

NCCOR WORKSHOP

Revisiting Rapid Infant Growth: Assessing Growth in Children Under Age 2

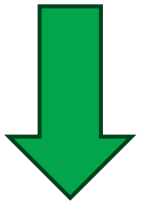
Understanding Growth Standards vs. References: Their Development, Purpose, and Appropriate Uses

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Growth, Growth Charts, and Growth Status

- Growth = process of increasing cell size and number
- Attained growth = measurement of size (e.g., how tall is this child?)
- Growth status = size relative to one's peers of similar age and sex (e.g., is this child shorter or taller than average compared to others of the same sex and age?)



Growth charts needed for assessment of growth status

Growth Charts

- Growth charts describe a statistical distribution of measurements.
- Cut-points to define “normal” growth are based on statistically defined thresholds, such as the 5th percentile or two standard deviations below the mean, and not necessarily on biological properties.
- Growth status is the assigned percentile rank or Z-score (SD score) relative to age and sex for a child’s attained size based on the statistical distribution of measurements.

Adequacy of Growth Charts

- Sample size sufficient to describe variability at all ages (definition of age categories)
- Sampling strategy to avoid bias (inclusion/exclusion criteria)
- Sufficient inclusion of subgroups (age, sex, population ancestry, geography) so that charts are representative of the population
- Accuracy and precision of measurements (including age determination)
- Statistical and graphic representation used to create growth charts (Cole 2012)

Types of Growth Charts

- Descriptive / reference charts
  - Describe growth in a population with minimal or no inclusion/exclusion criteria
  - Provide a frame of reference, but not necessarily “optimal’ growth
  - A restricted percentile range used in screening for growth concerns, e.g., 5th to 95th percentile
- Prescriptive charts / growth standards
  - Inclusion or exclusion criteria are applied to select children expected to have “optimal” health and thereby define how children “should” grow.
  - Use a broader range used for screening growth concerns, e.g., ±2 SD

History of U.S. Growth Charts for Infants and Young Children

- 1977 NCHS Growth Charts (NCHS/WHO 1977)
  - Weight-for-age, length-for-age, weight-for-length
- CDC 2000 Growth Charts
  - Weight-for-age, length-for-age, weight-for-length
- WHO Multicenter Growth Study (2006)
  - Weight-for-age, length-for-age, weight-for-length
  - BMI-for-age
  - Weight and length velocity

History of U.S. Growth Charts for Infants and Young Children

- 1977 NCHS Growth Charts (NCHS/WHO 1977)
  - Weight-for-age, length-for-age, weight-for-length
  - Based on data from the Fels Longitudinal Study
  - Lacked geographic and racial diversity
  - Almost all formula-fed

CDC 2000 Growth Charts – Birth to 24 months

Primary data sources	Measure	Supplemental data sources	Exclusions
• NHANES I (1971-84) 12-23 m • NHANES II (1976-80) 6-23 m • NHANES III (1988-94) 2-23 m	Weight	• National birth certificate data from U.S. Vital Statistics	Excl. BWT<1,500gm
	Length	• Birth certificate data from Wisconsin and Missouri state vital statistics • CDC Pediatric Nutrition Surveillance System (1975-1995) selected data for 0.5 to 4.5 months	Excl. BWT<1,500gm Excl. NHANES III for ages<3 m
	Weight for Length	• Birth certificate data from Wisconsin and Missouri state vital statistics	Excl. BWT<1,500gm

From Vital and Health Statistics, series 11, number 246

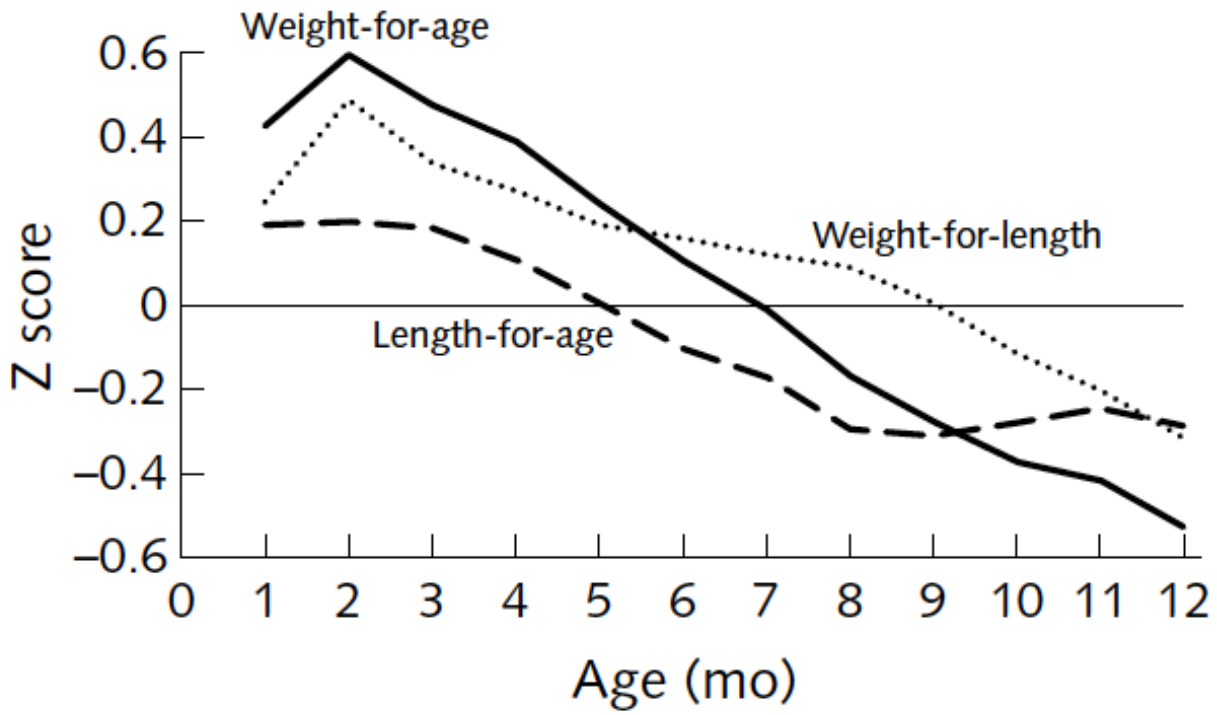
CDC 2000 Growth Charts – Statistical Methods

- Curves from birth to 3 months were modeled.
- Data from all sources were pooled, survey-specific sample weights were applied.
- Data were grouped in 1-month (or 1-cm) intervals, and selected empirical percentiles were smoothed using parametric and nonparametric regression procedures.
- Modified LMS estimation procedure was applied to the smoothed curves.
- The LMS method transforms the measurements at each age to a normal distribution using a Box-Cox power transformation (lambda), the coefficient of variation (sigma), and the median (mu) to summarize the distribution.

CDC 2000 Growth Charts – Birth to 24 months

- Includes data for formula-fed and breast-fed infants, proportional to the distribution of breast- and formula-fed infants in the population (~50% received some breast milk and ~1/3 were breast-fed for ≥ 3 months)
- Generally, breast-fed infants gain weight more rapidly in the first 2 to 3 months and gain weight more slowly from 6 to 12 months compared to formula-fed infants.

Growth of Breastfed Infants Compared to NCHS/WHO Reference



From: Garza C, de Onis M. Rationale for Developing a New International Growth Reference. *Food and Nutrition Bulletin*. 2004;25(1_suppl_1):S5-S13. doi:10.1177/15648265040251S102

Rationale for WHO Multicentre Growth Reference Study WHO Working Group on Infant Growth (1990)

- Growth charts to describe how children **should** grow (prescriptive)
- Based on an international sample—early childhood growth among healthy, well-nourished infants is similar across diverse groups
- Employ modern analytic techniques to generate curves
- Link anthropometric assessment to functional outcomes

Comparison of CDC 2000 and WHO Growth Charts

Characteristic	CDC growth reference (2000)	WHO growth standard (2006)
Data sources	U.S. Vital Statistics (birth weights) Missouri and Wisconsin vital statistics (birth lengths) Pediatric Nutrition Surveillance System (lengths, 0.1 to <5 mos) NHANES I (1971–1974) (12–23 mos) NHANES II (1976–1980) (6–23 mos) NHANES III (1988–1994) (2–23 mos)	Locations: Pelotas, Brazil Accra, Ghana Delhi, India Oslo, Norway Muscat, Oman Davis, California
Type and frequency of data collection	Cross-sectional data starting at age 2 mos, with mathematical models used to connect birth weights and lengths to survey data	Longitudinal data with measurements of weight and length at birth; 1, 2, 4, 6, and 8 wks; and 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 16, 18, 20, 22, and 24 mos
Sample size	N = 4,697	18,973 observations for 882 distinct children

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Grummer-Strawn et al. Centers for Disease Control and Prevention (CDC). Use of World Health Organization and CDC growth charts for children aged 0-59 months in the United States. MMWR Recomm Rep. 2010 Sep 10;59(RR-9):1-15. PMID: 20829749.

Comparison of CDC 2000 and WHO Growth Charts

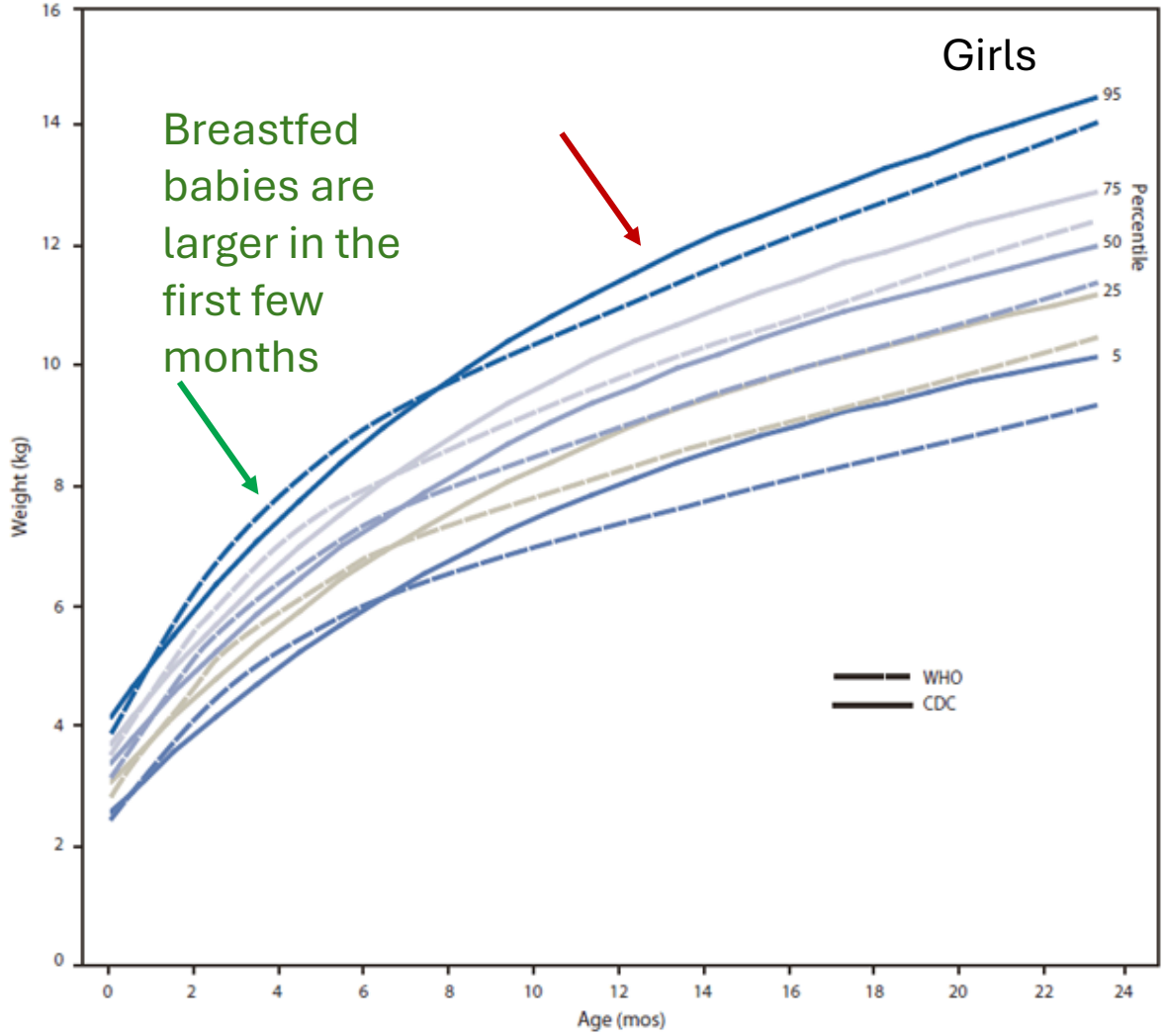
Characteristic	CDC growth reference (2000)	WHO growth standard (2006)
Exclusion criteria	Very low birth weight (<1,500 g [<3 lbs, 4 oz])	Low socioeconomic status Birth at altitude >1,500 m Birth at <37 wks or ≥42 wks Multiple birth Perinatal morbidities Child health conditions known to affect growth Maternal smoking during pregnancy or lactation Breastfeeding for <12 mos Intro of complementary foods <4 mos or >6 mos
Breastfeeding among infants in sample	Approximately 50% ever breastfed Approximately 33% breastfeeding at 3 mos	100% ever breastfed 100% predominantly breastfeeding at 4 mos 100% still breastfeeding at 12 mos

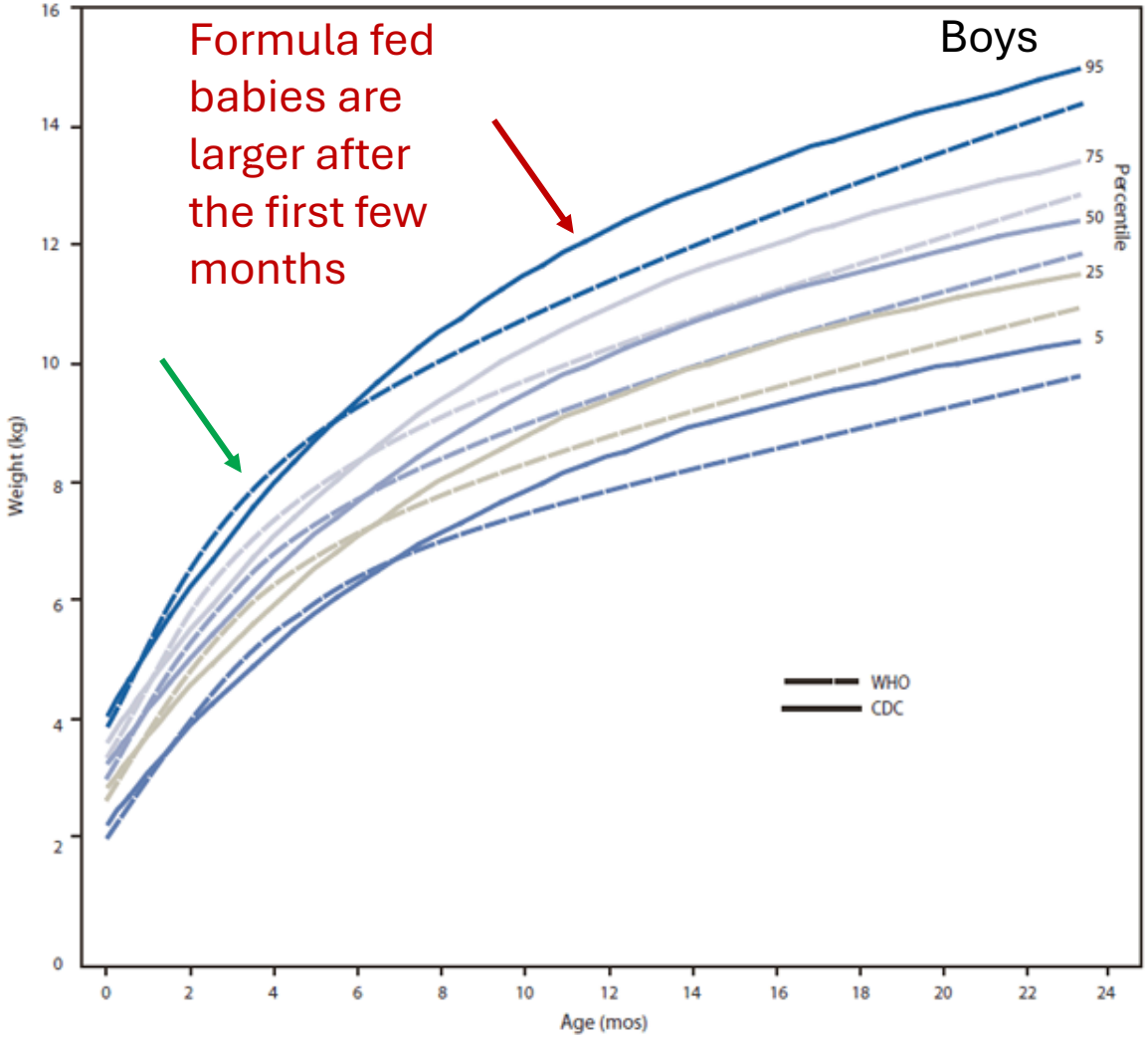
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WHO Growth Charts – Statistical Methods

- Data inspection – excluded observations outside ± 3 SD from the median
- Different data distributions and curve smoothing techniques were tested.
  - The Box-Cox Power Exponential distribution was selected (similar to LMS, but with an additional parameter, tau, for kurtosis).
  - Cubic spline smoothing technique was selected.
  - Generalized Additive Models for Location, Scale and Shape (GAMLSS) software was used.

Comparison of CDC and WHO Weight Charts





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Grummer-Strawn et al. Centers for Disease Control and Prevention (CDC). Use of World Health Organization and CDC growth charts for children aged 0-59 months in the United States. MMWR Recomm Rep. 2010 Sep 10;59(RR-9):1-15. PMID: 20829749.

Growth Increments/Velocity

- Increment: $Growth_{age2} - Growth_{age1}$
- Velocity: $Increment/(Age_2 - Age_1)$
- Tables for weight, length and head circumference for 1 (wt only), 2, 3, 4, 6-month increments
- Identify growth faltering before growth failure occurs
- Highly sensitive to measurement error

2-month weight increments (g) GIRLS
Birth to 24 months (percentiles)

World Health Organization

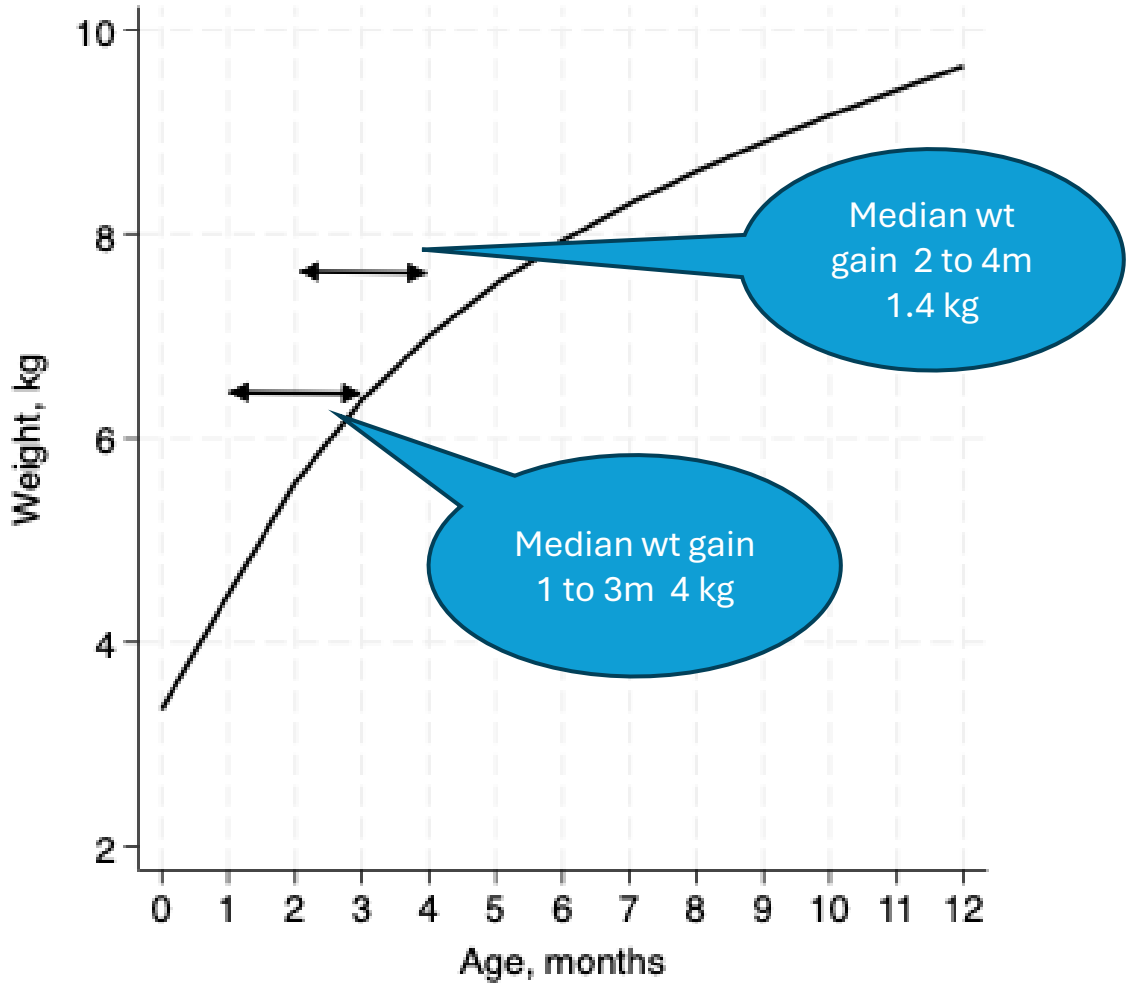
Interval	1st	3rd	5th	15th	25th	50th	75th	85th	95th	97th	99th
0-2 mo	968	1128	1216	1455	1604	1897	2210	2386	2696	2820	3062
1-3 mo	890	1030	1107	1317	1450	1714	2000	2163	2452	2569	2799
2-4 mo	625	740	804	978	1088	1307	1545	1681	1922	2020	2213
3-5 mo	451	556	615	773	874	1074	1290	1413	1632	1720	1894
4-6 mo	295	395	450	600	695	883	1085	1200	1403	1486	1646
5-7 mo	170	267	321	468	560	742	938	1048	1243	1321	1473
6-8 mo	76	175	229	377	469	651	846	955	1147	1223	1372
7-9 mo	3	103	157	306	399	581	775	883	1072	1147	1293
8-10 mo	-59	40	95	243	336	517	708	814	999	1073	1215
9-11 mo	-104	-3	53	203	297	478	670	776	960	1033	1174
10-12 mo	-135	-31	26	179	274	458	652	759	944	1018	1159
11-13 mo	-163	-57	1	157	254	441	637	745	932	1005	1147
12-14 mo	-185	-78	-19	140	238	428	626	736	924	999	1142
13-15 mo	-204	-95	-35	127	227	420	621	732	924	999	1144
14-16 mo	-219	-108	-47	118	220	416	622	735	930	1007	1154
15-17 mo	-231	-118	-55	112	216	418	627	743	943	1021	1172
16-18 mo	-243	-128	-64	106	212	417	631	750	954	1035	1189
17-19 mo	-255	-139	-75	97	205	413	631	751	959	1041	1199
18-20 mo	-267	-151	-86	88	196	407	628	751	962	1046	1206
19-21 mo	-279	-162	-97	79	188	402	626	750	965	1050	1213
20-22 mo	-291	-174	-109	67	178	393	620	745	963	1049	1214
21-23 mo	-305	-189	-124	53	164	381	608	735	954	1040	1207
22-24 mo	-318	-202	-137	39	150	367	596	723	942	1029	1197

WHO Growth Velocity Standards

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Importance of Interval When Assessing Growth Increments

- Rate of weight gain changes rapidly in the first 12 months.
- WHO tables provide increments over specific time intervals.
- For appropriate use, intervals must correspond.

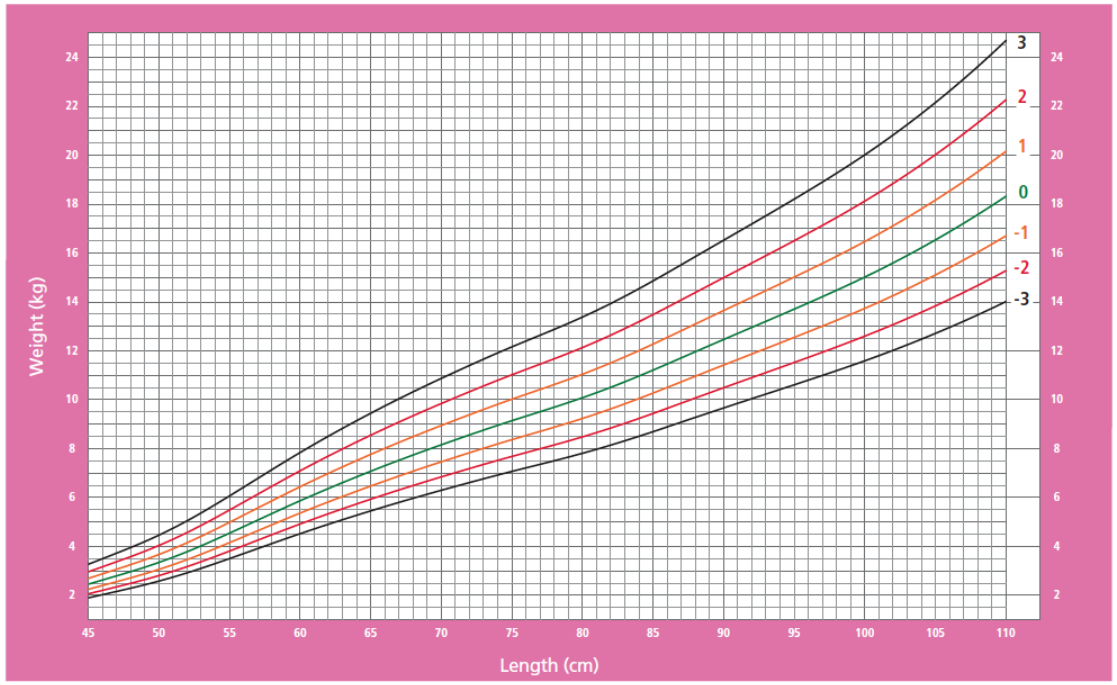


WHO: Weight-for-Length and BMI-for-Age Charts

Weight-for-length GIRLS

Birth to 2 years (z-scores)

World Health Organization

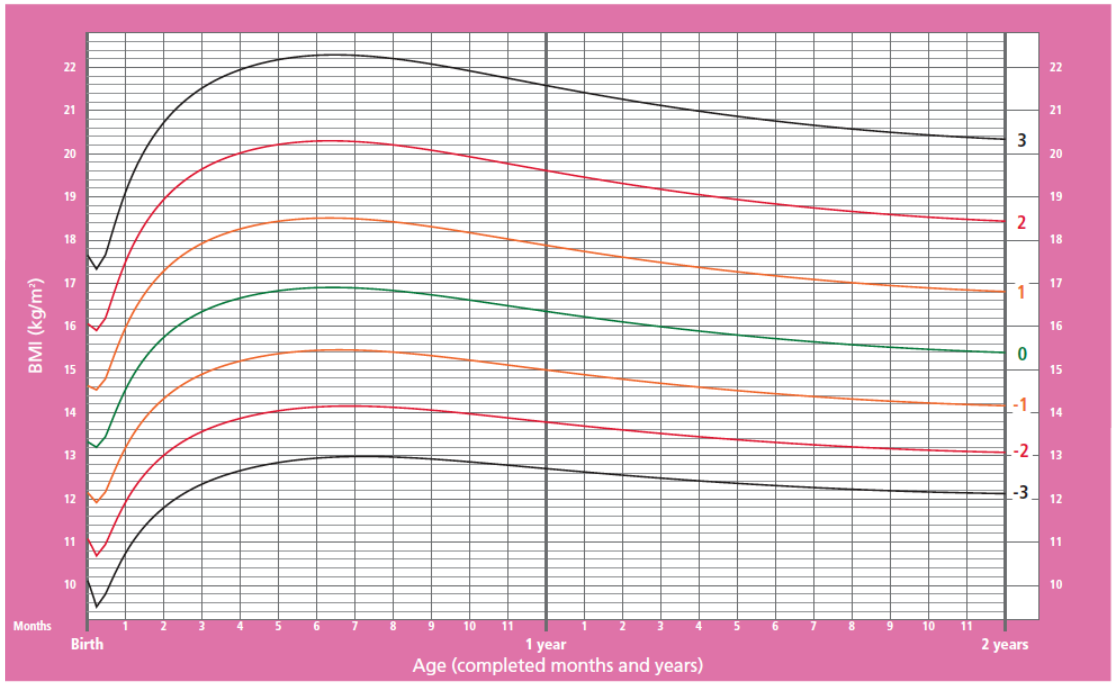


WHO Child Growth Standards

BMI-for-age GIRLS

Birth to 2 years (z-scores)

World Health Organization

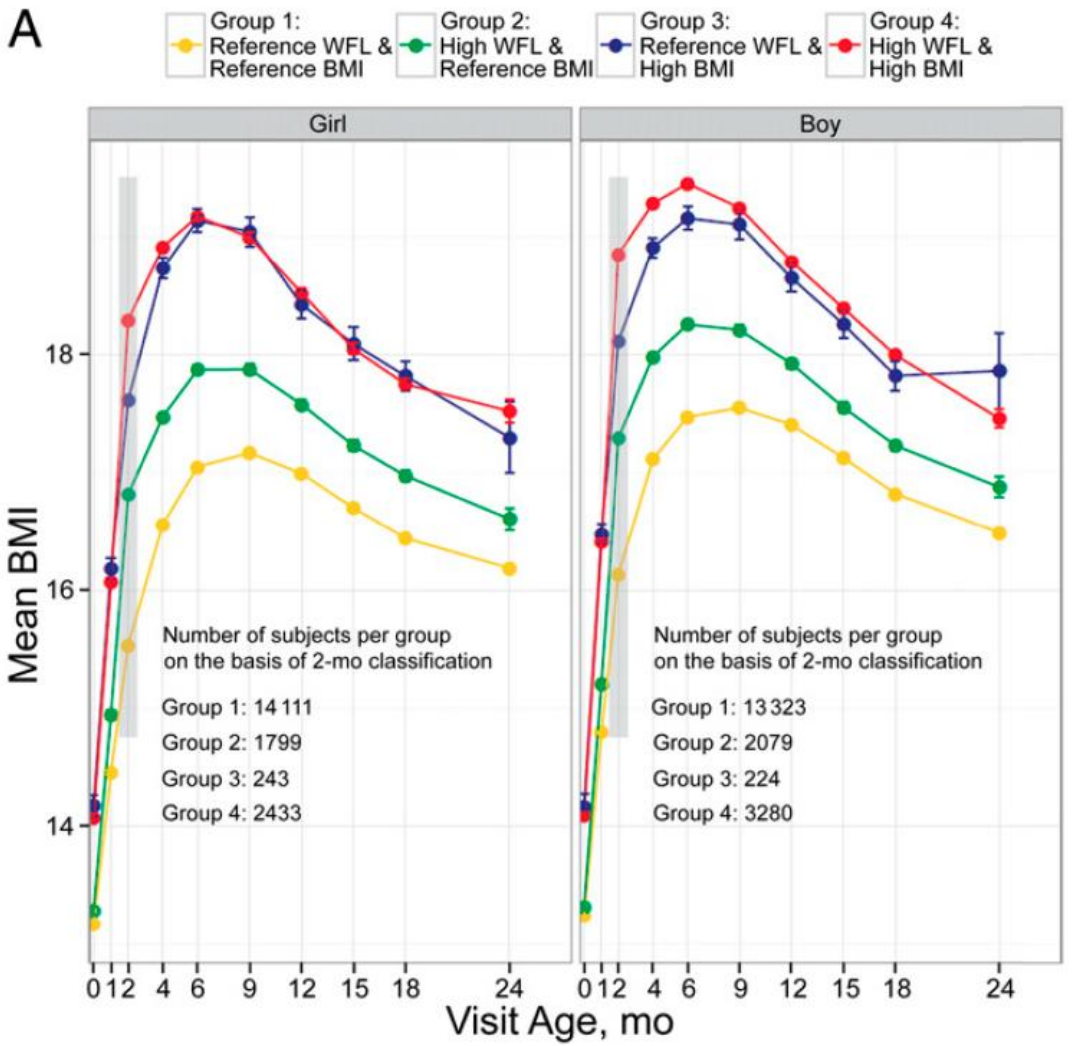


WHO Child Growth Standards

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Comparison of Weight-for-Length vs BMI

- Roy et al. *Pediatrics* (2016)
- Longitudinal electronic medical record data for 73,949 full-term infants
- Weight-for-length (WFL) and BMI at 2 months categorized as “reference” (5th to 85th %tile) or “high” (>85th %tile)
- High BMI at 2 months [RED/BLUE lines] was a better predictor of BMI status at 24 months than WFL [GREEN/YELLOW lines].

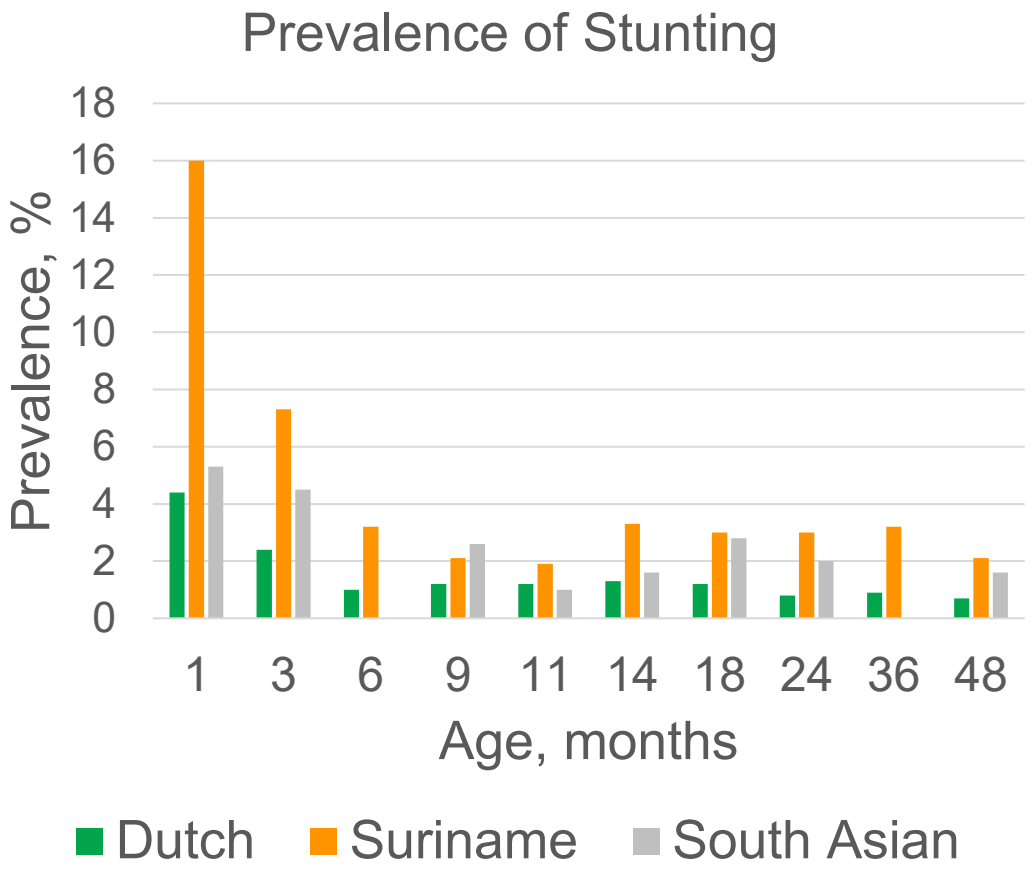


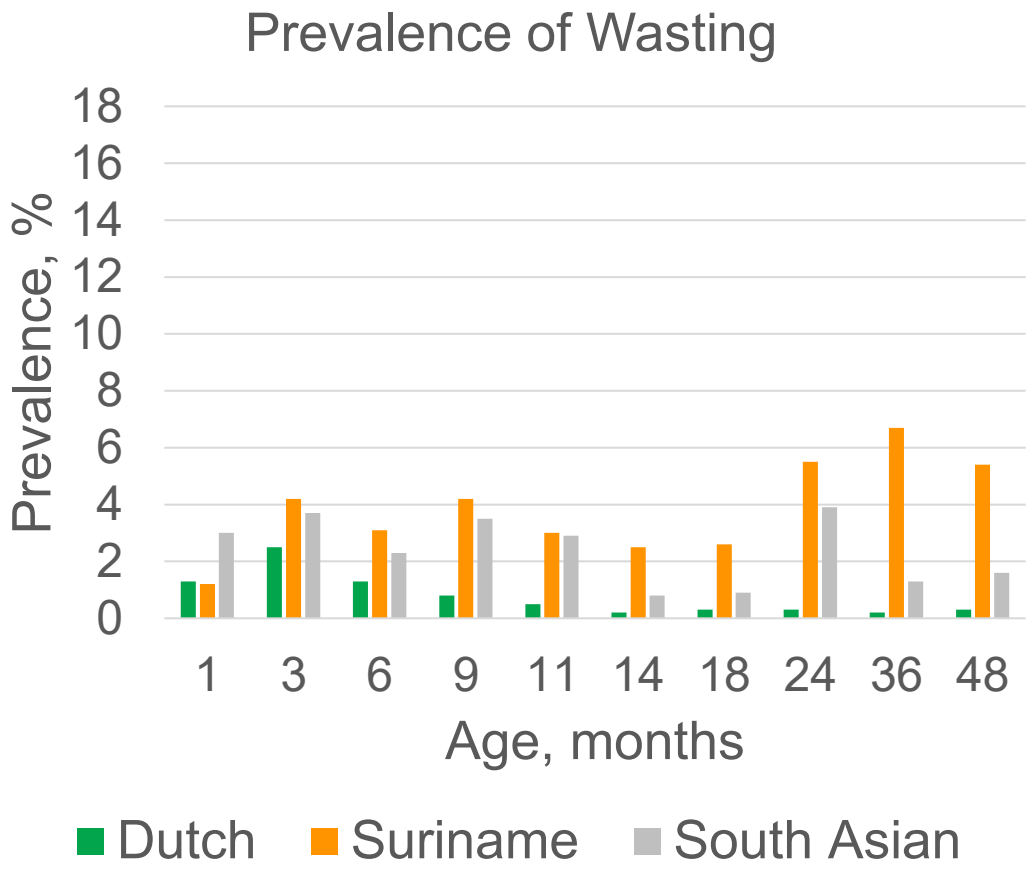
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Use of WHO Growth Standard

- Since adoption of WHO growth standard, some studies report overdiagnosis or underdiagnosis of growth faltering
- Example: Cross-sectional study (n= 11,935) of children in the Netherlands, collected 2012–2015, children 0–5 years of Surinamese Asian Indian, South Asian (Pakistan/India), and Dutch descent
- Wilde et al. *Public Health Nutrition*: 23(12), 2078–2087 2020

Case study – de Wilde et al. 2020
Prevalence of growth faltering – WHO Charts





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Wilde et al. *Public Health Nutrition*: 23(12), 2078–2087 2020

Summary

- Interpretation of growth measurements requires growth charts to establish growth status.
- Characteristics of growth chart development affect assignment of growth status.
  - Growth standard (prescriptive) vs. growth reference (descriptive)
  - Feeding mode affects early growth patterns.
  - Use of growth velocity standards is very sensitive to accuracy and timing of the measurements used to estimate growth increments.
  - Use of WFL vs BMI in early infancy may overdiagnose infants at risk for high BMI by age 24 months.