Physical growth and neurointegrative performance of survivors of protein–energy malnutrition

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1. The anthropometric measurements and neurointegrative performance of seventy-nine children aged 6–12 years who had survived kwashiorkor in early childhood were compared to those of 142 children who served as controls.

2. For the boys the differences in height and weight between those who had survived protein–energy malnutrition (PEM) and the controls were significant ($P < 0{\cdot}01$).

3. For the girls the differences in height and weight between those who had survived PEM and the controls were not significant.

4. In the tests chosen, the performances of the survivors of PEM was significantly poorer than that of the controls.

5. There was no improvement in the performance when thirteen survivors were reassessed at 10 years of age.

6. There was a significant difference in scholastic performance between the survivors of PEM and the normal controls. The scholastic performance of the siblings of PEM survivors was also significantly better than that of the PEM survivors.

7. The dietary intakes at the time of reassessment were unsatisfactory in 25% of the survivors, but did not relate to their scholastic abilities.

Severe protein–energy malnutrition (PEM) in infancy and early childhood is known to affect adversely the later neurological and intellectual development (Stoch & Smythe 1963; Cravioto *et al.* 1966). The following studies were undertaken to document the effects of severe forms of oedematous malnutrition as seen in children in southern India, on their later development and scholastic performance.

MATERIALS AND METHODS

The subjects of the study were children who had survived PEM. All of them had been admitted to the Nutrition Research Unit with the clinical and biochemical features of kwashiorkor or marasmic kwashiorkor (Gopalan & Ramalingaswami, 1955; Webb *et al.* 1963; Lancet, 1971). They were discharged on recovery, judged by disappearance of oedema, regeneration of serum albumin and satisfactory weight gain. Criteria for selection for the present study were: (a) residence within a radius of 20–25 miles from the hospital and (b) age between 6–12 years. One hundred and thirty children of a total of 641 children with PEM who were treated between 1962 and 1972 satisfied the criteria.

The children were identified by visits to their homes and, with the permission of their parents, participated in the study. Their heights and weights were recorded and details of socio-economic status and scholastic performance of the children and their siblings obtained. The subjects' dietary intake was also obtained by questionnaire (Pasricha, 1959). The tests of intellectual ability and neurointegration were given in the Nutrition Research Unit. In a small number of children the performance in the tests was reassessed when they were over 10 years of age. The performance of ten siblings of the survivors was also recorded.

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One hundred and forty-two children from three villages of comparable age and socio-cultural status, who had not suffered from overt PEM in the past, served as controls. The tests were conducted at the village school. The heights and weights of the control children were also recorded.

Selection of tests

The criteria for selection of the tests were: their applicability to the age range 6–12 years, freedom from cultural overtones and suitability for assessment of children who had not had a formal education.

Seguin Form Board

The method of conducting the test has been described (Cattell, 1953). The total period of time and shortest period of time taken for the subject to place the forms in three trials were noted.

Neurointegrative tests

These were conducted as described by Cravioto *et al.* (1966). Errors in recognition of identical and non-identical forms in visual-haptic, haptic-kinaesthetic and visual-kinaesthetic sensory modalities were recorded.

The Passalong test

This test consisted of nine graded problems in which an arrangement of coloured blocks was converted into another, by sliding the blocks about in a box. The scoring was on the period of time taken for the successful completion of each problem.

RESULTS

One hundred and thirty survivors of PEM satisfied the criteria for selection. The postal addresses recorded at admission were inadequate or incorrect in thirty-one case records. Twelve children had left with their families for more distant villages and were lost to the study. Six had died; their parents were interviewed and the cause of death ascertained. Three of the children had succumbed to a second episode of kwasiorkor after measles (two) and whooping cough (one). In the three other children, measles, a 3 d fever and cholera were the terminal illnesses. The parents of two children refused to cooperate in the study. Seventy-nine children were identified and tested.

The heights and weights of the seventy-nine survivors are compared with those of the hundred and forty-two normal children in Table 1. The heights and weights of the girls and boys in each age-group were combined for statistical analyses as the numbers were small. The survivors of PEM were shorter and lighter than the normal children. An analysis of covariance adjusted for age showed that there was no statistical difference between the heights and weights of the girls who survived PEM and controls. Differences in height and weight between the boys who survived malnutrition and the normal boys were significant ($P < 0{\cdot}01$).

Performance at the Seguin form board

The control children performed this test at slower rates than the accepted normal values (Cattell, 1953). In the age-group 6–10 years the mean speed of performance for each year corresponded with the normal values for children 2 years younger.

The survivors of malnutrition took a significantly longer period of time to place the blocks in the Seguin form board, when compared to the controls ($P < 0{\cdot}05$ for age-group 6–10 years) (Table 2). An analysis of covariance, adjusted for age, showed that the differences in performance between the survivors of PEM and the normal children were significant ($P < 0{\cdot}01$).

Table 1. *Heights and weights of Indian children who were survivors of protein–energy malnutrition (PEM) and of children who served as controls*

(Mean values and standard deviation for number of children given in parentheses)

Age (years)		Survivors of PEM: Height (mm) Mean	Height (mm) SD	Wt (kg) Mean	Wt (kg) SD		Control children: Height (mm) Mean	Height (mm) SD	Wt (kg) Mean	Wt (kg) SD
					Boys					
6	(6)	1026	24	15·85	2·19	(8)	1062	17	15·97	1·31
7	(8)	1068	45	15·94	1·67	(15)	1133	94	16·87	1·70
8	(10)	1095	44	15·86	1·61	(12)	1171	54	19·05	3·64
9	(8)	1180	33	18·88	1·82	(23)	1248	60	21·80	2·54
10	(5)	1128	47	18·50	2·00	(12)	1276	71	22·19	3·26
11	(1)	1175	—	18·55	—	(8)	1283	64	23·17	2·89
12	(3)	1244	—	21·91	—	(2)	1435	—	31·72	—
					Girls					
6	(5)	1023	40	14·51	0·73	(4)	1106	25	17·35	1·22
7	(10)	1092	45	16·55	2·03	(6)	1093	50	17·71	3·38
8	(9)	1132	48	17·48	2·24	(15)	1167	32	18·43	1·50
9	(5)	1183	86	20·14	4·00	(10)	1207	46	19·91	2·13
10	(7)	1285	81	23·91	6·30	(14)	1263	63	22·69	1·99
11	(2)	1260	—	20·98	—	(7)	1281	45	22·51	2·23
12	—	—	—	—	—	(6)	1310	66	24·67	3·54

Table 2. *Performance of Indian children who were survivors of protein–energy malnutrition (PEM) and of control children at the Seguin form board and Passalong tests*

Age (years)	Seguin form board: Survivors of PEM: Total period for three trials (s)	Shortest period of time (s)	Controls: Total period for three trials (s)	Shortest period of time (s)	Passalong test: Survivors of PEM: Mean score	Range	Controls: Mean score	Range
6	215	59	188	43	4	0–15	9	2–5
7	180	43	114	31	4	0–15	10	5–15
8	183	43	92	24	8	0–15	12	4–20
9	121	31	84	23	11	5–18	14	4–28
10	136	33	80	21	11	1–20	16	4–31
11		} Test not applicable			15	9–20	14	9–26
12–13		} to these age-groups			17	10–22	19	14–37

Passalong tests

The scores obtained by the control children and by the survivors of PEM are tabulated (Table 2). The difference in performance between the controls and the PEM survivors was significant ($P < 0{\cdot}05$ and $P < 0{\cdot}01$ for children aged 7 and 8 years respectively). The differences in performance were not significant for the other age-groups.

An age-adjusted analysis of covariance of the performance of the survivors of PEM compared to that of the control children showed a significant difference ($P < 0{\cdot}01$).

Table 3. *The average numbers of errors (+one standard deviation) made in neurointegrative performance of the Indian children who were the survivors of PEM and of control children in the sensory modalities tested*

(The numbers of children in the age group 11–13 years were too small to permit statistical analysis)

Age (years)	Visual-kinaesthetic				Visual-haptic				Haptic-kinaesthetic			
	Survivors of PEM		Controls		Survivors of PEM		Controls		Survivors of PEM		Controls	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
					Identical forms							
6	11·4	7·7	4·8	4·6***	11·5	11·0	3·4	1·7***	13·0	9·7	2·6	2·5**
7	14·5	11·6	3·9	2·1*	8·6	6·8	2·2	1·5*	11·2	10·9	2·7	0·8**
8	14·1	9·1	3·9	3·4*	8·5	7·8	2·4	2·1*	11·3	8·8	2·9	2·5*
9	13·1	6·9	4·1	3·2*	6·8	5·5	1·5	1·3*	8·9	8·1	2·3	1·9*
10	13·6	11·2	3·3	3·2*	9·5	13·2	1·3	1·1**	10·0	11·9	2·5	2·5**
					Non-identical forms							
6	8·3	3·8	7·5	3·6	5·0	3·3	1·0	1·0*	6·4	3·8	5·9	4·5
7	7·2	2·7	4·9	2·5***	2·4	1·6	0·6	1·1*	7·5	2·7	4·5	4·1**
8	6·0	3·6	3·5	3·6***	2·0	2·1	1·0	1·3	5·3	3·3	3·6	2·8
9	5·1	3·0	2·3	1·9*	1·5	1·4	0·6	0·9***	4·6	3·2	2·3	2·9**
10	4·4	2·7	2·5	1·7	1·4	3·0	0·5	0·2	3·7	2·8	1·0	2·3

* $P < 0{\cdot}001$, ** $P < 0{\cdot}01$, *** $P < 0{\cdot}05$.

Test of neurointegration

In the sensory modalities tested, the children who survived PEM made a significantly larger number of errors in the recognition of identical forms compared with the normal children. In the recognition of nonidentical forms also the survivors of PEM made more errors than the normal children. The average number of errors made by the survivors of PEM and the control children is indicated in Table 3.

Performance of siblings

Ten children, siblings of the PEM survivors, were given the three tests. Three of them performed the tests poorly, at a level comparable to that of PEM survivors. In seven children the scores obtained were within the normal range.

Reassessment of survivors' performance

Thirteen survivors of malnutrition, who were first tested when 8 years old, were reassessed when they were 10 years old. Their performance was significantly poorer than that of the controls ($P < 0.05$) indicating there was no improvement in performance with age.

Effect of age and severity of malnutrition on later neurointergrative performance

Comparisons were made between the performance of the youngest twenty children who were affected with PEM (mean age 1·49 years) and that of the twenty oldest children (mean age 3·61 years). The differences in performance were not significant. Similarly, there was no significant difference between the performance of the twenty children with the lowest serum albumin on admission (mean 10·6 g/l) and that of the twenty with the highest serum albumin (mean 21·3 g/l).

When body-weight after loss of oedema, expressed as a percentage of expected body-weight (Nelson, 1975), was taken as a criterion of severity of malnutrition there were no differences in performance, except in the visual-kinaesthetic modality when those children with greater deficits in body-weight (mean 40·5% expected body-weight) performed better than those with lower deficits in body-weight (63·6% expected body-weight).

Scholastic performance

Among the control children, all 6-year-old children were in the 2nd class in their school, and up to the age of 10 years the majority of the control children were in successively higher classes. The 11- and 12-year-old children were in the 6th and 7th classes in their schools.

Nineteen survivors of PEM were in classes appropriate for their age. Forty-two children were in classes lower than warranted by their ages, due to repetition of earlier classes or starting school late or both. Seven children had 'dropped out' of school in the 1st and 2nd classes. Eleven children had not attended school and neither had their siblings.

Eighty-eight siblings of the children with kwashiorkor were of 'school-going' age. Forty-three of the siblings were in classes appropriate for their age and twenty-three were in lower classes than their age warranted. Eleven children had 'dropped out' of school in the first three classes and eleven others had not attended school at all.

The scholastic performance of the siblings was significantly better than the performance of the survivors of PEM ($P < 0.001$).

Dietary pattern of survivors

The dietary pattern was similar to those of children studied in rural South India (Rao & Rao, 1958). On analysis, the mean energy intake was 20·7 MJ/kg and the protein intake 1·96 g/kg. Twenty of the seventy-nine children had inadequate energy and protein intakes compared with the recommended allowances (WHO, 1973). The scholastic performance of the children with poor food intakes was not significantly different from that of the PEM survivors given adequate diets.

DISCUSSION

In this study on the survivors of oedematous forms of PEM, an impairment of neuro-integrative development and scholastic abilities was demonstrated. The findings are in keeping with those of other workers in India and elsewhere (Stoch & Smythe, 1963; Cabak & Najdanvic, 1965; Liang *et al.* 1967; Botha-Antoun *et al.* 1968; Champakam *et al.* 1968; Cravioto *et al.* 1971; Monckeberg, 1975). Physical growth was also retarded in the boys who had survived malnutrition whereas in the girls growth was comparable to that of their peers.

There is always some valid criticism in studies of this nature on the selection of the children who serve as controls. A control group of well nourished children from an urban environment introduces the variable of a different cultural background. If they are taken from an environment which is strictly comparable in cultural and socio-economic terms, the controls might suffer from mild to moderate nutritional deficiencies which affect their performance. The selection of sufficient numbers of well nourished children from rural environs is difficult, considering the prevalence of nutritional deficiency signs, other than those of PEM, in this part of the world. The choice of siblings of the survivors of PEM eliminates variables such as genetic potential and environmental influences; marginal states of deficiency in siblings are more than likely, as families with children with overt malnutrition may belong almost entirely to the more disadvantaged or poorer end of the economic spectrum of the village. In the circumstances it appeared most appropriate to choose children with the same environmental and socio-economic background as the survivors of PEM and to include some of their siblings to study the differences in performance in children who had suffered overt, severe PEM in early childhood and others who had not.

The poor scholastic performance of the survivors of PEM compared to that of their siblings argues that PEM itself was responsible for the impaired intellectual ability, as both the survivors and the siblings shared the other socio-cultural, nutritional and genetic factors. These findings are in agreement with the studies of Cravioto *et al.* (1971).

An improvement in intellectual performance with increasing age has been reported in survivors of PEM (Champakam *et al.* 1968). Our experience was to the contrary, as the children continued to have an impairment of neurointegration even after the age of 10 years. In any case, a period of catch-up in life does not confer any advantage to the child, as by this time he has already 'dropped out' of school.

In countries where malnutrition is prevalent among children, the most strenuous efforts should be directed towards the early identification and treatment of the mild forms of malnutrition. The cost and effort of rehabilitating children with severe forms of PEM are prohibitive and of poor cost-benefit in most developing countries.

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