Socioeconomic Outcomes in Adults Malnourished in the First Year of Life: A 40-Year Study

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KEY WORDS

Hollingshead scales, social position, education, occupation, malnutrition, protein-calorie, life span, cross-cultural, longitudinal study

ABBREVIATIONS

BNS—Barbados Nutrition Study
CON—healthy comparison children
MRA—multiple regression analysis
PEM—protein-energy malnutrition

Dr Galler designed the research; Dr Bryce conducted the field research; Drs Fitzmaurice, Zichlin, and Eaglesfield analyzed the data; Dr Galler wrote the article; Drs Galler, Waber, and Fitzmaurice have responsibility for final content; and all authors read and approved the final manuscript.

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WHAT'S KNOWN ON THIS SUBJECT: Infant malnutrition is known to be associated with behavioral and cognitive impairment throughout childhood, adolescence, and young adulthood. However, controlled studies addressing adult outcomes in middle life, including earning potential, educational attainment, and standard of living, are limited.

WHAT THIS STUDY ADDS: A discrete episode of moderate to severe malnutrition in infancy, with good rehabilitation thereafter, is associated with lower adult social status and a widening income gap relative to healthy controls, partially attributable to cognitive impairment in the previously malnourished.

abstract

OBJECTIVE: Lifelong functional, adaptive, and economic outcomes of moderate to severe infantile malnutrition are not well known. We assessed social status and income at midlife in a cohort of Barbadian adults, hospitalized for protein-energy malnutrition (PEM) during the first year of life, with good nutrition and health thereafter, in the context of a 40-year longitudinal case-control study. We also examined to what extent childhood IQ mediated any group differences.

METHODS: Educational achievement, occupational status, and standard of living were assessed by the Hollingshead scales and a site-specific Ecology Questionnaire in Barbadian adults (aged 37–43 years) with a history of malnutrition ($n = 80$) and a matched healthy control group ($n = 63$), classmates of the index cases. Malnutrition effects, adjusted for childhood standard of living, were estimated by longitudinal multiple regression analyses, with and without childhood IQ, in the models.

RESULTS: PEM predicted poorer socioeconomic outcomes with medium to large effect sizes (0.50–0.94), but childhood IQ substantially attenuated the magnitude of these effects (adjusted effect sizes: 0.17–0.34). The gap in weekly household income between the PEM and control groups increased substantially over the life span ($P < .001$).

CONCLUSIONS: Moderate to severe PEM during the first year of life with adequate nutrition and health care thereafter is associated with significant depression of socioeconomic outcomes in adulthood, mediated in part by cognitive compromise in affected individuals. This finding underscores the potential long-term economic burden of infant malnutrition, which is of major concern given the continued high prevalence of malnutrition worldwide. *Pediatrics* 2012;130:e1–e7

Although the adverse impact of early childhood malnutrition on cognitive and behavioral development in children and adolescents is well documented,¹ lifelong functional and adaptive outcomes are only recently being investigated as the children who participated in these studies attain adulthood. In childhood, intelligence and academic performance are meaningful indicators of outcome, whereas for adults, employment, educational attainment, and economic productivity can be more relevant.

Correlational data suggest that early childhood malnutrition is associated with decreased potential for economic opportunity, with major implications for human capital. Prenatal and childhood undernutrition predict poorer functional outcomes in adulthood, including fewer years of schooling and reduced income levels.^{2,3} An epidemiologic analysis of 5 pooled birth cohorts from low- and middle-income countries indicated, moreover, that weight gain during the first 2 years of life predicts educational attainment,⁴ whereas weight gain between 2 and 4 years does not, highlighting the particular vulnerability of infants. Even in populations exposed to famine, where the malnutrition was presumably of limited duration, exposed infants are at increased risk for compromised educational attainment and earning potential as adults.^{5,6}

Because nutritional insults typically occur in a context of poverty and social disadvantage, distinguishing the effects of malnutrition per se from of the more global impacts of poverty can be challenging.^{1,7,8} Studies have typically used markers such as maternal schooling or father's occupation near birth, providing only a limited estimate of childhood socioeconomic influences (although the Jamaica study,² which assessed crowding and household possessions, is an exception). Further complicating the

interpretation of outcomes is the high prevalence of chronic undernutrition in severely impoverished environments.

Thus, although studies to date suggest that infantile malnutrition can have lifelong impacts on adult adaptive and economic outcomes, interpretation is compromised by limited characterization of childhood socioeconomic influences, potential confounding of acute malnutrition with chronic undernutrition, and lack of documentation of the malnutrition at the case level (in the case of the famine studies).

In the current study, we describe socioeconomic outcomes in adults malnourished as infants in the context of a 40-year longitudinal case-control study, the Barbados Nutrition Study (BNS). The adult follow-up also included measures of mental health, cognitive, and health outcomes that will be addressed elsewhere.⁹ The BNS was explicitly designed to evaluate the impacts of a well-documented period of malnutrition during the first year of life.^{10–16} Methodologic assets include the case-control design, detailed ecological data obtained throughout childhood and adolescence, and documentation of adequate nutrition after the malnutrition episode and of birth history.

The children recruited to the BNS had normal birth weights. They subsequently experienced moderate to severe protein-energy malnutrition (PEM) in the first year of life but had no further malnutrition after the first year of life. Their good health and nutrition were assured as part of a government-supported intervention program from infancy to age 12 years.¹⁷ These children were matched on the basis of gender, age, and handedness with a healthy comparison group recruited from the same classrooms. Despite their nutritional rehabilitation and complete catchup in physical growth,¹³ the previously malnourished children displayed persisting deficits in attention, IQ,¹² and academic

achievement¹⁸ through adolescence, as well as an increased level of conduct problems and depressive symptoms.^{15,19}

The primary aim of the current study was to compare these 2 groups at midlife on basic metrics of social outcome, including occupation, educational attainment, standard of living, and household income. We also investigated the extent to which childhood cognitive impairment accounted for any group differences. We hypothesized that malnutrition-related effects on socioeconomic outcomes would be mediated by cognitive impairment, which was more prevalent in the previously malnourished group^{10,12}. Finally, we assessed household income across the life span, hypothesizing that the trajectory of change in household income would differ in the 2 nutrition groups.

METHODS

Site

Participants were born in Barbados, an English-speaking Caribbean country. The majority of the population is of African origin (92%) and lower-middle class, with obligatory school attendance to 16 years and a 99% literacy rate. In 1970, during the era when the BNS sample was born, the infant mortality rate was 46 per 1000 live births, compared with 7.8 today. Although malnutrition was common in Barbados when the participants were born, it is now virtually eliminated because of an improved economy and an island-wide program to eradicate malnutrition.^{17,20,21}

Participants

Participants were born between 1967 and 1972.^{10,13,22} All children admitted to the Queen Elizabeth Hospital in their first year of life (mean age of admission: 6.9 ± 3.1 months) with grade II or III PEM (marasmus or kwashiorkor) based on the Gomez Scale, which classifies degree of malnutrition on the basis of expected weight for age,²³ were

eligible if they met the following inclusion criteria: normal birth weight (>2500 g), absence of pre- or postnatal complications, Apgar scores ≥ 8 , no encephalopathic events during childhood, and no malnutrition after the first year of life. These children were subsequently enrolled in a government-supported intervention program that provided health care, growth monitoring, nutrition education, subsidized foods, and regular home visits and followed to age 12 years.¹⁷ Healthy comparison children (CON) were recruited from the same classrooms and matched for gender, age, and handedness to the index children. They met the same inclusion criteria but had no histories of malnutrition.

Research Design

Participants were assessed comprehensively at 3 time points spanning childhood and adolescence and again as adults (see Fig 1). In 1977 (T1), we evaluated children with histories of marasmus ($n = 129$) and CON children ($n = 129$) who were 5 to 11 years old at that time. These children were reevaluated in 1982 (T2, not shown in Fig 1). In 1984 (T3), an additional group of children who had been hospitalized for kwashiorkor ($n = 54$) during the same period as those hospitalized for marasmus were recruited for comparison

purposes. At that time, a subgroup (marasmus, $n = 62$; CON, $n = 62$) of the original 258 children were selected for evaluation as the best matches for age, gender, and grade in school to the kwashiorkor group. The marasmus and kwashiorkor groups (PEM) were subsequently combined for analytic purposes because they did not differ on any behavior, cognitive, or anthropometric measure.^{11–14} In the period from 2007 through 2010, the cohort was studied as adults (PEM, $n = 80$; CON, $n = 65$). All but 2 had complete socioeconomic data. Although we accounted for 98% of the original participants, a limitation in funding resources for recruitment and data collection contributed to the reduction in the final number. The current study is based on 44% of the PEM group and 50% of the CON group, primarily individuals residing in Barbados.

Informed consent was provided by parents of all study participants when they were initially recruited under Protocol E1962, Boston University Medical Center Institutional Review Board, and by the Ethics Committee of the Barbados Ministry of Health. Current oversight (in adulthood) is provided by the Judge Baker Children's Center Human Research Review Committee (assurance no. FWA 00001811). All adult participants provided written informed consent.

Measures

Adult social position was measured by using the Hollingshead scales, which rank social position based on occupation and educational attainment.²⁴ The Occupation and Education Scales yield scores from 1 to 7, higher scores reflecting lower social status. Items are weighted (occupation score $\times 7$ and education score $\times 4$) and summed to produce an index of social position score (11–77), classified into 5 categories (1–5), with higher values indicating lower social status.

Childhood standard of living (T1, T2, and T3) was assessed by using the Ecology Questionnaire,^{25,26} the 50 items of which query conditions in the household and the educational and employment history of the parents. A household standard of living scale was derived by factor analysis, by using principal components factor-extraction followed by normal varimax rotation, applied separately at each time point. These data were subsequently combined because the factor structure and content across time points were comparable, although factor scores were calculated separately for each time. The standard of living scale had good internal consistency ($\theta = 0.86$).²⁷ Items contributing most strongly included possession of a refrigerator, bath, television, electricity, running water, closet, and gas or electric cooking fuel, number of bedrooms/rooms, household food expenditure, type of toilet, and weekly household income. This questionnaire was also administered at the adult follow-up. Principle components factor analysis similarly yielded a household standard of living factor (Table 1) with good reliability ($\theta = 0.81$). These scores were standardized at each time point to a mean of 0 and SD of 1.

For IQ, the Wechsler Intelligence Scale for Children²⁸ was administered at T1,¹⁰ and the Wechsler Intelligence Scale for Children—Revised at T2²⁹ and T3,¹²

FIGURE 1

Research design: BNS. Hollingshead scores were available for 143 adult participants.

TABLE 1 Items Represented in the Standard of Living Scale (Factor Loadings >0.45)

Standard of Living Factor ($\theta = 0.81$)	Factor Loadings
Total income per week	0.64
Type of work	0.61
How good were you at class work?	0.56
Part-time or full-time work this year	0.52
Months worked in the past year	0.48
Years employed in the past 10 y	0.48
Advice giver	0.49
Club member	0.46
Leader	0.46
Computer in the home	0.46
Type of house	−0.46
Type of transportation	−0.46

with minor alteration of items to include familiar local exemplars.

Statistical Methods

Data analysis was conducted by using SAS statistical software, version 9.2.³⁰ Demographic characteristics of participants who were or were not studied in adulthood were compared by using χ^2 and 2-way analysis of variance (nutrition group $\times$ participation in adult study). Because the nutrition groups differed significantly for standard of living at all time points in childhood, it was included as a covariate in all models. Because there were no main effects or interactions with gender, it was not included in the models.

Longitudinal multiple regression analysis (MRA) was applied (SAS PROC MIXED) to test the effects of malnutrition on adult social position. This analysis was repeated including childhood IQ (measured at T1, T2, and T3) to evaluate potential mediation. These analyses involved simultaneously fitting separate multiple regression equations at T1, T2, and T3, thereby allowing the effects of childhood standard of living and childhood IQ to vary over time. By simultaneously fitting these regressions, it was possible to evaluate formally how similar or different these effects were across time. Because the effects of childhood standard of living

and childhood IQ at each time point were similar, a simplified regression was fit, with common effects over time that pooled information regarding these 2 variables from all 3 periods. For inferences about the regression parameters, standard errors were based on the empirical (or so-called sandwich) variance estimator, thereby accounting for the correlation among the errors in the three regression equations (since the same adult social position outcome, albeit different covariate values for childhood standard of living or childhood IQ, appeared in the 3 regressions). Finally, household income was evaluated across time points by longitudinal MRA, by using SAS PROC MIXED.³⁰ The model included nutrition group and time (childhood/adolescence vs adulthood) as main effects and appropriately accounts for the correlation among the repeated assessments. A nutrition group $\times$ time interaction was tested to assess whether group differences changed over time. The significance level was set at $P < .05$, and we did not adjust for experiment-wise error.

RESULTS

Group Characteristics

Groups were comparable in gender and age (Table 2). Individuals who did and did not participate as adults did not differ significantly in terms of representation from the 2 groups ($\chi^2 = 0.80$, $P = .37$), gender, age, IQ, or household

standard of living in childhood. Thus, the participants could be assumed to be representative of the original cohort.

Distribution of Hollingshead Scores

The distribution of adult Hollingshead Index of Social Position scores for the nutrition groups is illustrated in Fig 2. The majority of the PEM group is represented in the lower-middle or lower social classes, whereas the CON group is represented primarily in the middle and lower-middle classes. In terms of education, only 13% of the PEM group attended university compared with 44% of the CON group [$\chi^2(1) = 13.64$; $P < .001$]. Conversely, 81% of the PEM group had manual jobs compared with 51% of the CON group [$\chi^2(1) = 11.33$; $P < .001$]. These analyses were not adjusted for covariates, however.

Effects of Nutrition Group and Childhood IQ

Table 3 shows mean values of the outcome variables and results of the multiple regression analyses. History of infant malnutrition, adjusted for childhood standard of living, was significantly related to all adult outcomes, with moderate to large effect sizes. Including childhood IQ in the model, however, greatly attenuated the malnutrition effects. There was a reduction of ~65% in the effect sizes for the Hollingshead Occupational and Educational Scales and 55% for Social Position. The attenuation was discernible,

TABLE 2 Characteristics of Subjects Studied in Adulthood Compared With Subjects Not Studied in Adulthood

	History of Malnutrition Studied as Adults		Healthy Comparison Studied as Adults	
	Yes	No	Yes	No
<i>n</i> at ages 37–43	80	103	63	66
Male, <i>n</i> (%) at ages 37–43	44 (55)	63 (61)	34 (54)	43 (65)
IQ score at 5–11 y, mean $\pm$ SD ^a	91.6 $\pm$ 14.6	89.9 $\pm$ 16.6	104.4 $\pm$ 11.8	102.7 $\pm$ 13.2
Standard of living at 5–11 y, mean $\pm$ SD ^a	−0.9 $\pm$ 0.9	−1.0 $\pm$ 1.0	−0.3 $\pm$ 0.8	0.0 $\pm$ 0.8
Age in 2010, mean $\pm$ SD, y	40.4 $\pm$ 1.9	40.0 $\pm$ 2.0	40.0 $\pm$ 1.9	37.9 $\pm$ 1.9

^a Nutrition group effects, $P < .001$; no effects of adult study group and no nutrition $\times$ adult study group interaction.

FIGURE 2

Malnutrition effects on Adult Hollingshead Index Social Position. (The Hollingshead Occupation Scales range from 1 (higher executives and major professionals) to 7 (unskilled labor), and the Educational Scale ranges from 1 (professional degree) to 7 (<7 y of school). These scores are weighted and summed to produce the Index of Social Position Score).

TABLE 3 Malnutrition Effects on Adult Socioeconomic Outcomes^{a,b}

Adult Outcomes	Hollingshead Occupation	Hollingshead Education	Hollingshead Index of Social Position	Standard of Living Scale
CON (n = 63), Mean ± SD	4.40 ± 1.72	4.25 ± 1.12	3.51 ± 1.05	0.50 ± 0.80
History of malnutrition (n = 80), Mean ± SD	5.70 ± 1.38	4.88 ± 0.58	4.33 ± 0.71	−0.39 ± 0.97
History of malnutrition				
β	−0.94	−0.50	−0.62	0.70
SE	0.29	0.16	0.16	0.15
P	<.01	<.01	<.001	<.001
History of malnutrition, adjusted for childhood IQ				
β	−0.32	−0.16	−0.26	0.33
SE	0.30	0.17	0.16	0.14
P	NS	NS	NS	< 0.05

All analyses adjusted for childhood standard of living factor scores at 3 childhood ages from 5 to 18 y (T1, T2, and T3). NS, not significant.

^a Longitudinal multiple regression analysis.

^b Unstandardized parameter estimates.

although modest, for the household standard of living, with a relative reduction of ~30% in the effect size. Thus, cognitive impairment, as measured during childhood and adolescence, appears to partially mediate the relationship between infantile malnutrition and adult social status. There were no interactions between malnutrition and IQ.

Household Income Across the Life Span

The estimated group disparity in weekly household income (based on the longitudinal MRA) increased between childhood/adolescence and adulthood (Fig 3). The interaction between nutrition group and time reflected the greater gap in the adult phase of this study, estimated at 238.66 (SE = 75.6,

$P < .01$) in Barbados dollars. There were significant differences in household income adjusted for inflation* in both the youth ($t = -2.63$, $P < .01$) and adult ($t = -3.15$, $P < .005$) phases of the study. In the youth phase, the malnourished group earned approximately \$60 less per week. Although adjusted incomes increased significantly over time for both groups, this was significantly lower for the malnourished group. Specifically, the control group had an increase of approximately \$385 per week compared with approximately \$145 for the malnourished group. Thus, the initial disparity in adjusted income seen in youth grew significantly over time.

DISCUSSION

Adults malnourished as infants achieved lower social status than did peers who had not experienced malnutrition, despite their participation in a comprehensive intervention program that ensured good health and nutrition from infancy to 12 years of age and even after taking into account the family's standard of living during childhood and adolescence. This relationship was partially accounted for by cognitive impairment in the previously malnourished group, documented since childhood.^{10,12} Moreover, the gap in household income between the 2 groups increased over time, becoming substantially greater in adulthood than in childhood.

The adaptive implications and potential economic costs of early malnutrition and its developmental consequences thus appear to be significant and life-long. The vast majority of participants with histories of early malnutrition, upward of 80%, did not complete high school and are employed as manual laborers. Conversely, nearly half of the

*Because inflation rates for Barbados were not available, household income was adjusted for inflation based on US rates at each study phase. The Barbadian economy is closely linked to the US dollar.

FIGURE 3

Malnutrition effects on adult weekly household income. Longitudinal model-based estimates on income, adjusted for inflation. Bds\$, Barbados dollars.

healthy control group attended some university, compared with only a handful of those in the malnutrition group, and only 51% are manual laborers. Thus, the neurocognitive impairment that emerged in childhood in participants who suffered from infant malnutrition appears to have major consequences in terms of life prospects.

Our data thus suggest that neurologic consequences of infantile malnutrition, manifest in cognitive compromise, limit educational and occupational opportunities in adulthood. Although it is theoretically possible that early malnutrition affects economic outcomes indirectly by impairing health and resulting in reduced school attendance and hence achievement,³¹ this scenario would not explain outcomes observed in Barbados, where significant resources were devoted to restoring and maintaining child health. We have in fact reported that school attendance at 5 to 11 years of age was not reduced in the malnourished group.²²

Our findings corroborate and complement those from studies of Greek⁶ and Chinese famines.⁵ In the Greek famine study, the adverse effects were greatest in individuals exposed as infants, consistent with our findings. Our findings are also consistent with outcome

studies in less developed countries, which consistently report lower educational attainment and income levels in adults who suffered from malnutrition or poor weight gain in the first 2 years of life.^{2,3,32–34}

Because the participants in the Barbados cohort were rehabilitated and their health and development monitored after the malnutrition episode, these findings can more confidently be attributed to the history of infant malnutrition and not to subsequent health impairment.¹³ The long-term outcomes of malnourished children growing up in less favorable conditions are therefore likely to be poorer than those seen in the Barbados sample. Moreover, the findings suggest that complete nutritional rehabilitation and catchup growth are inadequate to compensate for the neurodevelopmental impacts of early malnutrition.

Finally, the less favorable income trajectory observed in the previously malnourished participants deserves additional comment. The increased gap between these groups as adults compared with household income in childhood likely reflects reduced adult opportunity due to deficits in their cognitive functioning, and potentially their physical and mental health, predisposing them to “cumulative poverty.”³⁵ The

potential economic implications of this finding are considerable.

This study has several limitations. First, as is common in many longitudinal studies, sample sizes varied across time points. Individuals who did not participate as adults, however, essentially did not differ from those who did participate, arguing against any ascertainment bias. Another limitation may be generalizability of the findings to other settings. Given their access to good nutrition and health care, the outcomes in this sample may be more favorable than that which might be found in settings where such resources are not available.

CONCLUSIONS

According to the United Nations Children's Fund, childhood malnutrition continues to have an impact on nearly 34% of children worldwide.³⁶ More concerning, interventions after the fact, including early childhood programs, are only modestly effective in mitigating the effects of malnutrition on child development.^{31,37} The potential economic cost of early malnutrition could therefore be enormous in parts of the world where it is prevalent, especially in settings where there may be ongoing stunting and poor health care. Effective programs to prevent early malnutrition and to improve maternal and child nutrition and health, especially in the first 2 years of life, could have significant long-term economic benefit.³⁸

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