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ARTICLE

Association of anthropometric status and residential locality factors with cognitive scores of 4–6-year-old children in Kwazulu-Natal, South Africa

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Background: The Asenze study has the long-term goal of promoting better physical, cognitive and psychosocial functioning of children in a rural area in KwaZulu-Natal, 50 km from Durban, with a view to planning interventions to promote growth and development for very young children. The specific objective in this paper was to provide information for the Child Health and Development project of the Valley Trust to assist with intervention planning. The broader goal was to assess developmental delays in communities ravaged by the HIV epidemic. The Asenze study was designed in two phases from 2008 and 2012. The current paper reports on 1 581 4–6-year-old children in the baseline phase (2008–2010) in the five adjacent tribal areas in the study area.
Method: The participants included all the 4–6-year-olds whose parents had consented to inclusion in the project and their caregivers. Data were derived from a brief questionnaire administered in the homes of participants, and subsequently from medical and psychological assessments of the children and their caregivers at the Asenze clinic. The association between child factors and other factors (geographic area, socioeconomic status (SES), parental level of education, the child's preschool education) on the one hand, and the child's cognitive performance (as measured by the Grover Counter and subtests of the KABC-11) were analysed. Linear regression models were employed to determine which predictor variables of interest in a model were associated with the children's cognitive scores as the dependent variables.
Results: Based on the data, the principal factors associated with children's cognitive outcomes were height-for-age z-score (HAZ), preschool education and the area of residence. Generally children who had low cognitive scores were more often stunted (as defined by the WHO anthropometric tables), had not had preschool education, and came from areas less favourable in terms of local infrastructure and access to employment opportunities and arable land.
Conclusion: The finding from this cross-sectional analysis of baseline data showed that in addition to height for age and preschool education, which are commonly thought to impact on cognition, the local authority area where the children lived was associated with their scores on cognitive tests. This has implications for intervention planning. The functioning of local government in promoting the type of community development that will protect the rights of children should be taken into account.

Keywords: children, cognition, education, health, nutrition

Introduction

The level of cognitive development in early childhood has significant long-term consequences into adulthood. Research has documented the disadvantages of low cognitive development in children,[1] and highlighted the need to investigate the factors that are influencing the health and psychosocial well-being of children who are the nation's future.

A British cohort study found that children's performance in mathematics and reading skills at age seven significantly predicted the scores achieved when tested at later ages, with concomitant effects on educational attainment and wages as an adult.[1–3] Evidence from a later-born cohort study revealed that tests administered as early as 22 months of age are associated with adult education outcomes.[4] These authors found that the predictive effects of test performance in childhood on adult education and wages are particularly large for children from households with lower socioeconomic status (SES).[2,4] These results underscore the importance of understanding the determinants of cognitive development, especially among poor children.

Helminth infections have also been implicated as a route through which SES affects cognitive development. Children infected with intestinal helminths are more likely to be malnourished, and to have iron deficiency anaemia, which could impair their ability to learn.[5,6] Although the research states clearly that malnutrition in school-age children is an after-effect of childhood nutritional conditions,[7] there are several important knowledge gaps.

The negative effect of malnutrition on developmental domains such as motor skills,[8–10] language,[11,12] memory and executive function[13] has been documented. A study in Kenya has shown that the impact of malnutrition on specific skills seems to vary according to child-related and environment variables.[14] There is a correlation between the effect of nutritional status and environmental factors, of which socioeconomic status is the most influential on children's performance.[15] Other studies have investigated the influence of malnutrition and other factors on cognitive performance of children younger than school age.[9,16–19]

The Asenze study has the long-term goal of promoting better physical, cognitive and psychosocial functioning of children in the Valley of 1 000 Hills, a rural area in KwaZulu-Natal, 50 km from Durban. The broader goal is to develop an approach to assessing developmental delays in communities ravaged by the HIV epidemic.

The Asenze study was designed in two phases with the first phase starting in 2007, and the second phase was scheduled for two years later. The current paper reports on 1 582 4–6-year-old children in the baseline phase (2007–2009). The specific objective for the analyses conducted in this paper was to provide information for the Child Health and Development project of the Valley Trust to assist with intervention planning.

This study works at the local level, identifying the local authority areas where 4–6-year-old children are most at risk for developmental delays, so that targeted interventions can be planned. At present it is difficult to mount affordable and effective intervention programmes for children over the whole area because the houses are scattered, the terrain is steep and intersected by river valleys, and there are few roads. It is necessary to pinpoint the areas of greatest need, for planning purposes. The starting point in this study was to examine the relationship between poor nutrition and cognitive performance, using children's cognitive test scores as the outcome measures, and taking account of the impact of factors such as the health status of the children and their exposure to early learning programmes.

Methods

The research design for this analysis was cross-sectional, examining the association between child, family and neighbourhood factors and child scores on cognitive tests at baseline in a larger longitudinal study called the Asenze ('Let's do it' in isiZulu) study. Asenze is a population-based study investigating physical health, disability and psychosocial functioning of preschool children in KwaZulu-Natal, with cross-sectional and longitudinal components.

Study area

The study was conducted over an area that ranged from peri-urban to deep rural terrain in the KwaZulu-Natal province of South Africa. The province is situated on the east coast of South Africa, bordering the Indian Ocean, and has an estimated 11 million people.[20] With 21% of the country's population, it is the second most populous of the nine provinces in the country and 75% of the children below the age of six are living in households where the per capita income is below the poverty line which is approximately US$90 or ZAR1 060 per month.[21] The study area covered five adjacent local authority areas 50 km from Durban and it was surveyed moving from house to house using GPS. The purpose of the survey was to determine how many households in the study area had children in the focal age range.

The five tribal areas differed in terms of infrastructure with two areas (Site 1 and Site 5) being close to a large dam supplying water to the city of Durban. These two areas of the valley had more land for agriculture. The five areas differed primarily in terms of local political leadership (and consequently development of services) and access to job opportunities (personal communication, Valley Trust management):

Area 1: This area has job opportunities within its boundaries, being close to the main water supply dam, and also situated in close proximity to commercial and industrial developments outside the boundary. As in most of the sites there is some tension between the traditional tribal leadership and the more recent political leadership (councillor).

Area 2: This area is also situated closer to industrial areas but has the disadvantage of numerous informal settlements with the scourges of unemployment and poverty characteristic of populations in makeshift dwellings. The area has insufficient schools and health facilities for such a large population. The traditional leadership has been weak, although this situation is now improving.

Area 3: This area has no easy access to job opportunities, being far from the commercial centres. There is no local development and the traditional leader does not live in the area. The councillor does not enjoy the support of the ruling political party and thus the area does not attract development funding,

Area 4: This is similarly situated to Area 3, far from job opportunities. The tribal authority is, however, stronger.

Area 5: Like Area 1, it has commercial activities within its borders, a Nature Reserve and small boats on the dam. It also has good access roads to commercial and industrial centres and a stable and popular tribal authority.

Study sample

Children between the ages of four and six years were identified within the five adjacent local-authority areas, which extended from peri-urban to deep rural. All 4–6-year-old children in these areas were invited to participate in the study. Information concerning the project was given to the parents and an appointment was made for those parents who had signed the consent forms to visit the clinic with their children. In instances where the parent was not available to visit the clinic, the child's primary caregiver attended the clinic with the child. There were also some instances where the participants answered the original survey but were not able or willing to attend the clinic for assessment.

Data collection

During the home visit, we employed a household questionnaire based on the widely used approach to measuring household assets in demographic and health surveys used globally and specifically in the 2003 South African national DHS survey.[22,23] The data included the type of dwelling, cooking facilities, electric kettle, refrigerator, hot water geyser, television, radio, telephone, car, bicycle and donkey or horse. In total the data collected contained information on sociodemography, anthropometry, HIV status and cognitive test scores of the children.

The child and caregiver were transported to the Asenze clinic where the child received a clinical examination, and the cognitive tests were administered by mid-level trained research assistants. The caregiver responded to a questionnaire regarding the child's health and development. Where indicated, referrals were made for further testing, treatment and/or counselling.[24]

The variables of interest

The variables included the following: site (comprising the five adjacent local authority areas described above), HAZ (height for age z-score), WAZ (weight-for-age z-score), and age (in months).

Other variables included sex, education (whether or not the child attended or had attended a preschool or crèche), SES (socioeconomic status using a household asset index in quintiles, where 1 is the lowest), father's level of education, mother's level of education, child HIV (child's infection status), and child HB (child's haemoglobin level), The household asset index, which formed the basis of the SES variable developed from the household questionnaire, employed a principal component approach. Assets were grouped into 3 categories: land ownership, ownership of consumer goods, and characteristics of household dwelling (building material, water sources, toilet facility, energy source, etc.). Variables with zero variances and those with a prevalence of less than 2% were removed. The first component explained 16% of the variance and a KMO of 0.532.

The study hypothesised that these variables would be associated with the cognitive outcomes of the child. We also took into account possible correlation amongst anthropometric variables. Separate models were fitted for the cognitive tests, namely Atlantis, Hand Movement, Conceptual Thinking from the Kaufman ABC and the Grover Counter Scale to evaluate differences among the four child cognitive performances. The analysis also evaluated the possible correlations among the cognitive tests.

A linear regression model was used to determine which of the significant independent variables were associated with a child's cognitive scores. A one-way analysis of variance was also performed on the cognitive variables t-test for differences in the sites, as well as for differences in anthropometric measurements for the five sites. Site comparisons for cognitive scores were assessed using Tukey's test. The study examined the relationship between anthropometric scores using Pearson's product–moment correlation coefficients, which were computed. A multivariate analysis was also performed on the four cognitive scores jointly to investigate the association of the variables of interest on the four cognitive scores in the multivariate context.

Cognitive assessment

The assessors were mid-level research assistants, experienced in working with 4–6-year-olds. They were trained on the administration of the tests and retrained at six-monthly intervals using videos to ensure that assessments were administered in a standardised way. The Asenze clinic environment was designed to reduce anxiety and distractibility in children. Child participants came with their caregivers, were welcomed on arrival, and were given snacks at intervals during the day and toys to play with between assessments. Both the medical and cognitive assessments were made by experienced staff in separate interview rooms.

Inter-tester reliability was calculated at each stage and any minor discrepancies discussed and corrected and the assessments were kept short. During the piloting of the assessment tests those selected for the study were found to be attractive to children and able to hold their attention. However, if children appeared unwell, or failed to complete any of the cognitive tests because of disability, tiredness or refusal to go on, their incomplete scores were omitted from the analysis. Hence, the results from 1 386 children who completed the tests are reported here.

Grover Counter test[25]

The Grover Counter test, which is based on Piagetian principles, was developed in South Africa to assess 3- to 10-year-olds' cognitive function mainly for purposes of educational placement. The child is required to sort plastic counters and arrange them in shapes, patterns and sequences to test such cognitive processes as perceptual-motor abilities, memory and reasoning. The administration of the test does not require many verbal instructions or responses, which makes it particularly useful for testing children with expressive language difficulties.[25]

KABC II[26]

Age-appropriate and relatively culture-fair subtests were selected from the Kaufman tests based on Luria's neuropsychological theories (KABC-II). The Atlantis, Hand Movement and Conceptual Thinking[26] tests used are briefly described below:

Atlantis test: The examiner teaches the child the nonsense names for fanciful pictures of fish, plants and shells; the child demonstrates learning by pointing to each picture (from an array of pictures) when it is named.

Hand Movement test: The child copies the examiner's precise sequence of taps on the table with, initially, the palm or side of the hand.

Conceptual Thinking test: The child views a set of four or five pictures and identifies the one picture that does not belong with the others; some items present meaningful stimuli and others use abstract stimuli. The children were tested in the study clinic by a trained and experienced child development assessor.

Anthropometry

The child's height was measured using a fixed stadiometer and the weight using a Masskot electronic scale (Masskot Scale, Germiston, South Africa). Z-scores were calculated for the children's height-for-age (HAZ), weight-for-age (WAZ measuring underweight) and weight-for-hight (WHZ) using the WHO anthropometry package.[27]

Haemoglobin: The child's haemoglobin was measured on a continuous scale using a HemoCue Hb201 + [45] (HemoCue AB, Ängelholm, Sweden) and the cut-off for the classification of anaemia was 11.5 g/dl.[28,29]

HIV prevalence: All caregivers were asked whether they and their children had previously been tested for HIV and the results thereof. Caregivers were also offered HIV testing for themselves and their children as part of approved study procedures, following the KwaZulu-Natal Department of Health's protocol.

Ethical approval

The ethical clearance for this study was given by the Biomedical Research Ethics Committee of the University of KwaZulu-Natal, South Africa (BF036/07) and the Institutional Review Board of Columbia University, USA.

Results

Characteristics of participating children

Of 1 582 children enrolled in the study, complete anthropometric and cognitive data were collected from 1 386 children from the five geographic areas (Sites 1, 2, 3, 4 and 5), 1 572 children with five indices of socioeconomic status (Lowest 20%, Low middle, Middle, High middle, Top 20%) and 1 582 parents' education level (None, Primary, High School, Matric, College and Unknown). Approximately 50% ($n = 698$) of the children were male and 65% ($n = 883$) of all children had received preschool education (Table 1). The study recorded 62 HIV-positive children, 1 278 HIV-negative children and 241 children with unknown HIV status. (Table 1).

Table 1: Descriptive statistics of children's categorical variables

Variable		Frequency	Percent
Site	1	241	17.40
	2	222	16.00
	3	150	10.80
	4	461	33.30
	5	312	25.50
	Total	1 386	100.00
Sex	Male	698	50.40
	Female	688	49.60
	Total	1 386	100.00
Preschool education	None	481	35.30
	Received	883	64.70
	Total	1 364	100.00
Child HIV	Positive	62	3.90
	Negative	1 278	80.80
	Unknown	241	15.30
	Total	1 581	100.00
SES	1. Lowest 20%	327	20.80
	2. Low Middle	355	22.60
	3. Middle	250	15.90
	4. High Middle	314	20.00
	5. Top 20%	326	20.70
	Total	1 572	100.00
Mother's education level	0. None	65	4.10
	1. Grade 1–7 (primary)	223	14.10
	2. Grade 8–11 (High School)	665	42.00
	3. Grade 12 (Matric)	359	22.70
	4. > Grade 12 (College)	3	0.20
	5. Unknown	267	16.90
	Total	1 582	100.00
Father's education level	0. None	88	5.60
	1. Grade 1–7 (primary)	170	10.70
	2. Grade 8–11 (High School)	407	25.70
	3. Grade 12 (Matric)	437	27.60
	4. > Grade 12 (College)	2	0.11
	5. Unknown	478	30.20
	Total	1 582	100.00

- The overall percentage of stunting was 14.7%. In Site 1 the prevalence was 18.75%; Site 2, 16.22%; Site 3, 14.09%; Site 4, 10.43%; and Site 5, 17.04%.

The children's mean haemoglobin was below the anaemia cut-off (11.5 g/dl) ad there was a wide range in the children's anthropometry variables, with low HAZ the biggest problem, followed by underweight, 3.0% (Table 2).

There was a moderate positive correlation between all the KABCII subtest scores (Pearson product–moment correlation coefficient, two-tailed $p < 0.001$). The Grover Counter test scores were similarly correlated with each of the KABCII subtest scores (see Table 3).

There were only two cases of wasting (WAZ < −2). Because the WAZ and HAZ were strongly correlated, ($p < 0.001$) only HAZ was used as a predictor variable in all the regression models. Moreover, it is known that an HAZ score of −2 standard deviations or less (stunting) is an important nutritional measure of growth failure.

Factors associated with cognitive outcomes and differences in outcomes

As is evident from the univariate analysis in Table 4, in fitting a linear regression model with the cognitive score as the dependent variable we see that there is a significant 'Site' effect for all cognitive tests. The study observed an effect of sex, which was significant only for the Grover scores but not for the other three cognitive tests. Children who had attended a preschool were found to have significantly better scores in all four of the cognitive tests. Child HIV status was significantly associated with lower scores for two of the cognitive tests (Conceptual Thinking and Hand Movement) but not for the other two cognitive tests. The effect of HAZ was significant in all the cognitive tests and stunting reduced children's scores. Age had a significant effect in all four cognitive tests, with older children doing better. The effect of haemoglobin level was significant in only one of the cognitive tests, where low haemoglobin was associated with poorer results (Hand Movement) but not significant in the other three cognitive tests. Socioeconomic status was not significant in any of the cognitive tests. The effect of mother's education level was not significant in any of the four cognitive tests. The effect of fathers' education level was found to be significant in one of the cognitive tests, where better education of fathers was associated with higher scores (Hand Movement) ($p = 0.035$) but not in the other three tests of cognition.

Summary of results associated with children's cognitive scores

As expected, there was a positive regression coefficient for age in months in all the cognitive tests. The HAZ was significant in each cognitive test, indicating that low HAZ is associated with delayed cognitive development. Children who were HIV-negative performed better than those who were HIV-positive but this was only statistically significant for the Conceptual Thinking and Hand Movement tests. Haemoglobin was not significantly associated with any of the cognitive tests except the Hand Movement test ($p = 0.03$). Girls were less likely to do as well as boys on the Grover Test in our sample.

Table 2: Descriptive statistics of continuous variables for KwaZulu-Natal children aged 4–6 years

Variable	*n*	Minimum	Maximum	Mean	SD
Age (in months)	1 386	44.00	77.00	59.06	6.984
Height-for-age z-score	1 382	−4.52	2.82	−0.94	1.015
Weight-for-age z-score	1 384	−4.00	3.00	−0.16	0.949
Weight-for-height z-score	781	−3.00	4.00	0.72	0.931
Haemoglobin concentration (g/dl)	1 574	6.10	16.00	10.95	1.187

Table 3: Correlations between cognitive test scores

Cognitive scores	Atlantis	Conceptual Thinking	Hand Movement
Conceptual thinking	$r = 0.35$ $p < 0.001$	1	
Hand movement	$r = 0.34$ $p < 0.001$	$r = 0.32$ $p < 0.001$	1
Grover	$r = 0.38$ $p < 0.001$	$r = 0.47$ $p < 0.001$	$r = 0.44$ $p < 0.001$

Having received any preschool education was important in all the cognitive tests; all the regression coefficients have a *p*-value less than 0.05. Socioeconomic status was not statistically significant for any of the cognitive tests. There was a trend towards the level of mother's education being positively associated with Conceptual Thinking ($p = 0.056$) and the Grover Test ($p = 0.062$). The level of father's education was significantly associated with the Hand Movement test ($p = 0.035$).

The overall results show that children from Sites 1 and 5 perform significantly better than children from Sites 2, 3 and 4 in the cognitive scores with children from Site 2 at a distinct disadvantage.

Table 5 provides the regression coefficients, standard errors, t-values and *p*-values for the regression models fitted for the cognitive scores.

A multivariate analysis based on the four cognitive scores showed significant effects of site, sex, age, preschool education, child's HIV status and height-for-age, while haemoglobin level, mother's education, father's education and socioeconomic status were not statistically significant.

Discussion

In this paper, we report on children's cognitive scores (our outcome variables) and how these are associated with both proximal and distal factors, and we present evidence of a strong association between proximal factors such as health and nutritional status (low HAZ) and distal factors, such as the provision of preschool education on the cognitive test scores in 4–6-year-old children. Some of the results presented here underline findings that are well established in the literature on child development and point to the need for health and education programmes to prevent developmental delays in poverty-stricken areas. But the finding that the area of residence of the child's family is so strongly associated with the average scores on cognitive tests suggests another important avenue of intervention, improvements in service delivery at a local level: health centres, preschools, roads, and controlling the development of informal housing.

This study supports the well-accepted view that a child's health and nutritional status are important in his/her cognitive development. This emphasises the need for nutrition programmes to prevent the deleterious effects of stunting when families are unable to provide adequately for their very young children.[7–9] Another aspect in South Africa is the social support grants, which provide a safety-net for families living in poverty.

The child's haemoglobin level was significantly associated with only one of the four cognitive tests, namely Hand Movement (Table 4). It is possible that this test was more demanding for this age group and therefore more sensitive to anaemia.

The negative association between cognitive scores and HIV status[30,31] is also evident in this study, and highlights the importance of preventing mother-to-child transmission (much progress has been made in this regard in KwaZulu-Natal,) and

Table 4: *F* and *p*-values for variables in univariate regression for the four cognitive tests for KwaZulu-Natal children aged 4–6 years

	Grover		Atlantis		Conceptual Thinking		Hand Movement	
Cognitive test	*F*	*p*-value	*F*	*p*-value	*F*	*p*-value	*F*	*p*-value
Corrected model	24.04	< 0.001	10.93	< 0.001	14.28	< 0.001	13.55	< 0.001
Intercept	30.03	< 0.001	0.58	0.446	5.26	0.022	7.86	0.005
Site	12.88	< 0.001	9.16	< 0.001	30.28	< 0.001	5.19	< 0.001
Sex	14.06	< 0.001	0.09	0.762	1.64	0.200	0.02	0.887
Preschool education	36.67	< 0.001	16.24	< 0.001	6.33	0.012	16.17	< 0.001
Child HIV	0.90	0.408	0.89	0.412	4.29	0.014	4.43	0.012
Socioeconomic status	0.26	0.904	0.92	0.453	0.64	0.636	1.20	0.309
Mother's education	2.24	0.062	1.80	0.126	2.29	0.058	0.68	0.608
Father's education	1.11	0.348	1.31	0.263	0.37	0.830	2.59	0.035
HAZ	32.67	< 0.001	17.82	< 0.001	4.62	0.032	12.73	< 0.001
Age (in months)	226.27	< 0.001	85.85	< 0.001	87.04	< 0.001	139.29	< 0.001
Haemoglobin level	2.806	0.094	0.002	0.962	0.340	0.563	4.69	0.030

Table 5: Multivariable regression for the four cognitive tests for KwaZulu-Natal children aged 4–6 years

	Atlantis				Conceptual Thinking				Hand Movement				Grover test			
Parameter	$\hat{\beta}$	**S.E.**	***t***	***p*-value**	$\hat{\beta}$	**S.E.**	***t***	***p*-value**	$\hat{\beta}$	**S.E.**	***t***	***p*-value**	$\hat{\beta}$	**S.E.**	***t***	***p*-value**
Intercept	6.5	4.89	1.62	0.11	−0.33	1.24	−0.28	0.78	−0.93	0.65	−1.14	0.260	−18.20	4.53	−4.17	< 0.001
Site (Ref = Site 5)																
Site 1	−1.34	1.14	−1.17	0.24	0.18	0.29	0.63	0.53	−0.23	0.15	−1.53	0.130	−0.64	1.06	−0.60	0.550
Site 2	−6.60	1.18	−5.60	< 0.001	−2.32	0.30	−7.74	< 0.001	−0.68	0.16	−4.34	< 0.001	−4.35	1.09	−3.98	< 0.001
Site 3	−4.63	1.36	−3.40	< 0.001	−2.43	0.35	−7.01	< 0.001	−0.48	0.18	−2.65	0.01	−4.71	1.26	−3.73	0.005
Site 4	−3.35	0.10	−3.36	< 0.001	−1.98	0.25	−7.80	< 0.001	−0.48	0.13	−3.60	< 0.001	−6.18	0.93	−6.68	< 0.001
Sex (Ref = male)																
Female	0.15	0.71	0.28	0.840	−0.24	0.18	−1.32	0.190	0.02	0.09	0.16	0.880	−2.40	0.66	−3.66	< 0.001
Preschool education (Ref = received)																
None	−3.53	0.83	−4.28	0.001	−0.60	0.21	−2.86	< 0.001	−0.47	0.11	−4.30	< 0.001	−4.92	0.77	−6.42	< 0.001
HIV status (Ref = HIV negative)																
HIV-positive	−1.31	1.89	−0.70	0.490	−1.40	0.48	−2.91	< 0.001	−0.59	0.25	−2.35	0.020	−1.68	1.74	−0.96	0.340
Unknown	1.41	1.04	1.35	0.170	−0.02	0.27	−0.09	0.930	0.20	0.14	1.42	0.160	−0.67	0.97	−0.69	0.490
Age (months)	0.50	0.06	8.96	< 0.001	0.13	0.01	9.10	< 0.001	0.09	0.01	11.67	< 0.001	0.76	0.05	14.74	< 0.001
HAZ	1.61	0.36	4.46	< 0.001	0.23	0.09	2.46	0.01	0.18	0.05	3.70	< 0.001	2.05	0.34	6.10	< 0.001
Haemoglobin	0.05	0.31	0.15	0.880	−0.03	0.08	−0.37	0.720	0.10	0.04	2.34	0.020	0.58	0.29	1.99	< 0.001

monitoring children's HIV status both after delivery and six weeks later, in order to ensure that any HIV-infected infants receive immediate treatment.[32] Our study found that levels of stunting remain a concern and low HAZ is associated with low scores for the cognitive tests. Stunting has been measured in many South African surveys and a review in 2015 reported a decrease in the national prevalence, but recent studies continue to report high prevalence.[33,34] In KwaZulu-Natal a study in an adjacent district amongst children of the same age (4–6 years) reported a stunting prevalence of 21.1%,[35] while our study found 14.7%. Any level of stunting is a concern because the condition affects cognitive development and any deficit in early childhood has been shown to have long-term negative effects on school performance and on wage outcomes in adulthood.[36–38]

Of interest are reports in the literature (for example Golden, 1994) that stunted children can 'catch up' and that this is more likely if stunting is addressed before the child is two years old.[39] Children who are able to 'catch up' are also likely to achieve cognitive scores closer to those of children who were never stunted. However, there is now debate concerning the appropriate definition to use when measuring 'catch-up' and using the height-for-age difference score[40] and it seems likely that the catch-up was over-estimated when viewed at a population level. This offers further incentive for intervention programmes to identify stunted children early in order to address nutritional deficits. In South African studies the likelihood of 'catch-up' was reduced if stunting occurred early in infancy.[41] The prevalence of low HAZ in the 4–6-year age group and the low cognitive scores emphasise the importance of interventions to address linear growth faltering in this age group.

Moving now to more distal factors such as national policies, in South Africa education has been compulsory for both sexes since 1996 and the parents in this study had had similar amounts of schooling. Parental education appears to be associated with the cognitive scores of their children, probably because of a greater understanding of the need to provide stimulating activities for young children and because the increased earnings of educated parents enables them to provide more resources for their children.[42,43] In this study only the father's education level was significantly associated with improved cognitive scores.

In recent years there has been increased focus on the provision of preschool education for all children, and South Africa has instituted a national Grade R programme to provide children with a preschool year prior to formal school entry. In addition, in many disadvantaged communities a daily school meal is provided, which is available to the Grade R children.[44] In this study children who had received any preschool education performed better than those without preschool education in all the cognitive tests. Unfortunately no information was collected on the type and duration of preschool education, but the finding gives an indication that providing and supporting resources and facilities for early education is beneficial. Preschool education forms the foundation of a child's future cognitive development and this aspect should be made a priority by local authorities.

The socioeconomic status of the children's families was not associated with their cognitive scores, but in this rural area most people are poor, and the lack of variability in SES could have undermined our ability to assess the significance of small differences. The assessment of SES is thus difficult.[45] 'Site' is a more complex and comprehensive measure of the geographical and social context than SES. The term as it is used here refers to the five local authority areas of the Valley, which differ along multiple dimensions that are likely to affect not only family income but also health and safety:

> *Local governance*: Some tribal areas are carefully managed but in others there is a lack of social and political control. In one area excessive in-migration gave rise to a number of informal settlements where poverty, overcrowding in the dwellings and gang activities were prevalent. In other areas ineffective local governance resulted in poor health and education services, and a lack of local projects such as road-building, which might provide employment for local family members and health, and education services are minimal. All of these factors affect the safety and peace of mind of the families living in those areas.
>
> *Topography*: The dwellings in some sites are predominantly on very steep terrain, which does not allow the family to grow crops or keep livestock. Sites closer to the Umgeni River have fertile land and subsistence agriculture is possible.
>
> *Urbanisation*: Some sites are close to urban industrial areas and others are more rural. This affects employment opportunities, transport costs, availability of water and sanitation services and even the disease profile of the area.

The three sites that had the most disadvantages in terms of local governance, arable land and access to job opportunities were also the sites where children's cognitive scores were lowest. This implies that child well-being is dependent on much more than family income in under-developed areas, and that interventions aimed at improving local governance are of key importance for the safety and stability of families and for providing key health and education services for children.[45,46]

The Asenze study has provided evidence regarding needs at a local level and the relevance of development programmes to address the negative conditions affecting children. Because the study provided parents/caregivers with transport to and from their distant homesteads, data were collected even from relatively isolated families, thus controlling a bias towards those families that are more easily contacted. These participants may usually have difficulty in accessing the primary health care clinic and preschool facilities that could identify risks to development (such as stunting or HIV infection) and facilitate children's development. The results from the Asenze study have shown the need for preschool education even though the quality of the education was not investigated.

Our cross-sectional analysis found that stunting remains a problem and that both preschool education and good nutrition as measured by the HAZ score were highly significant in improving children's age-adjusted cognitive scores. The multivariate analysis also confirmed that site, age, preschool education and HAZ are significantly associated with the cognitive scores in the study area. The National Income Dynamics Study (NIDS), a longitudinal study using panel data, reports that more stunted children started school later and more failed a grade in their first years at school.[36] Our study found independent effects of age and preschool attendance, and provides further confirmation that the effects of low height-for-age result in both short- and long-term concerns.

By identifying the 'Site' the study has also indicated to service providers where to target interventions to reach the communities most in need. Addressing local issues such as health and early education services for infants and young children is essential, and these should be implemented with a focus on the disadvantaged communities in need. The function of local government includes promoting community development and the protection of children's rights to nutrition and education should be part of that.

Limitations of the study

The study measured a range of variables but parasite infections, which can affect children's nutritional status and haemoglobin levels, were not included. Similarly, we did not have information on the quality of preschool education. Given the ubiquitous nature of poverty in the households in the study sample, it was not possible to isolate an effect of SES on the child cognitive outcomes.

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