EFFECT OF UNDERNUTRITION ON COGNITIVE DEVELOPMENT OF CHILDREN

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Abstract: Undernutrition is a problem worldwide, especially among infants and young children, belonging to the poor socio-economic classes. Our aim was to explore the associations between undernutrition and Intelligence Quotient (IQ) and school performance in children. A total of 150 school going children were selected randomly from Allahabad district, U.P. (India). Selected Children (n = 150) were grouped into undernourished (n = 34) and adequately nourished (n = 116) on the basis of anthropometric measurements with respect to stunting and wasting, with reference to National Center for Health Statistics (NCHS) standards. It was continued by various cognitive function tests. On comparing undernourished and adequately nourished group on cognitive function showed statistically significant deficit was observed on attention, design fluency, verbal and visual working memory, mathematical calculations, visuo perceptual ability, intelligence, immediate verbal learning and visual and verbal memory. It can be inferred from the present study that undernourished children have deficit on most of the cognitive development such as attention, executive function, calculation, visuo-perceptual ability, long term learning and memory and intelligence.

Keywords: nutrition; anthropometrics; cognitive development; intelligence.

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INTRODUCTION

Nutrition is probably the single greatest environmental factor that plays an important role in the maturation and development of Central Nervous System (CNS) of children in both pre and postnatal, which affecting cognitive development. Cognition is concerned with how we come to know the world around us, dealing with the development of thought and knowledge.

Undernutrition is a problem worldwide, infants and young children, belonging to the poor socio-economic classes, being the most vulnerable segments of population. Based on the most recent estimates (1996–2005) in developing world, approximately 146 million children are underweight, of these 57 million children live in India. Also, in India 46% children are stunted (Height-for-age ≤2SD of the median) and 16% are wasted (Weight-for-height ≤2SD of the median) (UNICEF, 2006). In children, protein/calorie deficient diet results in underweight, wasting and lowered resistance to infection, stunted growth and impaired cognitive development and learning. Cross-sectional studies indicate that there are associations between stunting (which is assessed by height-for-age and thought to reflect sustained nutritional deficiency), Intelligence Quotient (IQ) and school performance in children (Halterman et al., 2001).

Nutrition is one of many factors that affect development of brain and cognitive development of children. Berk (2004) refers cognition as the inner processes and products of the mind that lead to 'knowing', Bamji et al. (2004) defined malnutrition mechanistically, as a state where in adequate nutrients are not delivered to the cells to provide the substrate for optimal functioning UNICEF (2006) used the term 'Undernutrition' and defined it as outcome of insufficient food intake (hunger) and repeated infectious diseases. On neural basis of cognition, Wainwright and Colombo (2006) suggests that cognition depends on the functions of multiple and dissociable neural systems. Caulfield et al. (2004) reported from the analysis of 310 national nutrition surveys that a significant proportion (52.5%) of deaths in young children worldwide is attributable to undernutrition. Identification of the nature and extent of the role of nutrition is important because it is one factor that can be modified in order to optimise cognitive development. Recent study of Handa et al. (2009) reported the effect of anaemia on cognitive development of 7–12 years of school going children's. Authors suggested that Iron Deficiency Anaemia (IDA) is most common micronutrient deficiency in the world, affecting mostly women of reproductive age and children. Previous study was established between IDA and cognition among children. With these observations, the present study was carried to find out the effect of undernutrition on cognitive development of 7–10 year old school going children.

MATERIAL AND METHODS

From the Allahabad district, Uttar Pradesh (India), 150-school going children (self-volunteered children aged 7–10 years) of four schools of varied economic strata were selected randomly (Repeated a million random digit with 100,000.00 normal deviates, RAND, New York, The Free Press, 1983) using random numbers (Minium et al., 1982). Study has been summarised in Figure 1. Anthropometric measurements (Ht), body weight (Wt) and Mid Upper Arm Circumference (MUAC) were recorded for all the 150 subjects using the methods prescribed by Gibson (1990). Various cognitive function tests assessing attention, executive functions, memory and intelligence were

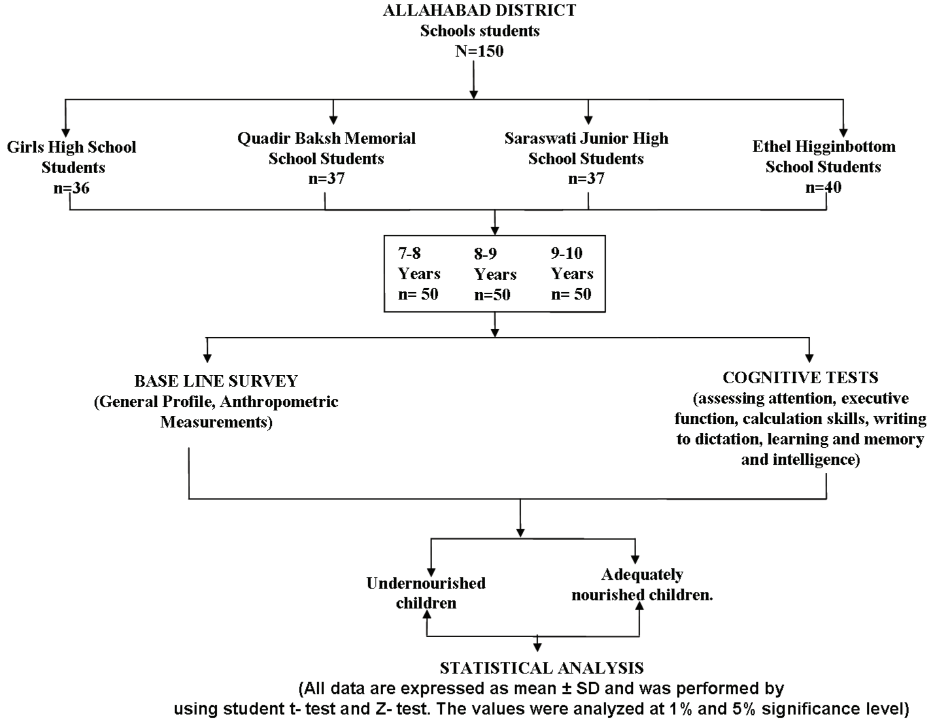


Figure 1 Summarising the plan of experimentation on 150 school going children

performed. All data are expressed as mean ± SD and was performed by using student *t*-test and *Z*-test. The values were analysed at 1% and 5% significance level.

Anthropometric survey

Nutritional status of all the selected children was assessed by measuring body height (cm), body weight (kg) and MUAC. Height of each subject was measured in a standing position to the nearest 0.1 cm using non-stretchable steel tape. A personal weighing machine was used to measure the body weight to the nearest 0.5 kg. (WHO, 1983). Moreover fiberglass tape with minimum count of 0.1 cm was used to measure the MUAC and it was compared with National Health and Nutrition Examination Survey (NHANES) standards.

Anthropometric status

Anthropometric assessment was conducted to identify children with moderate to severe undernutrition. Two indices were taken as a measure of chronic undernutrition that is, height for age (stunted) and weight for height (wasted), with reference to National Center for Health Statistics (NCHS) standards of growth and development. 50th percentile was taken as median percentile function. Children found ≤-2SD from the median on height for age and weight for height were considered as moderate to severe malnourished. Children ≤-2SD from the median on height for age were considered as stunted and those ≤-2SD from the median on weight for height were considered as wasted. Stunting is considered as a measure of chronic undernutrition indicating that protein deficiency can cause retardation in physical growth (UNICEF, 1997). The ≥50th percentile function on height for age and weight for height were considered as normal. Cognitive performance of under nourished and adequately nourished children were measured using following Cognitive Tests and were compared by using Stutent *t*-Test and *Z*-Test.

Cognitive tests performed with children

Children's cognitive development was assessed by using various tests.

1 Attention was measured in terms of sustained and focused attention. Their sustained attention was measured by Colour Cancellation Test (CCT). The test was followed according to Kapur (1974). Trail Making Test (TMT) (Colour Trails, 'Part A' and 'Part B') (D'Elia et al., 1996) was taken as a measure of focused attention.

2 Executive functions were measured in terms of verbal fluency by using FAS Phonemic Fluency Test (PFT) which was followed according to Lezak (1995). Design Fluency Test (DFT) was performed according to Jones-Gotman and Milner (1977). Verbal Working Memory (VWM) test was estimated by using Verbal Working Memory N-back task (VWM N) (Smith and Jonides, 1995). Visuospatial working memory was performed by using visuospatial working memory N-back task (VISWM N) (Smith and Jonides, 1995). Visuospatial working memory span task (VSWM) was done according to Milner (1971) and planning was performed by using Porteus maze test.

3 Visuo-perceptual ability was measured by using Motor-free Visual Perception Test (MVPT) which was followed according to Collarrusso and Hammill (1972).

4 Somatosensory perception test was performed by using Tactile Finger Localisation (TFL) test (Boll, 1974).

5 Two age appropriate tests writing to dictation and calculation were performed with children. Writing to dictation is a measure of learning power and memory. Age appropriate ten words were given for dictation. Basic calculation skills were assessed in terms of simple and graded additions, subtraction, multiplication and age appropriate mathematical questions. These assessments were curriculum-based.

6 Learning and memory were assessed in terms of

   a Verbal learning and memory by using WHO version of the Rey's Auditory Verbal Learning Test (RAVLT).

   b Visual learning and memory by using Memory for Designs Test (MFDT) (Jones-Gotman and Milner, 1977).

   Immediate and delayed recall were taken in both the tests.

7 Assessment of intellectual function was done by using Standard Progressive Matrices (SPM). The test was estimated according to Raven et al. (1983). SPM is equally useful with persons of all ages, whatever their education, nationality or physical condition.

RESULTS AND DISCUSSION

Anthropometric measurements of children (7–10 years)

The heights, weights and MUAC parameters are discussed in this section. Mean height in all the age group was significantly ($p < 0.05$) lesser than the NCHS standards except in 7–8 year boys and 8–9 year girls where a non-significant difference was observed. The mean height in the age group 7–8 years for boys and girls was 121.33 cm and 118.09 cm, respectively. Mean height of girls were higher (126.57 cm and 131.39 cm) than boys (124.81 cm and 128.54 cm) in the age groups 8–9 and 9–10 years.

The mean weight in all the age groups were significantly ($p < 0.05$) lesser than the NCHS standards but in 7–9 years girls difference was insignificant. The difference in weight was more in the age group 9–10 years for both boys (3.90 cm) and girls (3.22 cm) as compared to 7–9 years group. The mean MUAC in all the age groups were significantly ($p < 0.01$) lesser than the NHANES standards. The difference was more in 7–8 year age group (38.04 cm) among boys and 9–10 years age group (42.80 cm) among girls; however age and sex wise distribution based on the anthropometric parameters are shown in Tables 1 and 2. Anthropometry of the children revealed that the community was considerably lighter and shorter than the international (NCHS) standards. Table 3 shows that, out of the total children screened (N = 150), 17.3% children were found stunted and 3% were found wasted. Stunted children (22%) were found more in the age group 7–8 years. National Institute of Nutrition (NIN) (2004–2005) observed stunting in about 72% of preschool children, while wasting was noticed in about 13%. It indicating chronic undernutrition was more common among these children. Joshi (2004) reported that malnutrition is directly or indirectly responsible for more than half of the deaths of children below five years of age worldwide. Children found stunted (height-for-age ≤2SD) or wasted (weight-for-height ≤2SD) or both were included in the undernourished group (n = 34) and remaining were in the adequately nourished group

Table 1 Mean height of children (7–10 years)

	BOYS				GIRLS			
Age (years)	n = 71	Observed mean (cm)	50th percentile NCHS std.	Result	n = 79	Observed mean (cm)	50th percentile NCHS std.	Result
7–8	23	121.34 ± 6.32	124.0	NS	27	118.09 ± 11.0	123.5	S*
8–9	24	124.81 ± 8.34	129.6	S*	26	126.57 ± 7.80	129.3	NS
9–10	24	128.54 ± 10.9	134.8	S**	26	131.39 ± 7.58	135.2	S*

Mean weight of children (7–10 years)

	BOYS				GIRLS			
Age (years)	n = 71	Observed Mean (kg)	50th percentile NCHS std.	Result	n = 79	Observed Mean (kg)	50th percentile NCHS std.	Result
7–8	23	21.06 ± 2.80	22.9	S**	27	20.71 ± 3.23	21.8	NS
8–9	24	23.60 ± 3.19	25.3	S*	26	24.68 ± 5.19	24.8	NS
9–10	24	24.20 ± 3.92	28.1	S**	26	25.28 ± 3.53	28.5	S**

Note: Table value: t_{22} (5%) 2.074, t_{22} (1%) 2.819; t_{23} (5%) 2.069, t_{23} (1%) 2.807; t_{25} (5%) 2.060, t_{25} (1%) 2.787, t_{26} (5%) 2.056, t_{26} (1%) 2.779. Significant = S* (at 5%), Significant = S** (at 1%), Non-significant = NS.

Table 2 Mean MUAC of children (7–10 years)

Boys					Girls			
Age (years)	n = 71	Observed Mean (mm)	50th percentile NCHS std.	Result	n = 79	Observed Mean (mm)	50th percentile NCHS std.	Result
7–8	23	148.96 ± 10.74	187	S**	27	150.81 ± 1.72	183	S**
8–9	24	165.99 ± 19.59	190	S**	26	157.46 ± 2.39	195	S**
9–10	24	168.20 ± 20.68	200	S**	26	168.20 ± 4.05	211	S**

Note: Table value: t_{22} (5%) 2.074, t_{22} (1%) 2.819; t_{23} (5%) 2.069, t_{23} (1%) 2.807; t_{25} (5%) 2.060, t_{25} (1%) 2.787; t_{26} (5%) 2.056, t_{26} (1%) 2.779. Significant = S* (at 5%), Significant = S** (at 1%), Non-significant = NS.

Table 3 Undernutrition among children (7–10 years)

Nutritional status	N = 150	
	f	%
Stunting (ht-for-age≤-2SD)	26	17.33
Wasting (wt-for-ht≤-2SD)	5	3
Stunting and wasting both	3	2
Undernourished (pooled)	34	22.66
Adequately nourished (AN)	116	77

(n = 116) as shown in Table 3. Comparative study between Undernourished and Adequately Nourished (7–10 years) on cognitive development was shown in Table 4.

Cognitive tests performed with children

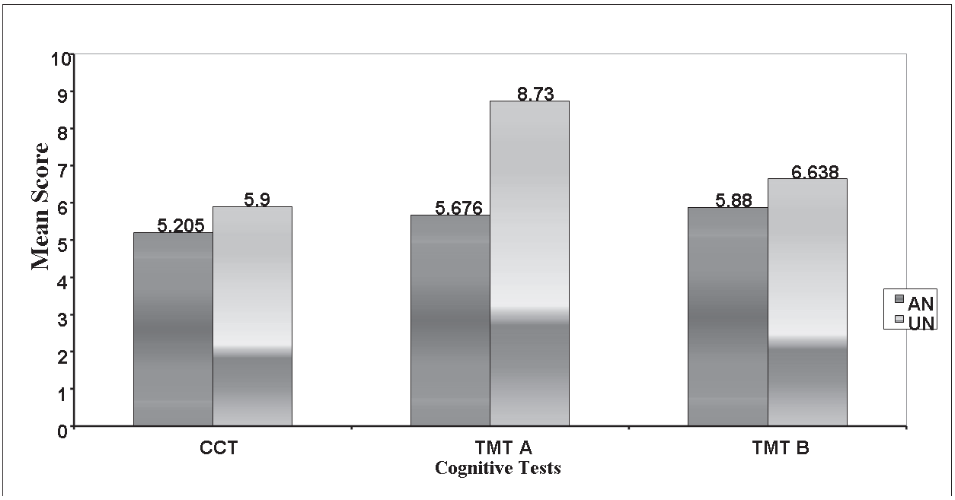
Attention

Sustained attention and focused attention was assessed using the CCT and TMT (A and B), respectively. CCT is a measure of accurate visual scanning, activation and inhibition of rapid response whereas TMT (A and B) measures mental or conceptual tracking and cognitive flexibility. TMT has been found to be highly sensitive to brain damage. O'Donell (1983) indicated in right frontal lobe patients have been found to exhibit attention difficulties. These tests which were time measure tests and deficits on sustained and focused attention were observed in terms of slowness of speed. Performance of undernourished children was significantly less than those of adequately nourished children on CCT ($p < 0.01$), TMT A ($p < 0.01$) and TMT B ($p < 0.01$) (Table 4 and Figure 2(a)). The undernourished children took longer time in completing the trail. The findings were consistent with the earlier researches

Table 4 Comparison between Undernourished and Adequately Nourished Children (7–10 years) on cognitive functions

Tests	Undernourished (n = 34)	Adequately nourished (n = 116)	Z value	Result
	Observed mean	Observed mean		
Attention				
CCT	203.059 ± 8.66	155.50 ± 75.62	2.840	S**
TMT A	237.56 ± 87.91	152.07 ± 68.65	5.217	S**
TMT B	292.20 ± 116.75	227.55 ± 91.26	2.974	S**
Executive function				
PFT	5.205 ± 1.70	5.90 ± 1.60	0.457	NS
DFT (Total)	5.676 ± 2.16	8.73 ± 2.49	7.006	S**
VWM N Back 1	5.88 ± 1.61	6.638 ± 1.42	2.475	S*
VWM N Back 2	6.470 ± 2.69	9.948 ± 2.69	6.626	S**
VSWM Span Task	5.205 ± 1.47	6.190 ± 1.41	3.476	S**
VISWM N Back 1	6.147 ± 1.59	6.59 ± 1.51	1.492	NS
VISWM N Back 2	2.764 ± 1.16	4.06 ± 1.46	14.484	S**
Porteus maze#	9.667 ± 1.37	9.506 ± 1.42	0.355	NS
Calculations	3.88 ± 1.36	5.284 ± 1.56	2.183	S*
Dictation	4.82 ± 2.02	5.517 ± 1.74	1.186	NS
Visuo-perceptual ability				
MVPT	20.03 ± 4.74	22.035 ± 4.51	2.194	S*
Somatosensory perception				
TFL	6.0 ± 1.54	6.319 ± 1.50	1.070	NS
Learning and memory				
RAVLT (Total)	22.47 ± 8.12	31.095 ± 9.79	5.186	S**
RAVLT (Delayed Recall)	5.705 ± 2.90	7.836 ± 2.43	3.905	S**
MFDT (Total)	32.26 ± 10.57	36.155 ± 8.93	1.957	NS
MFDT(Delayed Recall)	5.76 ± 2.49	8.793 ± 2.29	2.726	S**
Intelligence				
SPM	19.5 ± 7.5	23.23 ± 6.95	2.238	S*

Note: Undernourished (n = 18), Adequately Nourished (n = 82); Table value Z (5%) = 1.96; Z (1%) = 2.58; Significant = S* (at 5%), Significant = S** (at 1%), Non-significant = NS. CCT: Color Cancellation Test; TMT (A and B): Trail Making Test (A and B); PFT: Phonemic Fluency Test; DFT: Design Fluency Test; VWM N Back (1 and 2): Verbal Working Memory N Back test (1 and 2); VSWM Span Task: Visuospatial Working Memory Span Task; VISWM N Back (1 and 2): Visuospatial Working Memory N Back test (1 and 2); MVPT: Motor-Free Visual Perception Test; TFL: Finger Localisation; RAVLT: Rey's Auditory Verbal Learning Test; MFDT: Memory for Designs; SPM: Raven's Standard progressive matrices.



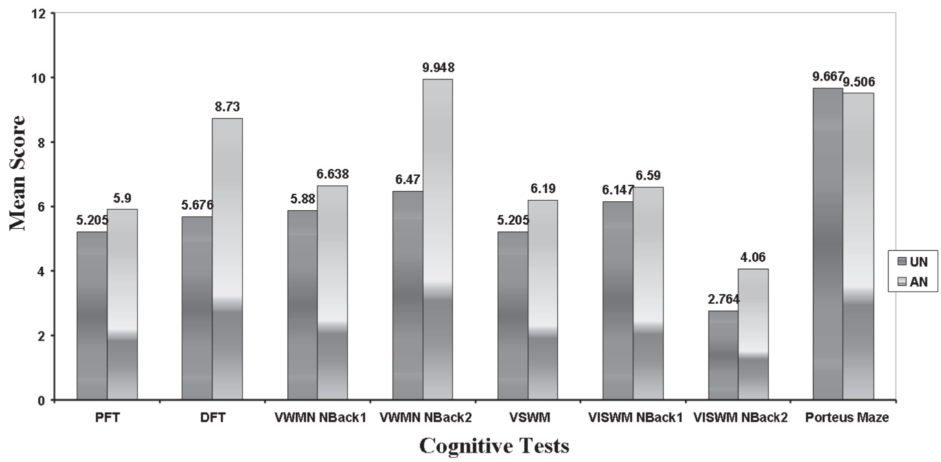


Figure 2 (a) Comparison between Undernourished (UN) and Adequately Nourished (AN) children (7–10 years) on cognitive functions assessing Attention, (b) comparison between Undernourished (UN) and Adequately Nourished (AN) children (7–10 years) on cognitive functions assessing Executive Functions, (c) comparison between Undernourished (UN) and Adequately Nourished (AN) children (7–10 years) on cognitive functions and (d) comparison between Undernourished (UN) and Adequately Nourished (AN) children (7–10 years) on cognitive functions

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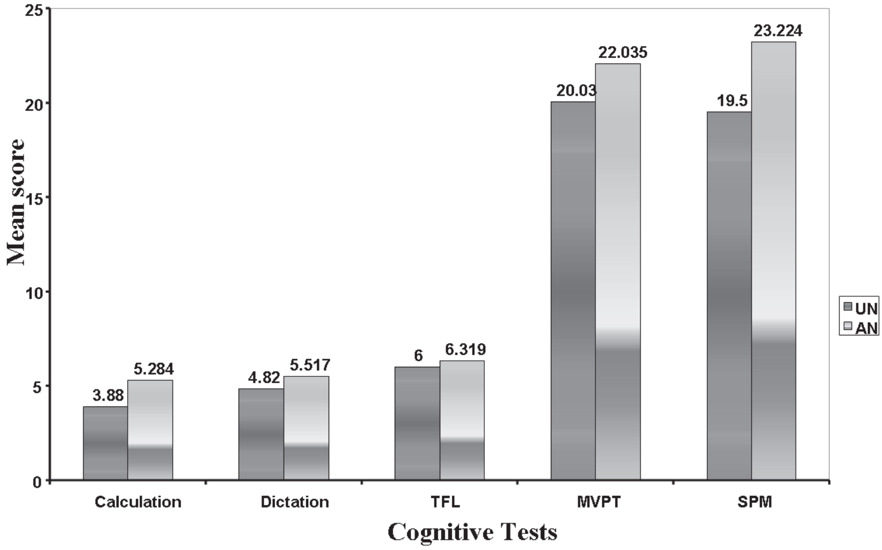

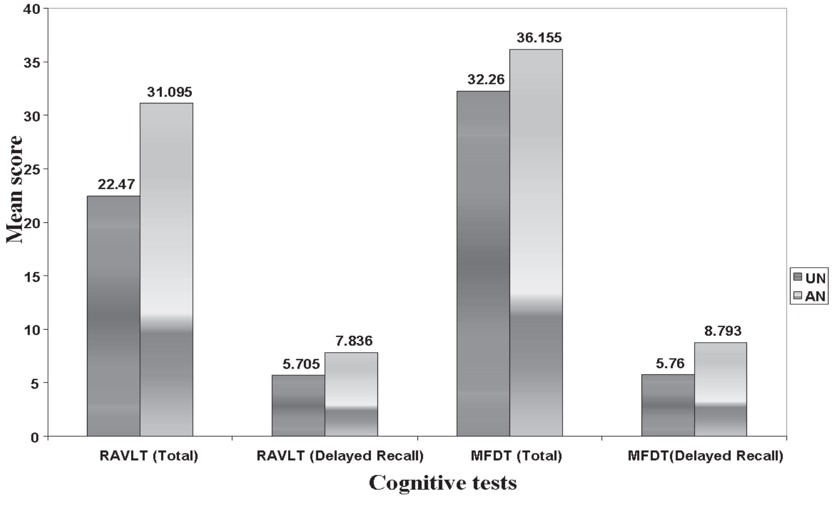

suggesting that the children who were undernourished in infancy had worse performance than the control group in same response time, when attention was evaluated (Perales et al., 1996).

Executive function

Executive function is a complex mental process involving emotional arousal, cognitive processing, planning and execution. It depends on both emotional need and cognitive processes. It has a critical role in coping up with novel situations in contrast with routine ones. Table 4 represents the comparisons of performance of undernourished children and adequately nourished children on executive functions.

1. *DFT*: this test was taken as a measure of the subject's ability to generate novel abstract designs. Creating novel designs is a complex task and involves cognitive processes like cognitive flexibility, creativity and constructional abilities. The scores of undernourished children were significantly less ($p < 0.01\%$) than adequately nourished children on DFT (shown in Table 4 and Figure 2(b)). Such a deficit was suggestive of inability to generate novel abstract designs indicates deficit in cognitive flexibility. The finding was consistent with the findings of Agarwal et al. (1995) study, reporting lower abilities for visual reproduction and associative learning in undernourished children as compared to adequately nourished children. Jones-Gotman and Milner (1977) and Jones-Gotman (1991) also reported that patients with right frontal or central damage had difficulty on DFT.
2. *Working memory*: it is closely related to attention, it involves keeping a limited amount of information active, frequently up-dated, and rapidly accessible for a brief time span. Positron Emission Tomography (PET) studies have revealed differential activations in the N back Task particularly the '2 back' VWM task: left posterior cortex responsible for storage of verbal material, prefrontal cortex and one in inferior frontal gyrus, one posterior to this in premotor cortex and one supplementary motor area. Their function is production of internal speech code required for rehearsal (1995). N back task (visual) is a measure of visuospatial working memory to assess executive control and active maintenance of spatial information. Functional Magnetic Resonance Imaging (fMRI) has shown activation in middle frontal gyrus, superior frontal sulcus and also inferior frontal gyrus, superior and inferior parietal lobule, anterior and posterior cingulated areas during the N back tasks of visuospatial working memory (1998).

The undernourished children performed poorly on the N Back tasks of Verbal (VWM N) Visuo-Spatial Working Memory (VISWM N), Visuo-Spatial Working Memory Span Task (VSWM). The scores of undernourished children were observed significantly less than the adequately nourished children on 1 back task of VWM and 2 back task of both verbal and visuo-spatial working memory. The difference in the visuo-spatial working memory 1 back hit task between undernourished and adequately nourished children was found non-significant, as shown in Table 4 and Figure 2(b). Poor performance on these tasks put load on executive process. Undernourishment during infancy presented lower scores in memory (number of the digits) and in problem solving (number of correct answers) (Perales et al., 1996; UNICEF, 2006) corroborates the result.

3. *PFT*: PFT was taken as a measure of verbal fluency. This test evaluates spontaneous production of words beginning with a given letter within a limited time. Test was estimated according to Lezak (1995). Deficits in verbal fluency have been found to be more in left frontal damage (70%) compared to right frontal damage (30%) (Benton, 1968). Porteus Maze Test was taken as a measure of planning and foresight that is, choosing, trying, rejecting and adopting alternative courses of conduct or thought. Porteus maze test can be quite sensitive to the effects of brain damage as reported in a study on

the psychological consequences of brain lesions and ablations.

The scores of undernourished children were not found significantly less than adequately nourished children on the basis of these two tests. These findings were inconsistent with the findings of Agarwal et al. (1995) but were in accordance with Whaley et al. (1918) who found no group difference on tests of verbal comprehension between the children supplemented with meat and energy, and children in the control group (no feeding).

Calculation skills

A basic calculation skill was assessed in terms of simple and graded additions, subtraction, multiplication and age appropriate mathematical questions. Functional neuroimaging studies performed during mental calculation tasks have reported a pattern of bilateral activation in the prefrontal, premotor and parietal cortices. The scores of undernourished children (as represented in Table 4 and Figure 2(c)) were found significantly less than adequately nourished children on calculation ($p < 0.05\%$), findings were in accordance with the results of Alaimo et al. (2001), who reported that children (6–11 year) from food-insufficient families had significantly lower arithmetic scores and were more likely to have repeated a grade.

Dictation

The undernourished children were also not found significantly different from the adequately nourished children in writing to dictation test. This test measured learning power and memory and was also a curriculum-based test. Both the groups scored approximately 50% marks in the test. It could be inferred from the results of the test that the ability to write to a dictation was also not affected by undernutrition, which was not in accordance with the findings of Chopra and Sharma (1992) and Morgan (1998). Dictation test measures learning and memory components of cognition which was also measured by VWM N Back, VISWM N Back, RAVLT and MFDT. Insignificant result in this test and significant result in VWM N Back, VISWM N Back, RAVLT and MFDT tests could be because of chance factor adopted by children for this test (Table 4 and Figure 2(c)).

Visuo-perceptual ability

MVPT is a test of visual perception, which avoids motor involvement and which is practical for screening, diagnostic and research purposes. This test is a measure of visuo-perceptual ability in terms of: Figure ground (distinguish an object from its back ground), Spatial relationships (orient one's body in space and to perceive the positions of objects in relation to one-self and to other object), Visual memory: (recall dominant features of one stimulus item), Visual closure (identify complete figures from the fragments) and Visual discrimination (discriminate dominant features in different objects). It can be inferred from the Table 4 and Figure 2(c), that the performance of undernourished children was significantly less than those of adequately nourished children on MVPT ($p < 0.05\%$). Same were the findings of Liu et al. (2003), who reported that malnourished children had poor verbal and spatial ability, reading, scholastic ability and other cognitive ability at both the ages; three years and when followed up to the age of 11 years.

Somatosensory perception

This test is a measure of identification, naming and localisation of fingers which was estimated according to Spreen and Strauss (1998). This test was used to examine finger agnosia in a clinical sample. Finger agnosia can occur with lesions on either side of the brain (Boll, 1974). According to Boll and Barth (1981) finger localisation develops steadily and rapidly with age before 6 and continues to develop up to age 12. The undernourished children were not found significantly different from the adequately nourished children on TFL test. Results (as represented in Table 4 and Figure 2(c)) indicate that the ability to detect basic visual, auditory and tactile sensations was not affected by undernutrition, which was not in accordance with the findings of Chopra and Sharma (1992) and Agarwal et al. (1989), who reported that motor and sensory nerve conditions exhibit significant abnormalities with grades of PEM, but the result was consistent with the findings of Agarwal et al. (1995) study, reported that the performance on the finger dexterity for fine motor coordination was not affected in undernourished children.

Learning and memory

The results (as represented in Table 4 and Figure 2(d)) indicate that performance of undernourished children was significantly ($p < 0.01\%$) less than those of adequately nourished children on RAVLT, (both RAVLT total and RAVLT Delayed Recall, respectively) and delayed recall component of MFDT whereas, no significant decrease in the scores of MFDT (Total) was found (Table 4 and Figure 2(d)).

Learning and Memory is the ability to encode new information, store information in a relational memory system and retrieve information. It is measured in verbal/auditory and in spatial/visual modalities. RAVLT was taken as a measure of verbal learning and memory, where RAVLT (total) is the measure of immediate memory and acquisition or new learning and RAVLT (Delayed Recall) measure retention or recall. This test has been found to be sensitive to the deficits of specific, clinically relevant components of the process of verbal learning and memory. Delayed verbal recall and verbal memory loss are sensitive parameters of cognitive deficits in patients with left and bilateral temporal lobe epilepsy (Elger et al., 1997).

Poor performance of undernourished children on both the tests indicates deficits of specific, clinically relevant components of the process of verbal learning and memory leading to delayed verbal recall and verbal memory loss. These findings were in accordance with the results of Agarwal et al. (1995) reported that undernourished children have poor memory. MFDT was taken as a measure of visual learning and memory, where MFDT (total) measures immediate visual memory and acquisition or new learning and MFDT (Delayed Recall) measures retention or recall (Figure 2(d)). The role of right temporal lobe in memory for visual patterns is well documented. Bilateral damage to the medial temporal lobe structures results in a profound amnesia (Jones-Gotman and Milner, 1977). Poor performance of undernourished children on MFDT (Delayed Recall) indicates deficits in visual retention and recall. The findings were in consistent with the earlier researches suggesting that immediate and delayed memory was affected in boys and girls who were mild to moderately malnourished (Upadhyay, 1989). Whereas, no deficit was seen in immediate visual memory which could be because of the chance factor adopted by children.

Intelligence

SPM, taken as a measure of intelligence, also measure visuo-spatial reasoning. SPM is a test of a person's capacity at the time of the test to apprehend meaningless figures presented for his observation, see the relation between them, conceive the nature of the figure completing each system of relations and by doing so develop a systematic method of reasoning. The performance of undernourished children were found significantly ($p < 0.05\%$) less than adequately nourished children on intelligence (Table 4 and Figure 2(c)). Below average performance of undernourished children on intelligence could be related to the poor performance of children on visuo-spatial working memory N-back task and MVPT. However, the N-back task targets the working memory processes involved in spatial location; SPM requires spatial planning and MVPT requires the visuo-perceptual ability in terms of spatial relationships. All these measures have a shared cognitive component of visuo-spatial ability as these tasks are processing visuo-spatial content. The deficit in SPM indicates that undernourished children were below average on intellectual functions but did not had mental retardation as their average score (19.5) was below 25th percentile (21.6) whereas, adequately nourished had average intelligence as there average score was falling between 50th and 25th (29.3–21.6) percentile, when compared with the reference norms. These findings are in agreement with the research of Liu et al. (2003) reported that malnourished children had poorer cognitive ability in terms of verbal and spatial ability, reading and scholastic ability at both 3 and 11 years age.

DISCUSSION

Moreover nutrition is one of many factors that affect development of the brain and the cognitive development of children. Investigating the role that nutrition plays in cognitive development is challenging, because nutrition is an outcome of internal and external environmental factors such as demographic, socioeconomic, health, social, behavioural and motivational influences and is likely to interact with genetic influences, making its effects difficult to specify. Despite the challenges, the identification of the nature and extent of the role of nutrition is important because it is one factor that can be modified in order to optimise cognitive development. Cognition is a psychological process involved in knowing, including perceiving and thinking. These aspects become active in child's mind from birth onwards and keep getting modified as the child grows and as the brain develops. The functional status of brain can be formulated by assessing the cognitive functions. The main principle of Cognitive development involves the growth of knowledge about people, things and events, and organising that knowledge so that it makes sense. Cognition includes learning, thinking, remembering and problem solving; cognition contributes to language skill and vice versa.

Present study entitled "Effect of undernutrition on cognitive development in 7–10 year old school going children" was aimed to study the effect of chronic undernutrition on the attention and intelligence of the children. Undernutrition was identified on the basis of anthropometric measurements with respect to two indices of growth and development: height for age (stunting) and weight for height (wasting) with reference to NCHS standards. Earlier, Waterlow et al. (1972) suggested that protein-energy malnutrition can be classified by the degree of wasting and stunting. In our case, children found stunted ($n = 26$), wasted ($n = 5$) or both ($n = 3$) were included in undernourished group ($n = 34$) and remaining in the adequately nourished group ($n = 116$). These are the base line study to evaluate the cognitive tests. Previously, we have analysed the base line study (Handa et al., 2008, 2009). On comparing undernourished and adequately nourished group on cognitive functions tests, statistically significant deficit was observed on attention, design fluency, verbal and visual working memory, mathematical calculations, visuo perceptual ability, intelligence, immediate verbal learning and visual and verbal memory. While in phonemic fluency, planning, dictation, somatosensory perception and immediate visual memory, a deficit was observed, however it was statistically non-significant. It is concluded from the present study that Undernourished children have deficit on most of the cognitive functions such as attention, executive function, calculation, visuo-perceptual ability, long term learning and memory and intelligence. The study of Bryan et al. (2008) has also investigated the impact of nutritional factors in children after infancy, with particular emphasis on effects on the developing cognitive factor.

The application of undernutrition on cognitive development was explored by many researchers. Bamji et al. (2004) defined malnutrition mechanistically, as a state wherein adequate nutrients are not delivered to the cells to provide the substrate for optimal functioning. Joshi (2004) also suggested that undernutrition results from a combination of three key factors: inadequate food intake, illness and deleterious caring practices, which is directly or indirectly responsible for more than half of the deaths of children below five years of age worldwide. The evidences stated here is clearly reveal the gravity of the adverse effects of undernutrition on brain. In such scenario, the status of cognitive functions as affected by the structural damage to the brain is an obvious resultant effect.

In India, a few researchers have addressed the effects of undernutrition and anemia on cognitive functions in view of the very high prevalence rates of undernourished and anemic children in India. Since cognition is also affected by micronutrient and malnutrition which is highly prevalent in India. The study provided reasonable evidence of an association between undernutrition and cognition among children. This is an important area of study which should be explored frequently.

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