

ANH Academy Week
June 24, 2019 Hyderabad, India

Appropriate use of linear growth measures to assess impact of interventions on child development and catch-up growth

Edward A. Frongillo, Jef L. Leroy, Karin Lapping

University of South Carolina

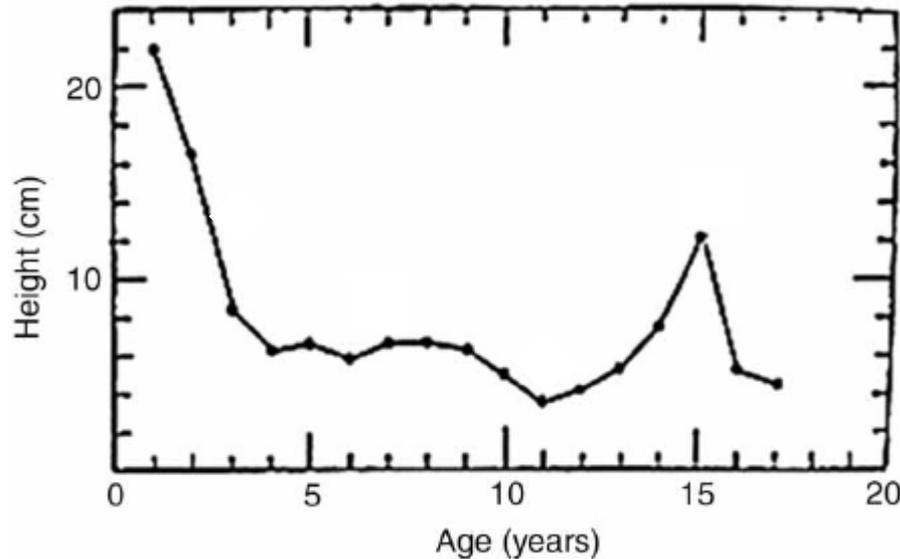
International Food Policy Research Institute

Alive & Thrive



First published growth curve – one child

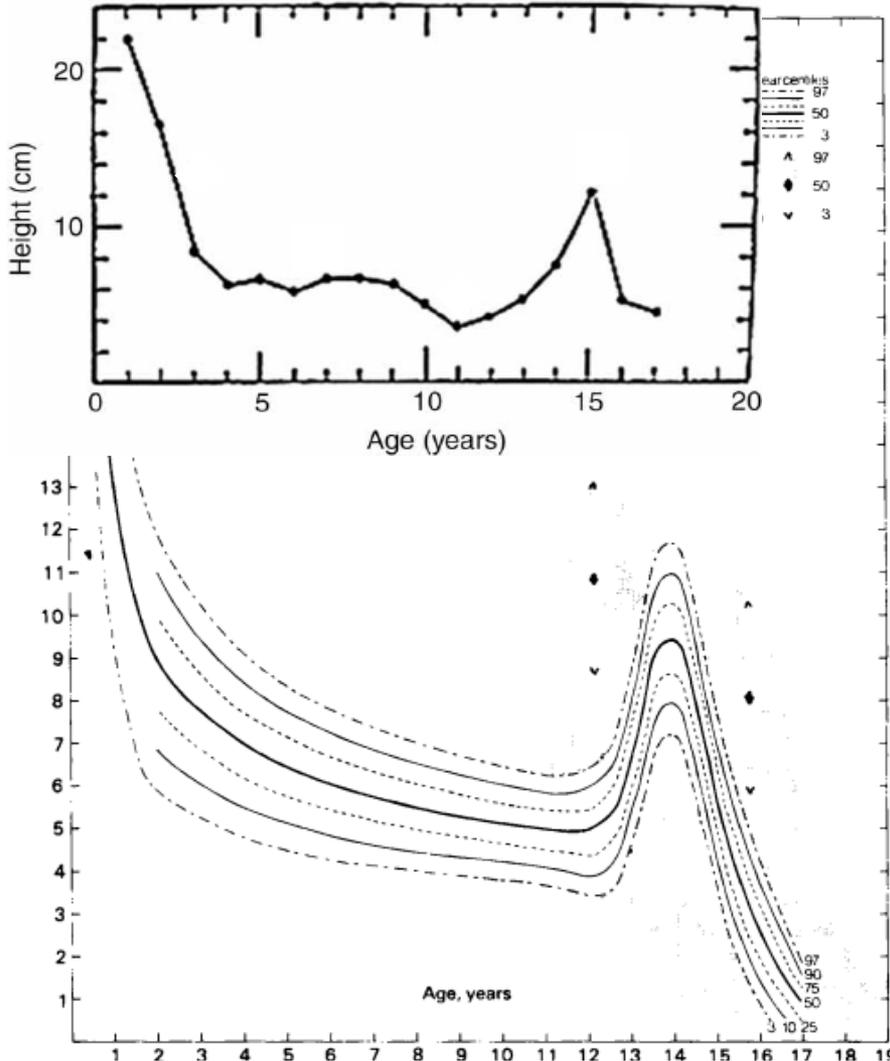
France - George Buffon's Histoire Naturelle – 1700's



- Count Philibert de Montbeillard plotted his son's growth - every 6 months from birth to 18 years
- George Buffon published this chart in Histoire Naturelle in the 1700's - first child height curve
- D'Arcy Wentworth Thompson showed changes in growth velocity using these data in 1942

First published growth curve – one child

France - George Buffon's Histoire Naturelle – 1700's



- Count Philibert de Montbeillard plotted his son's growth - every 6 months from birth to 18 years
- George Buffon published this chart in Histoire Naturelle in the 1700's - first child height curve
- D'Arcy Wentworth Thompson showed changes in growth velocity using these data in 1942
- **This pattern is typical for boys**

Milestone	Year
First published growth curve for son of Count Philibert de Montbeillard	1759-77
First recorded epidemiological study of child height and welfare in UK child factory workers	1833
Growth differences in height among child manual and non-manual workers shown in Northern England	Late 1800's
Coinage of term stunting	1972
Linear growth shown to be similar across well-nourished populations	1974
International reference from US national data developed	1979-83
UNSCN produced first report of world nutrition situation using weight-for-age	1987
WHO review on uses and interpretations of anthropometry	1991-95
WHO report Evaluation of Infant Growth made case for need of new growth standards	1994

Milestone	Year
WHO Multicentre Growth Reference Study designed	1996
Use by Fogel of recorded heights to indicate living standards in health and income over two centuries	1997
UNSCN produced Third Report of the World Nutrition Situation including height-for-age	1997
WHO Multicentre Growth Reference Study in field	1997-2003
International cross-sectional growth standards released for children 0-5 y	2006
Field-testing of growth standards in four countries	2007
WHO growth reference for school-aged children 5-19 y	2007
International velocity growth standards released for children 0-2 y	2009

Growth standards for 0-5 y

- How should grow with appropriate care and no constraints
- > 150 countries adopted standards
- Global databases updated using standards

Purposes for **separate** households or individuals

<i>Purpose</i>	<i>Question</i>
Screening	Is the household or individual at risk?
Diagnosis of problem	Does the household or individual have the problem, and what are the salient causes?
Diagnosis of solution	What is the most appropriate action?
Monitoring	How is the situation changing?

WHO (1995), Frongillo (1999), Leroy et al. (2015)

Purposes for **groups** of households or individuals

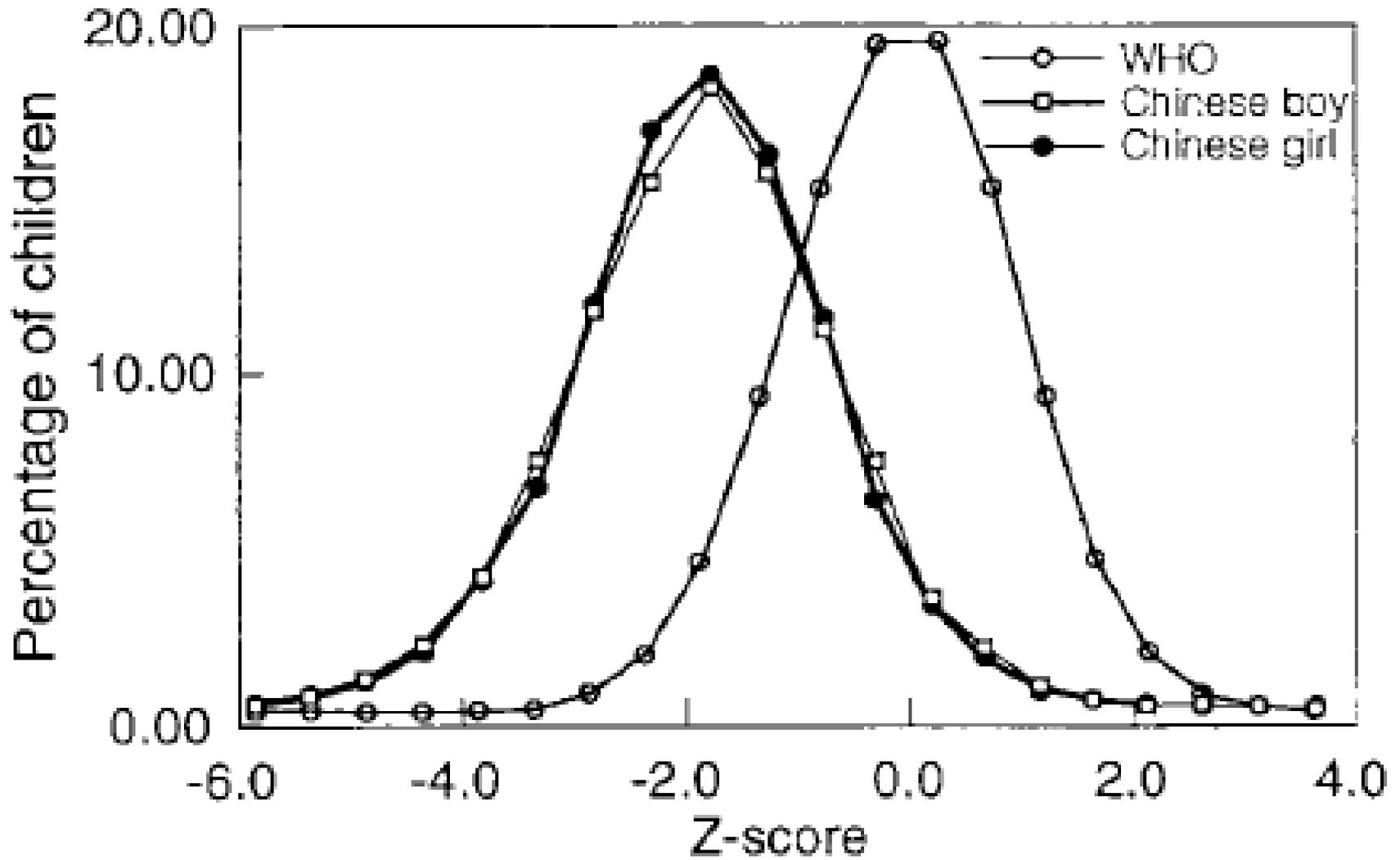
<i>Purpose</i>	<i>Question</i>
Estimation of prevalence	How many are affected?
Determination of causes and consequences	Why are they affected and what are effects?
Early warning	When is action needed?
Targeting	Who will receive which action?
Monitoring	How is the situation changing?
Impact evaluation	Has the action made a difference?

WHO (1995), Frongillo (1999), Leroy et al. (2015)

Assessing child physical growth

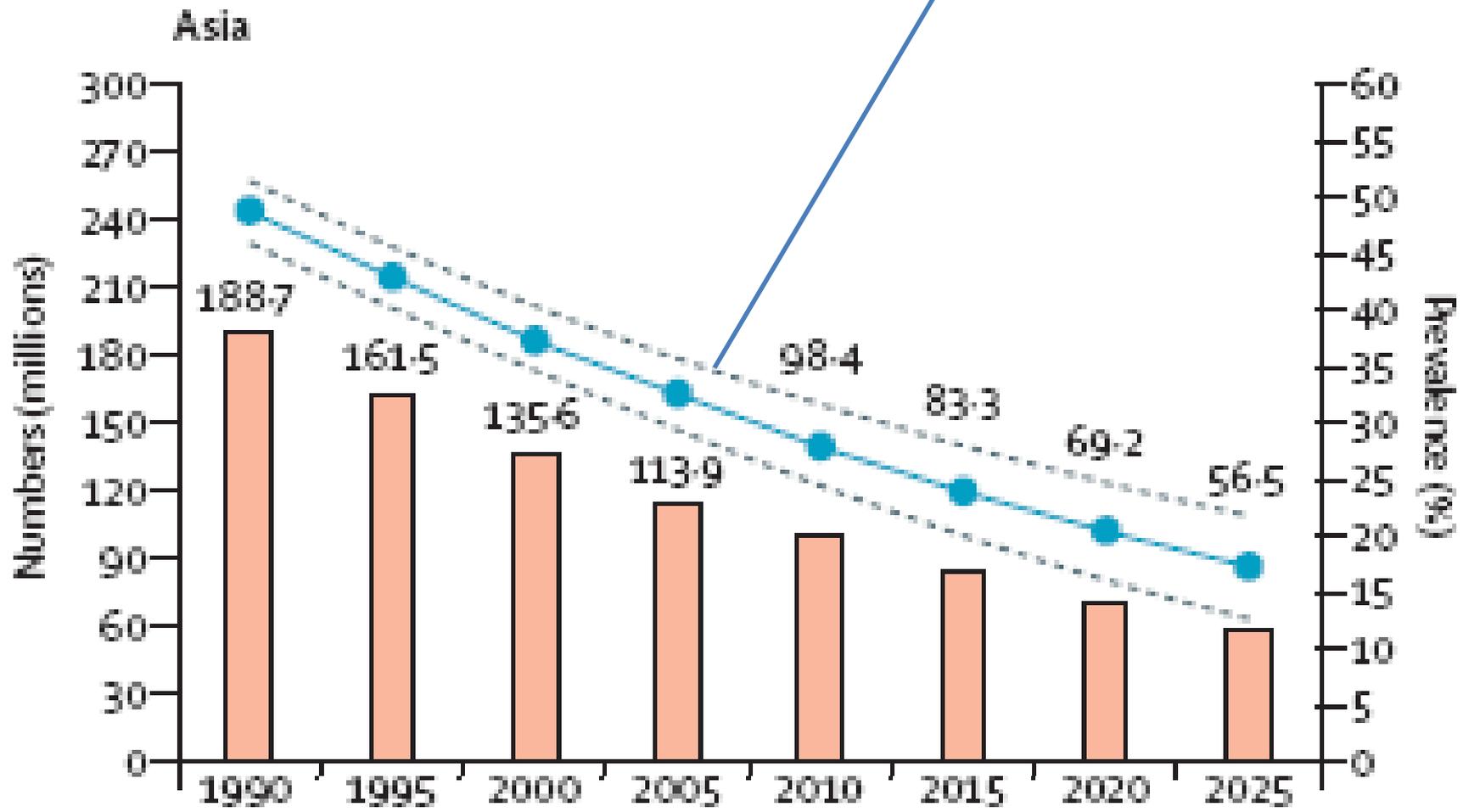
Method	Measure	Indicator
<p>Physical assessment using:</p> <ul style="list-style-type: none">• weighing scales• length boards• stadiometers• tape measures	<ul style="list-style-type: none">• Weight• Length• Height• Head circ.• Arm circ.• Z-scores	<ul style="list-style-type: none">• < -2 SD relative to WHO growth standards• Others

Height-for-age



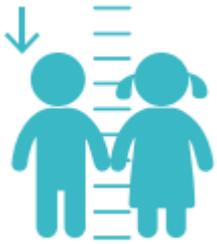
WHO (1995)

49% in 1990 to 28% in 2010 or 1 pp/y
Corresponding increase in HAZ: 0.6 or 0.03/y



From MDGs to SDGs

underweight to stunting



- MDGs were first set of global goals that promoted monitoring of malnutrition - underweight was used as an indicator of poverty
- Before the end of MDG period – stunting already proposed as a superior measure for healthy development of populations
- For Sustainable Development Goals – stunting reduction is a key target of Goal 2
- Some have suggested stunting could be a tracer for general progress in the SDGs and development in general



THE GLOBAL GOALS
For Sustainable Development



Why so much focus on measuring linear growth?

- Reflects accumulation of processes that affect the nutrition of a child
- Can be done well and objectively at large scale
- Measure of a construct tends to be seen as, and confused with, the construct itself
- Linear growth appears simple to understand and familiar
- Assumed if useful for some purposes, is useful for all purposes
- Human body often placed at the center of nutrition

Some consequences for too much focus on measuring linear growth

- Often lack of demonstrable program effects on reducing stunting
- Emphasis placed on biology of growth rather than on—and how to improve—the environments in which children live
- Evaluations not well-prepared to use measures that are responsive to nutrition-sensitive and integrated programs
- Insufficient emphasis on adolescent girls and women before conception and children after the first 1000 days
- Claims for catch-up growth of children from methods incapable of providing such evidence
- Insufficient investment to develop other measures

MINIMat Study – Bangladesh

Diff. in weight gain between usual invitation to food supplementation and food supplementation interventions

Biggest group difference: 52 g
Increase throughout 2 y of study: 80 g

	supplementation			Usual invitation to food supplementation		
	Fe30F	Fe60F	MMS	Fe30F	Fe60F	MMS
Birth weight	2689	2717	2696	2688	2665	2710
HAZ at 24 mo	-1.91	-1.92	-1.99	-1.99	-2.02	-2.06
Neonatal mortality*	28	33	12	25	38	42
Infant mortality*	43	43	17	31	44	47

*rate per 1000 live births

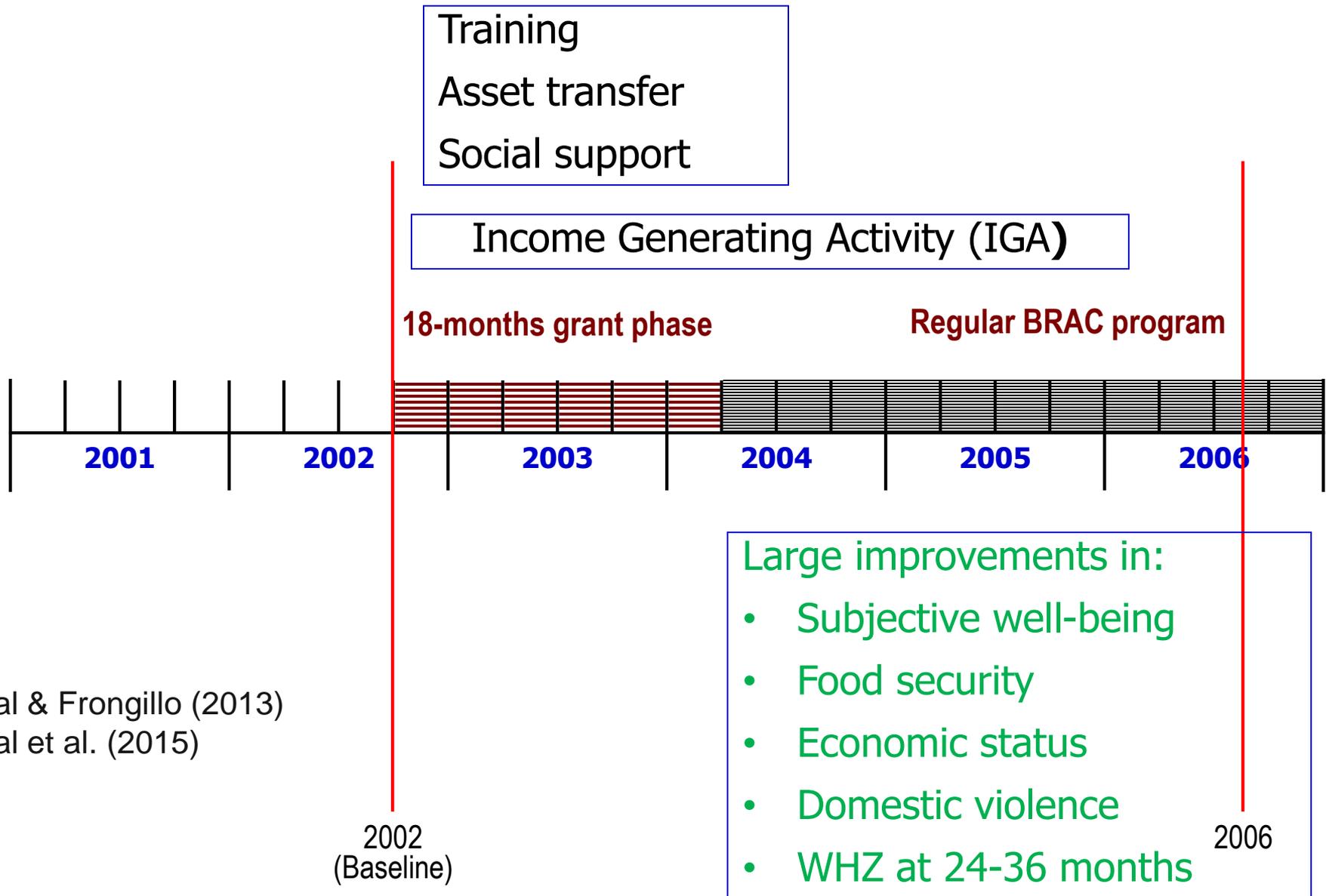
Khan et al. (2011); Persson et al. (2012)

Alive & Thrive in Bangladesh

2009-2014

- Large-scale intensive program delivery feasible
- Reached 1.7 million households through multiple platforms
- Intensive (compared with non-intensive) program
 - Substantially improved BF and CF practices
 - Advanced language and gross motor development
 - Partially explained through improved CF
 - No difference in stunting
 - Rapid positive secular trend in Bangladesh

BRAC program for ultra poor



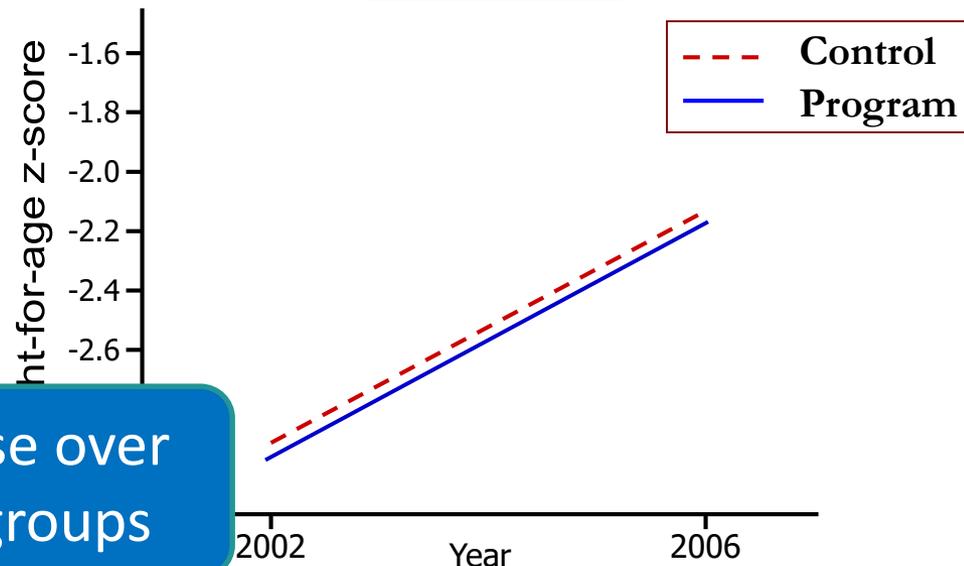
Jalal & Frongillo (2013)
Jalal et al. (2015)

Comparison of adjusted mean height-for-age z-score

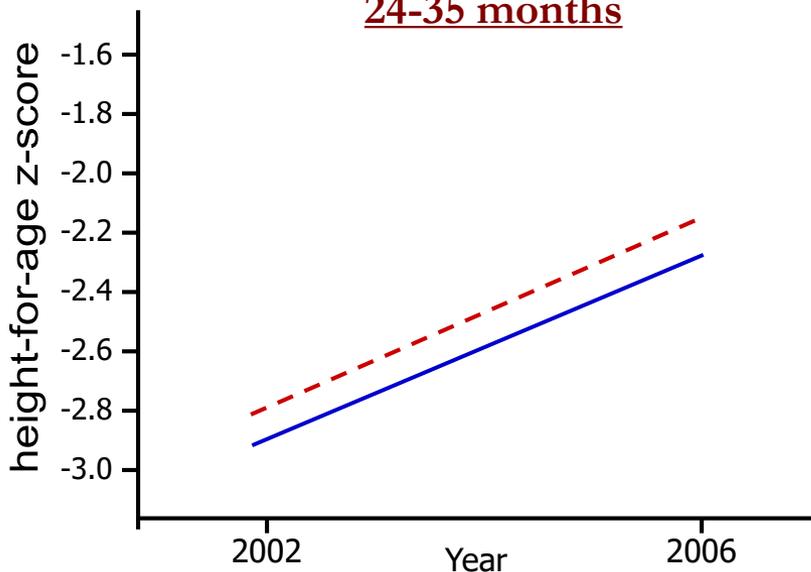
6-11 months



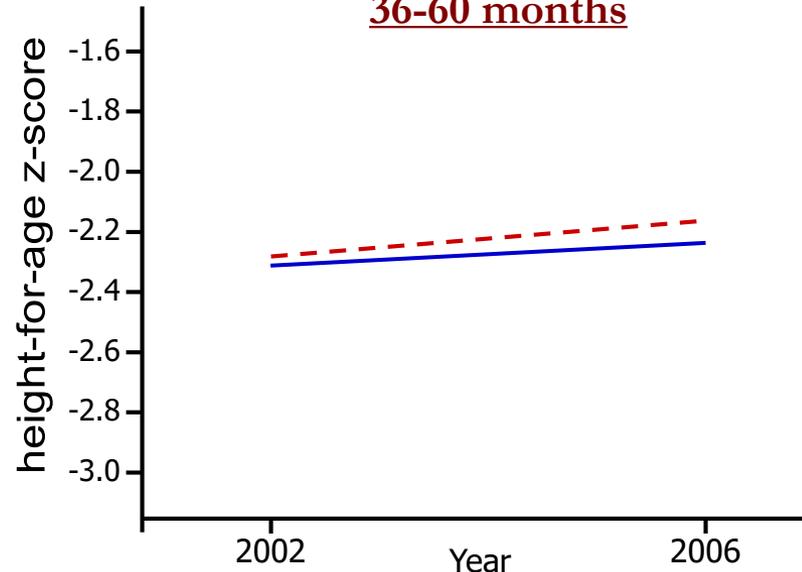
12-23 months



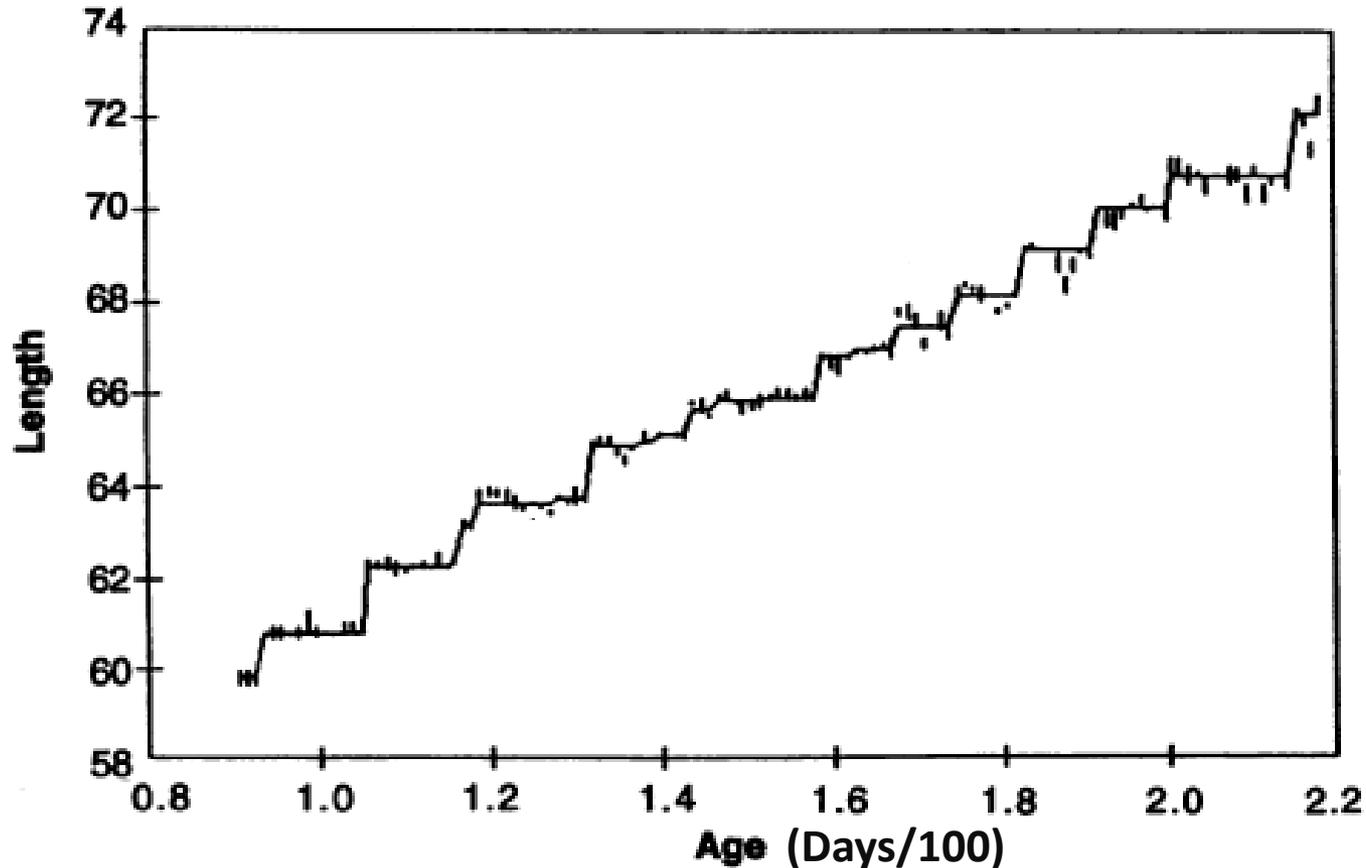
24-35 months



36-60 months



Child have linear growth on some days but not most days (Lampl et al., 1992, 2001)



- Infant measured daily during 3 to 7 months of age
- 13 saltations (12% of days), mean 0.9 cm per saltation

How could growth deficit and restoration theoretically occur?

Growth deficit	Growth restoration
Delayed saltation (i.e., extended stasis)	Rescheduled saltation
Canceled saltation	Replacement saltation
Reduced amplitude of saltation	Augmented amplitude of saltation

- Recovery of bone elongation rates is rapid
- Restoration to expected length is prolonged process, even if insult of very short duration

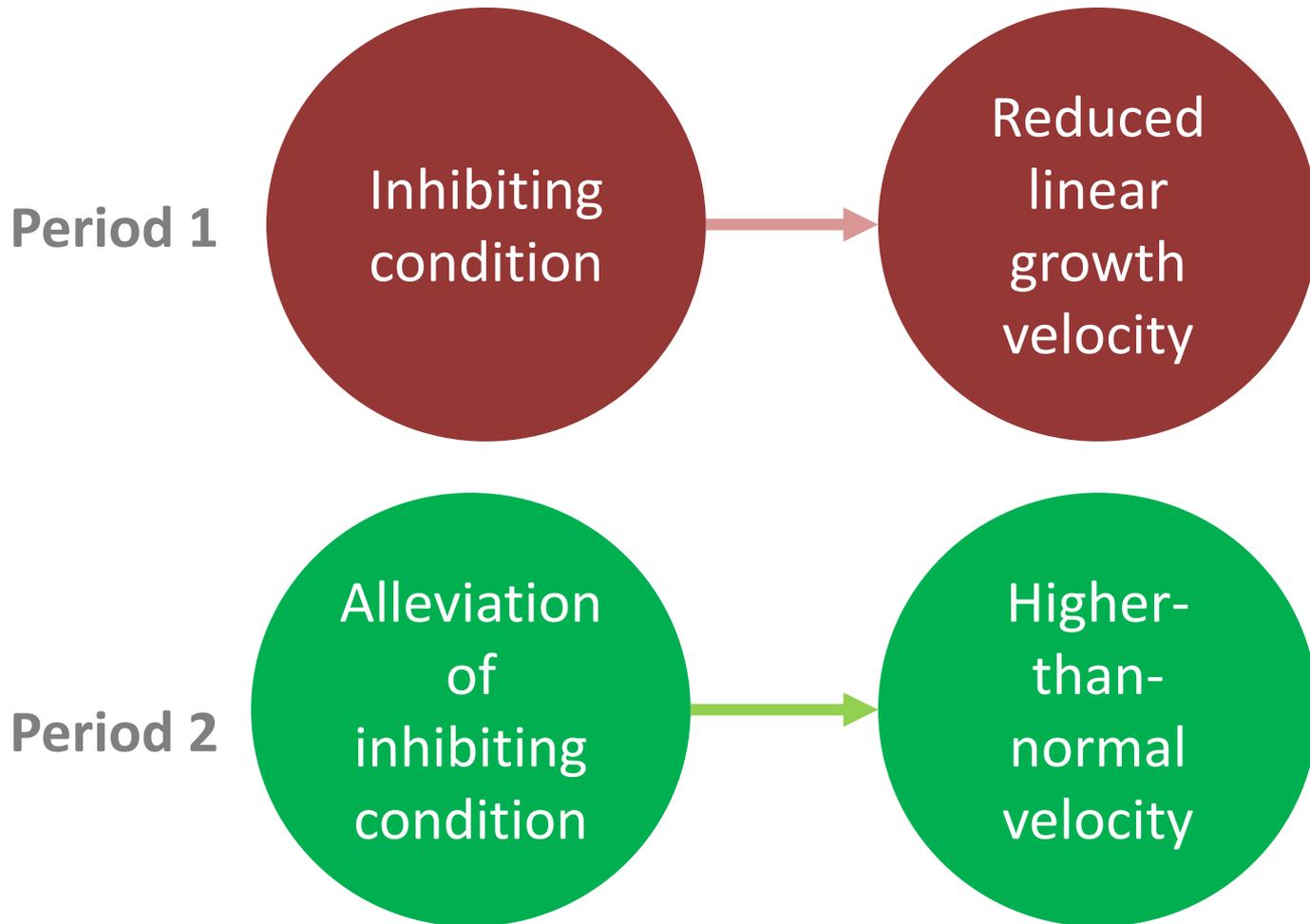
Farnum et al. (2003), rats

Idea of restorative growth

- **Homeorhesis:** “tendency of growing organisms to return to their paths of growth after deviating from them” (Prader et al., 1963)
- **Catch-up growth:** “Height velocity above the statistical limits of normality for age or maturity during a defined period of time, following a transient period of growth inhibition; the effect of catch-up growth is to take the child towards his/her pre-retardation growth curve.”
(Boersma & Wit, 1997; de Wit et al., 2013)

Full restoration of lost growth not required by this definition and unlikely to occur if prolonged inhibition

Demonstrating catch-up growth requires meeting four criteria

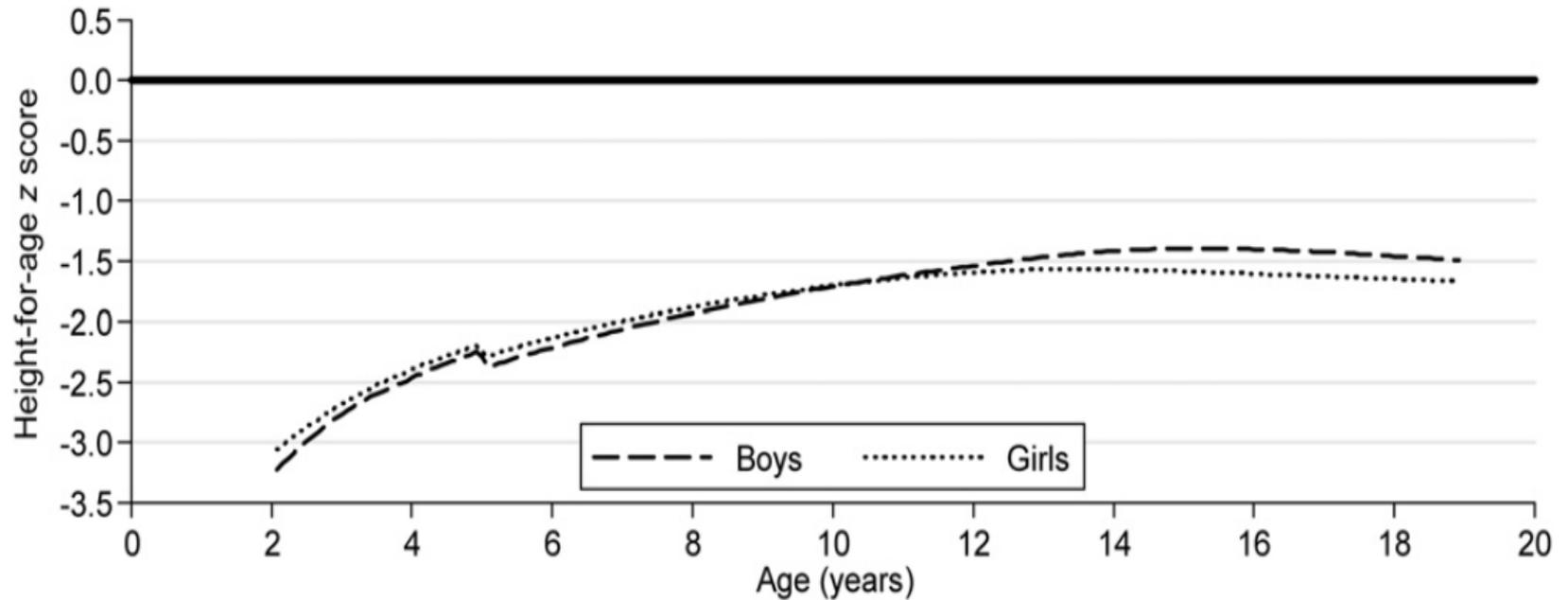


Questions:

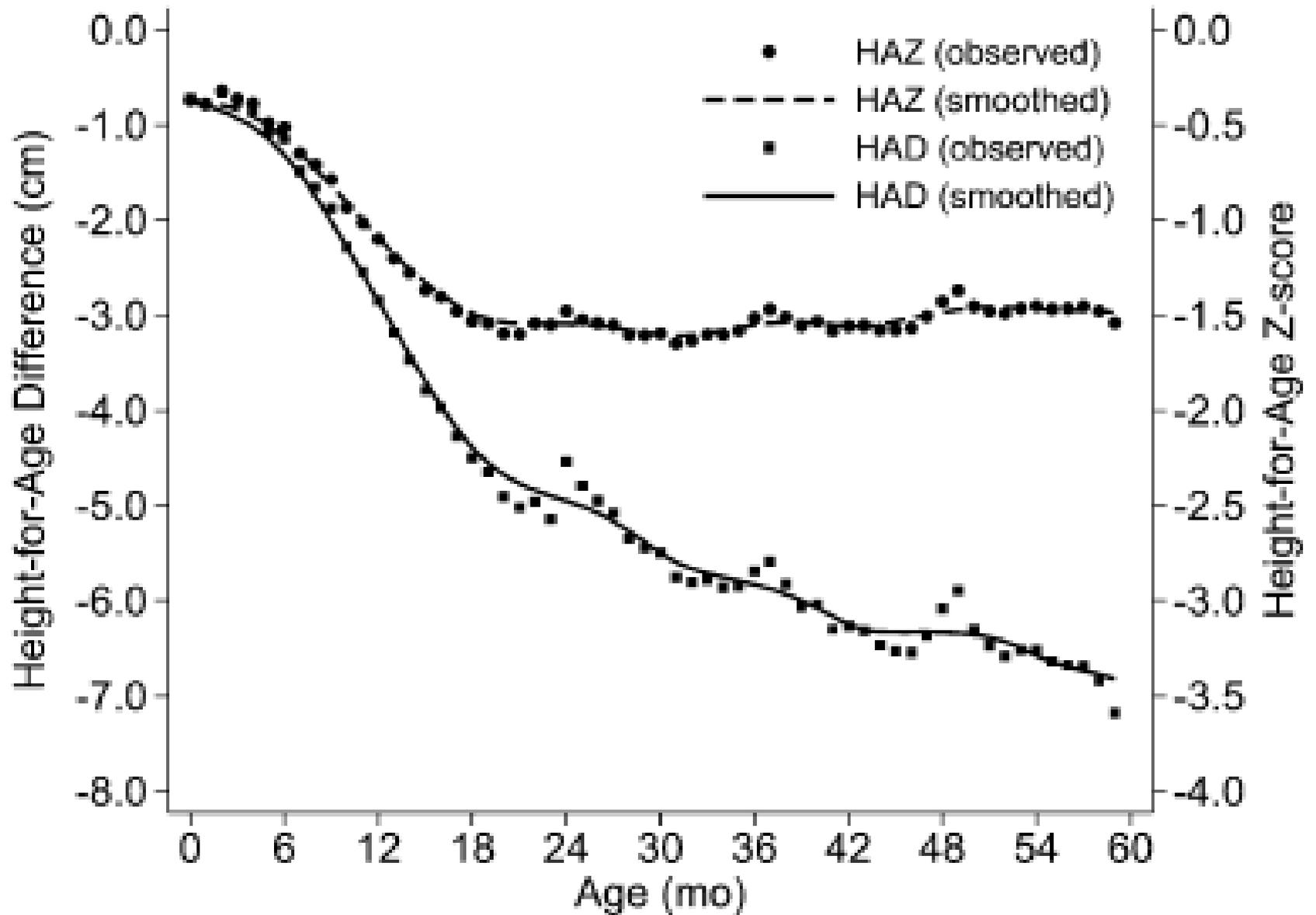
- What is higher-than-normal velocity?
- Velocity of what?

Fixed HAD, increasing HAZ

Holding HAD constant at -10cm...



Leroy et al, AJCN 2013 (98:854–8)



Bangladesh children over time (MINIMat, n=2,446)

	Stunting at 54 months (%)	
Stunting at 24 months	No	Yes
No	96	4
Yes	41	59

	24 months	54 months
Stunting	50%	31%
HAZ	-1.99	-1.56
HAD (cm)	-5.94	-6.65

WHO Standards:
SD at 54 mo
1.42 times
SD 24 mo

Is catch-up in linear growth possible?

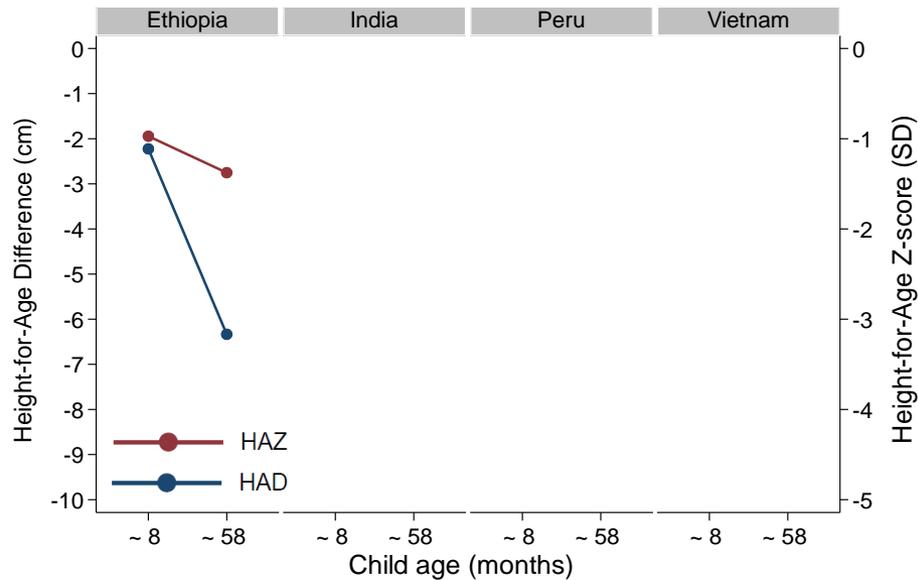
- Focus on **groups of children < 5 years** of age
- **Reason?**

Availability of a valid counterfactual

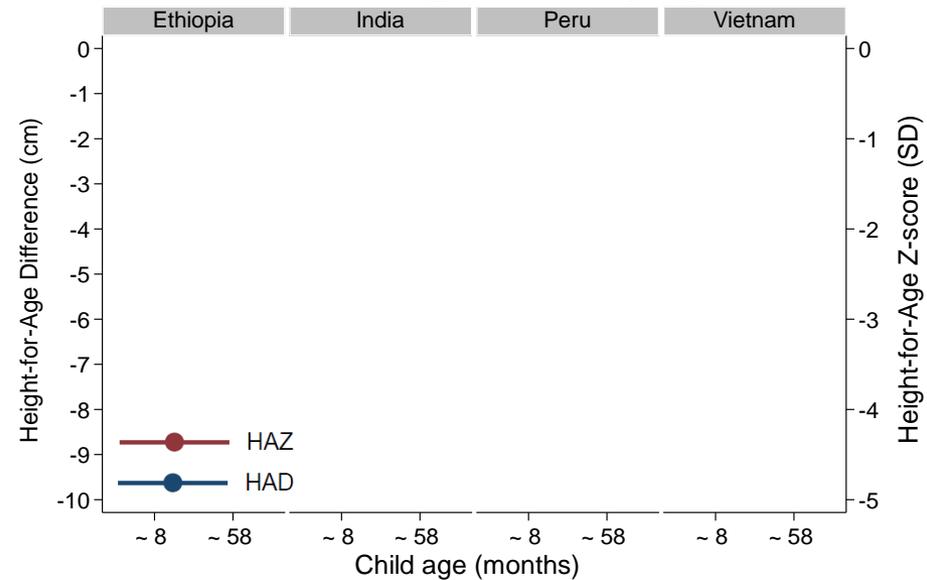
- Children > 5 years: no growth standard
- Individual child: impossible to know how child would have grown (in the absence of the inhibiting condition)

Evidence: studies **without** an intervention

Young Lives:
All children



Young Lives:
Children showing “catch-up” growth



Leroy et al., BMC Pediatrics 2015 (15:145)

Evidence: studies **without** an intervention

Catch-up in the absence of any intervention?

- Violates one of the criteria for catch-up growth, i.e. , *“Alleviation of inhibiting condition”*
- When using the appropriate metric (HAD): no evidence of catch-up in linear growth

Summary

1. Children grow through complex, integrated biological mechanisms that unfold daily
2. Length growth is a marker of nutrition useful for only some purposes, but is not nutrition
3. Nutrition interventions may reach and impact children, but may not discernably impact length growth deficits in short period
4. Interventions intended to have impact on one domain may have impact (positive or negative) on others
5. Partial restoration of lost growth is sometimes possible when constraints are removed, but not clear if this is important (and often poorly researched)
6. Child nutrition and growth are part of early childhood development

Implications

- To assess intervention impact on children, use broad set of measures and indicators of outcomes and immediate and underlying determinants
 - Nutrition, development, health
 - Breastfeeding, complementary feeding, and food
 - Caregiving
 - Hygiene and home health
- Develop, refine, and validate measures and indicators for intended purpose, for example
 - Validate child-development measures in LMIC
 - Develop innovative markers of child development
 - Develop measures of behavior that avoid or are resistant to recall and social desirability bias
- Use appropriate metric and design, based on the four criteria, to assess catch-up growth