Pediatric Malnutrition:
Under- and Over-weight in Children

Daniel Jackson, MD
University of Utah School of Medicine
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Undernutrition: Global and Local

Famine
- Political Instability
- Distribution of Resources
- Social Chaos
- Survival/Recovery
Nutrient Deficiency

Maternal-Child Dyad

- Maternal Nutrition/Health
- Intrauterine Onset
- Nursing insufficiency
- Weaning/transition
Malabsorption

- Environmental Factors
- Infection: parasitosis
- Malabsorption $\rightarrow$ reduced intake
- Inflammation $\rightarrow$ increased energy needs
Kwashiorkor

- Displaced from nursing
- Low protein alternatives
- Endemic Infection
- GI protein loss
- Hypoalbuminemia → Edema
Marasmus

Protein-Calorie Undernutrition
Fat and Muscle depletion
Preserved plasma proteins
Preserved homeostasis
Failure to Thrive: Our world

Genetics
Prenatal environment
Behavioral factors
Psychosocial context
Disease factors
To Thrive

- Homeostasis
- Full physiologic function
- Weight gain
- Linear growth
- Cranial growth
- Neurodevelopment
- Social integration
Navigating The Growth Curve

- Expectations
- Deviations
- Recovery
- Faltering
- Acute wasting
- Chronic stunting
- Cranial stasis
CDC Growth Curves: 0-36 months

Weight-for-age percentiles: Boys, birth to 36 months

Length-for-age percentiles: Boys, birth to 36 months

Head circumference-for-age percentiles: Boys, birth to 36 months
Body Mass Index: $\text{kg/m}^2$
Body Mass Index [BMI]: 2 years to 20 years
BMI = weight (kg) / height² (m²)

Extremely Obese: BMI ≥99th %ile
Obese: BMI 95th to <99th %ile
Overweight: BMI 85th to <95th %ile

Centers for Disease Control and Prevention
Determination of % weight for height age:

Actual Wt: 7 kg
Expected Wt: 8.4 kg

\[
\frac{7}{8.4} = 0.83 \text{ or } 83\%
\]
Hazards Around the Curve

- Inadequate nutrient intake
- Maldigestion
- Malabsorption
- Gut/Renal losses
- Metabolic demands
- Cardiopulmonary disease
- Endocrinopathy
- Neuropathology
- Psychosociopathology
Genetic/Congenital

- Dysmorphic/chromosomal syndromes
  - Down’s, Turner’s, Noonan’s, Prader-Willi
- Mutations
- Parental/sibling growth pattern
- Constitutional delay
- Familial short stature
- Intrauterine growth retardation
Patterns of Failure to Thrive

- Nutritional
  - Weight < Length < Head

- Endocrine
  - Length < Weight < Head

- Neurologic
  - Head < Weight < Length
Nutritional Pattern: DDx

- **Inadequate Net Intake**
  - Deprivation
  - Aversion, Dysphagia
  - Vomiting/Reflux

- **Maldigestion/Malabsorption**
  - Pancreatic Insufficiency: Cystic Fibrosis, Shwachman
  - Mucosal disease: Giardia/Cryptosporidia; viral enteritis; Celiac disease

- **Increased Metabolic Requirements**
  - Inflammation
  - Cardiopulmonary disease
Endocrine Pattern

Weight-for-age percentiles: Boys, birth to 36 months

Length-for-age percentiles: Boys, birth to 36 months

Head circumference-for-age percentiles: Boys, birth to 36 months
Short Stature: Patterns

Weight-for-age percentiles: Boys, 2 to 20 years

Stature-for-age percentiles: Boys, 2 to 20 years

Constitutional vs. Familial

GH deficiency
Endocrine Pattern: DDx

- **Hypothyroidism**
  - Low Thyroxine (Free T4), High TSH

- **Growth Hormone deficiency**
  - Low Insulin like growth factor (IGF-1)
    - Unreliable in undernutrition states
  - Low IGF Binding Protein 3 (IGFBP3)

- **Hypopituitarism**
  - Low cortisol, TSH, glucose, gonadotropins
Neurogenic Pattern

Weight-for-age percentiles: Boys, birth to 36 months

Length-for-age percentiles: Boys, birth to 36 months

Head circumference-for-age percentiles: Boys, birth to 36 months

- macrocephalic
- microcephalic
Neurogenic Pattern: DDx

- **Microcephalic**
  - Infarction
  - CMV viral infection
  - Embryogenic defect:
    - neuronal migration
  - Rett syndrome

- **Macrocephalic**
  - Hydrocephalus
  - Tumor
    - Brainstem: Diencephalic syndrome
  - Metabolic storage disease
  - Autism
Rett Syndrome

Autism

A

B
Fig 1. MRI images after gadolinium contrast injection: patchy contrast enhanced lesions in the insula and hippocampus in the right and in the hypothalamic-diencephalic region.
Diencephalic Syndrome

Fig 1. MRI images after gadolinium contrast injection: patchy contrast enhanced lesions in the insula and hippocampus in the right and in the hypothalamic-diencephalic region.
FTT: Definition

- **Static Criteria:**
  - Weight for Height < 5th %ile
  - Weight < 85% median weight for height
  - Triceps skinfold thickness < 5 mm or < 5th %ile

- **Dynamic Criteria:**
  - Subnormal growth velocity:
    - <20 g/d @ 0-3 months
    - <15 g/d @ 3-6 months
  - Drop of 2 major centiles
Diagnostic Approach

- Prenatal/Perinatal medical history
- History of medical/surgical illness
- Diet history
  - Weaning, Food introduction
  - Meal Structure: intervals, schedule
- Family History
- Physical Examination
- Strategic laboratories and Radiology
Diagnostic Evaluation

History:

- Maternal Health
- GA, BW, Perinatal, Infancy, Development, Medical and Surgical illness, interventions
- Link events to growth history: map on curve
- Feeding history
  - Nursing/weaning
  - Sequence of foods: introduction of solids
  - Frequency of feeding
  - Coercive feeding
  - Parental/infant feeding transactions/communication
- Psychosocial Problems
Diagnostic Evaluation

- **Physical Examination:**
  - Measurements
  - Hygiene
  - Dysmorphisms: craniofacial, skeletal, etc.
  - Epithelial integrity: skin, hair, nails, eyes, mucosa
    - Edema
    - Micronutrient deficiency
  - Body composition: fat and muscle stores
  - Cardiorespiratory status
  - Neurodevelopmental status
    - Dysphagia
  - Functional status: tone, responses, strength
  - Child-Parent and Child-Examiner interactions
Digital Clubbing
Digital Clubbing

Cystic Fibrosis
Celiac Sprue
Cyanotic Heart Disease
Cirrhosis
Crohn Disease
COPD
Candidiasis Mucocutaneous
Congenital
Acrodermatitis enteropathica

Zinc deficiency
Fetal Alcohol

- Small head
- Low nasal bridge
- Epicanthal folds
- Small eye openings
- Flat midface
- Short nose
- Smooth philtrum
- Thin upper lip
- Underdeveloped jaw
SUNKEN NASAL BRIDGE

PUFFINESS AROUND THE EYES

I CAN STILL SEE THE EPICANTHAL FOLD (EYE LID)

BLUE EYES WITH A STARRY PATTERN

LONG UPPER LIP LENGTH (PHILTRUM)

SMALL AND WIDELY SPACED TEETH

WIDE MOUTH (EAR TO EAR SMILE)

PROMINENT LOWER LIP

SMALL CHIN
Williams
Acute vs Chronic

- **Acute Undernutrition**—“wasting”:
  - Low weight for height or low BMI
  - “wasting” of fat and muscle mass
  - Prelude to stunting
  - Constitutional leanness

- **Chronic Undernutrition**—“stunting”:
  - Low height for age
  - Normalized weight for height and BMI
    - Consider constitutional growth delay
    - Consider Endocrinopathy: hypothyroidism, hypopituitarism
Cranial growth

- Reflects brain growth/volume
- Brain major metabolic demand in infants
- Relatively preserved in undernutrition
  - Early infancy: may follow weight deceleration
  - Low relative to Length:
    - 1° neurologic etiology
    - Intrauterine Insult
    - Metabolic
Composition of Metabolic Demand

\[
\text{TDEE} = [1.4 \text{ to } 1.6] \times \text{BMR}
\]

\[
\%\text{BMR} / 1.5 = \% \text{TDEE}
\]

- 60% BMR = 45% TDEE
- 40% BMR = 27% TDEE

7 month male with early growth arrest attributed to nursing insufficiency, followed by recovery.

His growth worsened after 5 months age when solids were introduced, despite parental efforts to feed him every 1-2 hours.
Laboratory

- Directed by History, Validated by Exam, Conditioned by Experience
- Otherwise: reserve for failure to respond to nutritional/behavioral/environmental intervention
- CBC/smear, Urinalysis, Sweat Chloride, Celiac serology, Stool parasites, FEP-Pb, quantitative IgA, Electrolytes-BUN-Creatinine, zinc/alkaline phosphatase, TSH
Problem with Disease Model:
-the hospital FTT workup

- Improbable or Bass-ackwards:
  - Minority with discernable relevant pathology
- Expensive
- Distraction of medicalization
- Morbidity of testing
- Hospital artifact
  - Social and family disruption
  - Patient out of problem context
  - Nosocomial hazards
Interventional Strategy

- **Schedule Meals q 3-4 hours:**
  - Establish and enhance endogenous rhythms of hunger/thirst followed by satiety
  - Eliminate between meal grazing/sipping
  - Trust survival physiology

- **Provide, do not Coerce:**
  - respect autonomy and survival instinct
  - avoid defensiveness/aversion

- **Harness thirst drive:**
  - Substitute formula/milks for juice, water, etc
  - Liquids follow solids

- **Increase nutrient density of foods offered**
Caloric Requirements

- Use median ("ideal") weight for height
  - Fat is metabolically inert
  - Brain > Visceral Organs > Muscle consume metabolic energy
  - Consider using weight for cranial (OFC) age if head relatively large compared to length
- Multiply x RDA kcal/kg for wt-age or ht-age
## Estimated Energy Needs (RDA)

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Kcal/kg body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>90-120</td>
</tr>
<tr>
<td>1-7</td>
<td>75-90</td>
</tr>
<tr>
<td>7-12</td>
<td>60-75</td>
</tr>
<tr>
<td>12-18</td>
<td>30-60</td>
</tr>
<tr>
<td>&gt;18</td>
<td>25-30</td>
</tr>
</tbody>
</table>
Actual weight: 5.2 kg
6 kg is median weight for height age:

[5.2 / 6 = 87% expected wt for length-age]
5.2 kg is 87% of 6 kg weight for length-age

Calorie goal: 100 kcal/kg x 6 kg = 600 kcal/day

For 24 kcal/oz formula (0.8 kcal/ml):
600 kcal/0.8 kcal/ml = 750 ml
750 ml / 30 ml/oz = 25 oz

Kcal/kg actual weight:
600 kcal/5.2 kg = 120 kcal/kg/day
7 month male with early growth arrest attributed to nursing insufficiency.

His growth worsened after 5 months age when solids were introduced, despite parental efforts to feed him every 1-2 hours.

He improved in wt, Then length after 7 months age when feeding schedule and strategies began.
Late cranial growth response
Other Interventions

- Specialized formulas
- Motility/Acid suppression Rx
- Cyproheptadine
- Zinc
- Oxygen
- Naso-gastric feeding
- Naso-jejunal feeding
- Percutaneous endoscopic gastrostomy
Accommodation /Refeeding Risks

- Chronically malnourished patient is adapted or *accommodated* to the undernourished steady state.
  - Reduced metabolic rate, cardiac demand
  - Depleted intracellular ions: K, P, Ca, Mg
  - Depleted fat and muscle stores, including myocardium

- Providing nutrients increases metabolic demand:
  - Increased cardiac demand/stress
    - Congestive heart failure, edema
  - Intracellular influx of P, K, Mg, Ca;
  - P bound in ATP, intermediary metabolism.
    - Risk of hypophosphatemia, hypoK, hypoMg, hypoCa
    - Risk of prolonged QTc and ventricular arrhythmia on ECG
Indications for Hospitalization

- Impaired homeostasis:
  - dehydration, hemodynamic or electrolyte disturbance, altered neurologic status, acute weight loss

- Complications/comorbidity:
  - infection, respiratory distress, CNS changes

- Negligence/noncompliance/abuse

- Unsuccessful outpatient intervention:
  - No weight gain x 2-4 weeks
  - Sub-optimal gain x 2 months
Indications for Discharge

- Restored Homeostasis
- Resolving Complications
- Established support/monitoring system
- Restored weight gain or anticipated weight gain in outpatient monitored context
That happy, healthy face recognized all over the world.
Thriving to Fail?

**Weight-for-age percentiles:**
Boys, birth to 36 months

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Boys, birth to 36 months
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**Extremely Obese:** BMI >99th %ile

**Obese:** BMI 95th to <99th %ile

**Overweight:** BMI 85th to <95th %ile

Centers for Disease Control and Prevention
To Over-Thrive

- **Rapid weight gain** before age 4 months is associated with overweight at 7 years.

- Correlation between rate of weight gain in infant males and fatness at 10.5 years

- AGA infants with rapid weight gain were taller and fatter at 9 years of age.
  Cameron et al. Obes Res 2003;11:457-60
To Over-Thrive

- *Adiposity Rebound* in BMI < 5 yrs related to increased adulthood BMI of 4-5 kg/m$^2$.

Undernutrition $\rightarrow$ Overnutrition: Metabolic Programming?

- Smaller (IUGR) FT infants with catch-up growth before age 2 yrs were taller and fatter at 5 years of age. (Ong et al. BMJ 2000;320: 967-71)

- Low rate of gain in infancy AND/OR rapid weight gain > 12 months associated with increased coronary disease risk. (Eriksson et al BMJ 2001; 323:572-3)
9 month FT AGA infant with GER, incarcerated father, nursed and fed hourly.

- Why is he so fat?
- What strategy do we offer?
Beyond FTT: Thriving to Fail

- Epidemic Obesity and associated morbidity
- Infantile antecedents of adult Obesity
- Interest in early recognition
- Symmetry with diagnosis of FTT
- Observation: Threshold for referral for overweight greater than that for underweight children.

Miller LA et al: J Pediatr 2002;140:121-4
Can Failure to Thrive Lead to Obesity?

- Prader-Willi paradigm
- Control rate of catch-up weight gain.
- Longer term monitoring of recovered FTT
- Intake restriction of over-thriving infants
- The paradox of grazing:
  - Impaired appetite for meals: faltering
  - Chronic insulinemia: obesigenic
Recognize Early Signs:

*Thriving to Fail*

- Rapid Weight Gain in early childhood = High Risk for Obesity in later life
- Designate overweight as Weight-for-Length greater than 95th%ile [WHO BMI curves exist for < 2 years.]
- Weight gain crossing 2 major percentiles (1 standard deviation) = up to 5 times increased risk of later overweight.


- Early or infantile obesity more likely associated with genetic or endocrine obesity syndromes.
Proposed Strategy

- Identify over-thriving infants/toddlers
- Schedule meals with 3-4 hour intervals
- No grazing, nibbling, sipping between
- Control Carbohydrates as well as Fats:
  - portion control, complex vs low glycemic foods and preparation;
  - eliminate fructose/limit sucrose
- Physical Activity: limit screen time
- Family Involvement/Education
9 month FT AGA infant with GER, incarcerated father, nursed and fed hourly.

Response to feeding strategies; mom also lost weight.
Body mass index response to slowed rate of weight gain.