
Source: The University of Iowa

Growth in School-age Children

Examining the evidence on catch-up

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Key questions

1. Do height and weight at school age matter?
2. Can height-for-age and weight-for-age change during this time?
3. What is the scale of the effect?
4. How much do such interventions cost?

Overview of the evidence

1. The human growth curve and defining catch-up
2. School-age and adolescent growth
3. Interventions at school age

1. The human growth curve

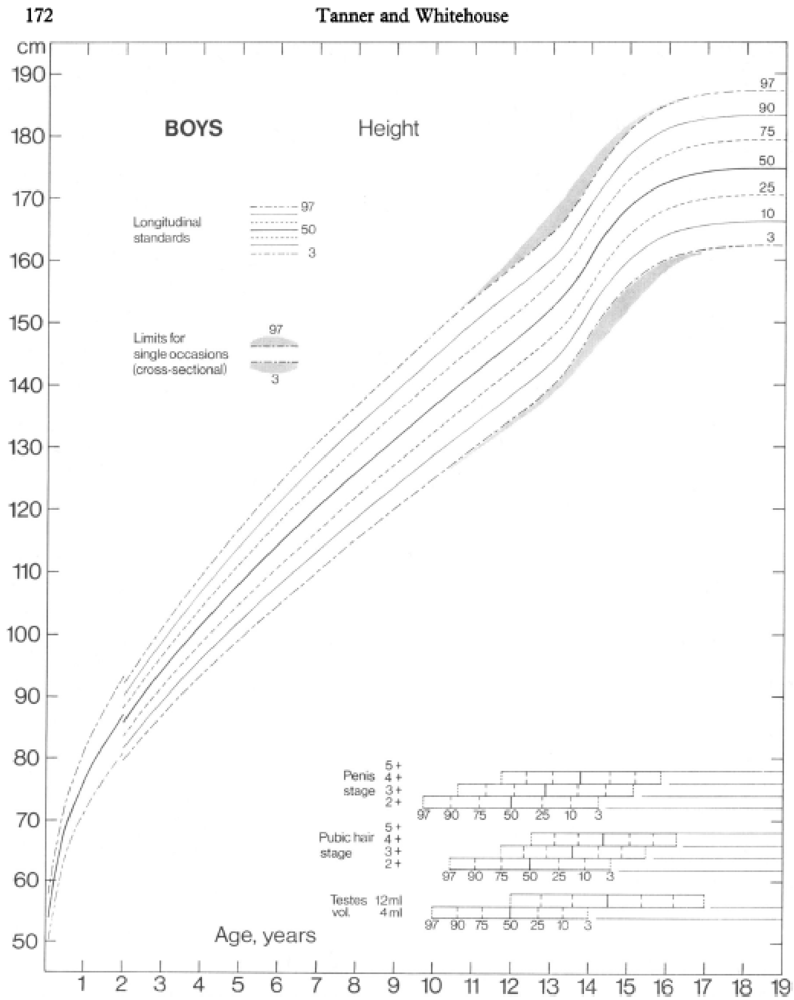


FIG. 1.—Longitudinal standards for height attained at given age, boys. The shaded areas represent the 97th and 3rd centile limits of cross-sectionally derived standards.

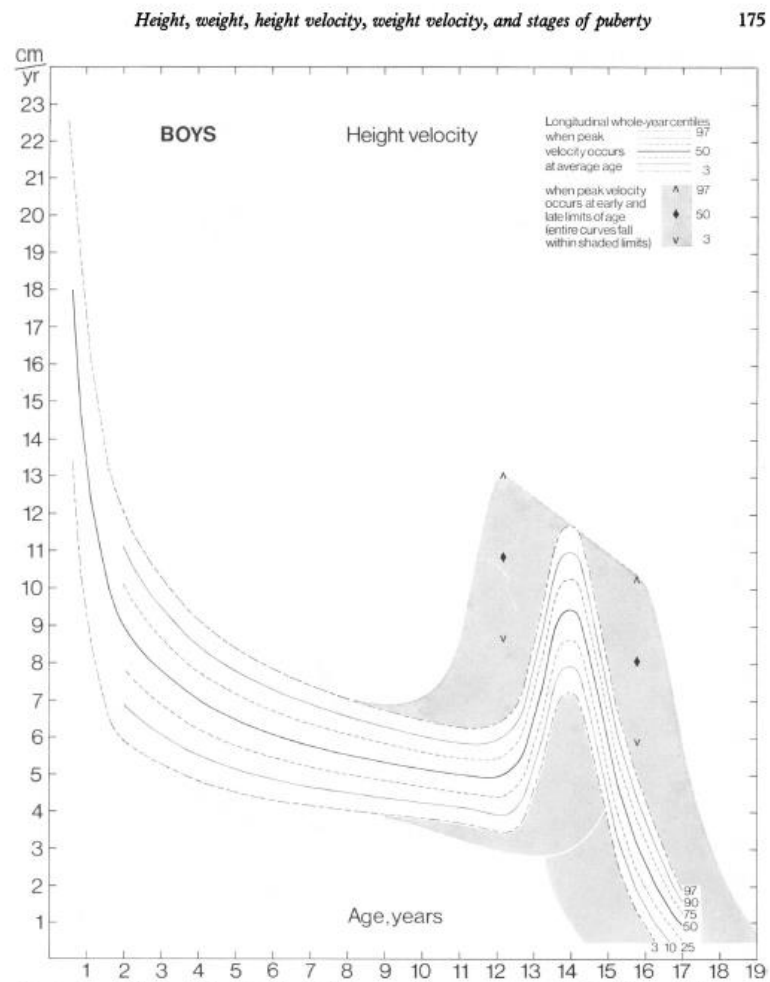
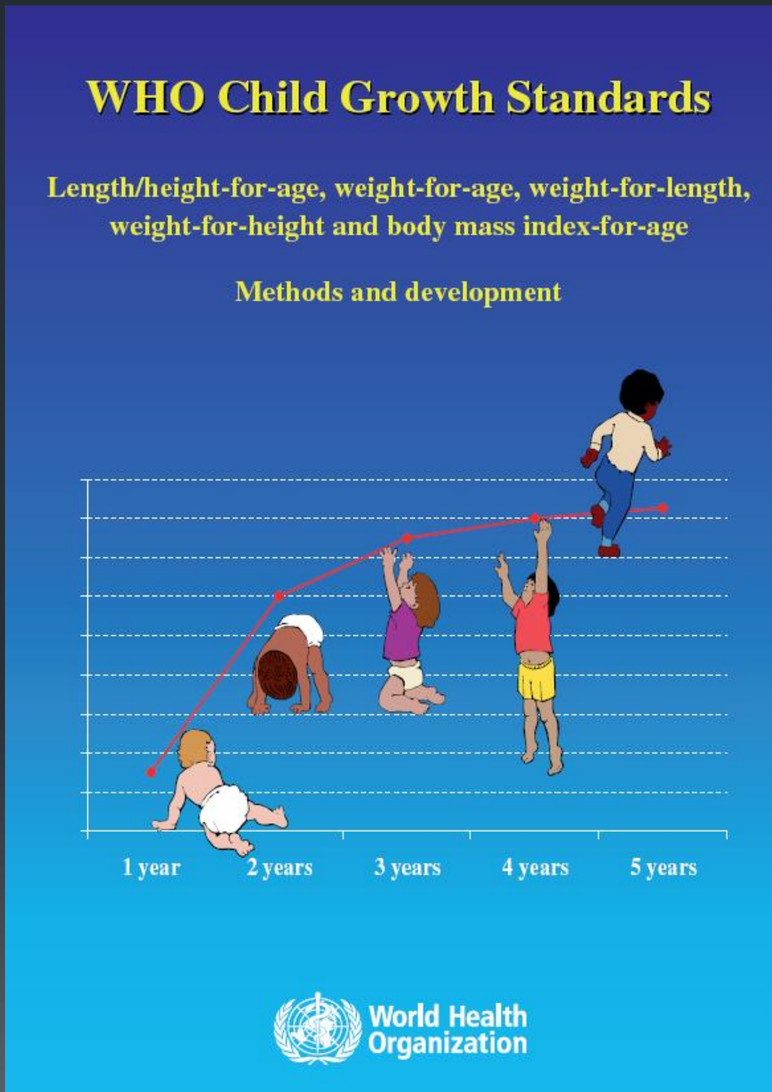


FIG. 4.—Longitudinal standards for height velocity, boys. Shaded area represents total of hatched areas in Fig. 3 upper and lower; it thus encloses all velocity curves within 3rd-97th centile limits for age and for peak velocity. 3rd, 50th, and 97th centiles for early- and late-maturing boys are indicated by arrowhead and diamond symbols.

Source: Tanner and Whitehouse 1976

Methodological considerations



Research

Development of a WHO growth reference for school-aged children and adolescents

Mercedes de Onis,[a] Adelheid W Onyango,[a] Elaine Borghi,[a] Amani Siyam,[a] Chizuru Nishida[a] & Jonathan Siekmann[a]

Objective To construct growth curves for school-aged children and adolescents that accord with the WHO Child Growth Standards for preschool children and the body mass index (BMI) cut-offs for adults.
Methods Data from the 1977 National Center for Health Statistics (NCHS)/WHO growth reference (1–24 years) were merged with data from the under-fives growth standards' cross-sectional sample (18–71 months) to smooth the transition between the two samples. State-of-the-art statistical methods used to construct the WHO Child Growth Standards (0–5 years), i.e. the Box-Cox power exponential (BCPE) method with appropriate diagnostic tools for the selection of best models, were applied to this combined sample.
Findings The merged data sets resulted in a smooth transition at 5 years for height-for-age, weight-for-age and BMI-for-age. For BMI-for-age across all centiles the magnitude of the difference between the two curves at age 5 years is mostly 0.0 kg/m^2 to 0.1 kg/m^2. At 19 years, the new BMI values at +1 standard deviation (SD) are 25.4 kg/m^2 for boys and 25.0 kg/m^2 for girls. These values are equivalent to the overweight cut-off for adults ($\geq$ 25.0 kg/m^2). Similarly, the +2 SD value (29.7 kg/m^2 for both sexes) compares closely with the cut-off for obesity ($\geq$ 30.0 kg/m^2).
Conclusion The new curves are closely aligned with the WHO Child Growth Standards at 5 years, and the recommended adult cut-offs for overweight and obesity at 19 years. They fill the gap in growth curves and provide an appropriate reference for the 5 to 19 years age group.

Bulletin of the World Health Organization 2007;85:660–667.

At school age, greater variability in growth due to:

ethnic differences

secular change

obesity

timing of puberty and the growth spurt

Source: WHO 2006; de Onis *et al*. 2007

Defining catch-up growth

Tanner 1986: a phase of recovery following nutritional incident, marked by a much higher growth rate for age than expected

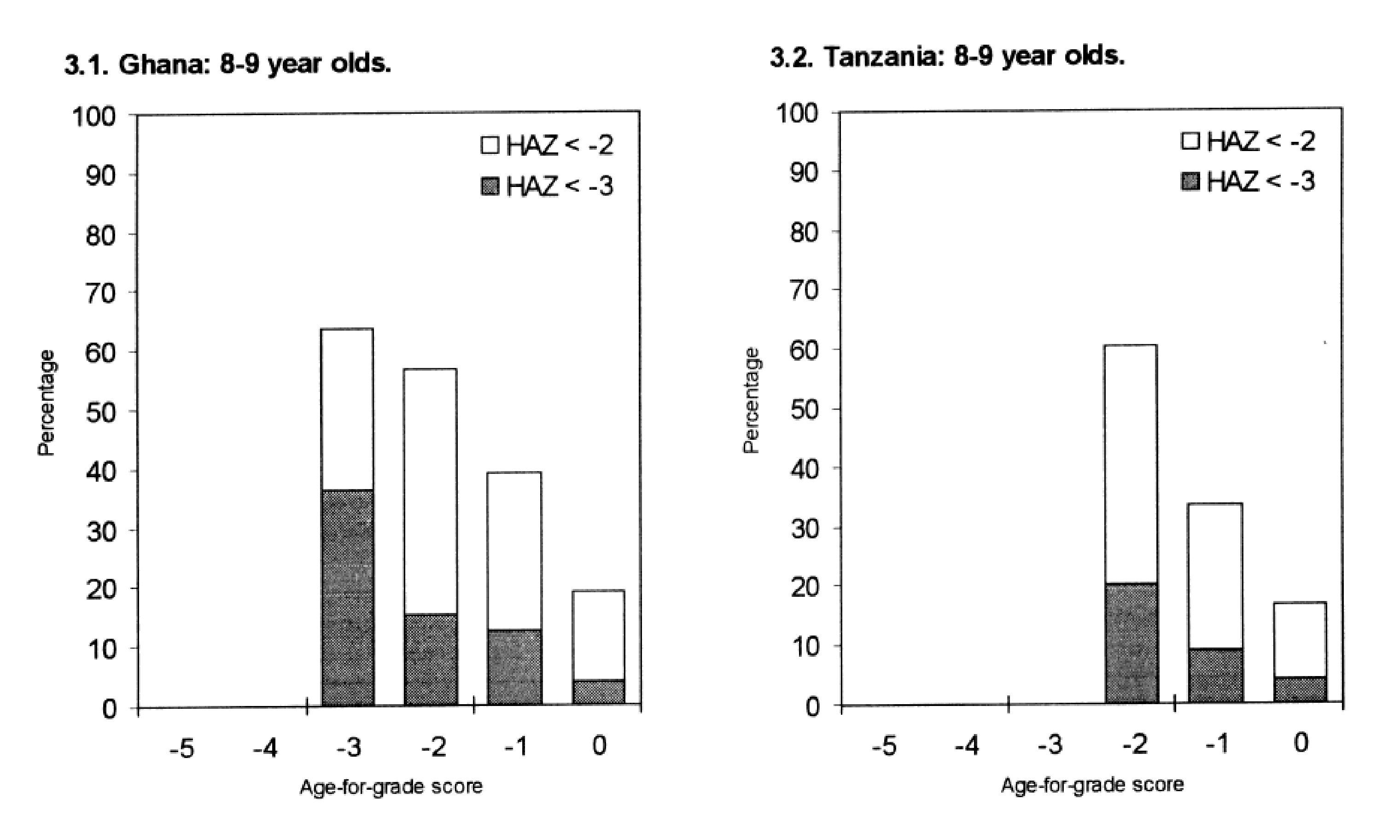
Two ways to achieve growth recovery:

- higher growth rate
- lengthening of the time period of growth

2. School-age and adolescent growth

- Stunting has been shown to impact education, productivity, and income later in life.
- Undernutrition also delays the adolescent growth spurt and puberty.

The impact of growth faltering on *education*



Stunted children enrol later in school

Source: PCD 1999

The impact of growth faltering on *education*

Stunted children lag behind in school

- In China, a one SD improvement in height was associated with a child being about one-third of a year less far behind in school.

Stunted children are more likely to drop out

- In the Philippines, at age 11, children stunted at age 2 were three times more likely to have dropped out of school in the past.

Source: Jamison 1986; Mendez and Adair 1999

The impact of growth faltering on *education*

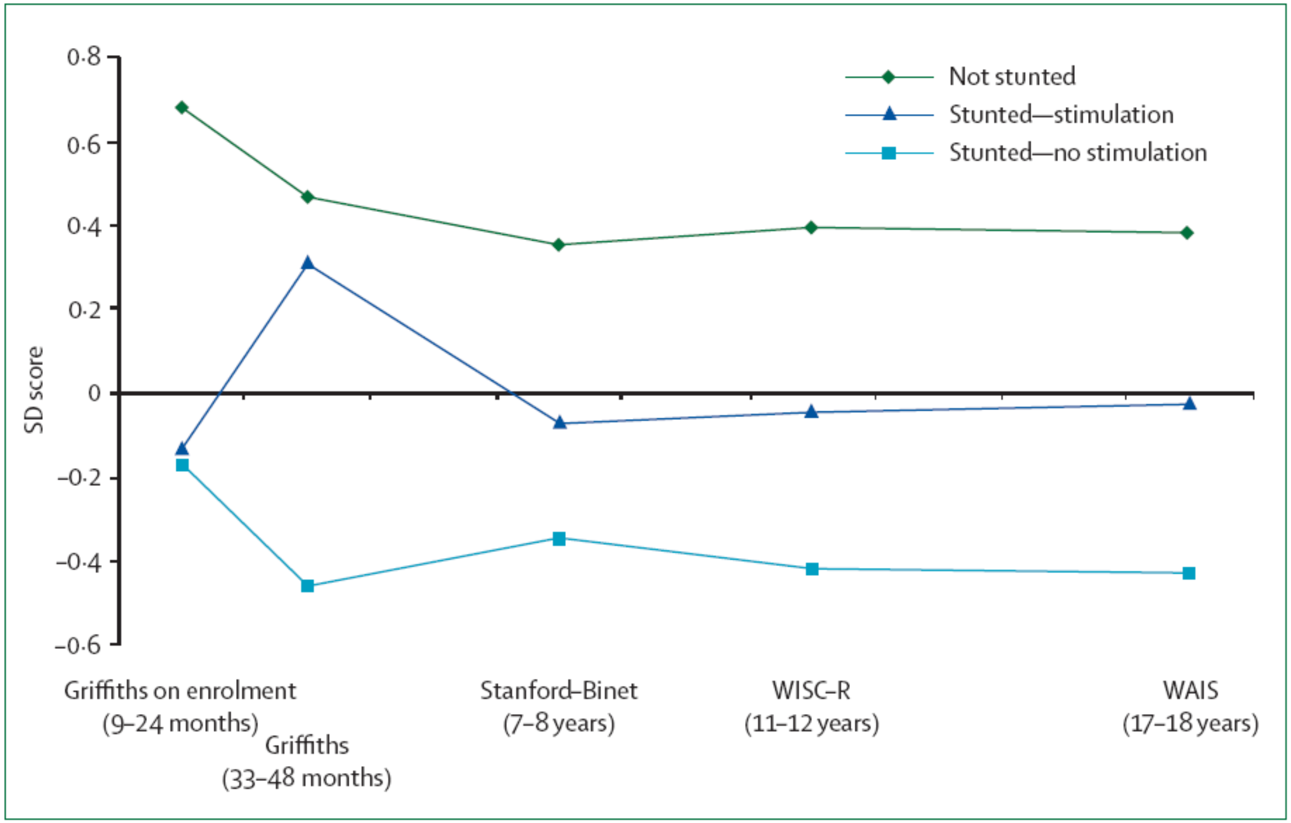


Figure 4: DQ or IQ scores of stunted and non-stunted Jamaican children from age 9–24 months to 17–18 years

Stunted children score lower on cognitive tests

Source: Walker *et al*. 2005

The impact of growth faltering on *productivity*

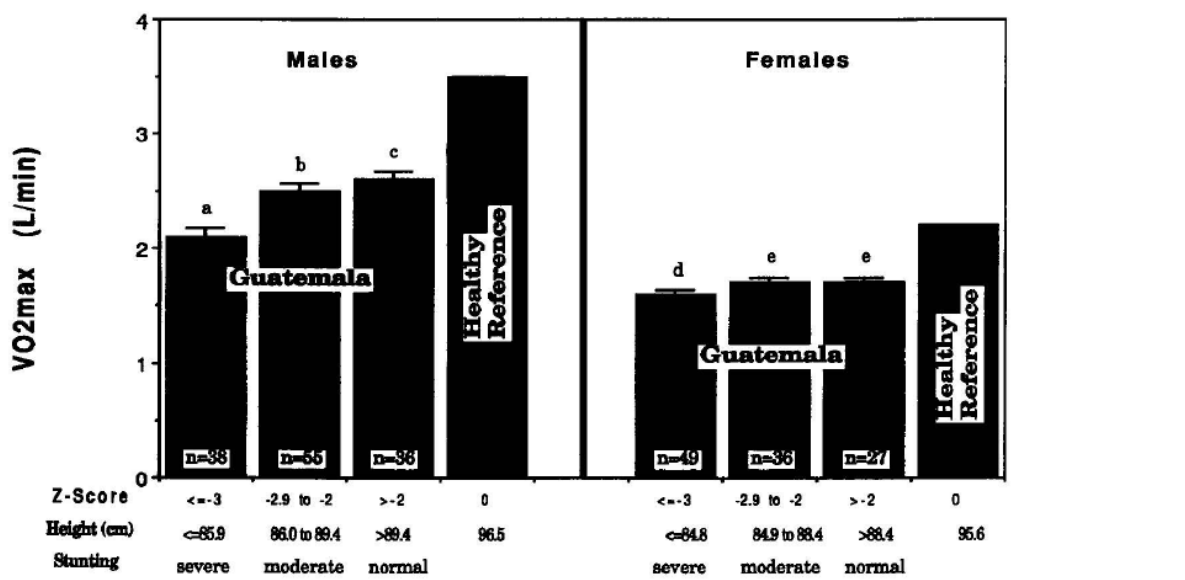


Figure 8. Mean age-adjusted VO_2max (L/minute) at adolescence by preschool height *Z*-score. Different letters represent statistically different means: $p < 0.01$; brackets = SEM.

Stunted children have significantly lower oxygen uptake at maximum exertion during adolescence

Source: Haas *et al*. 1996

The impact of growth faltering on *adult income*

	Deficit in school grades attained	Deficit in learning ability per grade in grade equivalents	Total deficit in grade equivalents	Percentage loss of adult yearly income per grade*	Total percentage loss† of adult yearly income (compounded)	Number (%) of children younger than 5 years in developing countries	Average percentage loss of adult yearly income per disadvantaged child
Stunted only	0·91‡	2·0	2·91	8·3%	22·2%	92·9 (16·6%)	19·8%
Poor only	0·71§	≥0 ¶	0·71¶	8·3%	5·9%	62·8 (11·2%)	
Stunted and poor	2·15‖	≥2·0 ¶	4·15¶	8·3%	30·1%	62·8 (11·2%)	
Evidence	Brazil[38]	Philippines[86] and Jamaica[37]	Sum of columns 1 and 2	51 countries[137] plus Indonesian study[138]	Combining columns 3 and 4	See table 4	Weighted average from columns 5 and 6

*An increase of one grade of schooling is assumed to increase income by 9%.[135,138] Implies that a reduction of 1 year of schooling will reduce income by 8·3% (1/1·09–1 = 0·083); that is, a person with an income of 91·7 due to a loss of 1 year of schooling would have had an income of 100 (91·7×1·09) had that person not lost that year of schooling. †($1/1{\cdot}09^{2{\cdot}91}$)–1=–0·222; ($1/1{\cdot}09^{0{\cdot}71}$)–1=–0·059; ($1/1{\cdot}09^{4{\cdot}15}$)–1=–0·301. ‡Deficit associated with stunting, controlling for wealth quintiles. (The estimate is a weighted average of the differences between stunted [<–2 z] vs non-stunted [>–1 z] children in the five wealth quintiles, with the weights inversely proportional to the square of the SE of the quintile-specific difference). §Deficit associated with poverty, controlling for stunting (similar method to [‡]). ¶Indicates that the figure is lower bound and under-estimates true figure because the effect of poverty on learning per year of schooling is unknown. ‖Difference between non-stunted and third quintile vs stunted and first quintile in Brazil (table 5).

Table 6: Deficit associated with stunting, poverty (first *vs* third quintile of wealth), and both, in schooling and percentage loss in yearly income in developing countries

Stunted children lose an estimated 22.2% in adult yearly income

Source: Grantham-McGregor *et al*. 2007

Undernutrition delays the adolescent growth spurt and the onset of puberty

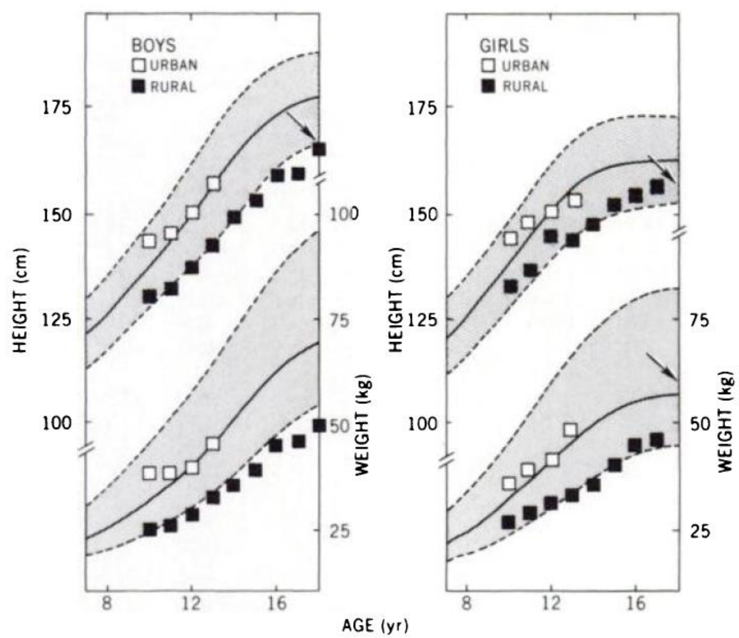


FIG. 1. Heights and weights of the two study populations compared to US standards, the 5th and 95th percentiles of which are shown in the *shaded areas* (38). The adult values provided in Table 1 are shown by the *small diagonal arrows*.

TABLE 2
Median (± SD) age for pubertal stage by probit analysis

Study group	Pubertal stage		
	2—Early	3—Mid	4 Late (includes menarche)
Girls			
Urban*	<10	11.5 ± 1.7	13.2 ± 1.5
Rural*	10.6 ± 2.4	13.7 ± 1.8	15.3 ± 2.2
Boys			
Urban*	9.7 ± 2.3	12.0 ± 1.8	13.6 ± 1.7
Rural*	12.8 ± 1.4	13.5 ± 1.5	14.7 ± 1.4

* All comparisons (urban vs rural), $p < 0.01$.

In Kenya, rural, malnourished children experienced significant delays in maturation, 3.0 years in boys and 2.1 years in girls.

Source: Kulin *et al*. 1982

Undernutrition delays the adolescent growth spurt and the onset of puberty

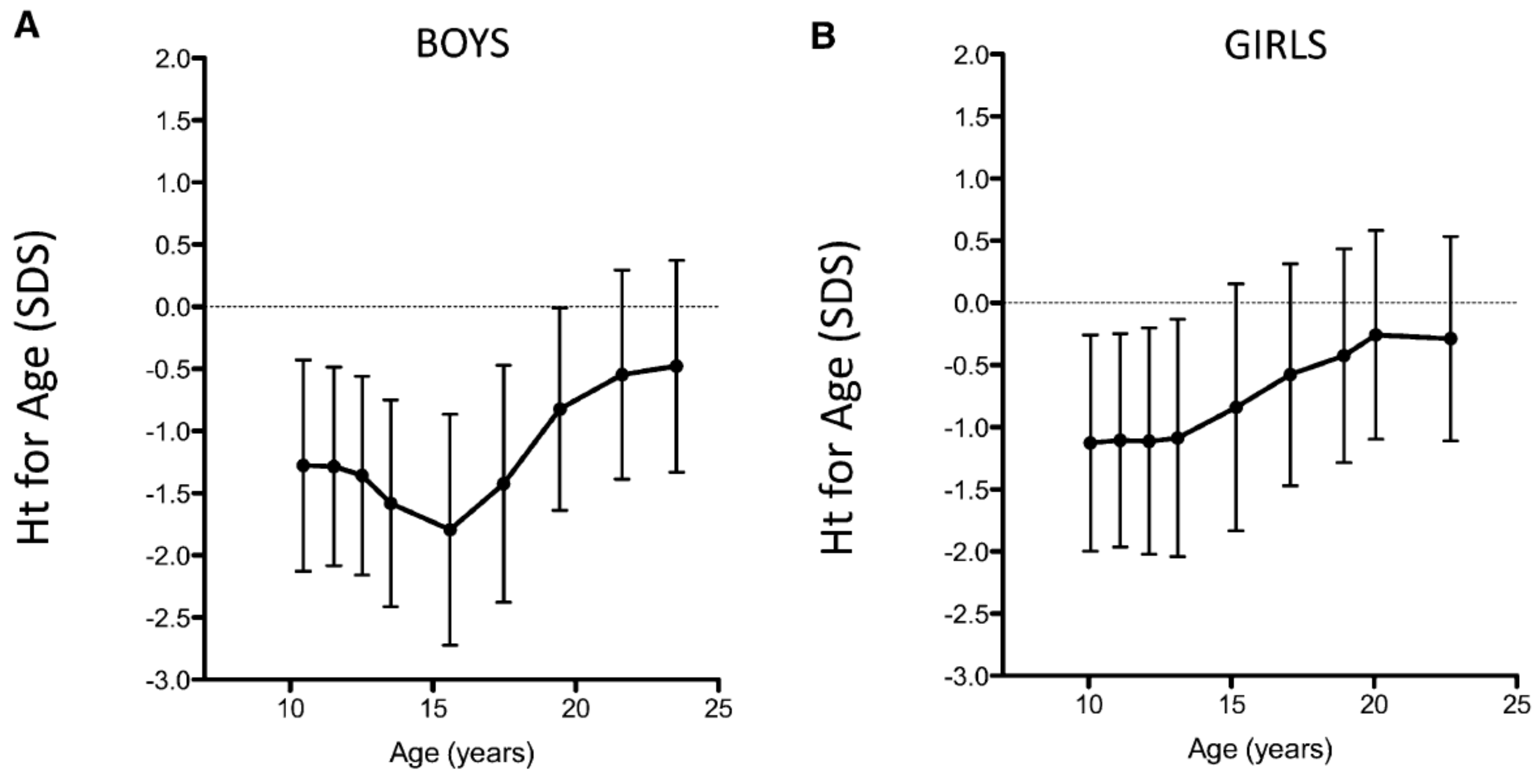


FIGURE 6. Changes in height relative to the UK 1990 reference in cohorts of 80 boys and 80 girls measured longitudinally in rural Gambia. Ht, height; SDS, SD score.

In the Gambia, catch-up was observed both at the delayed onset of puberty and through a prolonged period of growth.

Source: Prentice *et al*. 2013

3. Interventions at school age

- changes in environment
- interventions addressing secondary stunting and underweight
- food supplementation
- micronutrient supplementation
- deworming

Changes in environment
immigration studies

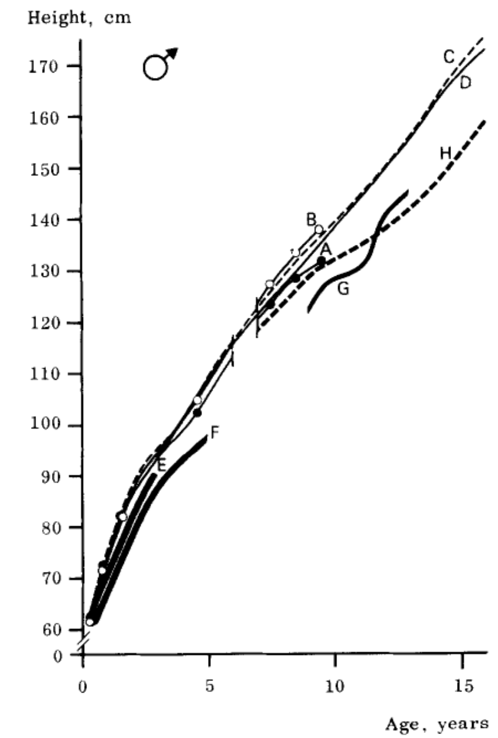


Figure 5. Mean height-for-age in a group of Turkish immigrant boys born and living in Stockholm (•——•, A); Swedish controls (○——○, B); and in selected Swedish and Turkish growth studies: Swedish standard (Karlberg *et al.* 1976) (---, C); Turkish élite group in Istanbul (Neyzi *et al.* 1978) (——, D); Turkish boys in rural area near Ankara (Oral 1973) (——, E); Turkish boys and girls, all regions and socio-economic groups (Köksal 1977) (——, F); Turkish boys rural area (Neyzi *et al.* 1973) (——, G); Swedish boys in Stockholm 1883 (Ljung, Bergsten-Brucefors, Lindgren 1974) (---, H).

Children born in Turkey who then immigrated to Sweden soon caught up in height and were not found to be short later on, with heights similar to those of Turkish children born in Sweden.

Source: Mjönes 1987

Changes in environment
adoption studies

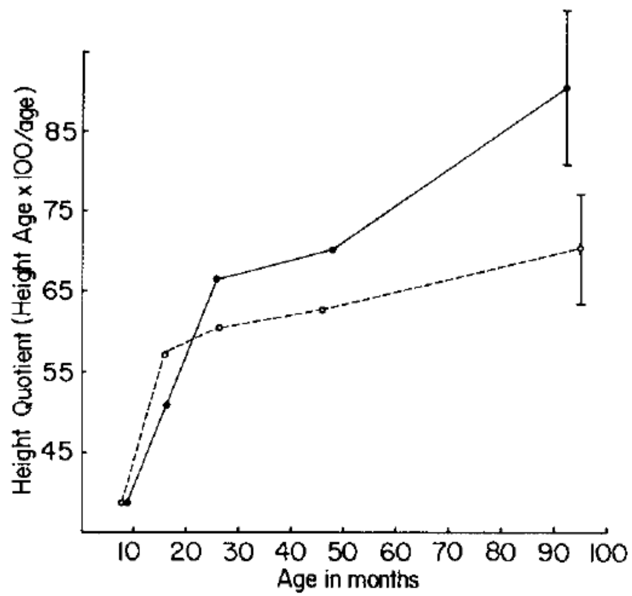


Fig 1. Linear growth of severely malnourished infants, half of whom (solid line) were "adopted" at time of fourth measurement. One SD above and below mean for each group shown at time of last measurement.

In Peru, previously malnourished children who were adopted were found to be significantly taller than controls by age 9.

Source: Graham and Adrianzen 1972

Changes in environment
other changes in environment

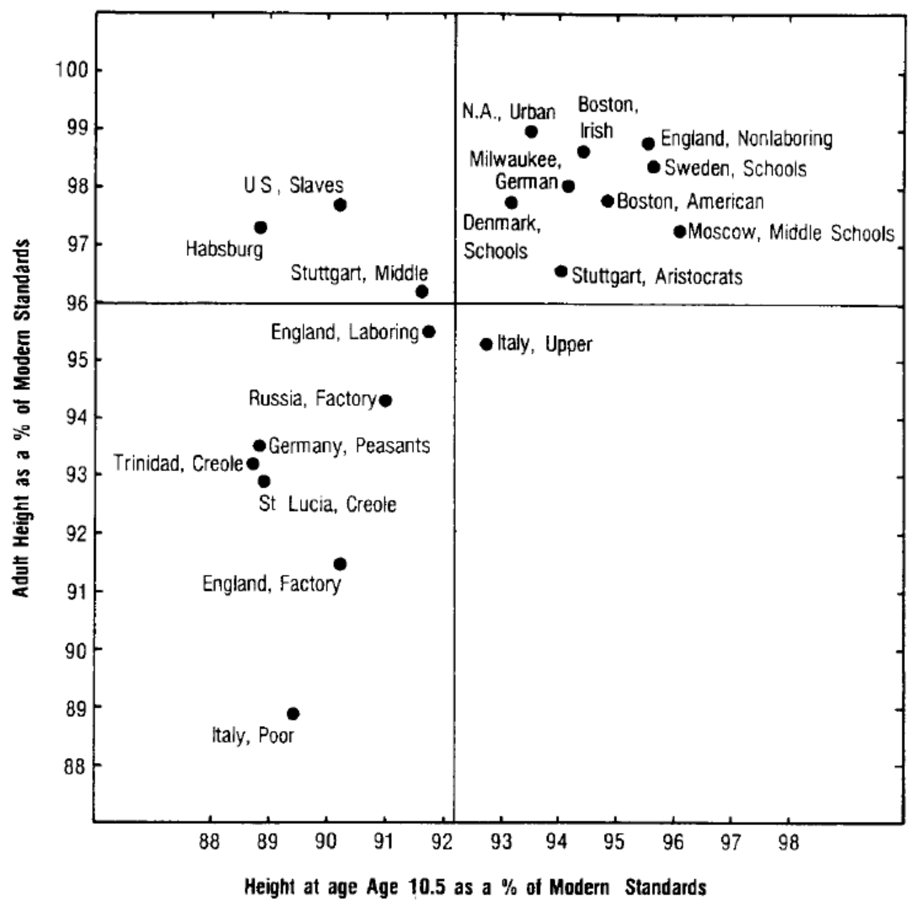


Figure 1. Percentage of modern standards attained at age 10·5 years and as adults: males. Source: table 4.

Source: Steckel 1987

Interventions addressing secondary stunting and underweight

treatment of coeliac disease

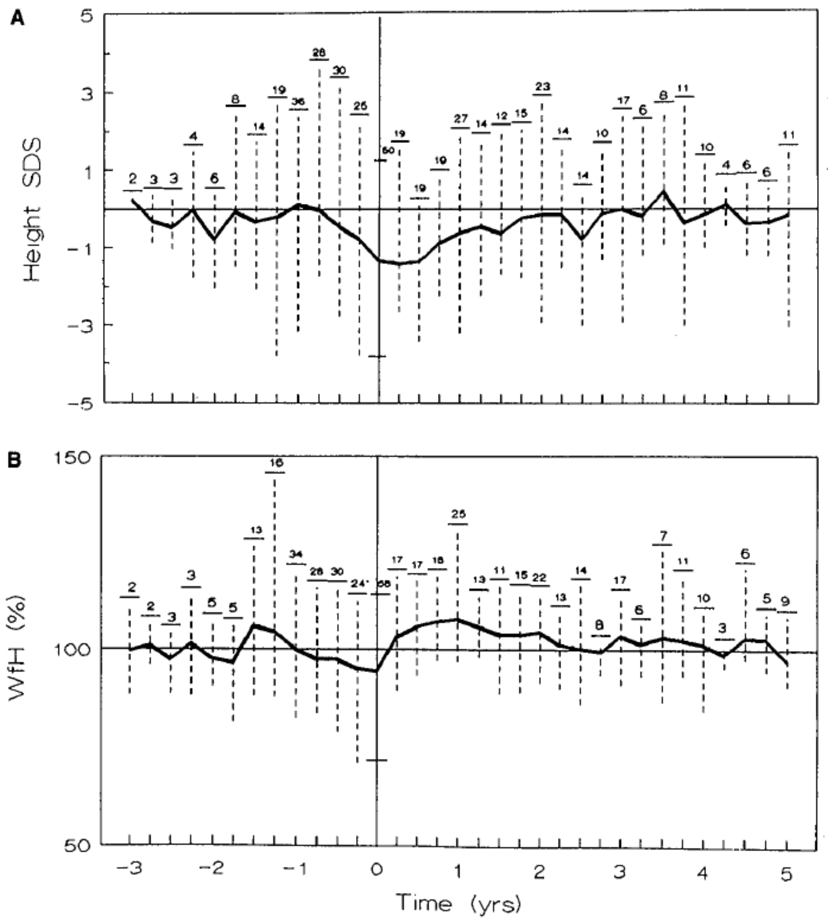


FIG. 2. Mean (solid lines) and range (interrupted lines) HSDS **(A)** and weight-for-height as percentage of the median **(B)** in relation to the onset of therapy. The numbers of patients are indicated at each point.

After initiation of a gluten-free diet, coeliac children experienced complete catch-up in height in 2–3 years.

Source: Damen *et al*. 1994

Interventions addressing secondary stunting and underweight

treatment of growth hormone deficiency

Following treatment, children with hormone deficiencies were found to be 2.3 SD below the mean (6 SD below in untreated).

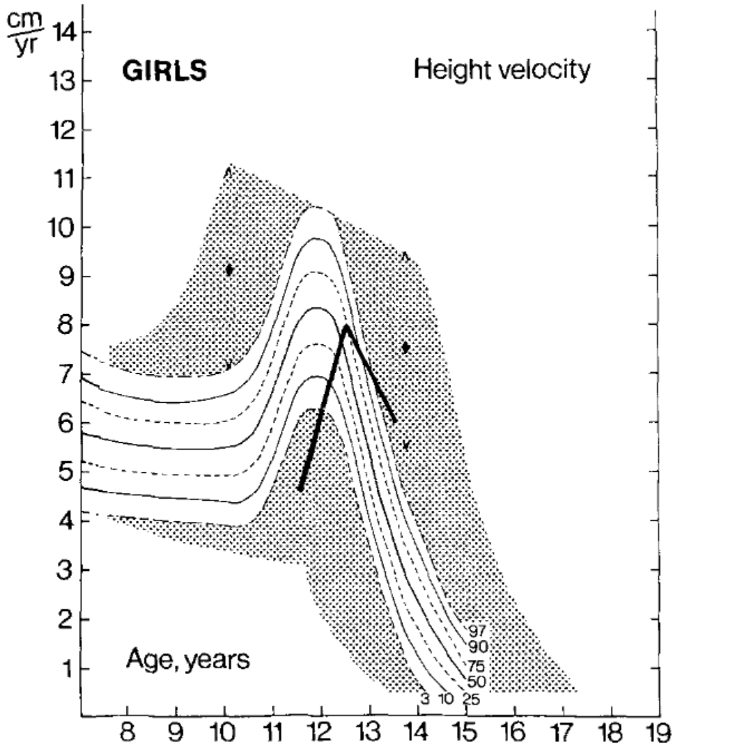


Fig. 2. Peak adolescent height velocity of girls with isolated growth hormone deficiency who were prepubertal when hGH began ($n = 8$)

Source: Burns *et al*. 1981

Interventions addressing secondary stunting and underweight

treatment of hypothyroidism

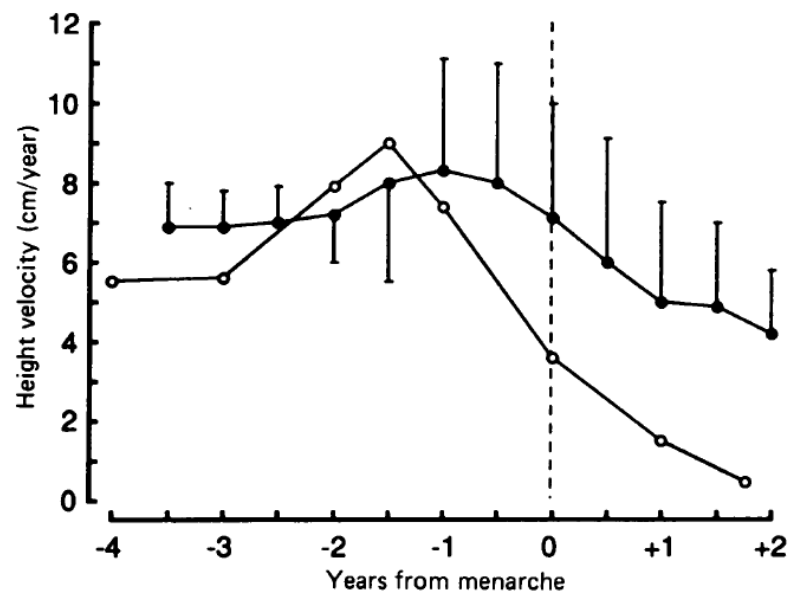


Figure 3 Growth velocity data from 17 girls with primary hypothyroidism treated with thyroxine, related to menarche. Solid circles and horizontal bars represent mean (SD) for patients with hypothyroidism. Open circles represent mean data for normal girls from Tanner et al.[10 15]

Studies of longstanding untreated hypothyroidism have also shown considerable if incomplete catch-up in growth following diagnosis and treatment.

Source: Pantsiotou *et al*. 1991

Interventions addressing secondary stunting and underweight

treatment of corticosteroid excess

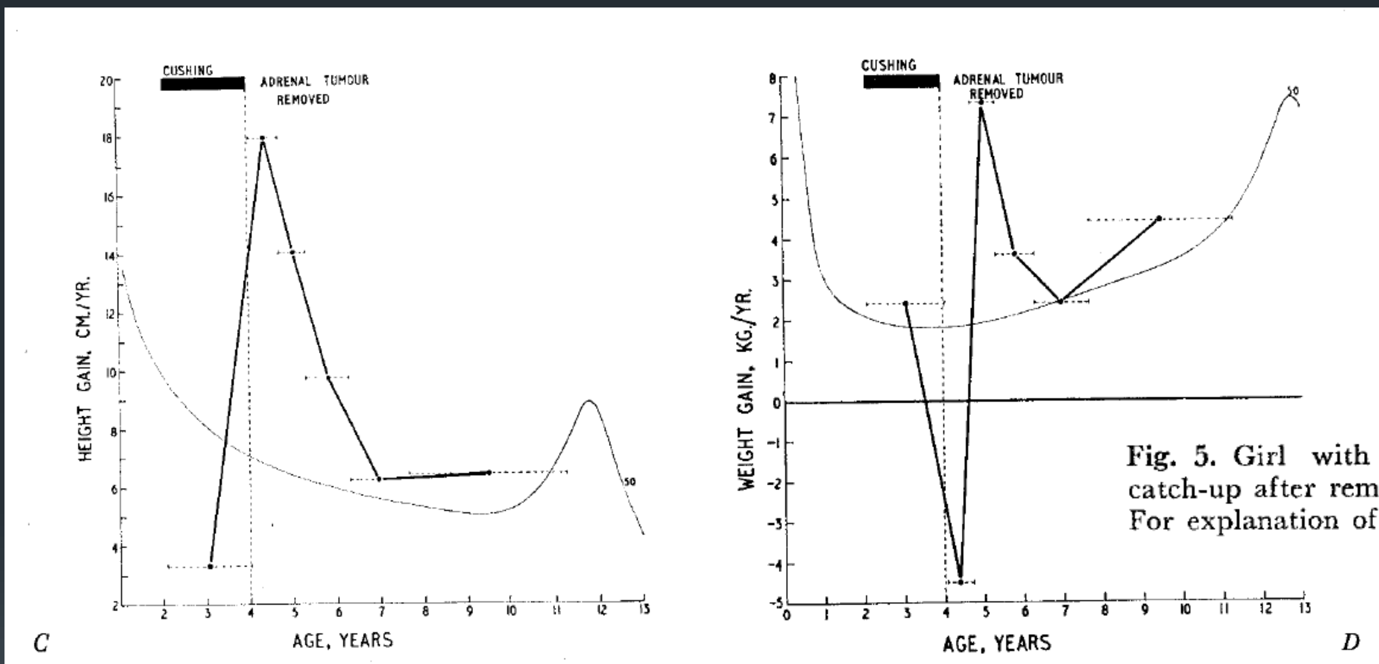


Fig. 5. Girl with Cushing's syndrome showing catch-up after removal of adrenal tumor at age 4. For explanation of charts see text.

Treatment of Cushing's syndrome resulted in a growth rate 3.5 times the average eight months afterward and twice the average two years later.

Source: Prader, Tanner, and Von Harnack 1963

Food supplementation

Cochrane systematic review of school feeding programmes, low-income countries, schoolchildren 5–19 years of age:

- *randomised controlled trials*: small, significant effect on weight gain (0.39 kg)
- *controlled before and after studies*: significant effect on height (1.43 cm) and weight gain (0.71 kg)

Source: Kristjansson *et al*. 2007

Food supplementation
randomised controlled trials

TABLE 4

Multiple regression analyses of height, weight, and BMI at the end of the intervention, controlling for the children's initial measures[1]

	Height (cm)	Weight (kg)	BMI (kg/m^2)
Age	0.01 (0.01)[2]	0.003 (0.004)	0.004 (0.001)[2]
Sex	0.43 (0.09)[2]	0.40 (0.09)[2]	0.10 (0.04)[2]
Treatment group	0.25 (0.09)[2]	0.42 (0.09)[2]	0.16 (0.04)[2]
Nutrition group	0.77 (0.14)[2]	0.22 (0.15)	0.18 (0.05)[2]
Initial measure	0.98 (0.01)[2]	1.08 (0.02)[2]	0.98 (0.02)[2]
Housing rating	−0.07 (0.03)[2]	—	—

[1] Coefficient; SE in parentheses. Sex, treatment group, and nutrition group were coded as in Table 3.

[2] $P < 0.05$.

Results from Jamaica (children in grades 2–5) suggest the breakfast programme could result in a 2.4 cm gain in height over the primary school years, an additional one-third SD in height by age 11.

Source: Powell *et al*. 1998

Food supplementation
randomised controlled trials

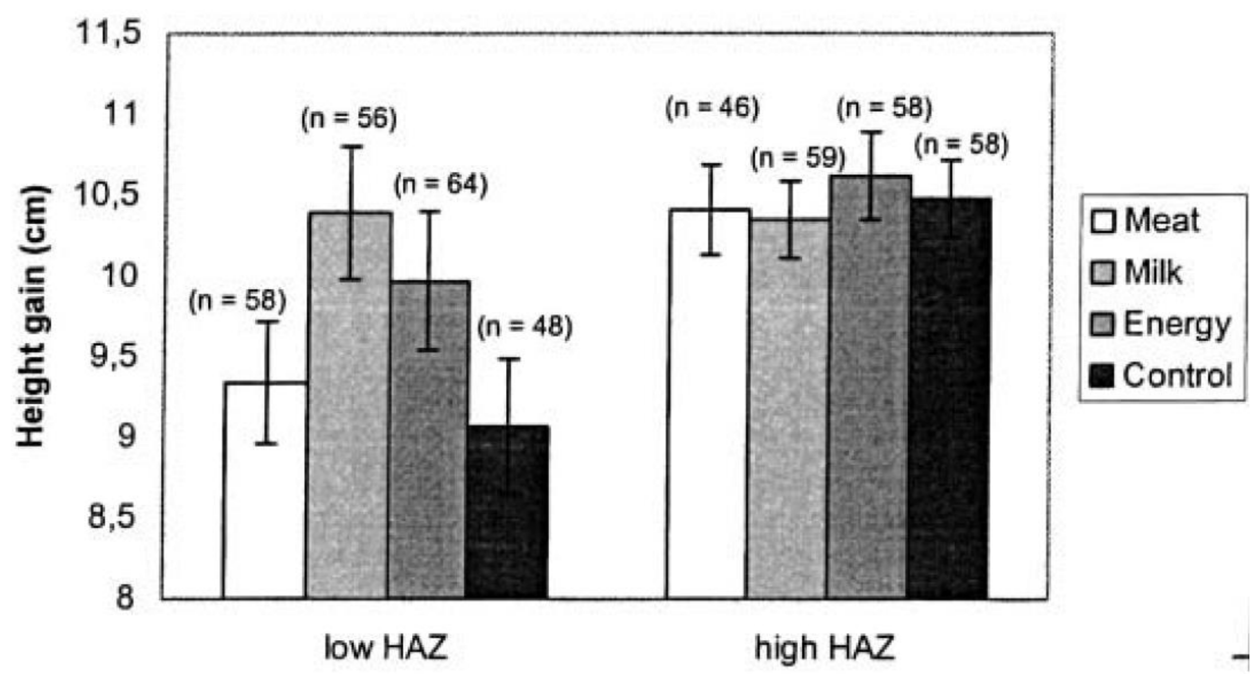


FIGURE 2 Height gain (means ± SE) for the supplementation and control groups by baseline HAZ (low HAZ, ≤ −1.4; high HAZ, > −1.4). None of the differences were statistically significant.

In a study of children in class 1, those in the milk group with baseline HAZ below the median gained 1.3 cm (15%) in height over the control.

Source: Grillenberger *et al*. 2003

Food supplementation
randomised controlled trials

Table 5: Impact of SFP and THR on HAZ of Preschool Siblings of Beneficiaries

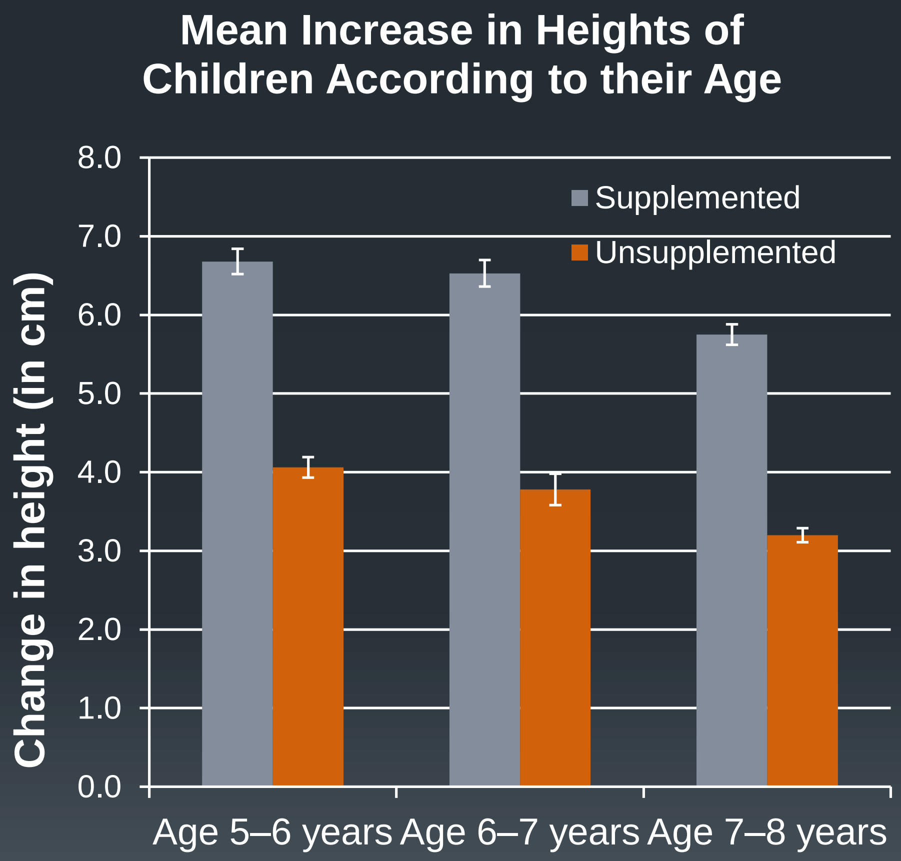
	Children age 6-59 months (1)	Children age 6-35 months (2)	Children age 36-59 months (3)	Children age 6-59 months: Female (4)	Male (5)	Pader district (6)	Lira district (7)
School meals	0.363*	0.589*	0.137	0.0637	0.615**	-0.231	0.987***
	[0.19]	[0.31]	[0.29]	[0.24]	[0.27]	[0.17]	[0.24]
Take-home rations	-0.335	-0.132	-0.447	-0.446	-0.347	-0.826***	0.249
	[0.22]	[0.35]	[0.32]	[0.28]	[0.27]	[0.23]	[0.32]
Observations	1024	515	509	474	550	549	475
R-squared	0.02	0.02	0.02	0.03	0.03	0.03	0.02
Test equality of impacts (p-value)							
H_0: SFP = THR	.004***	.053*	.040**	.020**	.003***	.019**	.053*

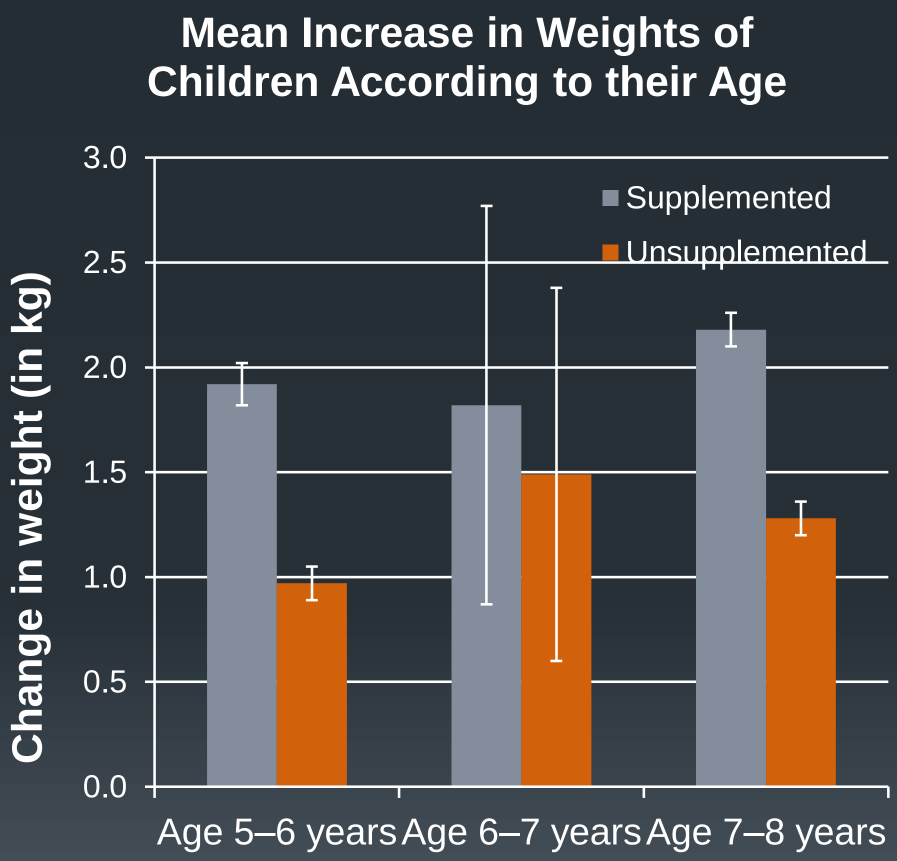
Notes: Standard errors in parentheses robust to clustering at baseline IDP camp level.
* significant at 10%; ** significant at 5%; *** significant at 1%

In Uganda, school feeding improved HAZ of younger siblings.

Source: Adelman et al. 2008

Food supplementation
controlled before and after studies



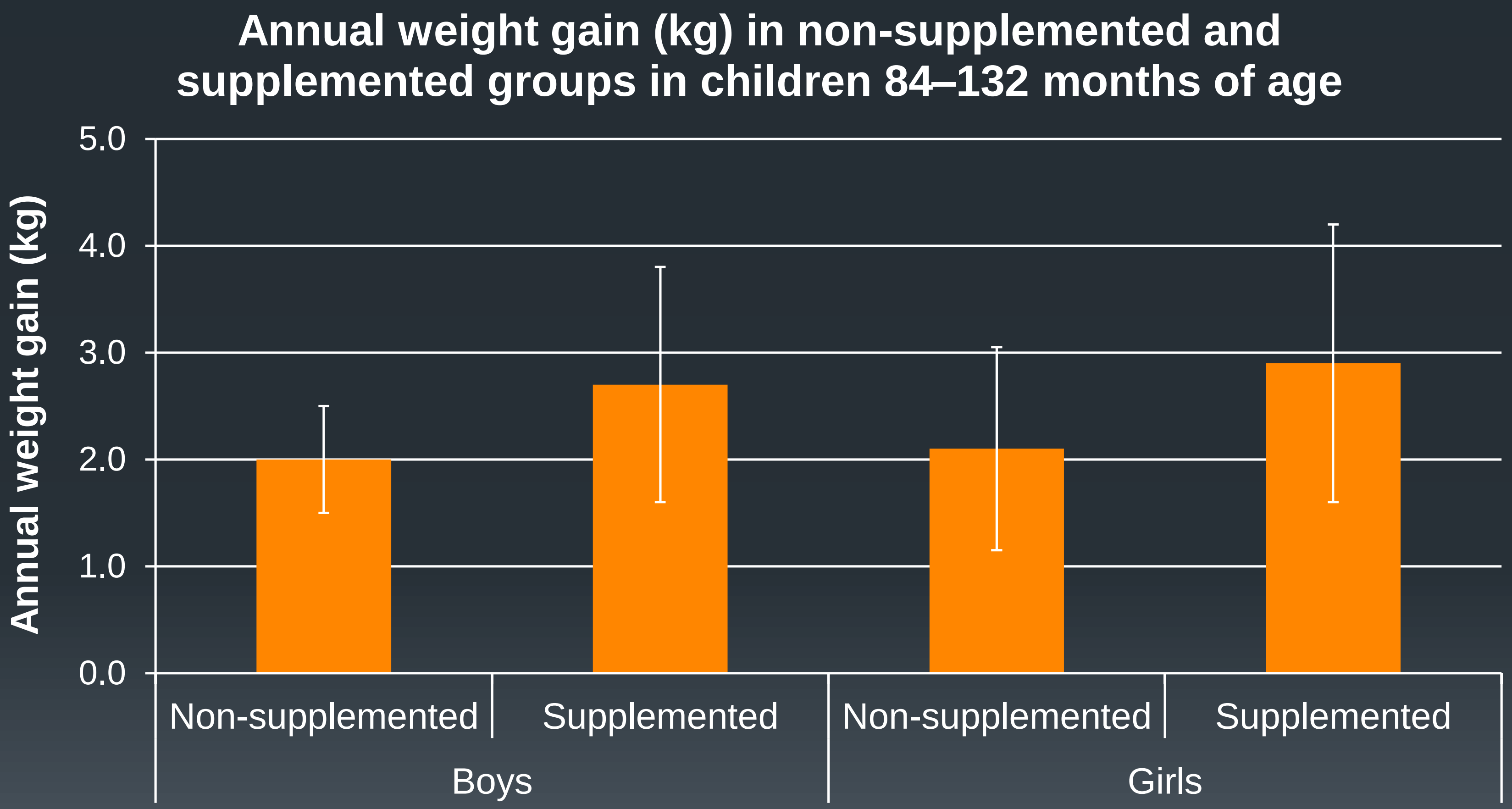


In India, supplemented schoolchildren experienced significant height and weight gains over a period of 10 months.

Source: Devadas *et al*. 1979

Food supplementation

controlled before and after studies



The India Mid-Day Meal Program was found to have a significant effect on weight.

Source: Agarwal, Agarwal, and Upadhyay 1989

Micronutrient supplementation

zinc supplementation

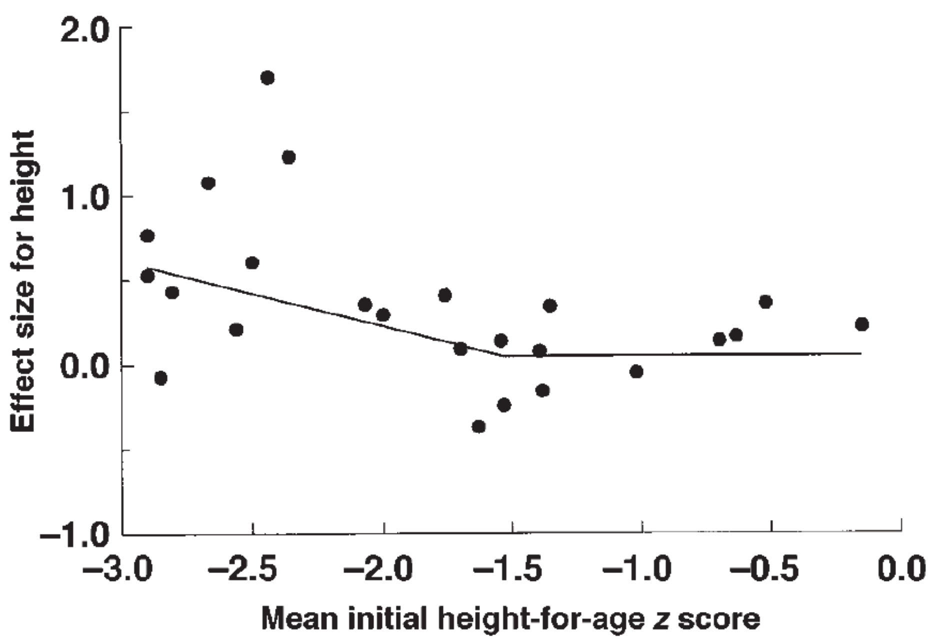


FIGURE 4. Relation between mean initial height-for-age *z* score and effect size (in SD units) for the effect of zinc supplementation on linear growth among children aged ≥6 mo.

Zinc supplementation studies in prepubertal children significantly impacted weight (0.31 kg) and height (0.35 cm).

Source: Brown *et al*. 2002

Micronutrient supplementation

multiple micronutrient fortification

Reference	Micronutrient deficiencies						Growth and weight		
	Iron	Hb/ Anemia	Iodine	Vitamin A	Zinc	B–vitamins	Height/ stunting	Weight/BMI/ underweight	**Duration of intervention**
MMN–fortified food versus unfortified food									
Abrams et al. (2003)[68]	✓	✓	–	×	–	✓	×	✓	8 weeks
Ash et al. (2003)[72]	✓	✓	–	✓	–	–	✓	✓	6 months
Hyder et al. (2007)[69]	✓	✓	–	✓	×	–	×	✓	12 months
Lien do et al. (2009)[62]	–	–	–	–	–	–	–	–	
Manger et al. (2008),[66,74]	×	✓	✓	×	✓	–	×	×	31 weeks
Nga et al. (2009)[67]	✓	✓	✓	✓	✓	–	–	–	
Osendarp et al. (2007)[63] (Australia)	✓	×	–	–	×	✓	–	–	
Osendarp et al. (2007)[63] (Indonesia)	✓	✓	–	–	×	✓	–	–	
Sivakumar et al. (2006)[65,70,73,75]	✓	(✓)[1]	✓	✓	×	✓	✓	✓	14 months
Solon et al. (2003)[64]	–	✓	✓	–	–	–	×	×	16 weeks
van Stuijvenberg et al. (1999)[71]	✓	✓	✓	✓	–	–	×	×	12 months
MMN–fortified food versus single–fortified food									
Zimmerman et al. (2004)[76]	✓	✓	–	✓	–	–	–	–	

× No significant effect.
✓ Significant beneficial effect of MMN (comparing change from baseline between or within groups, or means between groups at follow-up).
(✓) Significant beneficial effect of MMN in subgroup only (comparing change from baseline between or within groups, or means between groups at follow-up).
– Parameter not assessed.

A recent systematic review in school-age children reported significant weight gain in four studies and significant height gain in two studies.

Source: Best *et al*. 2011

Deworming

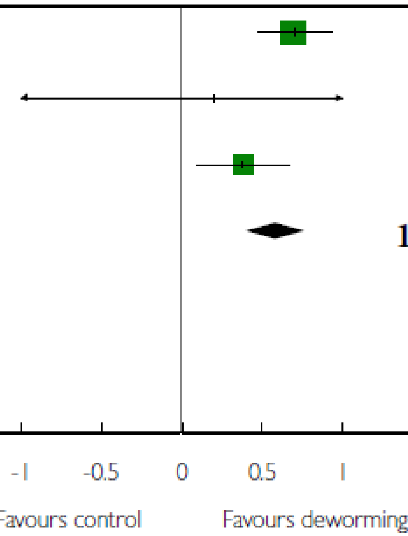
Screened for infection - single dose, outcome, weight (kg)

Study or subgroup	Deworming N	Deworming Mean(SD)	Control N	Control Mean(SD)	Mean Difference IV,Fixed,95% CI	Weight	Mean Difference IV,Fixed,95% CI
Adams 1994	28	1 (0.32)	27	0.3 (0.51)		62.7 %	0.70 [0.47, 0.93]
Freij 1979a (I)	6	12.3 (2.91)	7	12.1 (2.29)		0.4 %	0.20 [-2.68, 3.08]
Sarkar 2002	40	0.92 (0.84)	41	0.54 (0.45)		36.9 %	0.38 [0.09, 0.67]
Total (95% CI)	**74**		**75**			**100.0 %**	**0.58 [0.40, 0.76]**

Heterogeneity: $Chi^2 = 2.92$, df = 2 (P = 0.23); $I^2 = 32\%$

Test for overall effect: Z = 6.35 (P < 0.00001)

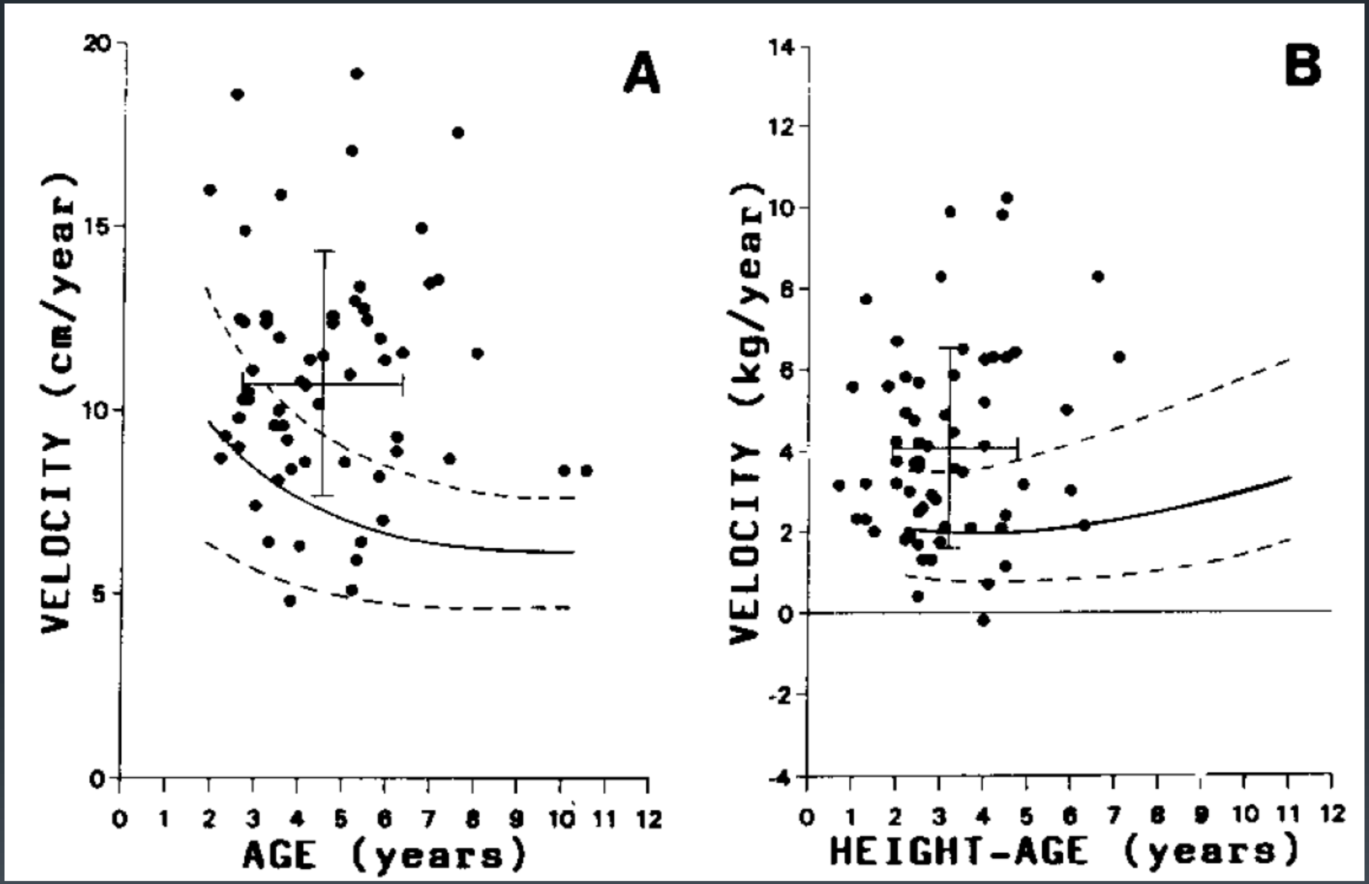
Test for subgroup differences: Not applicable



The latest Cochrane review of the effect of STHs on growth in children under the age of 17 found a significant increase in weight gain after one dose of deworming.

Source: Taylor-Robinson *et al*. 2012

Deworming



Following deworming, children in Jamaica experienced mean height and weight velocities 2 SD above the growth standard.

Source: Cooper *et al*. 1995

4. Conclusions

Victora *et al*. 2008: "Poor fetal growth or stunting in the first 2 years of life leads to irreversible damage, including shorter adult height, lower attained schooling, reduced adult income, and decreased offspring birthweight."

- In the absence of change, early stunting may well persist as decreased height throughout life.
- But these intervention studies counter the irreversibility claim with evidence that early deficits can, at least to some extent, be made up in childhood and adolescence.

4. Conclusions

Type of intervention	Types of evidence	Sample sizes	Overview of effects	Relative cost
Changes in environment				
Immigration studies	1 semi-longitudinal and 3 cross-sectional studies	medium to large	large, significant	$$$$
Adoption studies	5 longitudinal studies	small to medium	large, significant	$$$$
Other changes in environment studies	2 retrospective analyses of cross-sectional data sets	large	large, significant	$$$$
Interventions addressing secondary stunting and underweight				
Treatment of celiac disease	6 longitudinal studies	small	large, significant	$$$
Treatment of growth hormone deficiency	2 longitudinal studies	small to medium	large, significant	$$$
Treatment of hypothyroidism	5 longitudinal studies	small to medium	medium, significant	$$$
Treatment of corticosteroid excess	3 longitudinal studies	small	medium, significant	$$$
Food supplementation				
Randomised controlled trials	6 interventions, between 8 and 24 months in duration	medium to large	small, significant weight gain small, non-significant height gain spill-over effects on growth of younger siblings	$$
Controlled before and after studies	4 interventions, between 3 and 24 months in duration	medium	small, significant	$$
Micronutrient supplementation	2 meta-analyses and 1 systematic review	small to large	small, significant	$
Deworming	2 meta-analyses	small to large	small, significant	$

THANK YOU