Pediatric Nutrition Handbook: An Algorithmic Approach
To the inspirations in my life,
Rebecca, Elias, and Sadie and the
foundation from which I grew,
Mom and Dad.

– David L. Suskind

A special acknowledgment to my children
Natalie and Charles, who taught me
to “relax” about childhood feeding and
appreciate every day of life!

– Polly Lenssen
Pediatric Nutrition Handbook
An Algorithmic Approach

Edited by

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Preface

Each year, millions of children throughout the world are subjected to the life-threatening ravages of malnutrition. The nutritional issues that children face today have radically changed as knowledge on disease processes as well as their treatments have improved.

We know the effect of nutrition is profound. Good nutrition not only assures proper growth and development, but it also enables each organ system to do its job properly. In ill children, nutrition is paramount, affecting both morbidity and mortality. As medicine has specialized, the nutritional care of children has also become increasingly specialized. This handbook serves as a broad guide to the nutritional care for the developing infant and child as well as for children with specialized medical needs.

This handbook is the fruition of a long-held dream by many at Seattle Children’s Hospital to standardize the nutritional care of our patients. Collectively, it represents years of experience and specialized knowledge in the nutritional assessment and care of infants, children, and teens.

We would like to recognize our contributors for their time and effort. Additional thanks to the many reviewers who both recommended content and analyzed all the chapters. Our hope is that all health care providers – residents, nurses, dietitians, and other clinicians – find the handbook helpful. We welcome feedback to improve future publications.

David L. Suskind
Polly Lenssen

This handbook is designed to assist healthcare practitioners deal with the large number of nutritional issues which present during childhood. It is intended to be a quick reference only and not an in-depth review of either nutritional or medical issues that occur in childhood. This book is an educational resource only and none of its content is meant to be standard of care. The authors would like to acknowledge Seattle Children’s Hospital for its commitment to nutrition and the importance it plays in a child’s health.
The idea that good nutrition is essential for the optimal development of a child and to the child’s evolvement to a healthy adulthood seems simple. But translating that simple idea to effective truth is a challenge. It’s for that reason that this book is so important. David L. Suskind, M.D., and Ms. Polly Lenssen have created, with Seattle’s most expert nutritionists, a book which is essential for every physician and health worker dealing with children. They have, for the first time in medical history, provided the pediatric health worker with a systematic algorithmic approach to the nutritional support of all children and, most importantly, children with primary and secondary nutritional deficiencies.

With rare comprehensiveness, this volume provides the mechanism for the nutritional assessment of infants and adolescents as well as a comprehensive list of the pediatric diseases that impact on the nutritional status of children including the cardiac, gastrointestinal, metabolic, neurologic, pulmonary, renal, and rheumatologic systems.

Dr. Suskind and Ms. Lenssen have described the important role played by nutrition in maintaining the cellular integrity of the body, demonstrating that, without this integrity, organs and systems fail and the nutritional complications of disease processes contribute to the morbidity and mortality associated with the underlying disease. By developing an inductive algorithmic approach to the handling of these nutritional problems they provide those responsible for pediatric care a systematic, logical, effective approach to dealing with the nutritional impact of disease.

Pediatric Nutrition Handbook: An Algorithmic Approach is an outstanding textbook, critical to good pediatric care. I personally want to congratulate the editors and all of the contributors. Their contribution to this book is invaluable.

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Chapter 1

General Nutrition

1.1 General Pediatric Nutrition Assessment
Cheryl Davis and the Clinical Nutrition Department

The authors of the nutrition assessment chapters would like to acknowledge the contributions of the clinical nutrition staff over many years in developing standard guidelines.

1.1.1 Weight

1. Weigh on digital or calibrated scale (infant scale: 0–36 months; standing scale >3 years).
2. Plot on age- and sex-appropriate World Health Organization (WHO) growth chart.
3. Weight-for-age: A measure for acute malnutrition.
4. Interpretation: Gómez classification (Gómez et al., 1956).

<table>
<thead>
<tr>
<th>Malnutrition Level</th>
<th>Percentage of Theoretical Weight for Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>First-degree malnutrition</td>
<td>76–90%</td>
</tr>
<tr>
<td>Second-degree malnutrition</td>
<td>61–75%</td>
</tr>
<tr>
<td>Third-degree malnutrition</td>
<td>≤60%</td>
</tr>
</tbody>
</table>

1.1.2 Height or Length

1. Recumbent length (up to 36 months): Measure on length board with one person at the head and one at the feet, and plot on a 0–36-month sex-appropriate WHO growth chart. Do not use a tape measure.
3. **Height-for-age**: A measure for chronic malnutrition.

<table>
<thead>
<tr>
<th>Height deficit (%)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Actual height [cm] ÷ expected height at the 50th percentile for age) × 100</td>
</tr>
<tr>
<td>Normal height</td>
<td>95–100%</td>
</tr>
<tr>
<td>Mildly stunted</td>
<td>90–95%</td>
</tr>
<tr>
<td>Moderately stunted</td>
<td>85–90%</td>
</tr>
<tr>
<td>Severely stunted</td>
<td>&lt;85%</td>
</tr>
</tbody>
</table>

---

**1.1.3 Weight-for-Length (Up to 36 Months)**

Measure for acute malnutrition as well as obesity.

1. Plot on a 0- to 36-month sex-appropriate WHO growth chart.

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>High risk for underweight</td>
<td>&lt;5th percentile</td>
</tr>
<tr>
<td>Moderate risk for underweight</td>
<td>&lt;10th percentile</td>
</tr>
<tr>
<td>At risk for overweight</td>
<td>&gt;85th percentile</td>
</tr>
<tr>
<td>Overweight</td>
<td>&gt;95th percentile</td>
</tr>
</tbody>
</table>

---

**1.1.4 Body Mass Index (BMI) in kg/m² (2–20 Years)**

Measure for undernutrition and obesity.

1. Calculate \( \frac{\text{weight in kg}}{\text{height in meters}} \times \frac{\text{height in meters}}{\text{height in meters}} \).
2. Plot on a 2- to 20-year sex-appropriate WHO growth chart.

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt;5th percentile</td>
</tr>
<tr>
<td>Healthy weight</td>
<td>5–84th percentile</td>
</tr>
<tr>
<td>Overweight</td>
<td>85–94th percentile</td>
</tr>
<tr>
<td>Obese</td>
<td>&gt;95th percentile</td>
</tr>
</tbody>
</table>

---

**1.1.5 Ideal Body Weight**

1. **Methods:**
   a. Weight at which weight-for-length is 50th percentile for age (0–36 months) or BMI is 50th-percentile BMI for age (2–20 years).
   b. Weight at the 50th percentile at the age that matches the height-for-age.
2. \( \% \text{ Ideal body weight (IBW)} = \frac{\text{Actual weight}}{\text{IBW}} \).

<table>
<thead>
<tr>
<th>Normal nutrition</th>
<th>90–109%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild malnutrition</td>
<td>85–89%</td>
</tr>
<tr>
<td>Moderate malnutrition</td>
<td>75–84%</td>
</tr>
<tr>
<td>Severe malnutrition</td>
<td>&lt;75%</td>
</tr>
</tbody>
</table>

1.1.6 Growth Velocity or Incremental Growth

1. Detect abnormal rates of growth or weight gain before child is at extremes on growth chart; monitor efficacy of nutrition therapy.

2. Infants 0–24 months:
   a. Calculate weight gain in g/day and compare to standards: See Appendix A.
   b. Calculate linear growth in mm/day (cm/day × 100) and compare to standards. See Appendix B.

3. Children 2–10 years: Calculate weight gain in g/day and compare to standards listed here.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Expected Gain in Weight: &gt;2 Years Old (Fomon et al., 1982)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
</tr>
<tr>
<td>2–3</td>
<td>5.7</td>
</tr>
<tr>
<td>3–4</td>
<td>5.5</td>
</tr>
<tr>
<td>4–5</td>
<td>5.4</td>
</tr>
<tr>
<td>5–6</td>
<td>5.5</td>
</tr>
<tr>
<td>6–7</td>
<td>5.9</td>
</tr>
<tr>
<td>7–8</td>
<td>6.7</td>
</tr>
<tr>
<td>8–9</td>
<td>7.8</td>
</tr>
<tr>
<td>9–10</td>
<td>9.1</td>
</tr>
</tbody>
</table>

1.1.7 Specialty Growth Charts

1. Premature: Plot for gestational age until 50 weeks; then correct for prematurity on standard WHO growth charts until 24 months.

2. Charts for achondroplasia, cerebral palsy, Down syndrome, Noonan syndrome, Prader-Willi syndrome, Turner syndrome, and Williams syndrome are available. Use in conjunction with standard WHO growth charts.

1.1.8 Occipital Frontal Circumference (0–36 months)

1. Plot on sex-appropriate WHO growth charts.

2. Interpretation:
   a. Rapid increase in rate of growth may indicate hydrocephalus.
   b. Decrease in rate of growth may indicate developmental delay; associated with malnutrition.

3. Note if patient has a shunt.
1.1.9 Arm Muscle and Fat Stores (>12 months)

1. Use to detect serial changes in body composition; only valid when repeat measurements are made by the same observer and interpreted over time.

2. Measure mid-upper-arm circumference (AC) and triceps skin fold thickness (TSF) and calculate arm area (AA), arm muscle area (AMA), and arm fat area (AFA).
   a. Calculations
      - AA (mm$^2$): $(AC \text{[mm]})^2 \div 4\pi$
      - AMA (mm$^2$): $(AC \text{[mm]} - \pi TSF)^2 \div 4\pi$
      - AFA (mm$^2$): AA $-$ AMA.


1.1.10 Clinical Evaluation

1. Nutritional status is affected not only by the nutritional intake but also by developmental status, disease states, medications, and surgical/medical procedures.

2. Symptoms that may affect adequacy of intake: Vomiting, diarrhea, constipation, dysphagia, abnormal sucking or chewing, abdominal pain/gas, respiratory distress, heart failure, renal failure, and almost any chronic disease.

3. Physical examination results:
   a. Clinical signs in the malnourished child:
      - Marasmus: A form of severe malnutrition that occurs with total energy deficiency (i.e., “skin and bones”).
      - Kwashiorkor: A form of malnutrition that occurs when there is not enough protein in the diet.
      - Refer to Chapter 2, Section 2.10, for signs and symptoms of vitamin/mineral deficiency or excess.
   b. Hydration status:
      - Degrees and signs of dehydration in children (see table) (reference: Satter, 2000):

<table>
<thead>
<tr>
<th>Degree of Dehydration</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild dehydration (&lt;3%)</td>
<td>• Slightly dry mouth</td>
</tr>
<tr>
<td></td>
<td>• Increased thirst</td>
</tr>
<tr>
<td></td>
<td>• Decreased urination</td>
</tr>
<tr>
<td></td>
<td>• Sunken eyes</td>
</tr>
<tr>
<td></td>
<td>• Sunken fontanelle</td>
</tr>
<tr>
<td></td>
<td>• Skin not as smooth or elastic</td>
</tr>
<tr>
<td></td>
<td>• Dry mouth</td>
</tr>
<tr>
<td></td>
<td>• Few tears when child cries</td>
</tr>
<tr>
<td>Moderate dehydration (3–6%)</td>
<td>•</td>
</tr>
<tr>
<td></td>
<td>• Slightly dry mouth</td>
</tr>
<tr>
<td></td>
<td>• Increased thirst</td>
</tr>
<tr>
<td></td>
<td>• Decreased urination</td>
</tr>
<tr>
<td></td>
<td>• Sunken eyes</td>
</tr>
<tr>
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<td>• Sunken fontanelle</td>
</tr>
<tr>
<td></td>
<td>• Skin not as smooth or elastic</td>
</tr>
<tr>
<td></td>
<td>• Dry mouth</td>
</tr>
<tr>
<td></td>
<td>• Few tears when child cries</td>
</tr>
</tbody>
</table>
### Degree of Dehydration and Symptoms

<table>
<thead>
<tr>
<th>Degree of Dehydration</th>
<th>Symptoms</th>
</tr>
</thead>
</table>
| Severe dehydration (>6%) | • Signs of moderate dehydration plus:  
  • Rapid, light pulse  
  • Unusually blue skin  
  • Rapid breathing  
  • Cold hands and feet  
  • Listlessness, drowsiness  
  • Loss of consciousness |


### 1.1.11 Laboratory Assessment

Many tests are affected by disease and fluid status, and they may not be useful for guiding nutrition therapy. Ask, “Will the results change the nutrition intervention strategy?” before requesting a test be ordered.

1. **Protein indices:**
   a. Albumin: Affected by fluid status, infection, or inflammation; long half-life (~23 days).
   b. Prealbumin, transferrin, retinal-binding protein: Depressed during stress, infection, and acute illness; shorter half-lives.
   c. C-reactive protein (CRP): Elevated during stress, infection, and inflammation; may be used with other protein indices to help determine whether low protein level is due to stress or nutritional status.

2. **Iron status:**
   a. Hemoglobin and/or hematocrit: Low only in later stages of iron deficiency anemia. May be low due to other disease states (renal failure, B<sub>12</sub>, or folate deficiency, hematologic or cancer diagnoses) even with normal iron status.
   b. Ferritin: Indicative of iron status but elevated during infection or chronic inflammation.
   c. Total iron-binding capacity (TIBC); percentage saturation, serum iron: Use with ferritin to assess iron status.

3. **Immunologic function:**
   a. Total lymphocyte count: Depressed in malnutrition but also altered due to immunosuppressant drug therapy, chemotherapy or radiation, and/or trauma.

4. **Vitamin/mineral/trace element status:**
   a. Zinc: May be low secondary to inadequate intake, increased losses, or malabsorption.
   b. Vitamin A: May be low secondary to inadequate intake or fat malabsorption.
   c. Vitamin D: May be low secondary to inadequate intake, inadequate supplementation of high-risk patients, and/or fat malabsorption.