Recovery from stunting and cognitive outcomes in young children: Evidence from the South African Birth to Twenty Cohort Study.

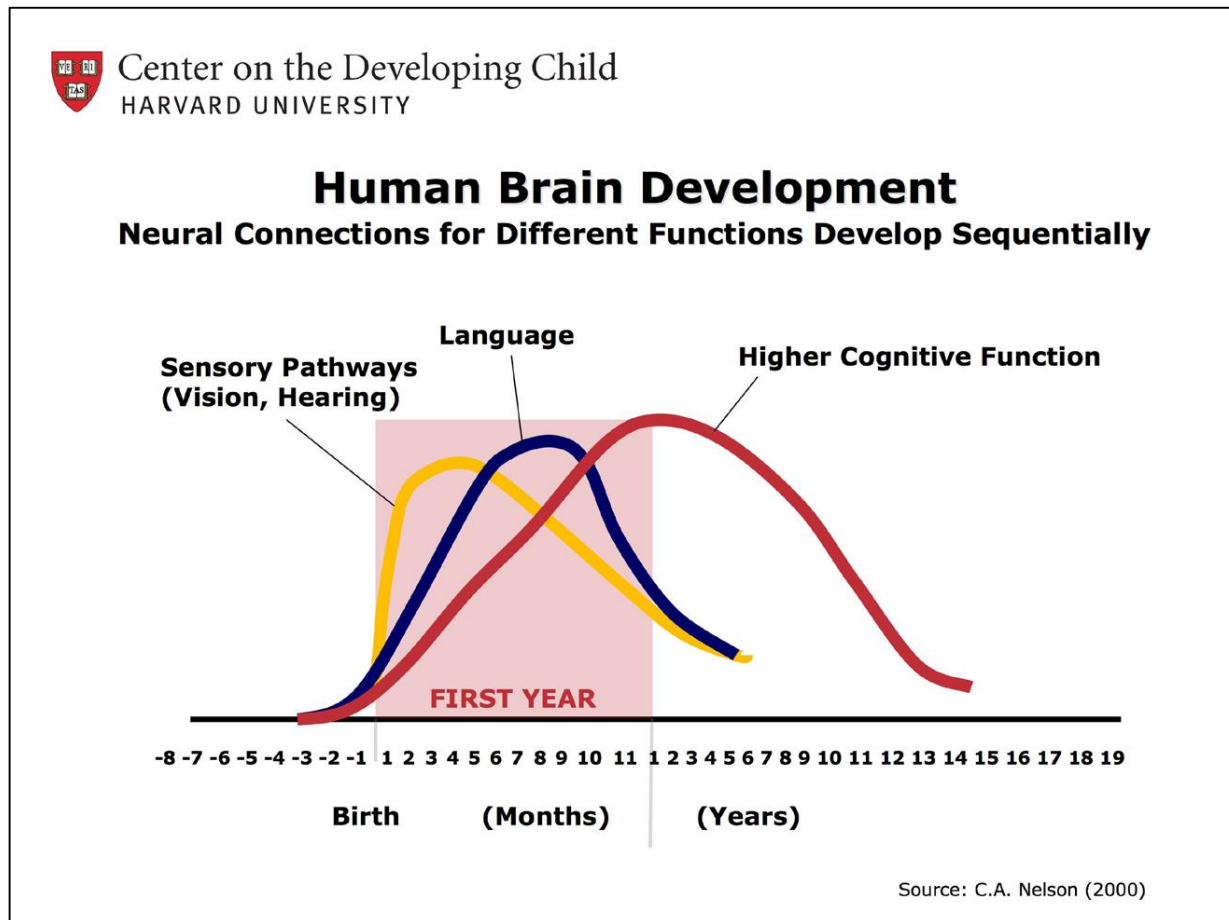Daniela Casale (School of Economic and Business Sciences, WITS)

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Background

- Substantial literature documenting the negative effects of early chronic malnutrition (stunting/HAZ <-2) on cognitive function and educational attainment.

- In previous work for South Africa, we found a large and significant negative association between **stunting at 2y** and **cognitive function at age 5y** (Casale, Desmond and Richter 2014).

- In this paper, we investigate **recovery from stunting** – **"catch up"** - in early childhood, and the implications for cognitive function.

- The extent to which the children who are stunted at 2y can catch up from this poor start and attain similar adult heights as the reference population continues to be debated (Golden 1994; Martorell et al 1994; Cameron et al 2005; Stein et al 2010; Prentice et al 2013; Leroy et al 2013; 2015).

- **Even if catch up is possible, the question remains: can later growth mitigate the harm caused by stunting within the first 1 000 day critical period?**

The debate centers on the **importance of the first 1 000 days for *brain development***.

These processes are energy intensive, suggesting brain development will be highly susceptible to the negative consequences of malnutrition.

Center on the Developing Child
HARVARD UNIVERSITY

Human Brain Development
Neural Connections for Different Functions Develop Sequentially

Source: C.A. Nelson (2000)

- A few researchers (using observational data) have tried to identify critical periods for cognitive function, but with mixed results.

  - Glewwe and King (2001) conclude that poor nutrition in the period **18-24 months** had the most significant consequences on cognitive function at **8y** in the Philippines.

  - Mendez and Adair (1999) on Philippines: children who recover from stunting between **2y** and **8y/11y** do **worse at school** than children who were never stunted, although less so than those who remain stunted.

    Focus on nutrition in first 2 years.

  - Crookston *et al* (2010; 2011) on Peru: group who catch up between **6-18m** and **4.5-6y** do **the same in cognitive tests** as children who were never stunted, and better than children who remain stunted.

    Focus also on post-infancy nutrition.

Today's presentation:

1) Extent of recovery from stunting between 2y and 5y ('catch-up'), using South African birth cohort data - plausible?

2) Implications for cognitive function at 5y: how important is timing?

Ongoing work:

Sensitivity to the definition of catch-up growth?

Birth to Twenty Data (DPHRU, WITS)

-Birth cohort study of children in Johannesburg metro area, born in a 7-week period between April and June 1990 in private and public hospitals.

- AN, delivery form, 3m, 6m, y1, y2, and so on…

-Large exodus from study within first year due to out-migration. Data collected from approx. 1500 to 2200 participants at each interview point (Richter *et al* 1995; 2007; Norris *et al* 2007*).

-No significant differences on key variables : mother's age, birth weight, birth order (Appendix table).

-Representative of (predominantly African) children born in Jhb and who **remained resident**.

-We use data mostly from delivery reports, y2 (n=1839), y4 (n=1858) and y5 (n=1586).

1) Recovery from stunting

Table 1. Stunting status and mean HAZ at 2 years and 5 years

| YEAR 2				YEAR 5	
	Prevalence (%)	HAZ		Prevalence (%)	HAZ
Not stunted	80.6	-0.751 (0.762)	Neither	79.3	-0.415 (0.767)
			Late incident	1.3	-2.216 (0.209)
Stunted	19.4	-2.72 (0. 711)	Persistent	4.7	-2.464 (0.357)
			Catch up	14.7	-1.287 (0.503)
	100	n=1574		100	n=1574

Notes: Standard deviations in parentheses

Rate of recovery → **75%** of children stunted at 2y no longer stunted by 5y

Plausible?

- **Not driven by small changes** to just above -2 SD cutoff:

  Mean ΔHAZ 2-5y = 1.34

  For 90% of recovered group, ΔHAZ > 0.5

  For 80% of recovered group, ΔHAZ > 0.75

  For 60% of recovered group, ΔHAZ > 1.00

- Among those stunted at 2y, **predictors of recovery by 5y consistent with literature**:

  - birthweight (+)
  - mother's height (+)
  - mother's schooling (+)
  - severity of initial stunting at 2y (-)
  - early stunting by 1y (-)

- **Similar rates of recovery found in a more recent national panel** (NIDS) 2008; 2010/11; 2014/15 (Ardington and Gasealahwe 2012; Casale 2016)

- **Similar patterns in other developing countries**...

Figure 2. HAZ at birth, 12m, 24m, and mid-childhood in five birth cohorts, by thirds of attained adult height.
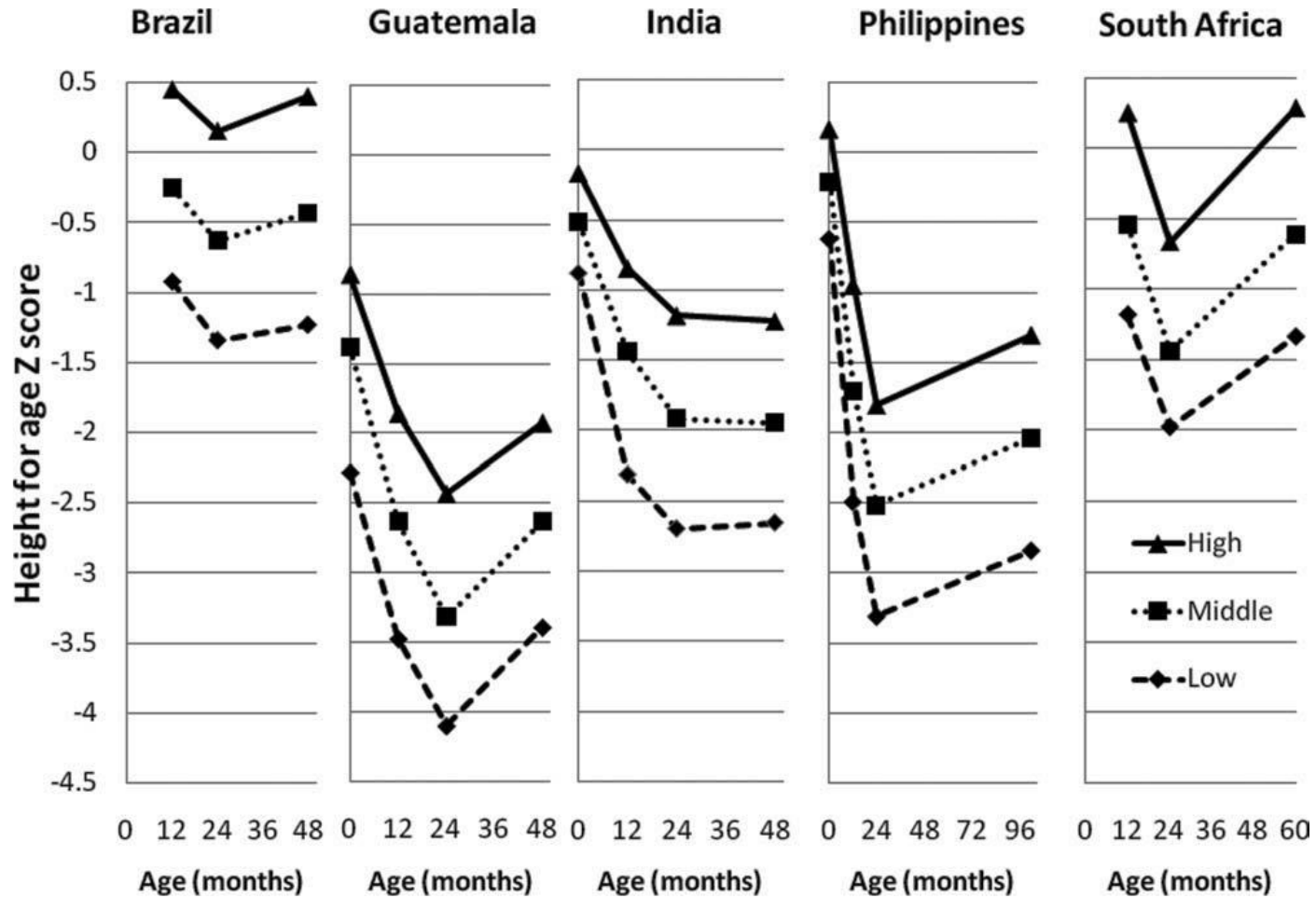
Source: Stein et al, 2010, *American Journal of Human Biology*

2) Implications for cognitive function?

-Year 5: Revised-Denver Prescreening Developmental Questionnaire (Frankenburg, Fandal and Thornton 1987)

-Composite score based on **32 items**, adjusted for decimal age, mainly based on **interviewer testing** (validity and reliability discussed in Hsiao and Richter 2014).

-Mean 43.91 (SD=4.70)

DAILY LIVING SKILLS	COGNITIVE
Dresses without help	Plays simple board/card games
Brushes teeth without help	Count blocks 1
Dishes up bowl of cereal	Count blocks 5
GROSS MOTOR	Pick the longer line
Balance on each foot 2	Draw a person - 3 parts
Balance on each foot 3	Draw a person – 6 parts
Balance on each foot 4	Knows use of objects – 3
Balance on each foot 5	Knows actions – 4
Balance on each foot 6	Understands prepositions – 4
Hopping on one foot	Names colours – 1
Heel-to-toe walk	Names colours – 4
FINE MOTOR	Defines words – 5
Build tower of blocks	Defines words – 7
Thumb wiggle	Knows adjectives – 3
Imitate vertical line	Opposites
Copy a circle	Interviewer rating of child's speech
Copy a cross	
Copy a square – demonstrated	

Table 2. Cognitive score regressions at 5y (OLS coefficients)

	I	II	III	IV
Stunting status 2-5y Reference: Neither (2y nor 5y)				
Persistent (2y and 5y)	-3.091***	-2.583***	-2.530***	-2.506***
	(0.808)	(0.785)	(0.776)	(0.778)
Late incident (5y only)	-0.590	-0.754	-0.381	-0.416
	(1.292)	(1.249)	(1.247)	(1.249)
Catch up (2y only)	-1.978***	-1.739***	-1.602***	-1.607***
	(0.438)	(0.425)	(0.423)	(0.425)
Controls				
Birth characteristics	Yes	No	No	No
Socio-economic status 2y	Yes	Yes	No	No
Home environment/caregiver 2y	Yes	Yes	Yes	No
Change in SES 2y-4y	Yes	Yes	Yes	Yes
N	**666**	**666**	**666**	**666**

Some methodological issues:

A note on endogeneity:

- We measure cognitive function at age 5y (before formal schooling begins) – parents are less likely at this early age to know the child's cognitive potential on which to base either **compensatory or complementary investments** in nutrition (Glewwe et al 2001).

- We have detailed data on **household environment and caregiver 'investment' in child**, and results are robust to inclusion of many different such measures in the regressions (Casale, Desmond and Richter, 2014).

Table 3. Full cognitive score regressions – 5y (OLS coefficients)

	I	II	III	IV
Stunting status Reference: Neither				
Persistent	-3.091***	-2.583***	-2.530***	-2.506***
	(0.808)	(0.785)	(0.776)	(0.778)
Late incident	-0.590	-0.754	-0.381	-0.416
	(1.292)	(1.249)	(1.247)	(1.249)
Catch up	-1.978***	-1.739***	-1.602***	-1.607***
	(0.438)	(0.425)	(0.423)	(0.425)
Birth characteristics				
Female	1.039***	0.975***	0.863***	0.867***
	(0.334)	(0.323)	(0.321)	(0.322)
Birthweight	0.001*	0.001*	0.001*	0.001*
	(0.000)	(0.000)	(0.000)	(0.000)
Socio-economic status 2y				
African		-1.589***	-1.798***	-1.783***
		(0.529)	(0.546)	(0.549)
Asset score		0.495***	0.440***	0.476***
		(0.119)	(0.121)	(0.136)
Mother's age		-0.045*	-0.028	-0.029
		(0.026)	(0.037)	(0.037)
Mother's schooling (yrs)		0.175***	0.110	0.107
		(0.067)	(0.069)	(0.069)

	I	II	III	IV
Home environment/caregiver 2y				
Mother main caregiver			0.702**	0.699**
			(0.321)	(0.321)
Birth order			-0.216	-0.206
			(0.231)	(0.232)
Birth spacing			-1.271*	-1.254*
			(0.709)	(0.712)
Reference: Caregiver never plays with child				
Plays at least an hour/day			1.662**	1.690**
			(0.813)	(0.815)
Plays more than an hour/day			0.976	1.001
			(0.795)	(0.797)
Caregiver teaching child			0.002	0.005
			(0.387)	(0.387)
Reference: Father(figure) never plays				
Plays with child once/week			0.135	0.146
			(0.526)	(0.527)
Plays with child 2-4/week			0.573	0.582
			(0.630)	(0.631)
Plays with child every day			0.573	0.556
			(0.473)	(0.474)
Toys (bought or made)			2.060***	2.052***
			(0.650)	(0.651)
Change in SES 2y-4y				
Reference: Decrease in asset score				
No change in asset score				0.257
				(0.381)
Increase in asset score				0.370
				(0.480)
N	666	666	666	666

- Concerns around **missing data** – compare unadjusted regressions on the full sample and the final regression sample

Table 4. Estimates from unadjusted cognitive scores regressions at 5y (OLS coefficients)

	Full sample	Final regression sample
Stunting status		
Reference: Neither		
Persistent	-2.276***	-3.390***
	(0.668)	(0.800)
Late incident	-0.563	-0.357
	(1.103)	(1.298)
Catch up	-2.192***	-2.258***
	(0.407)	(0.432)
N	1019	666

- **Sensitivity to age ranges**? Try to replicate work in Crookston et al (2010; 2011) because we have yearly data…

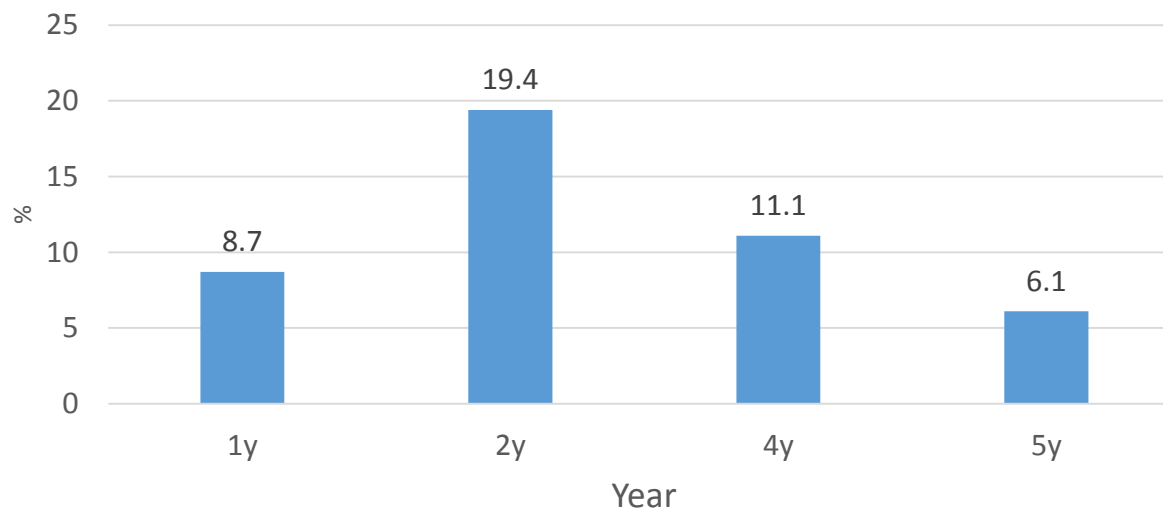**Figure 3. Prevalence of stunting in early childhood, Bt20**

Table 5. Cognitive score (5y) regressions using different age ranges, OLS coefficients

2y-5y	I	1y-5y (Crookston et al)	II
Reference: Not stunted (2y or 5y)		Reference: Not stunted (1y or 5y)	
Persistent (2y and 5y)	-2.506*** (0.778)	Persistent (1y and 5y)	-1.650* (0.950)
Late incident (5y)	-0.416 (1.249)	Late incident (5y)	-1.875** (0.879)
Catch up (2y but not 5y)	-1.607*** (0.425)	Catch up (1y but not 5y)	-0.944 (0.656)
N	666	N	660
	III		
Stunted 1y	0.058 (0.614)		
Stunted 2y	- 1.602*** (0.427)		
Stunted 5y	-0.877 (0.701)		
N	660		

Note: Full set of covariates included in regressions

Conclusions

- Recovery from stunting is possible between 2y and 5y, but children who recovered still did worse on cognitive tests at 5y. *Timing matters.*

- Results are sensitive to age ranges used in analysis. *More focus on the biological mechanisms in this work*.

- In SA, prevalence of stunting is high: 24% for <5y (NIDS 2008); 26.5% for 0-3y (SANHANES 2011).

- South Africa (SA) identified as one of 34 countries responsible for 90% of global burden of child malnutrition (Bhutta *et al.* 2013, *Lancet).*

- Important implications for human capital disparities in SA. *More investment in the first two years.*

Caveats

- **Causality**? Long-term interventions (Guatemala).

- Focus on the first 1000 days must not come at the expense of growth after 24 months. Catch up may have **other benefits** e.g. higher stature in adulthood, and associated improved reproductive outcomes (Prentice et al. 2013)

- **Definition of catch up** (Leroy et al 2013; 2015; Lundeen et al 2014) - in ongoing work, we test whether the results are robust to different measures of 'catch up'.

Table A.1: Comparing child characteristics across the initial sample and sample with HAZ and cognitive function data

	Initial sample		Unadjusted regression sample	
	Mean	SD	Mean	SD
Female	0.5141	0.4999	0.5083	0.5002
African	**0.7849**	**0.4110**	**0.8338**	**0.3724**
Coloured	0.1169	0.3213	0.1281	0.3343
Indian	0.0349	0.1835	0.0147	0.1203
White	**0.0633**	**0.2436**	**0.0235**	**0.1514**
Mother's age at birth	25.9611	6.0789	25.4614	6.2442
Birth weight	3070.7710	512.7932	3072.466	495.7170
Birth order	2.1212	1.0719	2.0264	1.0591
Gravidity	2.3966	1.4856	2.2854	1.5075
Parity	2.2488	1.3821	2.1535	1.3795
Public hospital	**0.8653**	**0.3414**	**0.9042**	**0.2945**
Private hospital	0.1347	0.3414	0.0958	0.2945
Soweto	**0.7368**	**0.4404**	**0.7947**	**0.4041**
Former Indian/Coloured area	0.1359	0.3427	0.1329	0.3397
Suburban Jhb	**0.0890**	**0.2849**	**0.0596**	**0.2369**
Inner city	**0.0370**	**0.1889**	**0.0117**	**0.1077**
Outside Jhb	0.0012	0.0350	0.0010	0.0313
N	**3268**		**1023**	

Table A.2. Mean values of the regression variables

	Mean (SD)/%	N
R-DPDQ 5y (score)	43.91 (4.70)	1019
Stunted 2y	20.1	1019
Stunted 5y	6.8	1019
HAZ 2y	-1.153 (1.095)	1019
HAZ 5y	-0.586 (0.949)	1019
Birth		
Female (%)	50.6	1019
Birth weight (g)	3071.8 (496.8)	1017
Socio-economic status		
Black African (%)	83.4	1019
Asset index 2y	3.86 (1.42)	856
Mother's age (years)	25.46 (6.24)	1019
Mother's schooling (years)	9.83 (2.55)	970
Home environment/caregiver inputs		
Mother is main caregiver 2y (%)	59.3	831
Birth order	2.03 (1.06)	1019
Child born within 24 months (%)	5.8	850
Caregiver plays 2y (%):		
- no time	4.0	855
- for less than an hr/day	36.7	855
- for more than an hr/day	59.3	855
Caregiver teaching child 2y (%)	78.1	850
Father(figure) plays 2y (%):		
- almost never	14.5	835
- once a week	21.8	835
- 2- 4 times/week	10.8	835
- every day	52.9	835
Child has toys (bought or made) 2y (%)		
	93.1	860
Change in SES 2y-4y		
Decrease in asset score	27.3	735
No change in asset score	47.3	735
Increase in asset score	25.3	735

Table A.3: Mean characteristics for varying samples

	Sample of children with data on HAZ at 2y & 5y	Regression sample without covariates	Regression sample with covariates
R-DPDQ 5y (score)	-	43.91 (4.70)	44.14 (4.38)
HAZ 2y	-1.135 (1.084)	-1.153 (1.095)	-1.220 (1.105)
HAZ 5y	-0.664 (0.895)	-0.586 (0.949)	-0.570 (0.932)
Stunted 2y (%)	19.44	20.12	22.52
Stunted 5y (%)	6.04	6.77	6.16
Birth weight (g)	3072.30 (508.95)	3071.76 (496.82)	3084.06 (489.37)
Black (%)	75.60	83.42	89.34
Female (%)	52.35	50.64	49.85
Mother's age (yrs)	25.59 (6.19)	25.46 (6.24)	25.37 (6.35)
N	**1574**	**1019**	**666**

Note: Standard deviations in parentheses

Table A.5. Sensitivity analysis (coefficient on stunted 2y)

Description of test	DENVER	
	β (SE)	**N**
Alternative 2y height-for-age measures		
1. Using z-scores	0.558*** (0.140)	795
2. Severe stunting (z-score < -3 SD)	-1.287* (0.669)	795
Restricted sample		
3. Africans only	-1.952*** (0.383)	684
Additional SES		
4. HH income quintiles (y1)	-1.478*** (0.486)	489
5. Paternal education	-1.958*** (0.414)	660

Table A.5. Cont'd

	DENVER	
	β (SE)	N
Additional home environment		
6. Mother respondent (2y)	-1.806*** (0.368)	795
7. Mother caregiver categories (mother is carer, at work, at school, other) (2y)	-1.953*** (0.380)	765
8. Maternal depression (PITT depression scale of 24 items) (6m)	-2.132*** (0.472)	509
9. Interviewer report of caregiver relationship with child/quality of care (6 items) (2y)	-1.767*** (0.380)	739
10. Maternal/caregiver stress (16 items) (AN)	-3.100*** (0.734)	254
11. Maternal/caregiver stress (20 items) (5y)	-1.790*** (0.368)	795
12. Add full home environment score (assets + 16 items) (y2)	-2.017*** (0.366)	834
Child-specific ability		
13. Maternal height	-1.758*** (0.433)	596
14. Measures of child development, mental and physical (Bayley and Griffiths scales) (6m/1y)	-2.391*** (0.733)	240