INTELLECTUAL LEVELS OF SCHOOL CHILDREN SEVERELY MALNOURISHED DURING THE FIRST TWO YEARS OF LIFE

Margaret E. Hertzig, M.D., Herbert G. Birch, M.D., Ph.D., Stephen A. Richardson, Ph.D., and Jack Tizard, Ph.D.

From the Rockland Children’s Psychiatric Hospital, Orangeburg, New York and Department of Psychiatry, New York University Medical Center, New York; Departments of Pediatrics and Community Health, Albert Einstein College of Medicine, Bronx, New York; and Department of Child Development, University of London, Institute of Education, England

ABSTRACT. Intellectual functioning at school age was studied in boys who had been severely malnourished during the first 2 years of life (index cases). IQ in these index cases was compared with that of male siblings closest in age and unrelated classmates or neighbors matched for sex and age (comparisons). Full Scale, Verbal and Performance IQs were lowest for the index cases. All IQ measures were significantly lower in the index cases than in the comparisons. Full Scale and Verbal IQ were significantly lower in the index cases than in the siblings. Siblings differed from comparison children only in Performance IQ. No association was found between the intellectual level of index cases and the ages at which they had been hospitalized for the treatment of severe malnutrition during the first 2 years of life. Pediatrics, 49: 814, 1972, MALNUTRITION, INTELLIGENCE, SIBLINGS.

This is a report of a study conducted in Jamaica, West Indies, on the long-term consequences of severe malnutrition during the first 2 years of life. In it we have studied school children who, during their first 2 years of life, had been hospitalized for severe clinical malnutrition (marasmus, kwashiorkor, or marasmic-kwashiorkor). They have been compared with two groups of school aged children of like sex. The first comparison group consisted of siblings of the cases. The sibs chosen were children in the sibship closest in age to the index case. The second comparison group was composed of unrelated classmates or neighbors closest in age to the index child. In later reports we will deal with the physique, neurologic characteristics, social and school functioning, as well as with the social and biologic background characteristics of these children. The present report, however, is restricted to a consideration of measured intelligence.

The concerns and design of the study

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This paper is one of a series exploring the consequences for growth and development of severe malnutrition in infancy. The studies were carried out in Jamaica in the Tropical Metabolism Research Unit of the Medical Research Council. The investigations also received active support from the Epidemiology Research Unit of the Medical Research Council in Jamaica. Though most patients had been treated initially in the Tropical Metabolism Research Unit, additional patients, particularly in the youngest age group at hospitalization were obtained with the help of the Department of Pediatrics, University of West Indies. The follow-up studies included anthropometric, pediatric, neurological, psychological, educational, and social evaluations. Different aspects of the inquiry will be considered in separate reports.

Support for this study was provided by the Association for the Aid of Crippled Children; the Nutrition Foundation, Inc., New York; The National Institutes of Health, NICHD (HD 00719); NICHD (NIH 71-2081); from the program support to the Child Development Research Unit, University of London, Institute of Education; and from the Medical Research Council. Dr. Hertzig received support from a Research Scientist Development Award, National Institutes of Health Type 1 (K1-38832).

ADDRESS FOR REPRINTS: (H.G.B.) Department of Pediatrics, Albert Einstein College of Medicine, Eastchester Road and Morris Park Avenue, Bronx, New York 10461.

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TABLE I
Ages of Index, Sibling, and Comparison Boys at Time of IQ Testing

<table>
<thead>
<tr>
<th>Age in yr-mo</th>
<th>Index</th>
<th>Sib</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-0 to 5-11</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6-0 to 6-11</td>
<td>19</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>7-0 to 7-11</td>
<td>16</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>8-0 to 8-11</td>
<td>15</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>9-0 to 9-11</td>
<td>19</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>10-0 to 10-11</td>
<td>4</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>11-0 to 11-11</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-0 to 12-11</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>74</td>
<td>38</td>
<td>71</td>
</tr>
</tbody>
</table>

gard is the clear possibility of increasing pools of survivors who may be handicapped in a variety of ways and for variable periods of time.”

These changed circumstances have, over the past decade, resulted in a growing number of investigations exploring the long-term consequences of both severe acute malnutrition and “chronic undernutrition” on growth and intellectual development. In addition, numerous experimental animal models for studying such consequences have been employed. In studies of human subjects where controlled experiment could not be undertaken, follow-up studies have been conducted in children for whom both direct or indirect evidence of malnutrition is available. Two types of study designs have been used to explore the consequences of malnutrition for cognitive functioning in children. In some studies the presence of antecedent malnutrition in school-aged and preschool children has been inferred from differences in height for age. In communities where the risk of malnutrition is endemic, short children have been judged to have been a greater nutritional risk than taller age-mates. Groups of tall and short children have then been compared for IQ level and intersensory competence. The absence of direct evidence of severe malnutrition and the wide range of variables other than nutritional ones which differentiate the families of tall children from those of short ones have made it difficult directly to attribute the differences between the tall and short groups to malnutrition per se.

In the second type of study children with known histories of severe malnutrition have been compared with children in their communities without such histories. While the fact of antecedent malnutrition has been clearly established in such studies, other factors limit the degree to which they can be interpreted as indicating a direct association between antecedent malnutrition and intellectual outcome. Children who are severely malnourished early in life come

TABLE II
Intellectual Levels of Index Cases, Siblings, and Comparison Children

<table>
<thead>
<tr>
<th></th>
<th>Index</th>
<th>Sib</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>71</td>
<td>38</td>
<td>71</td>
</tr>
<tr>
<td>Full Scale IQ</td>
<td>57.72</td>
<td>61.84</td>
<td>65.29</td>
</tr>
<tr>
<td>Mean Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>64.92</td>
<td>71.09</td>
<td>73.79</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>56.30</td>
<td>58.93</td>
<td>63.69</td>
</tr>
<tr>
<td>Full Scale IQ</td>
<td>10.75</td>
<td>10.82</td>
<td>13.59</td>
</tr>
<tr>
<td>S.D.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>11.80</td>
<td>12.87</td>
<td>14.53</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>11.85</td>
<td>10.47</td>
<td>13.50</td>
</tr>
</tbody>
</table>
from families which are at greater risk for disorganization, cultural limitation, social and economic disadvantage, poor housing, excessively frequent and short-spaced reproduction, maternal and child ill-health, and so forth, than are other families even of the same social class. These additional factors themselves are capable of influencing intellectual development. In all instances the children with whom index cases have been compared could not be sufficiently well matched on these non-nutritional variables to meet the requirements of rigorous experimental design. The most thorough attempt is that of Champakam, et al., in which age, sex, religion, caste, socioeconomic status, family size, birth order, and parental education were taken into consideration. However, in that study it was possible that the families of children hospitalized for kwashiorkor were either genetically different, or provided less adequate experiential opportunities for intellectual development than the comparison families.

Another tactic is to use siblings of the malnourished children as comparisons. Such sib studies, though admittedly imperfect, provide different opportunities for interpreting findings. Only two such sib studies have thus far been carried out. In one of these, sibs without a history of hospitalization for severe nutritional illness were found to be significantly superior in IQ to their hospitalized brothers or sisters. However, the conclusions from this study are limited by the facts that the sample studied was relatively small, the sibs not like sexed, and no general population comparison group examined. In the other sib study, age at which malnutrition was experienced ranged from 10 months to 4 years with only 10 of the children in the group under 18 months of age. Moreover, gross differences in IQ in different segments of the kwashiorkor sample as well as in their siblings make the data difficult to interpret.

In conducting a sibling comparison study it must be recognized that while sibs may have many background characteristics in common, a number of differences must be considered in the analysis of findings. Sibs, unless they are twins, are necessarily different in age and in ordinal position, both of which factors may affect child-rearing practices as well as intellectual outcome. Moreover, in a community such as Jamaica, sibs not infrequently have different fathers and experience different conditions of child-rearing. These factors must all be taken into account in designing and interpreting a sib comparison study.
TABLE III

LEVELS OF SIGNIFICANCE OF DIFFERENCE IN IQ OF THE INDEX, SIBLING, AND COMPARISON GROUPS

<table>
<thead>
<tr>
<th></th>
<th>Index vs. Comparison</th>
<th>Index vs. Sib</th>
<th>Sib vs. Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>t</td>
<td>p</td>
</tr>
<tr>
<td>Full Scale IQ</td>
<td>71</td>
<td>3.25</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>71</td>
<td>4.78</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>71</td>
<td>3.57</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

* All p values are one-tailed in view of the directional nature of the hypotheses. All t tests are matched pairs dependent t tests.

A second question with which the present study is concerned has emerged both from reports of animal investigation and from studies of recovery in children who have been hospitalized for severe malnutrition at different ages in early life. The evidence of the animal investigations indicates that the risk of defective myelination, reduced cell replication, and delayed biochemical maturation are greatest when malnutrition coincides with particular periods of rapid brain growth.24-27 In the human organism the period of most rapid growth of brain extends from about the beginning of the last trimester of pregnancy to the last 3 months of the first postnatal year. Moreover, during this period cellular replication in the central nervous system is completed.

These facts have led to speculation that severe malnutrition during the first 9 months after birth would have more severe consequences than severe malnutrition experienced later in infancy and early childhood. Some support for these expectations has derived from the study of Cravioto and Robles12 in which children admitted to hospital with severe malnutrition in the first 6 months of life were found during convalescence to recover behavioral competence less fully than children hospitalized for the same illness later in infancy. However, for several reasons, these data are by no means conclusive. Although cell replication is completed at an early age, other aspects of growth and differentiation in the nervous system such as dendritic proliferation, extranital branching, and synapse formation, all of which may be more important for integrative organization than cell number, continue to develop at very rapid rates throughout early childhood. Moreover, the Cravioto and Robles study12 did not follow the children in order to evaluate later aspects of development and their conclusions cannot be extended for outcomes beyond the immediate recovery period.

An additional issue requires consideration. Though animal experimental data have indicated that particular vulnerabilities to nutritional stress exist in brain in re-

TABLE IV

NUMBERS OF CHILDREN IN INDEX AND COMPARISON GROUPS PERFORMING AT OR BELOW THE FLOOR SCORING LEVEL OF THE TEST SCALES

<table>
<thead>
<tr>
<th></th>
<th>Full Scale IQ</th>
<th>Verbal IQ</th>
<th>Performance IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Index Comp.</td>
<td>Index Comp.</td>
<td>Index Comp.</td>
</tr>
<tr>
<td>≤46</td>
<td>17</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>&gt;46</td>
<td>57</td>
<td>71</td>
<td>70</td>
</tr>
<tr>
<td>X² = 7.69</td>
<td>X² = 1.03</td>
<td>p &lt; 0.01</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>≤46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X² = 9.38</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p &lt; 0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE V
ANALYSIS OF VARIANCE OF IQ LEVELS IN CHILDREN HOSPITALIZED FOR SEVERE MALNUTRITION AT DIFFERENT AGES IN THE FIRST TWO YEARS OF LIFE

<table>
<thead>
<tr>
<th>Age at Admission in Months</th>
<th>IQ Full Scale</th>
<th>IQ Verbal</th>
<th>IQ Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-7</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>8-12</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>13-24</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>57.93</td>
<td>64.93</td>
<td>56.93</td>
</tr>
<tr>
<td>SD</td>
<td>9.08</td>
<td>12.62</td>
<td>9.33</td>
</tr>
<tr>
<td>F Ratio</td>
<td>0.96</td>
<td>0.61</td>
<td>1.01</td>
</tr>
<tr>
<td>p</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

Analysis of variance of IQ levels in children hospitalized for severe malnutrition at different ages in the first two years of life. The table shows the mean IQ scores for full scale, verbal, and performance intelligence quotient (IQ) for different age groups. The F ratio and p values indicate the significance of the differences between the age groups. The analysis is based on 74 severely malnourished children who were all boys and had been treated in hospital for severe infantile malnutrition during the first 2 years of life. The study was conducted in the pediatric ward of the Tropical Metabolism Research Unit of the British Medical Research Council, Mona, Jamaica, W.I. The remaining 14 cases were added in order to have a fuller representation over the entire first 2 years of life. These were obtained from the Pediatrics ward of the University Hospital, University of the West Indies, Mona. All children were suffering from severe malnutrition at the time of hospitalization, reflected variously in syndromes of marasmus, kwashiorkor, or marasmic-kwashiorkor. In all cases detailed clinical and metabolic records were available. Children on the average received 8 weeks of inpatient care. In general, follow-up visits in the homes were conducted for 2 years following discharge.

Sixty-four male infants had been treated on the metabolic ward of the Tropical Metabolism Research Unit in the years relevant to the study. At follow-up two of these children and their families had moved and could not be traced. Two additional children were found but not included in the study, one because he was a mongoloid and the other because of the presence of infantile hemiplegia, most probably of perinatal origin. The remaining 60 children were all included in the follow-up study. The 14 cases deriving from the pediatrics ward were the first 14 to be located from an initial pool of 50 cases. Approximately half of these lived in the city of Kingston and the remainder in other towns, villages and rural districts, in some cases more than 100 miles from Kingston.
At the time of the study the index cases were 5 years, 11 months through 10 years of age. These ages were selected in order to be far enough removed from the time of acute illness to eliminate the effects of immediate sequelae and for the children to be at an age where intelligence testing has predictive validity for later life.

Wherever there was a male sibling of the index case between 6 and 12 years of age and nearest in age to the index case, and without a history of severe clinical malnutrition, he was included in the study. Because of widely varying patterns of family composition in Jamaica, a sib was defined as a child having the same biological mother as the index case and having shared a home residence with the index child for most of his life. Thirty-eight such sibs were available and studied. Because of the selection criteria used, the sibs were somewhat older than the index cases.

In addition to the sibs, a classmate or neighbor comparison was selected for each index case. For index children attending school, two classmates of the same sex closest in age to the index case were selected. If the first comparison child was not available for examination, the second comparison was used. Some of the index boys, though of school age, were not going to school. For these cases, a comparison case was chosen by finding the nearest neighboring child who was not a relative and who was of an age within 6 months of the index case. For some index cases at small schools no classmate was within 6 months of age. For these cases neighbor children were also used as comparisons. Of the 74 comparison cases, 63 were classmates and 11 were yardmates who meet all criteria of selection. As would be expected from the method of selecting comparison children, index and comparison children lived in the same general neighborhood from which the school drew its pupils. In three cases comparison children could not be brought in for study. This resulted in 71 matched pairs of index and comparison children. Table I summarizes the ages at testing of the children studied.

The comparison children should not be considered as controls but rather children who were identified because of their geographical proximity and their closeness in age to the index children. Detailed interviews were conducted on the background histories of all children. These indicated that eight of the comparison children had been sick either with malnutrition or with symptoms that could have been associated with malnutrition between the ages of 1 month and 2 years of life. Only one of these was hospitalized during this age interval. The reason was diarrhea and vomiting. The hospitalization was for 2 weeks.

Each child's intellectual level was individually evaluated by means of the WISC. Although this intelligence test has not been standardized for Jamaican children, its use in the present study is appropriate. It contains subtests which broadly sample cognitive abilities both verbal and nonverbal and standardized forms of administration of test items together with well-defined scoring criteria. As a standardized test it also provides scores across age groups which may be combined for meaningful group comparisons. Clearly the IQs obtained for Jamaican children are not directly comparable with those of children in the cultures for which the test has been standardized. However, as Vernon has pointed out, comparisons of children within a culture on a test standardized in another setting are entirely appropriate so long as the test is not so difficult or so easy as to produce scores which do not discriminate among individuals and groups in the population tested. In the present study the test discriminated across groups; individual differences were equally great at all ages; no trend in mean IQ by age was shown. Thus the test provides a useful basis for comparing relative levels of competence among groups of Jamaican children.

All testers were experienced examiners from the United States or England. All children were examined without the examiners being aware of the study group to which the child belonged. Cases were scheduled
for examination by a public health nurse who provided coded information on the group to which the child belonged (sib, index, or comparison) which was decoded after all examinations had been completed.

The characteristics of the groups selected would lead us to anticipate that the index cases having suffered acute malnutrition would be most severely impaired in intellectual functioning, that their sibs, some of whom would have experienced chronic subnutrition but not an acute severe episode, would have been moderately impaired, and that the comparison children, not identified by belonging to a family having a child with a history of severe clinical malnutrition, would be least impaired. The first set of analyses provide tests of these hypotheses by comparing Full Scale, Verbal, and Performance IQ in the three study groups. In the second set of analyses intellectual ability in the index children is related to the age of acute nutritional illness.

RESULTS

The Group as a Whole

For the Full Scale, Verbal, and Performance IQ measures the index cases have the lowest mean scores, the sibs occupy an intermediate position, and the comparison children have the highest scores (Table II). These differences are in accordance with expectation. The three IQ measures are seven to nine points lower for the index children than for the comparisons. Each of the differences is statistically significant at less than the 0.001 level of confidence (Table III).

That these mean differences in IQ score are not the result of a few cases of extreme competence in the comparison group or of extreme incompetence in the index cases, but represent differences over the whole range, is clearly indicated in Figure 1. As may be seen from this figure, the groups, in general, differed from one another in Full Scale IQs over the whole range of measures. The cumulative frequency percent curves for Performance and Verbal IQ in the two groups are almost identical in form and indicate that the comparison group is also superior on these measures.

Sibling Comparison

The index children also have lower scores on the three IQ measures than their sibs. The Full Scale and Verbal IQ differences are statistically significant (p < 0.025). Differences in Performance IQ are not significant. When the sibs are contrasted with the comparison children they are found to differ from them significantly only in Performance IQ.

Before the results can be interpreted two further analyses are required. In the first place, sibs tend to be older than index and comparison cases and the differences between the sibs and the other two groups could have derived from this age difference. Moreover, since ordinal position can affect IQ within a sibship, differences between sibs and index cases could have been the result of differences in ordinal position. To deal with the first question, the relation of IQ level to age was analyzed in each of the groups. No age trends for IQ were found. To deal with the second question, older sibs were separately compared with younger index cases and younger sibs with older index cases. Identical trends and directions of difference were found when the sibs were respectively in lower or higher ordinal positions in the sibships. These analyses indicate clearly that the differences among groups were not artifacts either of age or of ordinal position.

TEST LIMITATIONS

The structure of the intelligence test and its scoring result in the artificial inflation of mean IQ levels in groups having members where functioning is very poor. As a result of scoring convention, children who answer no questions correctly will receive IQs of 46 for Full Scale and Verbal Scale and of 44 on the Performance Scale. Therefore, if a significant number of individuals in the index group was functioning at the very lowest level, the arbitrary floor value for the scale would artificially inflate the mean for
the group and thus alter the size and significance of group differences. Because the index cases have the lowest scores, the effect of this artifact of scoring is to provide an excessively conservative estimate of the size of the differences in intellectual level between the index cases and comparison children and between index cases and sibs.

One can obtain a more accurate appreciation of the differences by comparing the groups with respect to the number of individuals who perform at or below the floor level. The number of children in the index and comparison groups who scored at the floor of the test are presented in Table IV. For Full Scale IQ 23% of the index cases as compared with 7% of the comparison children performed at or below the floor of the test. This difference is significant at less than the 0.01 level of confidence. A similar set of findings is obtained for the Performance Scale but not for the Verbal Scale. Sibs fall in an intermediate position and in no comparison are significantly different in the proportion of minimally functioning cases from either the index or comparison group. These findings indicate that mean differences we have found between the index cases and other groups are minimal differences and do not fully reflect the low level of IQ in the severely malnourished children.

**Age of Severe Malnutrition**

The age distribution of the children when admitted for the treatment of severe malnutrition ranged from 3 to 24 months, with admissions at almost every month between these ages.

If the age at which a child is hospitalized for severe malnutrition is systematically related to the severity of his intellectual impairment, we would expect a significant positive correlation to exist between age at admission and IQ at school age. When IQ and age at hospitalization are correlated, Full Scale, Verbal, and Performance IQs do not correlate significantly with age of hospitalization for severe nutritional illness. The respective Pearson correlations obtained are −0.13, −0.13, and −0.14, and indicate a random relationship between age of the severely malnourished child at hospitalization and IQ at school age.

Because the replication of cells in the central nervous system tends to be completed before the age of 9 months, it has been suggested that children experiencing severe malnutrition before this age are at particular risk of brain damage and lowered intellectual level. Therefore, we considered it desirable to compare those children who had been hospitalized before the age of 8 months with those admitted to hospital for severe malnutrition at later ages. When children admitted before 8 months of age, between 8 and 12 months, and between 13 and 24 months are compared, no significant differences are found between groups for Full Scale, Verbal, and Performance IQ (Table V). The data, therefore, provide no support for the hypothesis that systematic differences in intellectual outcome at school age attach to severe malnutrition experienced at different ages during the first 2 years of life.

**DISCUSSION**

In this report we have presented two sets of findings. The first indicates that children who have experienced severe malnutrition in the first 2 years of life have lower levels of intelligence at school age than their sibs and classmates. The second finding shows no association between the intellectual level of cases and the ages at which the children were hospitalized for the treatment of severe malnutrition during the first 2 years of life. Each of these findings has a bearing on the relation between antecedent malnutrition and mental development and their implications for this issue will be considered.

The lower level of intelligence of the index children compared with classmates or neighbors of the same sex and age is a result which agrees with the findings of previous studies. The method used for selecting the comparison cases has constricted the range of social, economic, and familial characteristics in the index and comparison
groups but has by no means fully controlled them. Thus, we have found that our ability
to interpret the differences between index
and comparison children is subject to the
same limitations as those which characterize
prior studies. Since the index and compari-
son children may also differ in other
attributes which may influence intellec-
tual level,\textsuperscript{6, 18, 31} the obtained differences in IQ
cannot be directly attributed to differences
in nutritional status during the first 2
years of life. Thus it is possible that the index
children could have been subjected to
stresses other than malnutrition either pre-
or postnatally. However, a consideration of
this issue will be presented in future reports
dealing with this study. We have examined
in detail these and other biological and so-
cial factors which may contribute to intel-
lectual differences in the children studied
and will report on these findings in subse-
quent papers. However, many of the diffi-
culties in interpretation are reduced when
the index children are compared with their
sibs. Sibs have shared the same familial and
social circumstances but do differ in ante-
cedent exposure to malnutrition. Though a
sib comparison does not control all nonnu-
tritional factors influencing mental growth,
it goes far toward doing so.

In the present study we have found that
like-sexed sibs as a group have scores which
are significantly higher for Full Scale and
Verbal IQ than their brothers who experi-
enced severe malnutrition during the first 2
years of life. These differences in level are
not the result of the age differences be-
 tween the sibs or of their different ordinal
positions in the families. The findings which
agree with and extend those of one other
sib comparison study carried out\textsuperscript{23} indicate
that the early experiences of severe malnu-
trition and the attendant hospitalization
contribute to depressed intellectual de-
velopment. Comparison of the findings with
those of the other sib study\textsuperscript{22} is not possible
because of the gross differences in age at
which severe malnutrition and hospitaliza-
tion occurred and because of the peculiar-
ities of the reported mean IQs.

The tendency of the sibs to have some-
what lower IQs than the comparison groups
can either derive from the experience of
chronic undernutrition,\textsuperscript{2} from differences in
familial environment, or from a combina-
tion of these factors. Although the likeli-
hood is high that children reared in a fam-
ily in which one child has been severely
maltreated have also been chronically
malnourished, one cannot with confidence
attribute the differences in IQ between the
sibs and the comparison group to nutri-
tional factors alone because of differences
in familial characteristics of the groups.
However, the gradient of intellectual level
obtained ranging from the index cases at
the lowest end to the comparison group at
the highest may parsimoniously be consid-
ered as reflecting a gradient of nutritional
experience across groups. It is of special in-
terest to note that these findings occurred
under circumstances in which the severely
malnourished children received excellent
care in hospital through a long convales-
cence and were followed by public health
nurses who advised the caretaker on feed-
ing for a 2-year period after discharge.

Our failure to find a systematic associa-
tion between the age during the first 2
years of life at which severe malnutrition
was experienced and the degree of intellec-
tual impairment, does not support the hy-
pothesis that brain vulnerability is limited
to the first year of life. Although it is true
that cell number and enzyme levels may be
altered by severe malnutrition, especially
when it occurs prior to the end of the first
postnatal year, the relations between dam-
age to such systems and the functional in-
tegrity of the nervous system is by no
means clearly defined. It must be recog-
nized that other aspects of nervous system
growth such as dendritic proliferation, ax-
onal branching, and synapse formation, all
of which are potentially of great functional
significance, have a developmental course
which is not restricted to early infancy.\textsuperscript{28, 29}

It can be argued, also, that whereas cell
number is most affected by early nutritional
stress, these other, less readily measured,
features of central nervous system development remain vulnerable to malnutrition at considerably later ages. If this is the case, continued vulnerability of the nervous system to malnutrition after cell replication has been completed should not be surprising. The results indicate a need for further and detailed studies of populations of children who experience malnutrition at even later ages than those we have been able to study.

Alternatively, it should be recognized that children experiencing severe malnutrition at different times of life are hospitalized at different ages. There is evidence to indicate that the effects of hospitalization on adaptive development are least great in children under 6 months of age and grow increasingly more severe thereafter. Consequently, if subsequent psychological development is being conjointly affected by the influences of nutritional illness on the nervous system and by hospitalization, the effect of the latter at later ages may compensate for possible diminution in the effects of the former. This, too, could result in the absence of a systematic relationship between degree of mental impairment and the age of severe malnutrition. Finally, it is possible that nutritional illnesses are systematically more severe in the older infants. All of these questions require further investigation and in view of the complexities noted we see the present study as one step in the exploration of a complex issue.

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