were the siblings directly preceding each of the 14 test, children received no supplementary feeding, but received medical attention and management. In each family an older child who previously had kwashiorkor (kwashiorkor group), and the nearest sibling who had received neither extra feeding nor medical management (kwashiorkor control group) were also available for comparison. A battery of psychological test was administered when the mean age of the test group was 8.9 years. The mean full scale IQ of the supplementary feeding group at an average age of 8.9 years was significantly higher than that of any other three groups. There was no significant difference between test of control groups, on nonverbal IQ. Measures of "brain damage" did not discriminate between any of the four groups. The results suggest that nutritional factors contribute especially to the elevation of nonverbal intelligence. Environmental stimulation (daily contact with a more alert child) apparently contributed to the elevation of the non-verbal scores of the controls.

Waber and his associates (1981) studied randomised control trial of pre-natal and post-natal nutritional supplementation on infants. Then the re-analysis was done, and the finding supports the conclusion that supplementation during childhood (3-36 months) had a concurrent effect on cognitive performance. This effect was observed from ages 12-36 months.
Weinberg, Brett, Levine, and Dallman (1981) studied the effect of iron on a group of rats and explored that rats who sustained early iron deficiency have persisting behavioural and learning deficits.

Lozoff, Brittenham, Viteri, Wolf, and Urrutia (1982) studied on a group of infants of Guatemala and observed lower mental development index score in iron deficient infants than the matched non-malnourished infants. Selective results from studies, sponsored by the food, nutrition and poverty programme of the United Nations University on the functional consequences on iron deficiency were presented at the 8th Annual Meeting of the International Anaemia Consultative Group held in Bali, Indonesia, in 1984. One of these studies focused on 119 children with an average age of 11.8 years with an anaemic and non-anaemic groups. It was found that non-anaemic children had significantly higher achievement scores than the anaemic children.

In a study in Jamaica done by Powell, Grantham - McGregor, and Elston (1983), when breakfast was given to a group of poor and mostly undernourished children for one semester, there was an improvement in school achievement but no impact on weight and height. In general, benefits have been found in school achievements, and it has been suggested that the alleviation of hunger may play an important part.

Walter and his colleagues (1983) have demonstrated infants to evaluate the effects of short-term iron therapy on developmental test scores of infants with varying stages of iron deficiency, 37 infants, all 15 months of age were tested with
the Bayley Scales of Infants Development before and 11 days after beginning a trial of orally administered iron therapy. They were separated into three groups according to iron status, 12 controls, with normal iron nutrition. The Mental Development Index was significantly lower in the anaemic infants before treatment as compared with that of normal controls. Improvement with iron therapy was also significant in those with anaemia and in non-anaemic patients. The rise in Mental Development Index was associated with improvement in attention span and cooperativeness. These findings suggest that mild iron deficiency has an effect on infant behaviour that is reversible with iron therapy.

In an American study done by Pollitt, Lewis, Garcia and Shulman (1983) on a group of (malnourished and well-nourished) children and it was found that short-term fasting had an adverse effect on problem solving of all subjects regardless of their IQs.

In an experiment done by Kaur, Singh, and Malhotra (1985) on the impact of malnutrition on the cognitive development of school children (7 to 10 years). 30 malnourished and 30 wellnourished female subjects from 2 Municipal Primary Schools in north Delhi, India, were selected and were administered the Raven’s Coloured Progressive Matrices and the Bender Gestalt Test for children. Results indicate that malnutrition adversely affected the cognitive development of the malnourished children.

A study was investigated by Soemantri, Pollitt, and Kim (1985) on the effect of iron supplementation on measures of school performance among 78 iron-
deficient anaemic and 41 non-anaemic children in an economically deprived rural area of central Java. Iron treatment was given for 3 months to the anaemic children. It was found that the change in iron status of iron-deficient children were associated with the significant changes in school achievement test scores. The study indicates that iron supplementation among iron-deficient anaemic children benefits learning process as measured by the school achievement test scores.

Evan (1985) has reviewed a number of studies on the effect of iron deficiency in children and showed that children with iron deficiency and anaemia exhibit minor defects in cerebral functioning, including poor attention, and co-ordination and impaired scores on developmental assessments. However, subjects improved rapidly after treatment with iron.

In an experiment done by Yehuda, Youdim, and Mostofsky (1986) on the effect of iron deficiency in rats. Male Sprague-Dawley rats made nutritionally iron-deficient (ID), and they showed a significant deficit in water-maze learning compared with normal subjects. The deficit in learning was established prior to any significant decrease in haemoglobin (Hb) level in the blood. Three weeks later, the ID subjects were placed on a control diet, the Hb level was restored to normal, but the cognitive deficit remained. It is concluded that iron deficiency affects learning and memory power.

In a follow up study done by Galler, Ramsey, and Forde (1986) on the intellectual performance of 216 children (age 9-15 years), half of whom had a history of moderate to severe protein-energy malnutrition during the first year of
life. This index group had significantly lower scores than the comparison group on verbal performance and full scale IQs as measured by Weschsler intelligence scale for children. It was concluded that intellectual performance remains depressed throughout the age 15 years following early malnutrition.

Halas and Eberhardt (1987) reviewed 102 studies and suggested that trace element deficiencies cause brain injury and subsequent aberrant behaviours (including memory, and cognitive impairments) in both humans and animals.

Galler and Ramsey (1987) studied over the performance on Piaget’s conservation tasks, and graded difficulty was measured in 129 Barbarian school children (age 9-15 years) with histories of protein-energy malnutrition (PEM) in the first year of life and 129 matched comparisons. Previously malnourished subjects below the age of 13 years showed delayed in performing conservation tasks. After the age of 14 this difference was no longer apparent, in contrast to persistent deficits in the IQ was prevalent in the same subjects.

A study done by Agarwal, Upadhyay, Tripathy, and Agarwal (1987) on a group of children who were suffering from mild to moderate malnutrition (not requiring hospitalization) and found that chronic malnutrition adversely affects intelligence.

An investigation was done by Singh and Agrawal (1987) on the effect of nutrition on IQ. They had selected 58 Indian boys with or without Kwashiorkor, and found that early dietary supplementation significantly elevated intelligence test
scores of subjects above those whose life histories had been characterized by chronic malnutrition.

Katharine, Stanley, Cynthia, and Stanley (1987), in a study, compared 21 male Sprague-Dawley albino rats deprived of Vitamin-D at weaning with 10 controls rats on open field, radial-arm-maze and spatial reversal tasks to test the hypothesis that Vitamin-D deficiency alters behaviour and learning. But it was found that Vitamin-D deprived subjects did not differ from control subjects on learning measures, indicating that Vitamin-D deficiency may not significantly impair cognitive functions in young adult rats.

A study was designed by Singh and Sidhu (1987) to determine differences in intelligence of well nourished and malnourished children of slum areas of Ludhiana, Punjab. The effects of age, sex, birth order on the intelligence of well nourished and malnourished slum children were studied. For this purpose 80 wellnourished and 40 malnourished children, between the age group of 6-8 years, were selected randomly. Nutritional assessment and anthropometric measurements of the children were done by a pediatrician. Draw-a-man was used to measure their intelligence. There was a significant difference in the intelligence of wellnourished and malnourished children; with the increase in age, there was a significant increase in the IQ of wellnourished children. In case of malnourished children the increase in IQ was statistically insignificant. Non-significant difference were found with regard to sex and birth order in the intelligence of wellnourished and malnourished children.
In a study done by Jiloha (1987) on 20 children (aged 3-6 years) with rickets were compared with 20 low socio-economic status (SES) children without rickets and 20 normal children of higher SES matched in age and sex. Results of intelligence showed that rickets as well as low SES had low IQ than the high SES children. The results reflected that rickets and low SES had an adverse impact on intellectual development of children.

Dasgupta and Roy (1987) found the evidence supporting the theory that the nutrition requirement of any individual varies in the long-term over a wide range and this variation was achieved through an auto-regulatory process of adjustment of body metabolism was examined. Support of this theory the extent of undernutrition has been over-estimated. An examination of the clinical evidence showed certain areas of the human system where adaptation is a possibility. This may involve a reduction in capacity for sustained physical and mental capacities, and a greater susceptibility to infection and disease.

Studies reported from the National Institute of Nutrition (NIN) (1988), have examined children who had suffered from Kwashiorkor (severe PEM) at 2-3 years of age and who had been successfully rehabilitated were examined again when they were 4 to 6 years. Results showed that they performed only half as well as did matched control children on a battery of intelligence tests.

Agarwal, Agarwal, and Upadhyay (1989) studied the effect of food supplementation in 146 rural primary school children on their physical growth and mental functions. Children received 450-500 calories with 10-12 grams of protein
for an average of 172 days a year for 2 years. Height was found not to differ significantly in supplemented group as compared to controls. However, there was marginally better weight gain. Children receiving the supplementation showed marginal increment in full scale, verbal and performance IQ. The improvement was significant for all subjects except for comprehension and maze tests. The observations on unstructured Piagetian developmental tasks also indicated that the performance of children on task conservation of liquid was improved marginally after supplementation. However, on Bender Gestalt tests, no change was observed. It appears that nutrition supplementation is beneficial for better school attendance and it improves intelligence and cognitive functions to a marginal extent.

Woo, Ho, Mak, and Swaminathan (1989) examined the nutritional and mental status in 418 healthy elderly Chinese subjects (aged 60+ years) leading an active life in the community. Mental status was assessed using abbreviated mental test score adapted from H.M. Hodkinson (1972), and found that low mental test scores were associated with low intake of protein, iron, and nicotenic-acid. They said that sub-clinical deficits of some nutrients may lead to impaired cognitive function.

Carl, Michael, and Jerry (1989) compared previously malnourished and wellnourished rats, 23, 30 and 90 days in 9 win-sheft version of a conditional spatial discrimination task. They found that early malnutrition impairs the development of learning and short term memory processes of the subjects.
Sigman, Neumann, Baksh, Bwibo, and McDonald (1989), in a study, found that insufficient nutritional intake was associated with limited cognitive abilities and poor ability to concentrate on classroom lessons. Infact, food intake at an earlier period is also related to cognitive scores and suggested that the relation between food intake and performance in this sample of school age children may reflect a process that had earlier roots.

Castro and Rudy (1989) compared 8 young (20-40-day-old) and mature (70-77-day-old) previously malnourished rats with 8 control rats on position brightness and pattern discrimination problems, using an aquatic version of the K.S. Lashley (1930) Jumpstand. Malnutrition did not affect performance on the position discrimination. Previously malnourished 24-34-day-olds failed to solve the brightness problem, and 40-77-day olds were impaired on the pattern problem. The impairments were attributed to the effects of early life malnutrition on the maturation of attention process that enable the rats to suppress responding to relevant cues.

Sigman, Neumann, Jansen, and Bwibo (1989) examined, whether nutritional factors, family characteristics and the duration of schooling were associated with cognitive and attentional capacities of 62 girls and 76 boys (aged 7.1 to 8.5 years) in rural Kenya. The subjects, who were better nourished, had higher composite scores on a test of verbal comprehension and on the progressive matrices. Better nourished females were more attentive during classroom observations than
malnourished females. The cognitive scores of the subjects were best predicted by a combination of factors including duration of schooling, food intake, physical stature and parental SES.

Upadhyay, Agarwal, and Agarwal (1989a) studied on the relationship between malnutrition and intellectual performance of 1336 rural primary school children in the age group of 6-8 years. Observations showed that the relative risk of having an IQ ≤ 89 in severe, moderate, and mild malnutrition was 3.5, 2.7, and 1.4 times for boys and in girls it was 2.4, 1.7, and 1.4 times, respectively. Mean full scale, verbal, and performance IQ as well as the scores of various sub-tests decreased with the severity of malnutrition. However, though the decrease in IQ scores was significantly below average, performance of malnourished children was observed only for performance IQ, and sub-tests information, digit span, picture completion, object assembly, and coding. The stunted children had lower IQ scores as compared to those who were wasted. The overall observations demonstrate that even moderate degree of malnutrition influences the IQ scores and its effect is of a higher magnitude on immediate memory and visual perception as compared to verbal reasoning and comprehension.

In a study, Grantham-McGregor (1989) investigated the effect of malnutrition on cognitive development on a group of malnourished children who had suffered from PEM in their early childhood with the siblings as the control group, to compare the effect. The results showed that the previously malnourished children had marked deficits in cognitive development in comparison to their siblings.
Agarwal, Upadhyay, and Agarwal (1989) designed a study on the cognitive development of 1336 children (6-8 years old) in relation to their nutritional state using 7 Piagetian Tasks. Weschler intelligence scale for Indian children was used to assess the IQ of each child. The percentage of malnourished children in stage-I of development (pre-operational) was significantly higher than that of wellnourished children. In boys performance on all the tasks was influenced by undernutrition. The results of the regression analysis showed that nutrition was more pronounced in conservation tasks indicating poor verbal reasoning and comprehension in malnourished children.

Jamaican children studied by Grantham-McGregor, Schofield, and Haggard (1989) who had recovered from severe malnutrition 3 years previously (CM group) were observed with their mothers in a structured play situation. Their behaviour was compared with two other groups: another severely malnourished group, which had participated in an intervention programme of psycho-social stimulation (IM group) and an adequately nourished group (controls). All children were subjects in a longitudinal intervention study (Grantham-McGregor, Schofield and Powel, 1987). Both malnourished groups had very low levels of development (DQ) initially. The CM group’s DQ remained low but the IM group caught up to the controls.

A study done by Simeon and Grantham-McGregor (1989) on the effects of omitting breakfast on the cognitive functions of the three groups of children: stunted, non-stunted controls, and previously severely malnourished. These children were admitted to the hospital twice. After an overnight, first half of
children received breakfast on their first visit and a cup of tea the second time. The treatment order was reversed for the other half. When breakfast was omitted, both the stunted and previously malnourished groups responded similarly. The malnourished groups had lower scores in fluency and coding whereas the control group had higher scores in arithmetic. The malnourished children were adversely affected in the digit span backward. These results indicate that cognitive functions are more vulnerable to missing breakfast in poorly nourished children.

To find out the influence of early childhood malnutrition on later life, NIN (1990) studied 66 adult males, between 23-30 years of age, belonging to poor and high SES, who had been followed up from 5 years of age over the last 18 years. To find out the nutritional status and its effect on intelligence, both verbal and non-verbal tests were applied. The results indicated that the subjects of well-to-do groups (better-nourished) scored higher than their poor counterparts (poor nourished) in both verbal and non-verbal tests of intelligence. These results suggested that there is an interaction and interdependence of nutrition and socio-economic status influences on intelligence.

Noreiga, Mejia, Saucedo, and Palacios (1990) conducted experiments on children, 4-6 years old, attending nursery schools, having poor or low school achievements (based on tests-intelligence quotient, teacher’s assessment, and a language test), were studied as a psychological, social and economic, and nutritional characteristics. The low group consisted of 12 girls and 15 boys, and the adequate group of 17 girls and 11 boys. Children from the low group had similar protein intakes to those from the adequate group, but their intake of energy
and iron were lower, and they showed mild to moderate malnutrition, belonged to larger families, lived in more crowded conditions, and had less stimulation at home than had the adequate children.

A study conducted by Saigal, Szatmari, Rosenbaum, Campbell, and King (1991) on intellectual, psycho-educational, and functional status of a regional cohort of extremely low birth weight (ELBW) survivors, who weighed 501 to 1000 grams at birth and born between 1977 and 1981, were compared with those of control children, matched for gender, age, and social class. Both ELBW and control groups were tested at a mean unadjusted age of 8 years with mean full scale IQ (Wechsler intelligence scale for children). The ELBW group did less well on the reading, spelling and mathematics tests (Wide Range Achievement Test). The motor performance of the ELBW were also poorer than the control group. It was found that ELBW children were significantly disadvantaged on every measure tested.

Aboud, Samuel, Hadera, and Addus (1991) studied children of 5-14 years old at the Jimma Community orphanage to assess their intellectual, social, and nutritional well being relative to a group of family reared controls. On 2 tests of intellectual ability, the Raven's Progressive Matrices and the Conservation test, the orphanage children performed as well as the family children. Children who entered the orphanage at an early age scored higher than those who entered later; stunted children of orphanage scored lower in Raven's test.
Sigman, McDonald, Neumann, and Bwibo (1991) explored the extent to which cognitive competence was associated with earlier nutritional factors, family conditions and characteristics of 83 toddlers of 5-years-old Kenyan children. These investigators found that food intake during the 18th and 30th months and physical stature at 30th month were associated with the cognitive skills at 5 years age of the children.

A follow up evaluation on a group of children, from Halillo, near San Jose, Costa Rica by Lozoff, Jimenez, and Wolf (1991), whose iron status and treatment were documented in infancy was presented. 85% of the 191 children in the original group underwent comprehensive clinical nutritional and psycho-educational assessments at 5 years of age. All the children had excellent haematological status and growth at 5 years of age. However, children who had moderately severe iron (Fe) deficiency anaemia as infants, with haemoglobin value less than 100 g/litre had lower scores on tests of mental and motor functioning at school entry than rest of the children. Although these children also came from less socio-economically advantaged homes, their test scores remained significantly lower than those of the other children after being controlled for a comprehensive set of background factors. It is concluded that children with Fe deficiency anaemia in infancy are at risk for long lasting developmental disadvantage compared with their peers with better Fe status.

A study was done by Walter (1991) on a group of children with moderate iron deficiency. Bayley scale of infant development was administered and it was found that moderately iron deficient (IDA) children scored 6-8 points lower on
mental development scores, and 9-11 points lower on motor scores than the control group. Increasing severity of iron deficiency correlated with greater neurological dysfunction. Assessments made at 2 weeks after supplementation and revaluation around 12 weeks was made when both iron deficiency and anaemia had improved, but 2-weeks duration did not produce immediate psychomotor gains in infants.

Ichitani, Okaichi, Yoshikawa, and Ibata (1992) investigated the effects of long-term Vitamin-E deficiency and supplementation on learning behaviour in an 8 arm radial maze learning tasks and in a step through passive avoidance response task. Male rats were served as subjects. Results suggest that long-term Vitamin-E deficiency or supplementation does not influence general activity to acquire and maintain memory tasks of rats, but it may affect learning behaviour depending on the kind of task in which the animals are trained.

Jemima, Kumar, and Sheela (1992) conducted a study on the influence of nutritional and psycho-social factors on the mental abilities of selected pre-school children in Coimbatore city. The children of middle income group were taller and heavier (17.34 Kg.) than those of the low income group (14.34 Kg.). Clinical assessment also showed better health among children of middle income group. Mental ability of preschool children was assessed through different mental tests. It was found that children of the middle income group scored higher (75.5%) as compared to the low income group children who scored 65.5%. For optimum mental development a child is dependent on continuous stimulus interaction with the environment.
The study conducted by Lopez, deAndraca Perales, Heresi, Castillo, and Colombo (1993) focused on the effects of breakfast omission on cognitive performances of children. The investigators studied 279 children from low socio-economic level background, age ranging from 8 years 7 months to 10 years 11 months, categorised nutritionally as normal, wasted, or stunted. Evaluation comprised three cognitive tasks designed to be applied with a micro-computer. After a mean of 14th of overnight fasting, some having received a standard breakfast at random while the remaining children continued a fast situation. The researchers found no consistent association between study conditions and performance in short-term visual memory, problem solving, and attention tasks in any of the three nutritional groups. Stunted children showed significantly lower scores in the attention test irrespective of having received breakfast or no breakfast. These results suggest that given a motivating short-term task and maintaining routine conditions, missing breakfast does not affect the accuracy of the cognitive performance of children. Nutritionally affected children did not show a particular vulnerability to the fasting condition, but did show a specific cognitive deficit.

Another interesting study was designed by Sankar, Rai, Pulger, Sankar, Srinivasan, Srinivasan, and Pandav (1994) to assess the level of intellectual functioning and motor performance of 90 school children in the age group of 10-12 years selected randomly from four severely iodine-deficient villages of Sikkim. Bender Visual Motor Gestalt Test, Binet-Kamath Test for mental ability and Raven's Coloured Progressive Matrices were used. The results show an impairment in intellectual and other neuropsychological functions in a high
percentage of children. Visual motor co-ordination was poor in 62 (69%) children. Binet-Kamath test results showed that 19 (21%) children were intellectually subnormal (IQ < 70). Majority of the children (> 80%) had significant impairment in language, meaningful memory, non-meaningful memory, conceptual thinking, numerical reasoning and motor skills.

Kalra (1994) experimented on a group of children of 6 to 7 years of age among the infants who had suffered from severe iron deficiency anaemia (IDA) between the age of 6-18 months compared to controls, indicating the long-term consequences. These children showed learning difficulties, and difficulties in school performance and behaviour. Iron therapy resulted an improvement in learning difficulties, school performance and behaviour in school children.

Grantham-McGregor, Powell, Walker, Chang, and Fletcher (1994) studied 18 severely malnourished children (IM), who participated in a 3-year home visit programme, were compared with two other comparison groups comprising 17 severely malnourished (NIM), and 19 adequately nourished children (controls). On enrollment, all the groups were with same hospital and both malnourished groups had lower developmental levels than the controls. The IM group received intervention for 3 years after hospitalization. At 7, 8, 9 and 14 years after leaving the hospital, the 3 groups were compared on tests of school achievement and IQ. The NIM group showed no sign of reducing their deficits, and at the 14-year-follow-up they had markedly lower scores on the WISC verbal performance scale, the Wide Range Achievement Test (WRAT), and the Peabody Picture Vocabulary Test (PPVT), than the controls. Throughout the follow-up the IM group’s scores
were intermediate between the NIM and the controls in every test. At the 14-year-follow-up their scores were significantly higher than those of the NIM group in WISC verbal scale, and in PPVT.

Grander, Grantham-McGregor, and Chang (1995) studied the activity and behavioural development of stunted and non-stunted children. It is frequently assumed that under-nutrition in young children lead to poor development through reduced activity. Three groups of 26 one-year-old stunted children were studied, nutritional supplementation, supplementation with psycho-social stimulation, and controls. Twenty-six non-stunted comparison children were also studied. Activity levels were measured by extensive observation in the homes and development using 4 sub-scales of the Griffith’s mental development scales. Initially the stunted children were less active than the non-stunted ones, but after 6 months, they caught-up regardless of treatment. The mental ages of the stunted children were lower than those of the non-stunted children initially, and improved with either treatment.

The research done by Sigman (1995) indicates that diet quality is related to cognitive outcomes while diet quality (mostly animal products) is important for the development of cognitive abilities. Most supplementation in which pregnant women, infants or mothers, and children provided with diets rich in calories, protein, or both. It was found that infants, whose diets were enriched, developed somewhat more advanced motor performance than other infants. The results showed that high protein, and calorie supplement was superior to low calorie supplement in affecting children’s cognitive test results.
Malnutrition affects adversely the development of the mental and cognitive abilities of children. But it was found from some of the studies done by different investigators that even though the children were malnourished, their performance scores in different tests were same to that of the control groups. Some of such studies are discussed below.

In an investigation of children, who had suffered from early protein-calorie malnutrition, Klein, Gilbert, Canosa, and DeLeon (1969) reported that these children did not differ from controls on discrimination learning tasks. However, malnourished children were inferior to adequately nourished controls on embedded figures task, in which the child has to locate an object or pattern in a complex stimulus. It was further noted that the problems could be solved by the malnourished children if the tapping sequence was showed down or the embedded figures originally pointed out. Thus, the deficiency was not one of the cognitive capacity, but one of attention. The children did not seem to attend to the critical cues which identified the embedded figures.

Pollitt, Leibel, and Greenfield (1981) studied a group of children in North America, aged 9-11 years, to find out the effect of omitting breakfast on short-term memory of children. It was found that omitting breakfast had a beneficial effect on short-term memory. However, it had an adverse effect on the problem solving ability of children with low IQs, but not in those with high IQs.

Another study on a group of secondary school students was conducted by Dickie and Bender (1982), and it was found that omitting breakfast had no effect on their performances in arithmetic, short-term memory, and attention demanding tasks.
A series of experiments were conducted by Staveren and Dagnelie (1988) on food consumption, growth, and development of Dutch children fed on alternative diets. A literature study indicated that regarding child nutrition the three important movements in the Netherlands were the ecological movements, the anthroposopohies, and the macrobiotics. A study on food consumption, weight and height in preschool children fed these diets showed that the group of macrobiotic children were most at risk. Anthropometric data collected in a cross-sectional study with 300 macrobiotic fed children, aged 0-8 years, showed the growth curves for boys and girls deviated from the Dutch standard curves. There was no catchup growth. In a selected sample of this latter group (43 children, aged 4-6 years) mental development was measured by the Snijders-Oomen-Nonverbal intelligence test. The results of this test did not indicate an abnormal mental development for this age group of macrobiotic children.

In an interesting study designed by Upadhyay, Agarwal, and Agarwal (1989b) on the social competence, visual motor co-ordination, and memory functions of 1336 rural primary school children, 6-8 years of age, were studied in relation to their nutritional status and socio-environmental factors. Malnourished children of Grades I, II, and III scored 4.4, 8.5, and 11.8 points lower, respectively, as compared to those of children in normal nutrition for the total social quotient. Observations on memory test indicated that malnutrition had a significant but very weak relationship with immediate and delayed memory.

In a study, Nelson, Naismith, Burley, Gatenby, and Geddes (1990) conducted on a total of 227 children, 7-12 year olds, weighed and recorded all
food and drink consumed for 7 consecutive days. Each child completed tests of verbal and nonverbal intelligence and was then randomly allocated to 1 or 2 groups after matching for age, sex, IQ, and height. One group received a vitamin-mineral supplement daily and the other group a placebo. On retesting, there were no significant differences in performance between the 2 groups. Furthermore, there were no consistent correlations between test scores and micronutrients intakes based on the weighed records.

Barbara, Kenneth, Andrew, and Paul (1990) studied cognitive function and metabolic status in 18 healthy 9th graders fed on the government supplied school breakfast and 16 controls fed a very low calorie meal. Serum glucose and β-hydroxybutyrate levels were repeatedly measured at predetermined intervals throughout the testing period. Acute cognitive and mood effects were evaluated in all subjects in a pre-post basis. No significant group differences emerged on a battery of psychological measures that assesses short-term auditory memory and mood.

Gupta (1990) studied on the influence of early protein-energy malnutrition (PEM) on subsequent behaviour and intellectual performance on a group of children. He said that early protein-energy malnutrition or malnutrition must be looked at, not as an independent variables, but as one factor in a cluster of variables.

Oyarzum, Lopez, and Alaiga (1991) studied the effect of early malnutrition on mental development after recovery, characteristics of family structure were
studied in 7 families with children, who as infants had been admitted to and treated in a nutritional recovery centre as a result of severe early malnutrition. During growth and development they had shown differences in intellectual development which could not be explained by the nutritional deficit alone. All showed a moderate delay in psychomotor development on admission, but all had made a significant recovery at discharge. At school age children of 4 families had an intelligence quotient (IQ) of 70-80 and those of 3 families had an IQ of 85 or more. Differences between the two groups were mainly related to the amount of help and instruction given by the parents of malnourished children; this was greater in the case of the group with higher IQ.

Impact of macrobiotic diets on the mental development of children of 4-5-year-olds with long-term growth deficits was studied by Herens, Dagnelie, Kleber, Mol, and Staveren (1992) using Snijder's-Oomen Non-verbal Intelligence (SONI) scale. In addition, food consumption and behavioural style of the children and parents' characteristics were assessed. The children's energy intake was 70% and calcium intake 40% of that reported for children of similar age on conventional diets, 15 of 44 children (33%) did not complete the SONI test, mainly due to difficulties in concentration. The non-completers scored lower on the parts of SONI test and educational level of their fathers was slightly lower; no other differences were observed. Intelligence quotient (IQ) of the children who completed the test were high (IQ=126) compared with reference population (IQ=100). No significant relation between IQ and educational level of parents was
observed, possibly due to lack of variation in education level within the study population. Family size was inversely related with IQ. It was concluded that long-standing mild to moderate malnutrition may not affect mental development in preschool children, if the children grow in a stimulating social environment.

Nelson (1992) claimed that vitamin and mineral supplementation is likely to improve intelligence quotient (IQ), particularly of non-verbal intelligence, in a substantial proportion, of children in developed countries. The conclusions of the studies from developing countries indicated that vitamin - mineral supplementation to school children with well characterised nutritional deficiencies can produce consistent and significant improvement in performance on intelligence tests depending on one's improvements. In western countries, it was found from studies that the children's poorer performance on IQ tests was due to marginal nutrient deficiencies. There are, however, no consistent results to suggest that vitamin-mineral supplementation would be value in improving the children's performance on IQ, tests.

Gregory, William, and BenRath (1993) examined the cognitive and language ability of 39 Khmer refugees (mean age 17.7 years) who had suffered from severe trauma and malnutrition. Post-traumatic stress disorder affects ability to acquire new language skill in another culture was also investigated. Subjects scored very low on intelligence tests, but this may have been due to a cultural bias of the tests, which essentially rendered them tests of proficiency in English language, and brain damage was the cause of low scores. Thus, earlier war trauma and malnutrition had not weakened the overall cognitive skills of these subjects.
Malnutrition and Reading Abilities

Cravioto (1971) designed a study to find out the reading abilities of children suffered from Protein-calorie-malnutrition at their early life. The results of the study showed that these children are poor readers, characterized by neurointegrative defective function, school failure, and subsequent subnormal adaptive function.

A case history of fraternal twin boys’ development was studied by Wing (1990), and the effects of chloride deficient soya based formula on language was illustrated. Both the twins were normal at birth and developed at the same rate before the formula was prescribed to one of them. While one twin developed normally, the twin that received the deficient formula exhibited delayed motor development and deficits in morphology, spatial and temporal concepts, and auditory discrimination. These deficiencies were remediated by age 8.5 years, but deficits in word retrieval, short-term auditory memory and reading remained.

In another study Pollitt, Gorman, Engle, and Martorell (1993) assessed the effects of early supplement feeding on cognition in 4 rural villages in Guatemala, comparing the differential effects of exposure in childhood (0-7 years) to high protein (Atole) or low-protein (Fresco) supplements on performance on a battery of psycho-education and information processing tests in adolescence and young adulthood (11-24 years). Data was collected longitudinally from 1969-1977 and in a cross sectional follow up from 1988-1989. Two cohorts are also contrasted: subjects who received supplements (i) pre-natally and during the first 2 years of
post-natal life, and (ii) only after 24 months of life. Adolescents from the 2 Atole villages scored significantly higher on tests of knowledge, numeracy, reading, and vocabulary.

The children who suffered from malnutrition at their early age when studied at a later age to see the effects of their early malnutrition, the results showed no correlation between their malnutrition and reading abilities.

Some of the studies supporting the above statement are given below:

Nayak and Dash (1987) studied the effects of grade, sex, nutritional status, and time of testing on children’s stroop scores. Thirty boys and 30 girls from Grades 2 and 4, classified into high and low nutritional levels on the basis of their height for weight percentiles, were administered with word reading, colour naming, and colour word naming. The interferences showed developmental improvement over the 3 grades. Nutritional status and time of testing had no effect on the stroop scores of children.

Grieve (1988) investigated the effects of chronic, subclinical undernutrition on psychological development, using 87 black pre-school children, who were classified as undernourished or wellnourished on the basis of anthropometric measures, dietary intake, and maternal stature, and scores on the Revised Denver Developmental screening test. An assessment of each subject’s developmental history, the nature of caregiver-child interaction, and the home and social environment was made. Significant differences were found between the subjects’ regarding language development, and the explanation is believed to be social rather
than physiological. It is concluded that this form of undernutrition does not have a large direct impact on development separate from the influence of environmental factors.

**Summary.** The review of literature on the late effects of malnutrition on the cognitive and reading abilities of children leads to contradictory and conflicting conclusions. Some researchers have reported that undernutrition/ malnutrition during infancy or in early period of life results in failure of the brain to achieve the potential size and which is not unreasonable to suppose that this may also predispose to inhibition of optimum intellectual and personality development.

There were numerous studies pointed out by the researchers regarding the relationship between the malnutrition and subsequent intellectual development and school performances. They were also found out that malnutrition causes stunting of growth, change of body composition and subsequently affects the neuromotor development and mental development. It was also evident from the review that even moderate undernutrition and an impoverished social environment together impair a child’s later intellectual/ cognitive performance and reading abilities. It was also well documented in the review that undernutrition in early childhood usually retain a marked deficiency in mental development several years later.

The review of the studies has also shown that there is a positive correlation between the nutritional level of children and their intelligence, and the education
of their mothers. The findings of some studies supported the conclusion that early under nutrition/ malnutrition is associated with intellectual/ cognitive impairment, which leads to permanent retardation in physical, and possibly, in mental development.

However, some other researchers have reported that supplementation of food/ nutrients in the diet improves the cognitive/ mental development and reading abilities in children. Some other findings also proved that there were no association between the nutrition and cognitive and reading skills of children. It is also found from the review of literature that children who suffered from severe malnutrition like PEM did not differ from the control groups on different intelligence tests and reading ability tests. Height and weight of children had no effect on their intelligence. Hence, it becomes a controversial issue that whether early malnutrition/ undernutrition, physical size, and body weight are associated with intellectual capacity, cognitive and reading abilities of children.
PROBLEM, OBJECTIVES, AND HYPOTHESES

Problem:

More than 50 percent of the world's children live in developing counties. India is one of the developing countries which is essentially a land of children and only healthy children can make contributions towards national development.

Undernutrition and malnutrition are major health problems among young children in developing countries of the world. It has been stated that nearly one-half of the world’s present population has survived a period of malnutrition and approximately half of the children of the world are currently at risk from the serious effects of malnutrition (Manocha, 1972).

There is evidence that malnutrition/undernutrition is an important environmental factor which can lead to retarded growth, reduced physical stamina, lowered work output, poor cognitive development, and impaired learning abilities.

Research evidences have already put forth that nutritional deprivation or malnutrition in early childhood is a risk factor in the development of brain which affects, in later age, the intelligence, cognitive and reading abilities of children. The problem of malnutrition among children has received wide spread attention. Researches all over the world have contributed towards providing an answer as to whether malnutrition adversely affects both physical and mental growth and development of children, and if so, whether there is a possibility of reversing this damage.
The relationship between undernutrition/ malnutrition and mental development of children is still controversial and has caused much global concern. Many attempts have been made to quantify the actual contribution of malnutrition per SC to poor mental development in order to confirm a casual relationship, if any, between the two. Most of these attempts so far, have failed to prove beyond doubt that malnutrition/ undernutrition causes retardation in mental development, which in turn, causes poor development of cognitive and reading abilities of children.

Some of the well documented studies have identified several environmental factors which were the causes of malnutrition. These factors are socio-economic status of the family (which includes education, per capita income, occupation, etc.) ignorance and poor sanitation.

Nutrition appears to be one of the greatest environmental influences on the developing organism. An appropriate supply of essential nutrients is a necessity for the maintenance of growth in all organisms for the normal development of physiological functions. Human brain has long been accepted as the seat of intellect. Evidence for structural and chemical changes in the brain as a consequence of severe malnutrition, probably leading to intellectual retardation, has been a matter of concern to research workers. It was not unreasonable to suppose that this may also predispose to inhibition of optimum intellectual, cognitive, and personality development in the later age.
The scientific evidences have already put forth that nutritional deprivation or malnutrition in early childhood is a risk factor in the development of brain which adversely affects, in later age, the intelligence, cognitive and reading abilities of children.

Review of the studies showed that previously malnourished children, who had shown clinical signs/ anthropometric signs of deficiencies in the early age, had the lowest scores on intelligence tests, and reading tests while those who had never been diagnosed as malnourished, had highest scores. There were two different statements on malnutrition that is: (i) malnutrition damages the brain, and (ii) malnutrition results in lower intellectual abilities.

Many studies found that the intellectual abilities of previously malnourished children were affected in later age. Evidences also showed from the review of the studies that the children, who were admitted to hospital for treatment of malnutrition, were tested one or two years later after recovery. These children were found to be poor performers than the control children in various cognitive tests. Almost all the studies included in review have shown that a deficit in test performance is associated with malnutrition.

Cross sectional studies were done by different research workers who viewed that malnourished/ undernourished children performed at lower levels in different tests, had lower IQs and lacked the prerequisites for reading, writing, and in other
creative thoughts, but proved only one thing, that in those cases the low physical growth accompanied by low mental performance.

It is also evident from the review that the children, who were malnourished in early age, have less sense in intersensory integration, and made more errors in different cognitive and reading tests than their siblings, who had no history of malnutrition in their early life.

Some research findings suggested that poor nutrition has detrimental effects which are not completely accounted for by associated environmental characteristics. Some research workers viewed that there were no association between malnutrition and intelligence/cognitive development of children.

Therefore, it can be presumed that nutrition is an important factor which affects the intellectual capacity, work ability and physical status of the children. The intellectual capacity, cognitive development and reading abilities of previously malnourished children differ significantly from the well nourished or normally nourished children. The present study, thus, looks into the nutritional status of children and its effects on their cognitive and reading abilities.

Moreover the present study aims to take into account the children of Grade-II and Grade-V. Because it would be possible to find out the late effects of malnutrition on Grade-II children who suffered from malnutrition just one or two
years back, and Grade-V children who were malnourished in their early age or some years back. Hence, the nature of the effects of malnutrition on the children’s cognitive and reading abilities due to age gap would be another important assessment of the present study.

In other words, the study under report, thus, proposes to assess the differences between the performances of wellnourished and malnourished children in the cognitive and reading abilities.

Lastly, the choice of appropriate tests to measure the cognitive and reading abilities of children is also an important aspect. In the present study it was decided to use the following tests for the measurement of cognitive abilities: (i) Raven’s Coloured Progressive Matrices (RCPM), (ii) Short-term memory (Digit Span-forward and backward; Letter Span - forward and backward), (iii) Long-term memory (story telling-four stories two for each grade, question-answers, correct and incorrect responses), (iv) Working memory (Dots counting and Reading span-sentence reading), and (v) Creative thinking (verbal and non-verbal forms). Moreover, reading ability was tested by an oral reading task.

Objectives:

The primary aim of the present study would be to find out the nature of the relationship between the early malnutrition/ undernutrition and the later mental development of children. The study has been designed to achieve the following specific objectives.
(a) To find out the relationship between early malnutrition and later development of cognitive and reading abilities of children.

(b) To investigate the differences in intelligence, short-term memory, long-term memory, working memory, creative thinking abilities and reading abilities of wellnourished and malnourished children.

(c) To investigate the late effects of early malnutrition on the cognitive, intellectual and reading abilities of Grade-II and Grade-V children.

(d) To find out whether the early wellnourished children, irrespective of Grades, would be superior to their malnourished counterparts in cognitive and reading abilities.

(e) To determine whether the Grade-V children, irrespective of their early nutritional status, would be better than the Grade-II children in cognitive and reading abilities.

(f) To assess whether the differences, if any, between the malnourished and wellnourished children in their cognitive and reading abilities maintain a constant or such differences would be bridged up over ages/grades.

Hypotheses:

In the light of the above objectives the following hypotheses were formulated.

1. There would be a positive relationship between early malnutrition/undernutrition and later development of cognitive and reading abilities of children. In other words, early malnutrition would lead to later retardation of mental abilities in children.
2. There would be significant differences between the wellnourished and malnourished children in their intellectual abilities, short-term memory capacities, long-term memory capacities, working memory capacities, creative thinking abilities, and reading abilities, and the differences would be maximum in favour of wellnourished children.

3. The Grade-II and Grade-V children would differ significantly from each other in their cognitive and reading abilities; and the differences would be maximum in favour of the Grade-V children.

4. The early wellnourished children, irrespective of Grades, would be superior to their malnourished counterparts in their cognitive and reading abilities.

5. The Grade-V children, irrespective of early nutritional status, would be better than the Grade-II children in their cognitive abilities and reading abilities.

6. The differences between the wellnourished and malnourished children in their cognitive and reading abilities would dissipate over ages/grades.