Growth charts and Z-scores

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Children grow –
If they don’t, there is a problem

Standardized tables or charts are used to assess weight, length or height, skull circumference, and growth velocity.
Factors affecting the individual’s growth

- Abnormal intrauterine environment
- Genetic endowment
- Abnormal genes
- Timing of puberty
- Nutrition
- Emotional health
- Endocrine disorder
- Chronic disease
Main influence on growth

• Infancy: (up to 2 years)
  Food/ nutrition
  Chronic disease

• Childhood
  Genes
  Growth Hormones
  Chronic disease

• Puberty
  Sex hormones
Is this boy really 6 years old?

Measurement is the only way to recognize whether growth is normal or not.
Length vs height
Measurement of stature

Feet flat together against the wall

Buttocks, Back against the wall

Stand straight!

Horizontal mark opposite top of head

Measure against the wall
Measurement of growth

- Length or height measurement
- Example of a little boy’s data:

<table>
<thead>
<tr>
<th>eg</th>
<th>Age</th>
<th>Ht</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.5 yrs</td>
<td>92 cm</td>
</tr>
<tr>
<td></td>
<td>3.0 yrs</td>
<td>95 cm</td>
</tr>
<tr>
<td></td>
<td>3.5 yrs</td>
<td>97 cm</td>
</tr>
<tr>
<td></td>
<td>4.0 yrs</td>
<td>99 cm</td>
</tr>
<tr>
<td></td>
<td>5.0 yrs</td>
<td>101 cm</td>
</tr>
</tbody>
</table>
Previous slide’s data plotted on the graph.

Growth charting identifies the divergence from the normal.

Growth chart is the only way to recognize whether growth is normal or not.
The most important feature of growth charts

- A measure to compare and monitor the physical status of an individual child with the childhood population on an ongoing basis.

- **Different types of growth charts**
  - Road-to-Health Chart: mainly a weight for age chart
  - Longitudinal growth charts
    - Percentile graphs
    - Z score graphs
  - BMI charts
  - Weight for length/height charts
  - Velocity charts

- Prenatal or combined pre- and postnatal growth charts
- Special populations: Down syndrome, Turner syndrome
There is a normal range
WHO Anthro for Personal Computers Manual

Software for assessing growth and development of the world's children

World Health Organization

www.who.int/growth
Percentile or Z-score graphs

- **Of 100 healthy children at a given age:**
  - 3 per cent have height measurements less than the 3rd percentile
  - 97 of 100 children have measurements below the 97th percentile
  - 50 per cent above or under the 50th percentile
  - 50th percentile measurements correspond to the mean and median

- **Z-scores or SD scores** are used to describe mathematically how far a measurement is from the median (average).

- The mean (median) is the same in both types of graph
Range of normal

50\textsuperscript{th} percentile corresponds to a Z score of 0
3 \textsuperscript{rd} percentile corresponds to Z score of $-1.72$
97\textsuperscript{th} percentile corresponds to a Z score of $+1.72$
How to calculate Z scores
(Standard Deviation Score)

\[ z\text{-score} = \frac{(\text{observed value}) - (\text{median reference value})}{\text{z-score of the reference population}} \]

Example:
Actual length 96.1 cm
Median 90.4 cm
Standard deviation 3.3
\[ Z\text{ score} = \frac{5.7}{3.3} \]
\[ = +1.73 \]
Comparison of growth charts

Percentile graphs have a narrower range, because the 97\textsuperscript{th} centile corresponds approximately to a Z score +2

A Z-score of +3 or -3 is more likely to be definitely abnormal
NCHS or WHO charts

• Growth charts are established on large populations of normal children living under near-optimal conditions and therefore representing the range of normal growth for children at different ages.

• NCHS : USA population, cross-sectional

• New growth standards have been developed by the World Health Organization (WHO) based on the growth of normal breast fed infants in various regions of the world. **International growth reference standard**
Growth of breastfed babies
Pooled data from affluent countries

- Growth patterns of BF babies similar in different populations
- Slower weight gain from age 3-12 months
- Deviation of growth occurs when babies are already on solids, ie not deficiency
- Less effect on length than weight
- At 2 years average weight close to reference

Comparison of breastfed growth with CDC growth curves

Figure 46 Comparison of WHO with CDC 2000 weight-for-age z-scores for boys

From: WHO 2006
Fig 5. Weight-for-length z scores (mean ± SEM) of breast-fed and formula-fed infants from birth to 18 months.

Dewey et al *Pediatrics* 1992; 89: 1035-1041
Final height of breastfed babies

• Slow growth in second 6 months of life despite additional solids
• Other factors than breastfeeding *per se* apparently responsible for associations
• Final height is no different from formula-fed babies
  
  Girls 165.3 vs 164.9 cm  
  Boys 175.3 vs 175.8 cm

*Zadik et al J Ped Gastroenterol Nutr 2003*
Example of data shift by wrong measurement:

8 years old. Weight 31kg Height 1.23 m: BMI = 20.5

If height is actually 1.26 m: BMI = 19.5

Remember influence of measurement on derived numbers
This Weight-for-height chart shows body weight relative to height in comparison to the median (0 line).

- A child whose weight-for-height is above the line 3 is obese.
- Above 2 is overweight.
- Above 1 shows possible risk of overweight.
- Below the line -2 is wasted.
- Below -3 is severely wasted. Refer for urgent specialized care.
After measurement, what next?

• Measurement does not improve growth
• Interpret the graph
• Action must follow:
  Any child with Z score < -3
  Any child crossing the lines
  Weight/height discrepancy
  Consider wasting
## Interpret the growth parameters

<table>
<thead>
<tr>
<th>Z-score</th>
<th>Length/height-for-age</th>
<th>Weight-for-age</th>
<th>Weight-for-length/height</th>
<th>BMI-for-age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 3</td>
<td>See note 1</td>
<td></td>
<td>Obese</td>
<td>Obese</td>
</tr>
<tr>
<td>Above 2</td>
<td></td>
<td>See note 2</td>
<td>Overweight</td>
<td>Overweight</td>
</tr>
<tr>
<td>Above 1</td>
<td></td>
<td></td>
<td>Possible risk of overweight (See note 3)</td>
<td>Possible risk of overweight (See note 3)</td>
</tr>
<tr>
<td>0 (median)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below −1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below −2</td>
<td>Stunted (See note 4)</td>
<td>Underweight</td>
<td>Wasted</td>
<td>Wasted</td>
</tr>
<tr>
<td>Below −3</td>
<td>Severely stunted (See note 4)</td>
<td>Severely underweight (See note 5)</td>
<td>Severely wasted</td>
<td>Severely wasted</td>
</tr>
</tbody>
</table>

*Note 1, 2, 3, 4, 5: Please refer to the specific notes for detailed descriptions.*
Length-for-age percentiles: Girls, birth to 36 months

- **Chronological age**
- **Height age**
- **Velocity slow**
- **Velocity normal**
- **Patient’s measured length**

**Notes:**
- This graph compares chronological age with height age, allowing for an assessment of growth velocity and percentile ranking.
- The red line indicates **Velocity slow**, while the blue line signifies **Velocity normal**.
- The black line marks the **Patient’s measured length** at a specific age.
Abnormal potential

Growth velocity normal

Abnormal Outcome

Growth velocity abnormal

Chronic disease
Malnutrition
Endocrine disease

Normal potential