Psychosocial Consequences of Early Childhood Growth Retardation

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Evidence for associations between childhood linear growth retardation and poor developmental outcomes has been increasing over the last two decades. The extent to which these are a consequence of growth retardation or the environment in which growth retardation occurs remains unclear. Given the high prevalence of stunting in many developing countries, it is important to establish its psychosocial consequences, as these will have implications for individuals’ economic and social success and, at a national level, the capacity for human resource development.

Work in this area has tended to focus on the consequences for cognitive ability. Less information is available on educational and behavioral outcomes. Deficits in these areas are likely to have social and economic repercussions, but almost no data exist on this aspect, limiting the conclusions that can be reached.

CROSS-SECTIONAL ASSOCIATIONS BETWEEN HEIGHT AND COGNITION

Infants and Young Children

Significant associations between height and developmental levels have been found in several studies of preschoolchildren in developing countries. In a study of Kenyan children aged 30 months, taller children had significantly higher scores on the Bayley Mental and Motor Scales (1). However, height was not a significant predictor of development in a multiple regression analysis, which included socioeconomic and child-rearing variables. The children’s weight entered the model, and it is likely that as height and weight are highly correlated, there was no further contribution of height to the variance in development.

Associations between height and several cognitive measures have been investigated in rural Guatemalan children. Using a Composite Infant Scale (CIS) constructed from items from the Bayley, Cattel, Merrill–Palmer, and Gessel Scales, mental and motor performance at 6 months was significantly associated with height (measured at 9 months) (2). In a later report again using the CIS, height was
correlated with concurrent mental and motor performance at ages 6, 15, and 24 months (3). The children were assessed again at age 3–7 years, and height was correlated with test scores in language, memory, and perception (4). When socioeconomic status was included in the regression model, a nutrition index comprising height and head circumference contributed significantly to the variance in a composite score of the three tests.

The relation between height and development was examined in children from two poor urban communities in Jamaica (5). Height for age was significantly correlated with developmental quotients (DQs), and the association remained significant in multiple regression analyses controlling for family and child characteristics.

In an attempt to determine the relative effects of acute episodes of protein–energy malnutrition and linear growth retardation, developmental levels were examined in children who were recovered from severe malnutrition compared with a group of children matched for height for age who had not experienced an episode of severe malnutrition. Height for age contributed significantly to the variance in development, but occurrence of an acute episode did not (6).

School-Age Children

An association between height and intelligence quotient (IQ) in schoolchildren in developing countries has been found in most studies. In Guatemala, height for age significantly predicted scores on the Wechsler Intelligence Scales for Children (WISC) after controlling for socioeconomic status in poor urban children aged 4–9 years (7). There was, however, a significant interaction with socioeconomic status. IQ increased with increasing height for age in children in socioeconomic status quartiles 2–4, but among children in the poorest quartile, there was no significant increase in IQ with increasing stature.

In a group of 142 Jamaican boys aged 6–10 years, half of whom were malnourished in early childhood, the IQs of the taller boys were significantly greater than those of the shorter ones, taking into account early nutritional experiences (8). In contrast, among schoolchildren in Chile aged 7–10 years, Colombo et al. (9) found no association between height for age and IQ (WISC scores) in 30 children who had protein–energy malnutrition in early childhood and in 27 children who had not suffered an acute episode of malnutrition. The IQs of this latter group were not significantly lower than those of nonstunted children from similar social backgrounds.

The cognitive abilities of Kenyan children aged 7–8.5 years were measured with the Raven Progressive Matrices and a verbal comprehension test similar to the Peabody Picture Vocabulary Test (10). Height for age was significantly correlated with the cognitive scores in girls but not in boys. In a stepwise multiple regression analysis, including socioeconomic status and years of schooling, height for age did not enter the model, although weight for age was significant.

Associations between height for age and IQ were found in most of these cross-sectional studies. However, children with linear growth retardation typically come from very poor home environments, which contribute to poor developmental outcomes.
Even when multivariate analyses are used to control for variability in social background, residual confounding is likely to remain, and it is not possible to fully distinguish whether low height for age is a marker for other factors related to development or whether poor development is partially a consequence of the process of becoming stunted.

LONGITUDINAL STUDIES OF HEIGHT AND COGNITION

Longitudinal studies of children with linear growth retardation provide information on the possible long-term psychosocial consequences. Although the time sequence strengthens the argument that the developmental effects are linked to stunting, these studies are again observational and do not clarify the relative importance of the experience of becoming stunted or other associated environmental factors.

Early height predicted later developmental levels in a study of young children in Guatemala in whom length at 6 months predicted mental and motor performance at 15 and 24 months of age (3). When current height was controlled, however, earlier height was no longer significantly related to development. Change in height was related to change in development, so that children who grew faster also had greater increases in development.

In Jamaica, Powell et al. (11) investigated the relation between growth and developmental change over 2 years in stunted Jamaican children initially aged 9–24 months. Concurrent linear growth predicted developmental change over the 2 years combined but not over 1-year intervals. In addition, children with greater height gain in the first year of the study increased significantly more in mental age in the second year. Thus, differences in growth rates preceded change in development. These associations between linear growth and change in mental development were seen after controlling for several environmental variables and strengthen the evidence linking physical growth to development.

Height at 30 months of age was associated with cognitive scores (Raven Matrices and Peabody Picture Vocabulary Test) at age 5 years in rural Kenyan children (12) but was not significant in multivariate analyses taking family background, caregiver characteristics, and early enrollment in school into account.

Mendez and Adair (13) reported the performance on a test of nonverbal intelligence at ages 8 and 11 years of a cohort of children in the Philippines according to their stunting status (height for age above or below $-2$ SD) at age 2 years. In the multivariate model adjusting for schooling and for child and family characteristics, children stunted in the first 2 years of life had significantly lower test scores at age 8 but not at 11 years compared with children who were not stunted at age 2. Deficits were greater in children who were severely stunted at age 2 (height for age less than $-3$ SD), and the difference in cognitive scores between these children and those who were not stunted was similar at ages 8 and 11 years.

In that study, the investigators also compared children who remained stunted at age 8 with children whose heights for age were more than $-2$ SD at 8 years. Both groups of children had lower scores than children who were never stunted, although the
difference was smaller in the children who were no longer stunted and not significant in the multivariate model. Further analyses indicated that initial severity was more important than remaining stunted.

In Jamaica, we have followed a cohort of stunted and nonstunted children from age 9–24 months to 11–12 years. The children were recruited by house-to-house survey of most of the poor areas of Kingston. The stunted children (n = 127) participated in a 2-year intervention study of supplementation and psychosocial stimulation, which will be discussed later. On enrollment, the stunted children’s developmental levels were significantly below those of the nonstunted children (14). The children were assessed every 6 months for the first 2 years of the study and then at 7–8 and at 11–12 years. At the most recent assessment, the stunted children had significantly lower scores on a wide range of cognitive tests including the revised WISC (WISC-R) and tests of reasoning ability, language, memory, and attention. (15). These differences remained after controlling for socioeconomic status, caretaker characteristics, and the level of stimulation in the home. In 11 tests administered, the stunted children performed significantly worse in all except digit span forward, a test of short-term memory.

The DQ or IQ levels of the group of stunted children who did not receive intervention are compared with those of the nonstunted children in Fig. 1. As different tests were used in the initial study (Griffiths Developmental Scales) and at the two follow-up sessions (Stanford Binet and WISC-R), the scores were converted to SD scores. The gap between the two groups was 1.06 SD on enrollment and remained similar throughout the follow-up, with no evidence of catchup in the stunted group.

Multiple regression analyses were conducted to compare children who were moderately stunted or severely stunted on enrollment with the nonstunted children. Age,

![Graph showing developmental quotients (DQ) and intelligence quotients (IQ) (SD scores) of stunted and nonstunted Jamaican children from ages 9–24 months to 11–12 years. Values are means; error bars denote SEM.](image-url)

FIG. 1. Developmental quotients (DQ) and intelligence quotients (IQ) (SD scores) of stunted and nonstunted Jamaican children from ages 9–24 months to 11–12 years. Values are means; error bars denote SEM.
TABLE 1. Multiple regression analysis comparing moderately and severely stunted children with nonstunted group on WISC-R at age 11–12 years

<table>
<thead>
<tr>
<th>Height for age on enrollment</th>
<th>B</th>
<th>SE</th>
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<tbody>
<tr>
<td>≥ −3 SD, &lt; −2 SD (n = 70)</td>
<td>−5.97</td>
<td>2.19a</td>
</tr>
<tr>
<td>&lt; −3 SD (n = 46)</td>
<td>−9.92</td>
<td>2.57b</td>
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WISC-R, Wechsler Intelligence Scale.
Additional variables in the model were age, gender, home stimulation (homework facilities and trips, books and newspapers), caretaker's verbal intelligence quotient, and participation in stimulation intervention.

ap < 0.01.
bp < 0.001.

gender, and participation in the stimulation intervention were entered, and then social background variables offered stepwise (housing, home stimulation, caretakers' verbal IQ, and education). Dummy codes for moderate and severe stunting were then entered. The deficit in IQ compared with the nonstunted children was greater in children who were severely stunted on enrollment than in those who were moderately stunted but was still significant in this latter group (Table 1).

In the Jamaican cohort, the majority of the children have shown catchup in growth, with only 11.2% remaining stunted (height for age less than −2 SD) at age 11–12 years. Regression analyses comparing children who achieved height for age of greater than or equal to −1 SD, those whose heights remained below this level, and the nonstunted children showed that catchup in growth was not associated with any substantial catchup in development (Table 2). This suggests that environmental conditions in which improved growth can occur may not be sufficient for developmental catchup.

Early height has also been shown to predict intellectual ability in young adults (average age 20 years) in Guatemala (16). Height at 3 years was significantly related to scores on the Raven Progressive Matrices in boys but not girls. Village of residence, maternal education, and household socioeconomic status were included in the

TABLE 2. Multiple regression analysis comparing children with and without catch-up growth with nonstunted group on WISC-R at age 11–12 years

<table>
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<th>Height for age at 11–12 yr</th>
<th>B</th>
<th>SE</th>
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<tbody>
<tr>
<td>&lt; −1 SD (n = 59)</td>
<td>−8.31</td>
<td>2.34b</td>
</tr>
<tr>
<td>≥ −1 SD (n = 57)</td>
<td>−6.20</td>
<td>2.34c</td>
</tr>
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WISC-R, Wechsler Intelligence Scale Revised.
Additional variables in the model were age, gender, home stimulation (homework facilities and trips, books and newspapers), caretaker's verbal intelligence quotient, and participation in stimulation intervention.

adefined as height for age above or below −1 SD at age 11–12 yr.
bp < 0.001.
cp < 0.01.
analyses. This is the longest follow-up of the intellectual ability of individuals who experienced linear growth retardation in childhood and is important in that it suggests that cognitive differences remain in adulthood and that differences in ability seen in childhood are not transient.

SCHOOL ACHIEVEMENT

Height for age was a significant determinant of school enrollment and grade level attained in a study of the effects of childhood undernutrition on schooling in Nepal (17). Stunted children were more likely to be older than appropriate for their school grade in recent studies in Ghana and Tanzania (18). This indicated late enrollment, as grade repetition was uncommon. Height for age was the only nutritional measure (others considered were weight for age, weight for height, and hemoglobin concentration) that was associated with enrollment, and in Tanzania the relation was independent of socioeconomic status (socioeconomic status was not assessed in Ghana). The results also suggested higher dropout rates among stunted children. Although late enrollment and stunting may be related through poverty and other social background factors, it is also possible that stunted children may be perceived as not ready for school, and parents may delay sending them until they are more physically developed, particularly in rural areas where the school may be some distance away. Later enrollment and more dropouts were also seen among stunted children in the Philippines (13). Late enrollment may lead to fewer years of schooling and contribute to poorer educational achievement and employment prospects.

Studies in which children’s achievement was measured also indicate associations with stunting. Clarke et al. (19) selected children from five primary schools in Kingston, Jamaica, who were either failing or succeeding in school, as defined by their scores on the Wide-Range Achievement Test (WRAT). Height for age was significantly lower in the failing children than in those who were succeeding. After controlling for socioeconomic variables, height for age contributed significantly to the variance between the groups. Of all the health and nutrition variables considered, height for age was the best predictor of school achievement. Height for age was also related to achievement in rural primary schoolchildren in Jamaica. After adjusting for socioeconomic status, height for age remained a significant contributor to the variance in the arithmetic subtest of the WRAT (20). Height for age was also associated with achievement in Indian schoolchildren even after controlling for socioeconomic status (21).

In the Jamaican cohort study described previously, the stunted children had significantly poorer school achievement levels at age 11–12 years than nonstunted children on the WRAT.

Height at 3 years was significantly related to achievement in numeracy, literacy, general knowledge, and highest school grade attained in young adults in Guatemala (16). These differences in achievement may affect employment opportunities at a time when the subjects are entering the work force and would suggest that linear growth retardation has consequences for later social and economic status.
BEHAVIOR

A change in the behavior of undernourished children is one of the mechanisms proposed for their poor cognitive outcomes. Undernourished children may be less active, explore their environments less, and elicit less stimulating behavior from their caretakers. This may lead to slower acquisition of skills. Undernourished children have been shown to play less (22,23) and have altered attachments to their mothers (22,24). In these studies, undernutrition was defined as low weight. There is surprisingly little information on the behavior of stunted children.

Whaley et al. (25) reported that infant sociability as measured by the Bayley Behavior Record (social orientation and reaction to tester, general emotional tone, and endurance) was associated with height for age in Kenyan infants at age 6 months, with shorter infants being less sociable. Sociability in turn predicted motor ability at 30 months, and both independently predicted verbal comprehension at 5 years. Children who were taller at age 30 months were observed to talk and play more (from 15 to 30 months), and the amount of vocalizations predicted Bayley mental development scores at age 30 months (1) and cognitive ability at age 5 years (12).

As part of the Jamaican study, Meeks Gardner et al. (26) conducted extensive observations of the children's activity and behavior in their homes on enrollment to the study (ages 12–24 months) and 6 months later. Stunted children were significantly less active than nonstunted children on enrollment (26), but this difference was no longer observed 6 months later, suggesting that the difference may have been the result of delayed motor development in the stunted children (27).

Stunted children were significantly more apathetic, less happy, and more fussy than nonstunted children. They also showed less enthusiasm for exploring their environment and less varied exploration (28). Although there were no differences in the amount of vocalizations and time spent playing with the child by the caretaker, other adults, and children, the vocalizations by the stunted children's caretakers were less likely to be positive (warm, encouraging, teaching).

Factor analysis of the behavior observations and ratings produced a child factor that described a happy, active, exploring child who was less fussy and less angry/frustrated. The stunted children had significantly lower scores on this factor than nonstunted children. The child behavior factor was also associated with concurrent development and, importantly, predicted change in development from enrollment to 12 and 24 months later. These studies suggest that stunted children have behavioral changes and that these differences predict later motor and cognitive development.

There are even fewer studies of the behavior of stunted children at older ages, and additional work in this area is needed. As children progress into adolescence and adulthood, their social competence and behavior may become critical for their ability to function successfully in society.

Stunted children aged 9–11 years were more vulnerable to the stress of short-term hunger, with their performance on cognitive tests deteriorating when they missed breakfast, whereas that of well nourished children was unaffected (29). This suggestion that stunted children may cope poorly with stress has been investigated among
children from the Jamaican cohort who remained growth retarded (height for age less than \(-1.5\) SD) at age 8–10 years (30). Behavior, heart rate, and salivary cortisol levels were measured during a test session comprising psychological and physical stressors (e.g., an interview, mental arithmetic, and two frustrating tasks). Stunted children talked less and were more inhibited during the interview and were less attentive in the frustrating task than nonstunted children; their heart rates were higher throughout the test session and were significantly higher than those of the nonstunted children at the end of the session but not at the beginning. Stunted children had higher cortisol levels than the nonstunted children before the test session, and these remained higher during and after the test. This important study suggests that the hypothalamic–pituitary–adrenocortical axis and autonomic nervous systems of stunted children may be altered and that these children are more responsive to stress. The findings need replication in other populations, as the ability to cope with stress may affect performance in school and the workplace and social functioning.

**REVERSIBILITY OF EFFECTS OF EARLY CHILDHOOD GROWTH RETARDATION**

Longitudinal studies of stunted children indicate that psychosocial effects remain at age 11–12 years (15) and in young adult life (16). In a study in the Philippines, only children who were severely stunted (height for age less than \(-3\) SD) had significantly lower test scores after multivariate adjustment than nonstunted children at age 11 years (13). However, only one cognitive test was used in that study. It is likely that with no change in environment, developmental catchup will be limited. The potential for reversibility of cognitive deficits may be indicated where the environment of stunted children is altered, either permanently through adoption or by interventions in early childhood.

**Adoption Studies**

There are few studies of the long-term development of undernourished children whose environmental circumstances are improved through adoption. Adoption will typically result in improvements in nutrition, health, and home environment (including the level of stimulation in the home and, in some cases, the level of education of the caretaker). All of these would be expected to improve developmental outcomes, and follow-up of these children should provide some information on the reversibility of the psychosocial consequences of stunting.

Korean orphans with heights below the 3rd centile of Korean reference growth data who were adopted into families in the USA before age 3 years (mostly before age 2 years) achieved IQ and school achievement levels above the average US norms (31). However, their IQ and achievement remained below those of similar orphans who were well nourished on adoption (height for age \(\geq 25^{th}\) centile). Children who were adopted later (after age 2 years) also had lower achievement levels than better-nourished children, and their scores were below the US average (32). There were no
significant differences between children who were moderately undernourished on adoption (height for age between the 3rd and the 24th centile) and the well-nourished children and both groups scored above average. Within each nutritional group, earlier adoption (before age 4 years) was associated with better achievement.

In a small study in Chile, 16 children who had been admitted to nutritional recovery centers and subsequently adopted (before age 3 years) were compared with 11 children who returned to their biological families (33). On admission, the children’s mean height for age was about 90%. At follow-up (age 5.7–11.2 years) the height for age of the two groups was not significantly different and both were in the normal range. The mean IQ of the adopted children, measured with the WISC-R, was 13 points higher than that of the other children. Multiple regression analysis indicated that IQ was predicted by current nutritional status and being adopted.

In a recent report of Romanian adoptees in the United Kingdom, children adopted before age 2 years made substantial improvements in development by the age of 4 years, with those who were adopted by 6 months having similar IQs to children adopted within England (34). The Romanian children came predominantly from institutions and were both nutritionally and psychosocially deprived, the extent of psychosocial deprivation being greater than would be typical for low-income children in developing countries.

Although the information on the development of stunted children whose environments are improved through adoption is limited, it suggests that such children can make substantial gains—particularly with early adoption—and achieve levels similar to the average for well-nourished populations. It is impossible to say whether any deficits remain from the period of undernutrition as the original potential of the children is unknown. The outcome for children adopted later is not as good (32), and their nutritional status on adoption continues to affect their achievement levels.

**Intervention Studies**

There are few studies in which the effects of intervention given to stunted children on their cognitive development have been evaluated. The focus here will be on studies concerned with children who were already undernourished; only one (the Jamaican study) was specifically focused on stunted children, but in the others, the majority of the children had low height for age. Several studies in which supplementation was given to women during pregnancy and then to their children will not be considered here; these have been reviewed recently (35).

Intervention studies show whether initial deficits associated with stunting can be reduced and the type of intervention that is most effective. In addition, where the intervention involves nutritional supplementation, the studies can provide evidence for the role of nutrition in the link between stunting and poor development.

A combined nutrition and education intervention provided at daycare centers was evaluated in Cali, Colombia, among undernourished children, 90% of whom were stunted at age 3 years (36). The children were randomly assigned by neighborhood to five groups that participated in the intervention for one to four 9-month periods,
beginning at 42, 52, 63, or 75 months of age. Two groups participated only in the final intervention period, but one of these groups received prior nutritional supplementation and health care. At age 7, when the interventions ended for all the children, there was no difference in general cognitive ability between these two groups. Cognitive ability increased with the number of treatment periods, the rate of improvement being greatest when the children first joined the program. The ability of children who received four intervention periods remained significantly below that of a group of well-nourished children of high socioeconomic status. Thus, the intervention was successful in reducing the deficit in cognitive ability in undernourished (predominantly stunted) children, but a significant deficit remained. The role of nutrition in achieving the gains in ability cannot be determined. At age 9 years, benefits remained to the children’s IQ, which increased with the number of treatment periods. School grade level achieved was slightly greater and school failure lower at age 10 years with increasing intervention (37).

Children aged 6–59 months attending daycare centers in rural areas of Indonesia were randomly assigned by center to 3 months of supplementation (mean height for age $-2.34$ SD) or to a control group (mean height for age $-2.42$ SD). Results at the end of the intervention were reported only for the children aged 6–20 months. The supplemented group showed significant benefits for motor development on the Bayley Scale but not for mental development (38). Eight years later, benefits were seen in one test of memory in those children who were supplemented before 18 months of age (39). No benefits were seen in several other tests administered.

In the Jamaican study, stunted children aged 9–24 months were randomly assigned to one of four groups: control, nutritional supplementation, stimulation, or both treatments. The supplement was delivered to the home weekly and comprised 1 kg of a milk-based formula for the child, which provided 3135 kJ and 20 g of protein daily. Further information concerning the supplement and the children’s intakes has been reported (40,41). The stimulation comprised weekly sessions with the mothers and children at home, in which play with homemade toys was demonstrated (42). Emphasis was placed on improving the mothers’ teaching techniques and the quality of verbal interactions between mother and child.

There were significant independent benefits to the children’s DQ from supplementation and stimulation (14). Stimulation benefited all four subscales of the Griffiths Mental Development Scales used, whereas supplementation improved the locomotor and performance subscales. The effects on DQ were additive, and by the end of the 2 years of intervention, the group receiving both interventions caught up to the nonstunted group. This indicates that the stunted children’s deficits could be reversed while the interventions were ongoing. The benefits from supplementation suggest that lower developmental levels of stunted children can be partly attributed to nutrition.

We have conducted two follow-up studies of the children at ages 7–8 and 11–12 years to determine whether benefits from the intervention were sustained. At the first follow-up, the intervened groups had better scores than the controls in more of the tests than would be expected by chance (sign test $p < 0.05$), although differences
were not significant for the individual tests. This suggested small global benefits from each intervention, but the benefits were no longer additive in the group that had received both (43).

At the most recent follow-up conducted 8 years after the interventions ended, we detected no significant benefits from supplementation. The children who received stimulation, with or without supplementation, had significantly higher scores on the WISC-R full scale and verbal scale, Raven Progressive Matrices, and a vocabulary test (15). These results suggest that interventions to enrich the psychosocial environment of stunted children could reduce the developmental consequences.

Although supplementation had concurrent benefits for stunted children’s development, the long-term results are disappointing and may suggest that nutritional interventions would have to be continued for longer periods to have sustained benefits.

Early childhood intervention programs in the USA have had long-term educational and social benefits (44,45). It is likely that given the sustained benefits of the stimulation intervention in the Jamaican study, there will be similar benefits in adult life to occupation and earnings and social competence. Further follow-up of the cohort will be necessary to determine if this occurs.

CONCLUSIONS

There is fairly consistent evidence for associations between linear growth retardation and poor developmental or cognitive outcomes. The benefits from supplementation to motor (14,38) and mental (14) development indicate that there is a nutritional component to these deficits. Thus, they could be considered, at least in part, a consequence of growth retardation and not only the result of environments leading to both poor growth and development. The long-term benefits of supplementation in children already stunted have been disappointing, the only positive finding being an improvement in a single test in children supplemented before 18 months (39).

The available evidence suggests that educational outcomes are also affected in children with growth retardation. These children may be enrolled in school later and drop out sooner (13,17,18). Their achievement levels are also lower than those of nonstunted children (16,19–21).

There is some evidence for behavioral changes in stunted children that may contribute to their poor cognitive development. Children with low height for age have been reported to be less sociable (25), to vocalize less (1), to be less active and happy, and to be more apathetic and fussy (28). These behavioral differences predicted later development (25,28).

Poor educational achievement and behavioral effects such as being less attentive and more vulnerable to stress (29,30) are likely to lead to social consequences in adult life related to employment opportunities and social competence. There is, however, no direct evidence for this in adults, and information is needed on possible social and economic effects of childhood growth retardation in adults.

Stimulation programs conducted in a center (37) or at home (15) have had sustained effects on children’s cognitive function up to age 11–12 years, and longer-term
benefits are likely (45). The studies to date have shown the efficacy of stimulation. Additional research is needed to determine the most feasible approach to deliver psychosocial stimulation to undernourished children and its effectiveness.

Full recognition of the psychosocial consequences seen in children with linear growth retardation is needed, as they have important implications for human resource development and may limit the potential for social and economic improvements in many developing countries.

REFERENCES


DISCUSSION

Dr. Soedjatmiko: As you mentioned, and this is also the case in my country, children with growth retardation have impaired cognitive ability. If we just focus on nutritional support, they may achieve catchup in growth but still have a low level of cognitive ability. You mentioned that 8 years after nutritional supplementation, you were unable to detect any significant effects on cognitive ability. What kind of nutritional supplements did you give? Should we make a special supplement to stimulate the myelination and networking of brain cells and the production of neurotransmitters? And what kind of stimulation did you use? I think home-based stimulation is needed because the children are at home all day, but that is a big undertaking, especially in developing countries. We have somehow to improve parenting and the interaction between mother and child and also the provision of toys. How can we measure that the quality of stimulation is adequate?

Dr. Walker: The supplement we gave was just a milk-based formula. It wasn’t specially designed to improve neurodevelopment. I think, while that might be interesting at a research level, it’s not really practical in terms of how we are going to improve development in the real world. As far as the stimulation goes, ours is home based. We have to acknowledge this is very labor intensive, because the community health workers do one-on-one visits with the mothers, and they do this every week. We have tried in other studies reducing the intensity of the intervention, going every 2 weeks or once a month. Once a month doesn’t work, and once every 2 weeks does show some benefit, but less. So, you could try that. The other option that we have just started is to work with groups of mothers, so you can reach more mothers at once. This is obviously more economical of resources but not yet evaluated for efficacy. We do at least know that the individual visiting scheme works.

As to assessment, because this is a research study, we are really assessing efficacy rather than effectiveness. We have regular meetings with the community health aides, who are specially trained, and we go on visits with them to ensure that everything is going as it should. Obviously, once you translate this into a program approach, you are likely to lose some of that, but it is important to sustain the quality; if that is not there, then you may well not get the benefits.

Dr. Guesry: Your data seem to support the view that nutritional deprivation induces both somatic growth retardation and psychosocial retardation, but not that psychosocial retardation is a consequence of the growth retardation.

Dr. Walker: This is one of the reasons why I said I was a little uncomfortable with the word “consequence”; I think the jury is still out on that. The supplementation trials show very limited benefits. The only really long-term benefit so far is the one from the Indonesian study (1), and that’s on a single test in a subgroup of the children. So, I agree with you completely: It is much more likely that, while there may be a nutritional component, the problem also reflects the fact that the children come from poor homes, their mothers are less educated, have lower IQs, the quality of the care they get is different, and there is little stimulation in the homes. However, I don’t
think we should throw nutrition completely out of the argument. There is a suggestion from the data that it has a part to play, if not the major one.

Dr. Uljaszek: You stated that enrichment of the psychosocial environment can reduce the cognitive consequences. Now, children live in communities, younger children live alongside older children, and older children play with the younger children. Could you comment on the extent to which interactions between older children and younger children affect cognitive development? Do families with more children, who may also be stunted, have different scores on cognitive development from smaller families? If there is this kind of effect, at what age might it start to occur?

Dr. Walker: In the behavior observations that we did, I only drew your attention to the child factor, but we did also look at interactions with the caregivers and with other children in the home. You are right. A substantial part of the children's interactions during the day were with other children, but when we looked at that factor, it wasn't predictive, either concurrently or in the future. It is not always the amount of interaction that matters, it's the quality of interaction. When we looked, for example, at mothers vocalizing, it was not the amount of vocalization that was important but its quality—the warmth and other qualitative features, as opposed to just the amount.

Dr. Frongillo: I want to add something based on the work one of our doctoral students, Katherine Alaimo, relating to the fact that we are probably looking at the effects of community and home deprivation of various kinds on what are likely to be some very sensitive outcomes to those forms of deprivation. Katherine has been looking at the consequences of the mildest form of food deprivation found in the USA, which is usually referred to as "food insecurity": uncertainty of access to and availability of food. In a cross-sectional design, but with the ability to control for various confounding factors, she has found strong associations with cognitive outcome, school performance, some psychosocial outcomes, and, in teenagers, depression and attempts at suicide (2,3). Some of these, especially the last two, are not related to poverty in the USA. So, this is an indication that even the mildest forms of deprivation that might be related to food and nutrition can appear to share these kinds of outcome.

Dr. Adair: I think it is really challenging to try to separate out the factors that simultaneously influence stunting and cognitive development. You cited the work of Michelle Mendez. In her doctoral dissertation, she is trying to use structural equation modeling techniques to look separately at these different pathways. She is also looking at positive deviance, taking children from the lowest socioeconomic stratum in Cebu and looking at factors within those poor environments that promote better development. She finds that even when you take all these factors into consideration and control for stunting, some maternal care practices are very important. She is finding, for example, that dietary variety contributes significantly to better performance on the IQ tests. Thus, the mothers who are more educated and who provide greater variety in the diets seem to achieve better outcomes in their children.

The other important factor is that as the children get older, the effects of stunting start to diminish. A major effect relates to schooling. The longer the children are in school, the less important stunting is for some of these developmental outcomes. That's the good news—there is a way to catch up; given additional time in school, these children are able to catch up substantially. That does not mean that all stunted children catch up, but it does give us a glimmer of hope that both maternal care practices and schooling practices can mitigate some of the effects of stunting.
Dr. Walker: I think schooling can certainly be helpful, but it isn’t clear that it operates like that in all environments. We need studies within different populations. In Jamaica, we really don’t see any evidence that schooling has helped to reduce the deficit, but most of our children do enter school at approximately the same age and there isn’t a stagger, with some children entering later and staying longer. You also have to consider the quality of the schooling, which is very poor in many countries; so, I’m less optimistic than you about the extent to which we can rely on the school system to remedy the deficiencies. It hasn’t done so in Jamaica or in Guatemala. One of the differences between the Jamaican study and the Cebu study is the comparison group. Our comparison group was children who were originally above -1 SD of mean height (nonstunted), and their mean height for age at the beginning of the study was at the National Center for Health Statistics median. Thus, they were substantially better than the comparison group in the Cebu study, who were only just above -2 SD. I think that makes quite a big difference: We were making comparisons with children who came from the same very poor backgrounds, but their growth was substantially better than the stunted group. That may be one of the reasons for the differences between the studies.

Dr. Martorell: Could you comment on anemia and the other micronutrients? Anemia, for example, appears to have concurrent effects on learning, and follow-up studies show that being anemic as a child has implications for the future (4).

Dr. Walker: I did not really have the time to cover the micronutrients. The anemia studies suggest that it is not just the concurrent effects that are important, but even after treatment and later in childhood there are still deficits (5,6). Effects on brain development because of lack of iron are postulated. Zinc is also starting to be researched more, and the outcome may be very fruitful because we think it may contribute to stunting as well, and there are plausible reasons for effects on behavior and cognitive development. There are relatively few data yet on zinc supplementation in early childhood, but there are some more recent studies in school-aged children that have shown benefit (7). There are many other specific nutrients that have effects on development and that may be critical to the process.

REFERENCES