Effects of early childhood psychosocial stimulation and nutritional supplementation on cognition and education in growth-stunted Jamaican children: prospective cohort study

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See **Comment** page 1756

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Growth retardation affects about a third of children younger than age 5 years in developing countries and is associated with poor development. Previously, we did a trial of nutritional supplementation and psychosocial stimulation in stunted children aged 9–24 months. Non-stunted children were also assessed. Both types of intervention improved development. We now present the effects of early interventions on cognition and education in 103 of the 129 stunted children and compare them with 64 of the 84 non-stunted children now aged 17–18 years. We recorded no significant effects of nutritional supplementation. Compared with no intervention, stimulation resulted in higher full scale IQ scores (coefficient 0·38, 95% CI 0·06–0·71, p=0·02) and higher scores on the verbal subscale (0·37, 0·07–0·68, p=0·02), Peabody picture vocabulary test (7·84, 0·73–14·95, p=0·03), verbal analogies (0·26, 0·03–0·49, p=0·03), and reading tests (4·73, 1·31–8·14, p=0·007, and 2·7, 1·12–4·37, p=0·001). Overall, stunted non-stimulated participants had significantly poorer scores than the non-stunted group on 11 of 12 cognitive and educational tests. Stunting in early childhood is associated with cognitive and educational deficits in late adolescence, which are reduced by stimulation at a young age.

Growth retardation (stunting) affects 30% of children younger than age 5 years in developing countries. Early childhood stunting is associated with poor development, poor school achievement, and poor cognition up to age 12 years with limited evidence of poor educational achievement and non-verbal reasoning in young adults.[1,2]

In 1986–89 we did a trial in Kingston, Jamaica, of the effects on development of providing nutritional supplementation or psychosocial stimulation, or both, for 2 years to stunted (length for age less than –2 SD of US National Center for Health Statistics' references) children aged 9–24 months. We systematically assigned the children (n=129) to one of four groups—control, supplementation, stimulation, or supplementation and stimulation. The initial order of group assignment was ascertained randomly. We also enrolled 32 children who were not stunted, but who were otherwise matched to the control group for age, sex, and neighbourhood. We visited all children once a week for 2 years. Supplementation comprised 1 kg of milk-based formula per week. Stimulation comprised weekly 1-h home visits by community health workers, with the objective of improving mother-child interactions through play. Both interventions significantly benefited development.[3] The development of children who received both treatments caught up with that of the non-stunted children.

At ages 7 and 11 years, we visited the children again. At these ages, we also followed up 52 additional children who were not stunted and who we had identified during the original survey. At both ages, stunted children originally assigned no intervention had poorer intelligence levels and had poorer cognitive function than the children who were not stunted.[4] Furthermore, at age 11 years, the stunted children were not doing as well at school.[5] Stunted children who received stimulation had significant benefits to cognition.[4] Small benefits from supplementation noted at age 7 years were no longer present at age 11 years.

Here, we present the results of a follow-up study done in 2002–03 of these children at age 17–18 years (see webappendix for full article). Our aims were to ascertain whether the interventions in early childhood had sustained benefits on cognition and on school achievement and dropout rate in late adolescence, and to identify the degree and type of any remaining deficits in the stunted children who received no intervention.

We assessed cognitive function with the Wechsler adult intelligence scales (WAIS), non-verbal reasoning ability with Raven's progressive matrices, visual spatial working memory with the Corsi blocks test,[6] and auditory working memory with the digit span forwards and backwards subtests of the WAIS. We assessed language with a test of verbal analogies and with the Peabody picture vocabulary test (PPVT). Tests were administered by two observers who were unaware of the group to which children were assigned. We used the group reading test 2-revised[7] to look at reading ability (sentence completion and context comprehension) and the wide-range achievement test (WRAT) for mathematics. We obtained information on the highest grade attained or current grade if still at school. Our interest was the comparison between study groups rather than with the standardised population. We therefore express the WAIS IQ in SD scores for the study population and use raw scores for the other tests.

We derived a housing score by factor analysis of water and toilet facilities, crowding (persons per room), and number of household possessions. Information on the mothers' education and occupation was recorded. We had assessed the mothers' verbal intelligence with the PPVT at the previous follow-up. We asked participants about the frequency of hunger because of lack of food in the home during the previous year.

All participants and their parents provided written informed consent and the study was approved by the Ethics Committees of the University of the West Indies and of the Institute of Child Health, University College, London.

We ascertained effects of supplementation and stimulation on cognitive and educational outcomes by multiple regression analysis with each type of intervention coded as yes=1, no=0: supplementation—supplemented and both interventions=1, control and stimulation=0; stimulation—stimulation and both=1, control and supplementation=0. We did unadjusted and adjusted analyses. In the adjusted analyses the background variables that were significantly correlated with the outcomes or that differed between tested children and those lost were offered to the regression model in a stepwise way before entering the intervention variables.

The sponsor of the study approved the study design but had no role in data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

We assessed 167 individuals (78% of 213 children enrolled in initial study). Loss to the study was not different by group and the main reason for loss was migration. Enrolment characteristics did not differ between participants and those lost except for lower weight-for-height (p=0·02) and younger mothers (p=0·001) in children lost from the non-stimulated stunted groups. Weight-for-height was not related to any of the outcomes, and mothers' age was associated with the results of only the context comprehension reading test.

Table 1 shows there were no significant effects of supplementation. The effect of stimulation is shown in table 2. Children who received psychosocial stimulation had significantly better scores on the WAIS full scale and verbal subscale, and on the PPVT, verbal analogies test, and sentence completion and context comprehension reading tests (table 2). After adjustment for covariates, the benefits remained significant and the effects of stimulation approached significance for Raven's progressive matrices and the performance subscale of the WAIS.

Comparisons with the non-stunted group were done for participants who received or did not receive stimulation. In multiple regression analyses, we offered covariates to the regression model in a stepwise way and then entered two dummy variables—stimulation (stimulation and both=1, else=0) or no stimulation (control and supplemented=1, else=0) with the non-stunted group as the reference. The non-stimulated stunted children had significantly poorer scores than the non-stunted group on all cognitive and educational outcomes except digit span forwards (table 2). By contrast, those who participated in the intervention had significantly lower scores only in the WAIS verbal subscale and verbal analogies test, and the difference in the full scale IQ approached significance.

To ascertain whether the difference in IQ at age 17–18 years was the result of covariation with poor initial home environment, we repeated the analyses for the WAIS, offering the initial housing rating and stimulation in the home (Caldwell home observation for measurement of the environment, HOME). The HOME score was a significant predictor of full scale IQ (coefficient 0·046, 95% CI 0·01–0·08, p=0·02) and performance subscale (0·053, 0·01–0·09, p=0·008), however the effect of stunting was little changed (full

	Stunted				Not stunted (n=64)
	Control (n=27)	Supplemented (n=28)	Stimulated (n=21)	Both interventions (n=27)	
WAIS					
Full scale IQ	−0·55 (0·66)	−0·31 (0·92)	0·07 (0·95)	−0·09 (1·00)	0·38 (1·03)
Performance IQ	−0·53 (0·69)	−0·17 (1·08)	0·12 (1·05)	−0·09 (0·99)	0·30 (0·98)
Verbal IQ	−0·51 (0·74)	−0·34 (0·79)	0·04 (0·95)	−0·08 (0·98)	0·39 (1·07)
Non-verbal reasoning (Raven's matrices)	24·6 (9·1)	27·0 (11·1)	31·1 (10·5)	28·4 (11·9)	32·4 (9·6)
Visual-spatial working memory (Corsi blocks)	9·3 (3·2)	10·4 (3·9)	11·3 (2·7)	10·7 (3·7)	11·5 (2·6)
Auditory working memory					
Digit span forwards	7·7 (1·9)	8·5 (2·6)	7·9 (2·3)	8·0 (1·6)	8·8 (2·3)
Digit span backwards	4·4 (1·6)	4·8 (2·5)	5·3 (2·8)	4·5 (2·0)	5·8 (2·7)
Verbal analogies	7·3 (3·4)	7·2 (3·5)	9·3 (4·3)	8·7 (4·0)	11·0 (4·7)
Vocabulary (PPVT)	82·8 (14·2)	97·4 (23·3)	103·8 (21·0)	95·0 (21·4)	106·9 (22·3)
Reading					
Sentence completion	13·5 (7·2)	16·1 (10·0)	21·4 (10·4)	18·3 (9·5)	23·6 (12·0)
Context comprehension	6·0 (3·7)	7·7 (4·9)	10·0 (4·2)	9·1 (4·6)	11·1 (4·9)
Mathematics (WRAT)	29·8 (5·6)	28·9 (7·6)	32·0 (6·9)	31·0 (6·7)	34·2 (7·4)
School dropout	8 (30%)	8 (29%)	2 (10%)	5 (19%)	9 (14%)

Data are mean (SD), WAIS IQ in SD scores all other tests in raw scores, or number (%).

Table 1: **Cognitive and educational test scores at age 17–18 years**

	Regression 1: effect of stimulation in stunted children		Regression 2: comparison of stunted and non-stunted groups			
			Stimulation		No stimulation	
	Coefficient (95% CI)	p	Coefficient (95% CI)	p	Coefficient (95% CI)	p
WAIS*						
Full scale IQ	0·41 (0·06 to 0·76)	0·023	–0·33 (–0·67 to 0·01)	0·053	–0·71 (–1·03 to –0·38)	0·001
Performance IQ	0·34 (–0·04 to 0·72)	0·08	–0·21 (–0·57 to 0·14)	0·24	–0·50 (–0·85 to –0·15)	0·005
Verbal IQ	0·39 (0·05 to 0·73)	0·024	–0·34 (–0·67 to –0·01)	0·047	–0·70 (–1·02 to –0·38)	0·001
Non-verbal reasoning (Raven's matrices)	3·75 (0·47 to 7·97)	0·08	–1·61 (–5·35 to 2·14)	0·40	–5·23 (–8·86 to –1·60)	0·005
Visual-spatial working memory (Corsi blocks)	1·11 (–0·25 to 2·46)	0·11	–0·57 (–1·74 to 0·61)	0·34	–1·52 (–2·68 to –0·36)	0·010
Auditory working memory						
Digit span forwards	–0·15 (–0·99 to 0·69)	0·72	–0·59 (–1·42 to 0·24)	0·16	–0·46 (–1·26 to 0·34)	0·26
Digit span backwards	0·26 (–0·62 to 1·13)	0·56	–0·82 (–1·72 to 0·08)	0·07	–1·11 (–1·98 to –0·24)	0·013
Verbal analogies†	0·29 (0·04 to 0·54)	0·022	–0·25 (–0·48 to –0·02)	0·036	–0·48 (–0·71 to –0·25)	0·001
Vocabulary (PPVT)	8·44 (0·2 to 16·67)	0·045	–5·39 (–13·10 to 2·32)	0·17	–12·71 (–20·28 to –5·14)	0·001
Reading						
Sentence completion	4·85 (1·17 to 8·53)	0·010	–2·55 (–6·21 to 1·11)	0·17	–6·52 (–10·11 to –2·92)	0·001
Context comprehension	2·64 (0·91 to 4·38)	0·003	–0·97 (–2·59 to 0·66)	0·24	–3·29 (–4·89 to –1·69)	0·001
Mathematics (WRAT)	2·18 (–0·46 to 4·82)	0·10	–1·81 (–4·25 to 0·63)	0·14	–3·41 (–5·81 to –1·03)	0·005

Regression 1: dummy variables for stimulation and supplementation entered. Regression 2: coefficients are difference between stunted groups (stimulation or no stimulation) and non-stunted group. Covariates (participant's age, sex, hunger, housing factor, mother's PPVT, occupation, and education) offered stepwise before entering dummy variables for stimulation (yes=1, else=0) and no stimulation (yes=1, else=0) with non-stunted groups as reference. *WAIS IQ score in SD scores all other tests in raw scores. †Square-root transformation used in analyses.

Table 2: **Results of two regression analyses, showing effects on cognitive and educational test performance at age 17–18 years of psychosocial stimulation in early childhood and stunting in early childhood**

scale IQ –0·74, –1·15 to –0·32, p=0·001). We repeated the analyses entering birthweight, but it was not significant in any regression.

Significantly fewer non-stunted children dropped out of school (14%) compared with the stunted children who did not receive stimulation (29%, χ^2=4·03, p=0·045). Dropout among participants who received stimulation was 15%, similar to the non-stunted group.

Our results indicate that stunted children who receive home-based stimulation in early childhood compared with those who do not have sustained cognitive and educational benefits at age 17–18 years with effect sizes of 0·4–0·6 SD. We noted no sustained benefits from supplementation.

Home-visiting programmes in the USA have led to inconsistent results for child development, and participants have rarely been followed-up in adolescence.[8] Our study therefore provides some of the most extensive evidence of sustained benefits from home-based early childhood interventions.

Although the stunted children who received stimulation showed substantial benefits, their performance on two tests was significantly worse than that seen in children who were not stunted, and scores for all tests were lower. The children's improvement with stimulation suggests that environmental deprivation contributed to their poor development but does not rule out the role of nutrition. Benefits from supplementation were not sustained, but this finding could be because the provided milk was shared or substituted for other food, reducing the net increase in intake. Furthermore, more effective supplementation or supplementation of longer duration might have benefited later cognition. Findings of studies suggest that prevention of undernutrition through supplementation during pregnancy and from birth is more effective than trying to reverse the effects of undernutrition with food at an older age. Our results cannot explain whether the lack of sustained benefit from supplementation is attributable to inadequate supplementation or difficulty in reversing the effects of undernutrition.

In late adolescence the stunted children who were not stimulated had a wide range of cognitive deficits compared with those who were not stunted but who were from the same neighbourhoods. The deficits remained after adjustment for early and current environmental factors and birthweight. Although we cannot account for all the differences in socioeconomic status, these results strongly suggest that stunting during the first 2 years of life affects development. The findings suggest a global cognitive deficit, which includes verbal and performance IQ, non-verbal reasoning, language, and working memory. Participants in the non-stimulated stunted group also had marked deficits in reading and mathematics and were more likely to drop out of school. Lower educational attainment has implications for future employment and is likely to increase the risk of poverty among these individuals.

Our results indicate that developmental and educational deficits in stunted children continue into late adolescence and have implications for human-resource development. The findings emphasise the need to increase efforts to prevent childhood growth retardation. Furthermore, important benefits can be achieved for children who are already undernourished through early childhood stimulation. We have shown[9] that such intervention can be integrated successfully into health services for young children.

Contributors

All authors were responsible for the conceptualisation and design of the study. S P Walker and S M Chang were responsible for doing the study. S P Walker and S M Grantham-McGregor analysed the data and S P Walker drafted the manuscript. S M Grantham-McGregor contributed to data interpretation. All authors participated in critical revision of the report.

Conflict of interest statement

We declare that we have no conflict of interest.

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