Growth in School-age Children
Examining the evidence on catch-up

Kristie L. Watkins
Dean T. Jamison
Donald A.P. Bundy

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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. A thin envelope 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 arrowheads and diamond symbols.

*Source: Tanner and Whitehouse 1976*
Methodological considerations

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

Research

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

Mercedes de Onis,* Adelheid W Onyango,* Elaine Borghi,* Amani Silam,* Chizuru Nishida* & Jonathan Siekmann*

**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 0.8 kg/m² to 0.1 kg/m². At 19 years, the new BMI values at +1 standard deviation (SD) are 25.4 kg/m² for boys and 25.0 kg/m² for girls. These values are equivalent to the overweight cut-off for adults (≥ 25.0 kg/m²). Similarly, the +2 SD value (29.7 kg/m² for both sexes) compares closely with the cut-off for obesity (≥ 30.0 kg/m²).

**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.

**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

Stunted children score lower on cognitive tests

Source: Walker et al. 2005
The impact of growth faltering on productivity

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

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.

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

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

<table>
<thead>
<tr>
<th>Study group</th>
<th>Pubertal stage</th>
<th>2 – Early</th>
<th>3 – Mid</th>
<th>4 – Late (includes menarche)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Girls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban*</td>
<td>&lt;10</td>
<td>11.5 ± 1.7</td>
<td>13.2 ± 1.5</td>
<td></td>
</tr>
<tr>
<td>Rural*</td>
<td>10.6 ± 2.4</td>
<td>13.7 ± 1.8</td>
<td>15.3 ± 2.2</td>
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</tr>
<tr>
<td><strong>Boys</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban*</td>
<td>9.7 ± 2.3</td>
<td>12.0 ± 1.8</td>
<td>13.6 ± 1.7</td>
<td></td>
</tr>
<tr>
<td>Rural*</td>
<td>12.8 ± 1.4</td>
<td>13.5 ± 1.5</td>
<td>14.7 ± 1.4</td>
<td></td>
</tr>
</tbody>
</table>

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

**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.

Source: Kulin et al. 1982
Undernutrition delays the adolescent growth spurt and the onset of puberty

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

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

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

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).

Source: Burns et al. 1981
Interventions addressing secondary stunting and underweight treatment of hypothyroidism

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

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

Source: Pantsiotou et al. 1991
Interventions addressing secondary stunting and underweight

treatment of corticosteroid excess

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

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

<table>
<thead>
<tr>
<th>TABLE 4</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.01 (0.01)²</td>
<td>0.003 (0.004)</td>
<td>0.004 (0.001)²</td>
</tr>
<tr>
<td>Sex</td>
<td>0.43 (0.09)²</td>
<td>0.40 (0.09)²</td>
<td>0.10 (0.04)²</td>
</tr>
<tr>
<td>Treatment group</td>
<td>0.25 (0.09)²</td>
<td>0.42 (0.09)²</td>
<td>0.16 (0.04)²</td>
</tr>
<tr>
<td>Nutrition group</td>
<td>0.77 (0.14)²</td>
<td>0.22 (0.15)</td>
<td>0.18 (0.05)²</td>
</tr>
<tr>
<td>Initial measure</td>
<td>0.98 (0.01)²</td>
<td>1.08 (0.02)²</td>
<td>0.98 (0.02)²</td>
</tr>
<tr>
<td>Housing rating</td>
<td>−0.07 (0.03)²</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

¹Coefficient; SE in parentheses. Sex, treatment group, and nutrition group were coded as in Table 3.
²P < 0.05.
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

In Uganda, school feeding improved HAZ of younger siblings.

Source: Adelman et al. 2008
In India, supplemented schoolchildren experienced significant height and weight gains over a period of 10 months. 

Source: Devadas et al. 1979
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

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

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
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

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