Child: care, health and development
Original Article
doi:10.1111/cch.12143

The association between stunting and psychosocial development among preschool children: a study using the South African Birth to Twenty cohort data

D. Casale,* C. Desmond†‡ and L. Richter†‡

*School of the Built Environment and Development Studies, University of KwaZulu-Natal, Durban, South Africa
†Human Sciences Research Council, Durban, South Africa, and
‡Developmental Pathways to Health Research Unit, University of the Witwatersrand, Durban, South Africa

Accepted for publication 28 March 2014

Abstract

Background A large literature in developing countries finds a strong association between stunting in early childhood and educational attainment and/or cognitive performance among children of school-going age. We contribute to the literature on the effects of stunting in childhood by exploring the links between linear growth retardation and measures of development among preschool-aged children.

Methods We analyse the association between stunting (height-for-age z-score <–2) at age 2 years and children's scores on the Vineland Social Maturity Scale (VSMS) at age 4 years, a measure of social competence or 'daily living skills', and the Revised-Denver Prescreening Developmental Questionnaire (R-DPDQ) at age 5 years, a test which places greater emphasis on cognitive functioning. The sample is drawn from the Birth to Twenty cohort study, a prospective dataset of children born in 1990 in urban South Africa. We conduct multivariate regression analysis controlling for socio-economic status, various child-specific characteristics, home environment and caregiver inputs.

Results No significant association between stunting and children's performance on the VSMS, but a large and significant association with the R-DPDQ scores, was found. A disaggregated analysis of the various components of the scores suggests that children with low height-for-age at 2 years do not fall behind in terms of daily living skills or social maturity, but do substantially worse on measures capturing higher order fine motor skills and cognitive functioning.

Conclusions Stunting in early childhood is strongly related to impaired cognitive functioning in children of preschool age, but does not seem to affect social maturity, at least as measured by the VSMS. These relationships between stunting at 2 years and psychosocial development at 4 and 5 years hold with extensive controls for socio-economic status, home environment, caregiver inputs and child characteristics included in the multivariate analysis.

Keywords
birth cohort, cognitive functioning, preschool children, social maturity, South Africa, stunting

Correspondence:
Daniela Casale, School of the Built Environment and Development Studies, University of KwaZulu-Natal, Durban 4001, South Africa
E-mail:
casaled@ukzn.ac.za

Introduction

Estimates for 2011 suggest that globally 165 million or 26% of children under the age of 5 years suffer from malnutrition, as measured by stunting, with Africa and Asia the regions most affected. While prevalence appears to have declined since 1990, the rate of decline has been slowest in Africa, such that the *number* of children stunted has in fact increased (Black *et al*. 2013). South Africa, despite its middle-income status, has been identified as 1 of 34 countries that account for 90% of the global burden of child malnutrition (Bhutta *et al.* 2013). The prevalence of stunting for children under five in SA was estimated at 32.8% in 2003 and 23.9% in 2008 (WHO 2012). The most recent South African data suggest stunting for 0- to 3-year-olds is 26.5% (Shisana *et al.* 2013).

The effects of poor nutrition among children have been widely studied (Grantham-McGregor *et al.* 2007; Walker *et al.* 2011; Black *et al.* 2013). These include increased risk of death from infectious diseases, delayed cognitive development in childhood, poorer educational outcomes and shorter stature, as well as reduced income in adulthood (Hoddinott *et al.* 2008; Stein *et al.* 2010). For low- and middle-income counties, there is a large empirical literature on the relationship between linear growth and educational attainment and/or cognitive outcomes among children of school-going age (Glewwe & Jacoby 1995; Mendez & Adair 1999; Glewwe *et al.* 2001; Glewwe & King 2001; Alderman *et al.* 2001, 2006, 2009; Berkman *et al.* 2002; Victora *et al.* 2008; Yamauchi 2008; Martorell *et al.* 2010; Adair *et al.* 2013). However, we found little recent work, and certainly not for South Africa, involving large samples, on the impact of stunting on outcomes in preschool children. One reason for this is the difficulty of measuring cognition among young children; another is the emphasis on schooling in many developing countries. One exception is a study by Paxson and Schady (2007) in which they explore language ability in children aged 36–71 months using cross-sectional data for Ecuador. They find that, in addition to child health (height-for-age and iron deficiency), household wealth, parental education and parenting quality are all positively and significantly related to cognitive development in very young children.

This study seeks to contribute to the literature on the impacts of child undernutrition by exploring the relationship between stunting in early childhood and measures of child development at preschool age, using longitudinal data from a study of children born in 1990 in Johannesburg, South Africa.

Although still not fully understood, three main pathways have been identified through which poor nutrition may affect developmental outcomes in children. First, a lack of nutrients can cause both structural and functional damage to the brain, particularly in the early years of a child's life when rapid brain development occurs; second, children who lack energy withdraw and engage less with their environment, affecting how they learn; and third, caregivers or teachers may treat smaller children differently, challenging them less than may be appropriate for their age (Brown & Pollitt 1996).

There are at least two key methodological challenges to making causal links between undernutrition and developmental outcomes in children using survey data (Behrman 1996). The first is that causality may run in the opposite direction: as described in the economics literature, parents may give more or less food to cognitively weaker children, thereby making either compensatory or complementary investments based on perceived ability. The second is that there may be child- or household-specific variables that confound the relationship between stunting and child outcomes. Measures of socioeconomic status such as household wealth and parents' education are commonly adjusted for in empirical research. However, there are other factors that are harder to control for using most large-scale surveys. For example, the child may be born with a certain condition that affects both physical growth and cognitive function (Behrman 1996). Or, a child may do well in terms of both growth and cognition because the home environment or parents' involvement in the child's development are particularly enabling.

In this study, we exploit the rich nature of birth cohort data to attenuate a number of methodological concerns. First, our longitudinal data allow us to measure undernutrition in an early period (in our case by age 2) to predict later developmental outcomes in preschool-aged children, reducing concerns of reverse causality. Second, we control for a range of confounding effects by adjusting for socio-economic status as well as the child's home environment and caregiver inputs. In alternative specifications, we are also able to control for very early measures of the child's development (both physical and mental) prior to age 2, which might signal if there was some cognitive or physical delay which preceded stunting.

Methods

Data and sample

The data are from the Birth to Twenty (Bt20) cohort study. Bt20 is a longitudinal study of children born in Soweto-Johannesburg, the largest urban metropolis in South Africa, over a 7-week period between April and June 1990 in both private and public hospitals and clinics. Information was collected from mothers at antenatal clinics, in delivery centres, and through face-to-face interviews with the caregiver and child at least once a year. The sample of eligible singleton births was 3273; however, data are collected from approximately 1600 to 2200 participants at each interview point, resulting in response rates of between 50% and 68% per data collection wave, which compares favourably with birth cohort studies in other developing countries (Richter *et al.* 2007). As is documented in detail elsewhere (Norris *et al.* 2007), attrition seems to have been most prevalent among white South Africans (who are generally

Table 1. Summary statistics for full sample, and bivariate relationships between stunting and outcome and explanatory variables

	Mean (SD)/%	*n*	Bivariate relationship with stunting (coefficient and SE)
Outcome variables			
VSMS 4 years (score)	49.82 (5.474)	1258	−0.0009 (0.002)
R-DPDQ 5 years (score)	43.90 (4.701)	1024	−0.016 (0.003)***
Birth			
Female (%)	52.25	1403	−0.076 (0.022)***
Birthweight (g)	3075.15 (509.03)	1400	−0.0002 (0.00002)***
Socio-economic status			
African/Black (%)	81.40	1403	0.029 (0.028)
White (%)	1.92	1403	−0.102 (0.079)
Coloured (%)	14.54	1403	0.006 (0.031)
Indian (%)	2.14	1403	−0.147 (0.075)**
Asset index (PCA)	0.095 (1.430)	1164	−0.033 (0.009)***
People/sleeping room	3.413 (1.654)	1293	0.018 (0.007)***
Mother's age (years)	25.45 (6.200)	1403	−0.002 (0.002)
Mother's schooling (years)	9.79 (2.609)	1344	−0.018 (0.004)***
Home environment/caregiver inputs			
Birth order	2.04 (1.067)	1403	0.012 (0.010)
Child born within 24 months (%)	6.06	1156	0.075 (0.053)
Caregiver plays (%):	4.30	1164	0.001 (0.063)
No time			
For less than 1 h/day	37.46	1164	0.013 (0.026)
For more than 1 h/day	58.25	1164	−0.013 (0.026)
Caregiver teaches child (%)	78.45	1160	0.008 (0.031)
Father (figure) plays (%):			
Almost never	14.21	1133	0.036 (0.036)
Once a week	21.09	1133	−0.004 (0.031)
2–4 times/week	10.15	1133	0.011 (0.042)
Every day	54.55	1133	−0.019 (0.026)
Child has toys (%)	92.07	1173	−0.051 (0.046)

Sample consists of those with non-missing values on stunting and either the VSMS score or the R-DPDQ score.
$^{***}P < 0.01$; $^{**}P < 0.05$; $^{*}P < 0.10$.
SD, standard deviation; SE, standard error; VSMS, Vineland Social Maturity Scale; R-DPDQ, Revised-Denver Prescreening Developmental Questionnaire; PCA, principal component analysis.

wealthier), and over time the panel has become less representative of those born in private hospitals/clinics and living in suburban Johannesburg.

We use data mostly from delivery reports, year 2 (n = 1839), year 4 (n = 1858) and year 5 (n = 1586). The sample size for children that have non-missing data on stunting at age 2 and the outcome variables of interest at age 4 or 5 is 1258 and 1024 respectively. The summary statistics for all children in the analysis as well as the bivariate relationship between stunting and the other explanatory variables are presented in Table 1.

Outcome measures

We use two measures of early childhood development in our analysis, the Vineland Social Maturity Scale (VSMS) (Doll 1965) collected at age 4 and the Revised-Denver Prescreening Developmental Questionnaire (R-DPDQ) (Frankenburg *et al.* 1987) collected at age 5. The VSMS is a measure of social competence based on 22 items for this age group assessing daily living skills, socialization, motor skills and communication. The information is based on reports by the caregiver. Some examples of the items included are: child washes face without help, eats food with an implement, helps with little things around the house, opens/closes buttons, walks down stairs, tells you about things that happened/simple stories etc. The R-DPDQ, in contrast, is based on a series of tests and observations by the interviewer, covering the child's personal-social, fine motor, gross motor, and language abilities. In the assessment conducted in Bt20, adapting some items to be locally appropriate, the score is based on 32 items, including arranging and counting blocks, balancing on one foot, hopping, drawing lines/shapes, identifying colours, defining words, and an interviewer rating of speech. While the VSMS is predominantly a measure of social maturity, the R-DPDQ focuses more on cognitive functioning. Scores on the VSMS have been shown to have significant positive associations with IQ in South Africa (Pillay 2003). Internal consistency in this sample, calculated by Cronbach's α, is 0.73. The R-DPDQ has been found to be significantly associated with the Griffiths Scale of Mental Development in South Africa (Luiz *et al.* 2004). Internal consistency is 0.71.

We avoid using age-specific norms that might not be applicable to our sample of South African children, and instead use the within-sample variation on the scores, which are adjusted for the child's age. The mean value for the VSMS score at age 4 is 49.82 (SD = 5.47, n = 1258) and for the R-DPDQ at age 5 it is 43.90 (SD = 4.70, n = 1024) (Table 1).

Key explanatory variable

The key exposure is stunting at age 2, defined as a height-for-age z-score (HAZ) <2 SD below the mean of the reference population, using the WHO Child Growth Standards (WHO 2007). The prevalence of stunting in our sample at age 2 (in 1992) is 21.1%. This is somewhat lower than the national average of 31.5% recorded in 1993 for children under five using an alternative data source from the same period (WHO 2012). This would be expected given that we have an urban sample of children living in Johannesburg, who are likely better off than their rural counterparts.

Data analysis

We use Ordinary Least Squares regressions for our multivariate analysis. Our main results, however, are robust to using ordered probits on decile categories of the scores, or probits on binary variables capturing high scores (>1 SD above mean) or low scores (<1 SD below mean). We estimate four regressions for each of our two outcome measures, introducing additional controls at each stage. The first specification (I) shows the unadjusted correlation between stunting and the outcome variable. In the second specification (II) we add child characteristics from birth, in this case, the child's sex and birthweight. In the third specification (III) we also adjust for socio-economic status. Specifically, we include an asset index at age 2 (derived from a principle components analysis of 6 assets available in the survey, namely, fridge, car, washing machine, television, phone and radio), a measure of crowding in the household (the number of people per sleeping room in the house), mother's age at birth and mother's years of schooling. These last three variables were based on data collected between birth and 2 years. We also include race indicators here because institutionalized racial discrimination in South Africa under *Apartheid* resulted in very large disparities across race in almost all aspects of social and economic well-being. The majority of our sample (and the South African population) consists of the groups most affected by discrimination, Africans (81.4%) and Coloureds (14.54%).

In the fourth specification (IV), we add controls for the home environment and parental/caregiver involvement. Birth order and birth spacing (the latter measured by a dummy variable for whether another child was born within 24 months of the index child), are likely to capture competition for resources in the household, particularly the mother's energy and attention. In the year 2 questionnaire, the mother/primary caregiver is asked a series of questions about the home environment that provide some indication of the quantity and quality of time spent with the child, and a sense of whether the environment is 'enabling'. We use the responses to the following questions in our analysis as these aspects of the home environment are most likely to represent confounding effects: 'how much time each day do you spend "just playing" with your child?' (no time, less than an hour, more than an hour); 'is there anything you are trying to teach your child at the moment?' (yes/no); 'how often does his/her father (or other men important to the child) spend time playing with him/her?' (almost never, at least once a week, 2–4 times a week, every day); and 'does your child have any playthings, bought toys or things you have made or given him/her to play with?' (yes/no). However, when a composite 'home environment' index (which includes assets) is used instead, we find a positive effect of the index on both outcome variables as expected, and the results on stunting, remain largely unchanged.

In a series of robustness checks, we examine whether the use of alternative/additional variables affects the results. Because none of these were significant in the fullest specification, and because their inclusion led to a much reduced sample size in many cases, we chose not to include them in the main regressions. We conduct the following analyses: (1) instead of the <–2 HAZ cut-off, we the use <–3 HAZ cut-off (i.e. severe stunting), and the full range of Z-scores; (2) we restrict our sample to Africans only (given higher attrition in the other race groups); (3) we include additional measures of SES, namely household income quintiles, and paternal education; (4) we include additional aspects of the child's environment and care i.e. whether the mother was reported as the main caregiver, a measure of the mother/caregiver's relationship with/attitude to the child (based on an interviewer rating), maternal depression (postnatal), and maternal/caregiver stress; and (5) we include measures which might signal inherent/inherited problems unrelated to the child's nutrition, i.e. maternal height, and early measures of infant mental and physical development from 6 months/1 year.

Results

Figures 1 and 2 plot the bivariate relationship between stunting and the outcome measures. A visual inspection of the VSMS scores by stunting suggests little difference between the two distributions. By contrast, the distribution of the R-DPDQ scores for children stunted at age 2 sits clearly to the left of the distribution for non-stunted children. These descriptive results are mirrored in the regression results (Tables 2 and 3). The unadjusted correlation between stunting and the VSMS indicates that on average, children who were stunted scored only −0.553 (around a tenth of a SD) less than children who were not stunted, and this relationship was not significant. For the R-DPDQ, stunting was associated with a −2.417 average difference in scores (just over half a SD), significant at the 1% level.

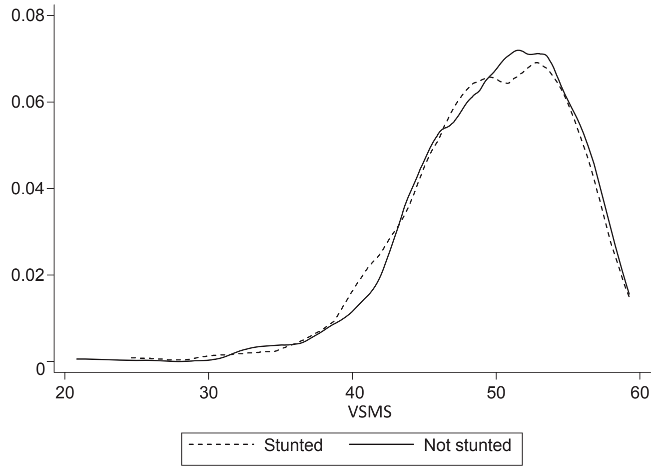

Figure 1. Kernel density plot of VSMS score by stunting. VSMS, Vineland Social Maturity Scale.

Table 2. Regression results for VSMS at age 4, OLS coefficients

Outcome variable = VSMS score	I	II	III	IV
Key explanatory variable				
Stunted	−0.553 (0.407)	−0.388 (0.419)	−0.308 (0.410)	−0.331 (0.413)
Birth				
Female		0.866** (0.352)	0.984*** (0.342)	0.933*** (0.347)
Birthweight		0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Socio-economic status				
White			−5.521** (2.141)	−5.566*** (2.153)
Coloured			−3.673*** (0.561)	−3.740*** (0.584)
Indian			−5.445*** (1.525)	−5.345*** (1.542)
Asset index			0.485*** (0.128)	0.445*** (0.131)
People/sleeping room			−0.110 (0.107)	−0.093 (0.108)
Mother's age at child's birth			0.038 (0.028)	0.032 (0.040)
Mother's years of schooling			0.062 (0.069)	0.052 (0.073)
Home environment/caregiver inputs				
Birth order				0.099 (0.244)
Child born within 24 months				0.283 (0.755)
Caregiver plays for less than an hour/day				−0.238 (0.858)
Caregiver plays for more than an hour/day				−0.249 (0.839)
Caregiver teaches child				0.104 (0.418)
Father (figure) plays once a week				−0.587 (0.575)
Father (figure) plays 2–4 times/week				−0.788 (0.689)
Father (figure) plays every day				−0.693 (0.510)
Child has toys				1.603** (0.652)
Constant	50.415*** (0.199)	49.199*** (1.158)	48.887*** (1.559)	48.263*** (1.814)
R^2	0.00195	0.00844	0.076	0.0839
n	945	945	945	945

Standard errors in parentheses.

***$P < 0.01$; **$P < 0.05$; *$P < 0.10$.

Omitted categories are not stunted, male, white, no child born within 24 months, caregiver spends no time playing with child, father(figure) almost never plays with child, child has no toys. The regressions are run on the sample of children who had non-missing data on the full set of explanatory variables in Regression IV.

VSMS, Vineland Social Maturity Scale; OLS, ordinary least squares.

When we include controls progressively in Regressions II-IV, the association tends to attenuate. For the VSMS, the coefficient on stunting falls to −0.331 and remains insignificant, and for the R-DPDQ, the coefficient falls to −1.772, but strong statistical significance is maintained.

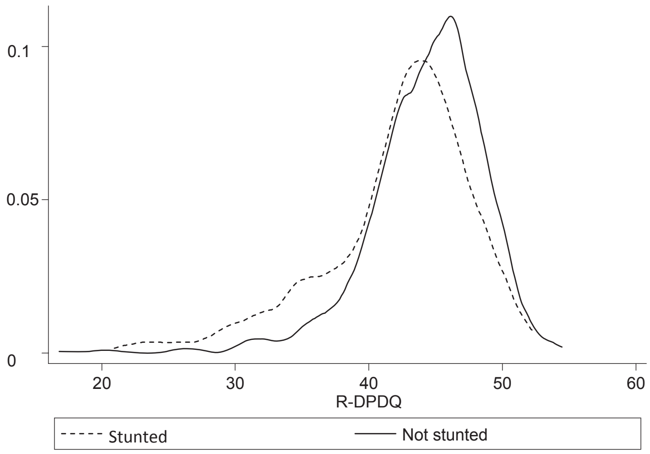

Figure 2. Kernel density plot of R-DPDQ score by stunting. R-DPDQ, Revised-Denver Prescreening Developmental Questionnaire.

Although stunting seems to have no effect on the VSMS, some of our other controls predict the scores on this measure. Girls do better than boys in terms of social maturity. The asset index has the expected positive effect. White, Coloured and Indian children do worse than African children. Of the home environment/caregiver variables, whether the child has any toys to play with is significantly related to higher scores on the VSMS.

The explanatory variables fare better at predicting scores on the R-DPDQ. In addition to the large negative effect of stunting, girl children on average have higher R-DPDQ scores, as do children with higher birthweight. When the full set of controls is included, White, Coloured and Indian children achieve higher scores than African children, although the relationship is only significant for Coloureds (possibly because of the small samples sizes for the other two groups). Both the asset index and mother's schooling result in higher R-DPDQ scores. The home environment and caregiver's input in the child's life have a more pronounced effect on the R-DPDQ than the VSMS. Both birth order and spacing are significant predictors, as are whether the caregiver played with the child for at least an hour every day (compared with no time) and whether the child had toys to play with.

Table 3. Regression results for R-DPDQ at age 5, OLS coefficients

Outcome variable = R-DPDQ score	**I**	**II**	**III**	**IV**
Key explanatory variable				
Stunted	−2.417*** (0.370)	−2.158*** (0.378)	−1.844*** (0.367)	−1.772*** (0.364)
Birth				
Female		0.914*** (0.311)	0.874*** (0.300)	0.804*** (0.299)
Birthweight		0.001** (0.000)	0.001* (0.000)	0.001** (0.000)
Socio-economic status				
White			−0.039 (0.948)	0.242 (0.954)
Coloured			1.314*** (0.504)	1.520*** (0.520)
Indian			0.163 (1.424)	0.615 (1.424)
Asset index			0.582*** (0.117)	0.496*** (0.118)
People/sleeping room			0.031 (0.099)	0.051 (0.099)
Mother's age at child's birth			−0.039 (0.025)	−0.001 (0.036)
Mother's years of schooling			0.233*** (0.062)	0.159** (0.065)
Home environment/caregiver inputs				
Birth order				−0.362* (0.215)
Child born within 24 months				−1.368** (0.658)
Caregiver plays for less than an hour/day				1.627** (0.800)
Caregiver plays for more than an hour/day				1.108 (0.783)
Caregiver teaches child				−0.176 (0.371)
Father (figure) plays once a week				0.340 (0.503)
Father (figure) plays 2–4 times/week				0.544 (0.600)
Father (figure) plays every day				0.522 (0.451)
Child has toys				2.037*** (0.602)
Constant	44.529*** (0.176)	41.950*** (1.048)	40.564*** (1.420)	37.301*** (1.644)
R^2	0.0511	0.0649	0.145	0.175
n	794	794	794	794

Standard errors in parentheses.
***$P < 0.01$; **$P < 0.05$; *$P < 0.10$.
Omitted categories are not stunted, male, white, no child born within 24 months, caregiver spends no time playing with child, father(figure) almost never plays with child, child has no toys. The regressions are run on the sample of children who had non-missing data on the full set of explanatory variables in Regression IV.
R-DPDQ, Revised-Denver Prescreening Developmental Questionnaire; OLS, ordinary least squares.

Table 4. Sensitivity analysis – coefficient on stunting displayed

Description of test	VSMS		R-DPDQ	
	β (SE)	***n***	**β (SE)**	***n***
Alternative 2 years height-for-age measures				
1. Using z-scores	0.156 (0.162)	946	0.545*** (0.138)	795
2. Severe stunting <–3 SD	–0.605 (0.703)	946	–1.305** (0.659)	795
Reduced sample				
3. Africans only	–0.404 (0.449)	828	–1.901*** (0.376)	684
Additional SES				
4. HH income quintiles (y2)	–0.287 (0.531)	587	–1.430*** (0.476)	489
5. Paternal education	–0.445 (0.460)	777	–1.907*** (0.408)	660
Additional home environment/caregiver inputs				
6. Mother caregiver categories (mother is carer, at work, at school, other) (2 years)	–0.364 (0.421)	908	–1.950*** (0.374)	765
7. Maternal depression (PITT score) (6 months)	–0.368 (0.530)	615	–2.074*** (0.464)	509
8. Interviewer report of caregiver relationship with child (2 years)†	–0.258 (0.423)	876	–1.718*** (0.374)	735
9. Maternal/caregiver stress (principal components analysis of 16 items) (Antenatal)	–0.337 (0.760)	305	–3.006*** (0.720)	254
10. Maternal/caregiver stress (principal components analysis of 20 items) (5 years)	–	–	–1.743*** (0.363)	795
Child-specific ability				
11. Maternal height	–0.581 (0.478)	699	–1.723*** (0.427)	596
12. Measures of child development, mental and physical‡	–0.290 (0.731)	297	–2.279*** (0.718)	240

Standard errors (SE) in parentheses.
***$P < 0.01$; **$P < 0.05$; *$P < 0.10$.
Full set of controls are included in these regressions as in Regression IV in Tables 2 and 3.
†Based on 6 items: the child looks clean and well looked after; the child appears happy, confident and secure in mother's presence; the mother seems unhappy and worn down by worries and troubles; the mother demonstrates any negative feelings towards the child, the mother appears to be confident and assured in her care and management of child; the mother shows affection towards the child.
‡Based on Bayley Scales: Mental Development Index and the Physical Development Index calculated on South African norms. Age standardized measures at 6 months or 1 year, if both were available, the average was used.
VSMS, Vineland Social Maturity Scale; R-DPDQ, Revised-Denver Prescreening Developmental Questionnaire.

In Table 4 we display the results on stunting from a number of alternative regression specifications as described above. None of the additional variables were themselves significant after a full set of controls was included. However, the relationship between stunting and the R-DPDQ remained robust, while the coefficient on stunting in the VSMS regressions was never significant.

Possible reasons for this difference might be that the VSMS is based on caregiver reports, whereas the R-DPDQ is based predominantly on observations/tests by a trained interviewer, or that there is a one year gap between the two outcome measures (and the impacts of stunting might become more pronounced with age). To probe this further, we ran separate regressions (using specification IV) on each individual item comprising our scores and on groupings of these (daily living skills, fine motor, gross motor and cognitive) to see if there was consistency in the results across the types of abilities tested, despite the different timing and method of collection. The results are summarized in Tables 5 and 6. It appears that stunting has little effect on the child's daily living skills and gross motor function, but a more pronounced effect on fine motor skills and cognitive functioning.

Discussion

In a large scale longitudinal study, we find no significant association between stunting at age 2 and the VSMS at age 4, but a large and significant association with the R-DPDQ at age 5, after controlling for a wide variety of birth, SES and home environment factors. These results survive the variety of robustness checks we conducted. While we have to be cautious in claiming a causal link between stunting and developmental outcomes in young children given the methodological problems identified earlier, we do attempt to control for many of the confounding

Table 5. OLS coefficient on stunting in individual regressions for each item and for each grouping of the VSMS

Individual item	β (SE)
Daily living skills/socialization	**0.047 (0.292)**
Tells when wants to go to toilet	0.025 (0.029)
Plays without supervision	0.027 (0.026)
Takes off clothes without help (excl. buttons/zips)	0.021 (0.027)
Gets a glass of water	–0.023 (0.042)
Dries hands without help	–0.019 (0.024)
Avoids simple dangers	0.033 (0.056)
Puts on clothes without help (excl. buttons/zips)	–0.024 (0.048)
Plays with other children same age (sings song/ pretend game)	–0.028 (0.017)
Tells you things that have happened/simple stories	–0.014 (0.026)
Helps with little things around house	–0.010 (0.020)
Performs for people (stunts, singing, rhymes)	0.033 (0.029)
Washes hands without help	0.005 (0.022)
Goes to toilet on own	0.054 (0.073)
Washes face without help	–0.010 (0.083)
Goes up and down street to nearby neighbour on own	0.062 (0.066)
Generally dresses on own (excl. difficult fasteners/ties)	–0.088 (0.060)
Gross motor	**–0.087 (0.103)**
Walks down stairs with one foot on each step	–0.042 (0.082)
Plays competition exercise games ('dassie', hopscotch, etc)	–0.045 (0.054)
Fine motor	**–0.308 (0.138)****
Eats food with an implement	–0.033 (0.017)*
Uses scissors under supervision	–0.189 (0.097)**
Opens and closes buttons	–0.122 (0.068)*
Uses a pencil/crayon for drawing	0.036 (0.035)

Standard errors in parentheses.
***$P < 0.01$; **$P < 0.05$; *$P < 0.10$.
Full set of controls are included (as in Regression IV) in Table 2. Sample size is 945 in each regression. Coefficients in bold are for regressions run on composite indices of the items in that grouping.
VSMS, Vineland Social Maturity Scale; OLS, ordinary least squares.

Table 6. OLS coefficient on stunting in individual regressions for each item and for each grouping of the R-DPDQ

Item	β (SE)
Daily living skills	**–0.065 (0.057)**
Dresses without help	–0.030 (0.028)
Brushes teeth without help	–0.008 (0.034)
Dishes up bowl of cereal	–0.026 (0.024)
Gross motor	**–0.279 (0.130)****
Balance on each foot 2	–0.005 (0.004)
Balance on each foot 3	–0.016 (0.015)
Balance on each foot 4	–0.056 (0.027)**
Balance on each foot 5	–0.065 (0.042)
Balance on each foot 6	–0.078 (0.053)
Hopping on one foot	–0.008 (0.015)
Heel-to-toe walk	–0.052 (0.043)
Fine motor	**–0.254 (0.061)*****
Build tower of blocks	–0.006 (0.010)
Thumb wiggle	–0.026 (0.019)
Imitate vertical line	0.002 (0.008)
Copy a circle	–0.071 (0.020)***
Copy a cross	–0.083 (0.023)***
Copy a square – demonstrated	–0.083 (0.031)***
Cognitive	**–1.173 (0.272)*****
Plays simple board/card games	0.012 (0.063)
Count blocks 1	–0.080 (0.042)*
Count blocks 5	–0.151 (0.064)**
Pick the longer line	–0.019 (0.031)
Draw a person – 3 parts	–0.057 (0.021)***
Draw a person – 6 parts	–0.186 (0.046)***
Knows use of objects – 3	–0.006 (0.022)
Knows actions – 4	–0.193 (0.050)***
Understands prepositions – 4	–0.095 (0.051)*
Names colours – 1	–0.075 (0.053)
Names colours – 4	–0.128 (0.065)**
Defines words – 5	–0.002 (0.062)
Defines words – 7	–0.005 (0.042)
Knows adjectives – 3	–0.098 (0.054)*
Opposites	–0.079 (0.039)**
Interviewer rating of child's speech	–0.013 (0.015)

Notes. Standard errors in parentheses.
***$P < 0.01$; **$P < 0.05$; *$P < 0.10$.
Full set of controls are included (as in Regression IV) in Table 3. Sample size is 794 in each regression. Coefficients in bold are for regressions run on composite indices of the items in that grouping.
R-DPDQ, Revised-Denver Prescreening Developmental Questionnaire; OLS, ordinary least squares.

relationships that have been described in the literature. We thus conclude that there was no association between stunting and social maturity, or age-appropriate daily living skills among these preschool-aged children, but a robust and significant association with a measure of cognitive and fine-motor capacities. This finding suggests that, apart from height, the impact of stunting on children's development may be relatively 'invisible' to parents who do not anticipate that their children will achieve specific intellectual milestones during the preschool years (Goodnow *et al.* 1984; Miller 1988). If this finding is upheld, it has important implications for policy, advocacy and programmes to prevent stunting. Stunting has long-term effects on schooling (Martorell *et al.* 2010), income (Hoddinott *et al.* 2008) and health (Victora *et al.* 2008; Adair *et al.* 2013). These adverse effects can be prevented with effective early interventions that include both supplementary nutrition and compensatory developmental stimulation (Grantham-McGregor *et al.* 1999; Gertler *et al.* 2013). For these reasons, stunting needs to be prevented at all levels: primary prevention through greater public awareness of the nutritional needs of young children and the impact of stunting on development and long-term outcomes; secondary prevention with targeted messages to pregnant women and families with infants; and tertiary prevention of ill-effects through the promotion of catch-up growth, supplemental nutrition and compensatory stimulation.

In order to increase attention given to stunting and to make every effort to avoid its deleterious effects on health and human capital, parents and the public need to be made aware of the impact of stunting on young children's cognitive capacity. This involves greater understanding of the way in which stunting affects the functioning of young children. Our findings suggest that daily living skills of children, so-called social maturity, is more resilient to stunting effects than cognitive skills. As a result, parents and health professionals may enjoy false comfort that a child who is increasingly becoming shorter than his or her peers, is doing alright developmentally despite their small size. Stunted children may be 'keeping up' in daily living skills, but starting early to fall behind in the higher order cognitive and fine-motor functions that are fundamental for their learning and later education.

It is possible that, despite its widespread use, the measure of social maturity is not reliable. However, the interpretation we have given to the findings from the two measures is supported by a number of subsidiary findings from the analysis. For example, girls do better than boys in social maturity, which is an expected finding (Hutt 1972). Also as expected, the asset index was positively associated with social maturity. Controlling for assets, White, Coloured and Indian children do worse than African children even though these groups would be better off than African children in terms of SES. This implies that race is capturing some key cultural differences in socialization, consistent with findings in the cross-cultural psychology literature that African parents value independence in their children (Leiderman *et al*. 1973; Super 1976; Welch 1978).

Many of the explanatory variables in the R-DPDQ analysis also exhibit expected relationships. In addition to the large association with stunting, girl children on average perform better, as do children with higher birthweight. Both the asset index and mother's schooling are positively related to R-DPDQ scores. The latter result probably reflects higher SES and that more educated mothers tend to encourage the child's cognitive abilities (Scarr & Weinberg 1978; Carneiro *et al*. 2013). The home environment and caregiver's input in the child's life have a more pronounced effect on the R-DPDQ than the VSMS. Both birth order and spacing are significant predictors, as are whether the caregiver played with the child for at least an hour every day and whether the child had toys to play with.

These associations build confidence in our findings. Our results suggest although very young children may be able to keep up in terms of daily living skills or social maturity, growth retardation in the first two years has more severe effects on their higher order abilities, such as fine motor operations and cognitive functioning. This has important implications for large and persistent inequality in human capital in South Africa, as research elsewhere shows that poor cognitive development in early childhood has adverse consequences for test scores at school, the years of schooling completed and productivity (measured by wages) among adults (Grantham-McGregor *et al*. 2007).

Key messages

- The effects of stunting on schooling, and on cognitive performance in the early school years, are well established.
- Much less is known about the impact of stunting on cognitive development in infancy and the preschool years, mainly because of challenges to measurement in low and middle income countries.
- This study suggests that stunting has little or no discernible effect on young children's social maturity or day-to-day functioning, but significantly affects their cognitive development.
- These findings could account for the fact that stunting in early childhood may be 'invisible' to parents and health care staff.
- Highlighting the cognitive effects of stunting in early childhood is necessary to generate greater policy and advocacy action to prevent stunting.

Conflicts of interest

The authors have no conflicts of interest.

Acknowledgements

Funding received from the Wellcome Trust, the University of the Witwatersrand, the South African Medical Research Council and the South African Human Sciences Research Council. The authors would like to acknowledge the help and advice of Celia Hsiao from the Developmental Pathways to Health Research Unit, University of the Witwatersrand, South Africa.

References

Adair, L. S., Fall, C. H. D., Osmond, C., Stein, A. D., Martorell, R., Ramirez-Zea, M., Sachdev, H. S., Dahly, D. L., Bas, I., Norris, S. A., Micklesfield, L., Hallal, P., Victora, C. G. & for the COHORTS group (2013) Associations of linear growth and relative weight gain during early life with adult health and human capital in countries of low and middle income: findings from five birth cohort studies. *Lancet*, **382**, 525–534.

Alderman, H., Behrman, J. R., Lavy, V. & Menon, R. (2001) Child health and school enrollment: a longitudinal analysis. *Journal of Human Resources*, **36**, 185–205.

Alderman, H., Hoddinott, J. & Kinsey, B. (2006) Long term consequences of early childhood malnutrition. *Oxford Economic Papers*, **58**, 450–474.

Alderman, H., Hoogeveen, H. & Rossi, M. (2009) Preschool nutrition and subsequent schooling attainment: longitudinal evidence from Tanzania. *Economic Development and Cultural Change*, **57**, 239–260.

Behrman, J. R. (1996) The impact of health and nutrition on education. *World Bank Research Observer*, **11**, 23–37.

Berkman, D. S., Lescano, A. G., Gilman, R. H., Lopez, S. L. & Black, M. M. (2002) Effects of stunting, diarrhoeal disease, and parasitic infection during infancy on cognition in late childhood: a follow-up study. *Lancet*, **359**, 564–571.

Bhutta, Z. A., Das, J. K., Rizvi, A., Gaffey, M. F., Walker, N., Horton, S., Webb, P., Lartey, A., Black, R. E. & The Lancet Nutrition Interventions Review Group, & the Maternal and Child Nutrition Study Group (2013) Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *Lancet*, **382**, 452–477.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., Uauy, R. & the Maternal and Child Nutrition Study Group (2013) Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet*, **382**, 427–451.

Brown, J. L. & Pollitt, E. (1996) Malnutrition, poverty and intellectual development. *Scientific American*, **274**, 38–43.

Carneiro, P., Meghir, C. & Parey, M. (2013) Maternal education, home environments, and the development of children and adolescents. *Journal of the European Economic Association*, **11** (S1), 123–160.

Doll, E. A. (1965) *Vineland Social MaturSity Scale*. American Guidance Service, Circle Pines, MN, USA.

Frankenburg, W. K., Fandal, A. W. & Thornton, S. M. (1987) Revision of denver prescreening developmental questionnaire. *Journal of Pediatrics*, **110**, 653–657.

Gertler, P., Heckman, J., Pinto, R., Zanolini, A., Vermeersch, C., Walker, S., Chang, S. M. & Grantham-McGregor, S. (2013) Labor Market Returns to Early Childhood Stimulation: a 20-year Follow up to an Experimental Intervention in Jamaica. NBER Working Paper No. 19185.

Glewwe, P. & Jacoby, H. G. (1995) An economic analysis of delayed primary school enrollment in a low income country: the role of early childhood nutrition. *Review of Economics and Statistics*, **77**, 156–169.

Glewwe, P. & King, E. M. (2001) The impact of early childhood nutritional status on cognitive development: does the timing of malnutrition matter? *World Bank Economic Review*, **15**, 81–113.

Glewwe, P., Jacoby, H. G. & King, E. M. (2001) Early childhood nutrition and academic achievement: a longitudinal analysis. *Journal of Public Economics*, **81**, 345–368.

Goodnow, J., Cashmore, J., Cotton, S. & Knight, R. (1984) Mothers' developmental timetables in two cultural groups. *International Journal of Psychology*, **19**, 193–205.

Grantham-McGregor, S., Bun Cheung, Y., Cueto, S., Glewwe, P., Richter, L., Strupp, B. & The International Child Development Steering Group (2007) Developmental potential in the first 5 years for children in developing countries. *Lancet*, **369**, 60–70.

Grantham-McGregor, S. M., Powell, C. A., Walker, S. P. & Himes, J. H. (1999) Nutritional supplementation, psychosocial stimulation, and mental development of stunted children: the Jamaican Study. *Lancet*, **338**, 1–5.

Hoddinott, J., Maluccio, J. A., Behrman, J. R., Flores, R. & Martorell, R. (2008) Effect of a nutrition intervention during early childhood on economic productivity in Guatemalan adults. *Lancet*, **371**, 411–416.

Hutt, C. (1972) Sex differences in human development. *Human Development*, **15**, 153–170.

Leiderman, H., Babu, B., Kagia, J., Kraemer, H. & Leiderman, G. (1973) African infant precocity and some social influences during the first year. *Nature*, **242**, 247–249.

Luiz, D. M., Foxcroft, C. D. & Tukulu, A. N. (2004) The Denver II Scales and the Griffiths Scales of Mental Development: a correlational study. *Journal of Child and Adolescent Mental Health*, **16**, 77–81.

Martorell, R., Horta, B. L., Adair, L. S., Stein, A. D., Richter, L., Fall, C. H. D., Bhargava, S. K., Biswas, S. K. D., Perez, L., Barros, F. C., Victora, C. G. & Consortium on Health Orientated Research in Transitional Societies Group (2010) Weight gain in the first two years of life is an important predictor of schooling outcomes in pooled analyses from five birth cohorts from low-and middle-income countries. *Journal of Nutrition*, **140**, 348–354.

Mendez, M. A. & Adair, L. S. (1999) Severity and timing of stunting in the first two years of life affect performance on cognitive tests in late childhood. *Journal of Nutrition*, **129**, 1555–1562.

Miller, S. (1988) Parents' beliefs about children's cognitive development. *Child Development*, **59**, 259–285.

Norris, S. A., Richter, L. M. & Fleetwood, S. A. (2007) Panel studies in developing countries: case analysis of sample attrition over the past 16 years within the birth to twenty cohort in Johannesburg, South Africa. *Journal of International Development*, **19**, 1143–1150.

Paxson, C. & Schady, N. (2007) Cognitive development among young children in ecuador: the roles of wealth, health and parenting. *Journal of Human Resources*, **42**, 49–84.

Pillay, A. L. (2003) Social competence in rural and urban children with mental retardation: preliminary findings. *South African Journal of Psychology*, **33**, 176–181.

Richter, L., Norris, S., Pettifor, J., Yach, D. & Cameron, N. (2007) Cohort profile: Mandela's children: the 1990 birth to twenty study in South Africa. *International Journal of Epidemiology*, **36**, 504–511.

Scarr, S. & Weinberg, R. A. (1978) The influence of 'family background' on intellectual attainment. *American Sociological Review*, **43**, 674–692.

Shisana, O., Labadarios, D., Rehle, T., Simbayi, L., Zuma, K., Dhansay, A., Reddy, P., Parker, W., Hoosain, E., Naidoo, P., Hongoro, C., Mchiza, Z., Steyn, N. P., Dwane, N., Makoae, M., Maluleke, T., Ramlagan, S., Zungu, N., Evans, M. G., Jacobs, L., Faber, M. & SANHANES-1 Team (2013) *South African National Health and Nutrition Examination Survey (SANHANES-1)*. HSRC Press, Cape Town, South Africa.

Stein, A. D., Wang, M., Martorell, R., Norris, S. A., Adair, L. S., Bas, I., Sachdev, H. S., Bhargava, S. K., Fall, C. H., Gigante, D. P., Victora, C. G. & Cohorts Group (2010) Growth patterns in early childhood and final attained stature: data from five birth cohorts from low- and middle-income countries. *American Journal of Human Biology*, **22**, 353–359.

Super, C. (1976) Environmental effects on motor development: the case of African infant precocity. *Developmental Medicine and Child Neurology*, **18**, 561–567.

Victora, C. G., Adair, L., Fall, C., Hallal, P. C., Martorell, R., Richter, L., Sachdev, H. S. & for the Maternal and Child Undernutrition Study Group (2008) Maternal and child undernutrition: consequences for adult health and human capital. *Lancet*, **371**, 340–357.

Walker, S. P., Wachs, T. D., Grantham-McGregor, S., Black, M. M., Nelson, C. A., Huffman, S. I., Baker-Henningham, H., Chang, S. M., Hamadani, J. D., Lozoff, B., Meeks Gardner, J. M., Powell, C. A., Rahman, A. & Richter, L. (2011) Inequality in early childhood: risk and protective factors for early child development. *Lancet*, **378**, 1325–1338.

Welch, M. (1978) Childhood socialization differences in African and nonafrican societies. *Journal of Social Psychology*, **106**, 11–15.

WHO (2007) *WHO Child Growth Standards: Methods and Development: Head Circumference-for-age, Arm Circumference-for-age, Triceps Skinfold-for-age and Subscapular Skinfold-for-age*. World Health Organization, Geneva, Switzerland.

WHO (2012) *WHO database on child growth and malnutrition*. Available at http://www.who.int/nutgrowthdb/database/countries/zaf/en/ (last accessed 23 April 2014).

Yamauchi, F. (2008) Early childhood nutrition, schooling, and sibling inequality in a dynamic context: evidence from South Africa. *Economic Development and Cultural Change*, **56**, 657–682.