Growth status in children with cystic fibrosis based on the National Cystic Fibrosis Patient Registry Data: Evaluation of various criteria used to identify malnutrition.

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Running title: Growth status in children with cystic fibrosis

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ABSTRACT

Objectives: To determine growth status and identify malnutrition using various anthropometric indicators in children with cystic fibrosis (CF) based on cross-sectional analysis of the 1993 National Cystic Fibrosis Patient Registry data.

Methods: Heights and weights of 13,116 children with CF were evaluated using percentile, percent of reference median, Z-score and percent ideal weight-for-height based on NCHS/CDC growth references. Malnutrition was defined by four criteria: I, height-for-age < 5th percentile ("stunting") or weight-for-age < 5th percentile ("wasting"); II, height-for-age < 90% of reference median or weight-for-age < 80% of reference median; III, height-for-age < 5th percentile or percent ideal weight-for-height < 85%; and IV, height-for-age < 90% of reference median or weight-for-height < 85% of reference median.

Results: Mean and median height- and weight-for-age were found to be at the 30th and 20th percentiles in children with CF. Malnutrition (height- or weight-for-age < 5th percentile) is particularly pronounced in infants (46%) and adolescents (34%) as well as in newly diagnosed CF patients (44%). A significant gender difference (p < 0.01) in the occurrence of stunting (height-for-age < 5th percentile) was observed during adolescence: males 11-14 years of age showed lower occurrence of stunting (25%) compared to females (29%) whereas the opposite trend was observed at 15-18 years (34% in males versus 19% in females). The overall occurrence of malnutrition was not significantly different by all criteria, however, more than one-third of the malnourished children have inconsistent classification of "stunting", "wasting" or both.

Conclusion: Twenty percent of all children in the 1993 National CF Patient Registry were below the 5th percentile for height- or weight-for-age. A significant discrepancy was found when using different criteria to distinguish "stunting" versus "wasting" in malnourished children with CF.
LIST OF ABBREVIATIONS:

CF Cystic fibrosis
NCHS/CDC National Center for Health Statistics/Centers for Disease Control
WHO World Health Organization
CFF Cystic Fibrosis Foundation
HAP Height-for-age percentile
WAP Weight-for-age percentile
HAZ Height-for-age Z-score
WAZ Weight-for-age Z-score
HAM Height-for-age percent of reference median
WAM Weight-for-age percent of reference median
WHM Weight-for-height percent of reference median
IWH Percent ideal weight-for-height
INTRODUCTION

Growth failure and malnutrition, resulting from pancreatic dysfunction, inadequate energy and nutrient intake, malabsorption and increased metabolic needs, are well documented as unfavorable prognostic factors in cystic fibrosis.\textsuperscript{1-3} It is useful to characterize the nature and degree of poor growth and malnutrition in the CF population for the development and evaluation of intervention strategies.

The reported occurrence of poor growth and malnutrition associated with CF varies among studies.\textsuperscript{4-7} One factor contributing to the reported difference is the criterion used to define poor growth and malnutrition. Height-for-age, weight-for-age and weight-for-height expressed as percentile, Z-score and percent of reference median are commonly used as the indices for growth status.\textsuperscript{8-11} However, definitions of the number at risk and the choice of cutoff points for malnutrition are inconsistent.\textsuperscript{9-12} For example, Waterlow's classification of nutritional status uses height-for-age $< 90\%$ of the reference median to identify "stunting" and weight-for-height $< 80\%$ of the reference median to identify "wasting".\textsuperscript{9,10} On the other hand, WHO recommended the use of the 3rd percentile or -2 standard deviations as the cutoff points to identify malnutrition.\textsuperscript{11} A third indicator (percent ideal weight-for-height\textsuperscript{13}) was recommended by the CFF Nutrition Consensus Report\textsuperscript{14} to evaluate nutritional status in CF patients. It is not clear which indicators are most useful clinically for the assessment of growth and nutritional status in children with CF.

Another factor influencing the reported occurrence of malnutrition is the reference standard used to determine growth status. For example, the growth references developed by the NCHS/CDC\textsuperscript{15-19} are used by the National CF Foundation to evaluate growth of CF patients in the United States, whereas the the British standards developed by Tanner et. al.\textsuperscript{20} are used by the Canadian CF Foundation.\textsuperscript{7} These standards differ in their sample populations, nature of the data
collected (cross-sectional versus longitudinal), and methods of curve construction. Therefore, plotting growth data with different standards is likely to produce different results regarding the growth status of an individual or a population, making interpretation of results difficult.

The primary objective of this study was to determine growth status and identify malnutrition using various anthropometric indicators in children with cystic fibrosis based on cross-sectional analysis of the 1993 National Cystic Fibrosis Patient Registry data. Heights and weights of 13,116 children with CF were evaluated using percentile, percent of reference median, Z-score and percent ideal weight-for-height based on NCHS/CDC growth references. Four criteria were used to determine the occurrence of malnutrition and agreement between these criteria were assessed: criterion I, height-for-age < 5th percentile or weight-for-age < 5th percentile; criterion II, height-for-age < 90% of reference median or weight-for-age < 80% of reference median; criterion III, height-for-age < 5th percentile or percent ideal weight-for-height < 85%; criterion IV, height-for-age < 90% of reference median or weight-for-height < 85% of reference median. Lastly, we examined the occurrence of malnutrition associated with CF as influenced by sex, age and time of CF diagnosis.

METHODS

Study population. The heights and weights of 13,116 children (age 0-18 years) from 114 CFF-accredited CF centers for the year 1993 were obtained from the National CF Patient Registry. This pediatric CF population constituted 68% of all CF patients registered at the National CF Patient Registry for the year 1993.

Computation of growth percentiles, Z-scores and percent ideal weight-for-height. HAP, HAZ, HAM, WAP, WAZ, WAM and WHM were calculated using the Epi Info computer program, which utilizes normalized growth reference curves developed by NCHS/CDC. A computerized program was developed to calculate IWH as defined by Moore et al. Briefly,
reference tables for the mean weights and the corresponding standard deviations for specific sex-age groups were calculated using the Epi Info program\textsuperscript{21} and SAS (Version 6.0, SAS Institute Inc., Cary, NC, 1991) based on the Z-score method.\textsuperscript{17,18} Ideal weight for each patient was then calculated by taking his or her mean weight-for-age plus the HAZ multiplied by the corresponding standard deviation and then IWH was obtained by dividing the patient's actual weight by the ideal weight and multiplying by 100%.

**Determination of growth status.** The heights and weights of the study population were used to construct the 5th, 50th and 95th percentile curves for children with CF. These percentile curves were compared to the 5th, 50th and 95th percentile curves of the NCHS/CDC reference population, as shown in Fig. 1. To characterize the growth status of the study population, height-for-age and weight-for-age were categorized into six percentile channels (< 5th, 5th-10th, 10th-25th, 25th-50th, 50th-75th, 75th-90th and > 75th) and six Z-score channels (-6 to -4, -4 to -2, -2 to -1, -1 to zero, zero to 1 and > 6) and the proportions of patients classified in each category was calculated. In addition, IWH was evaluated according to the recommendation from the CFF Nutrition Consensus Report\textsuperscript{14}: overweight, >110%; normal, 90-110%; underweight, 85-89%; early malnutrition, 80-85%; moderate malnutrition, 75-80%; and severe malnutrition, < 75%.

**Definition of malnutrition using anthropometric indicators.** Four criteria were used to define malnutrition based on various height and weight indices at different cutoff points. Specifically, malnutrition was defined as: criterion I, HAP < 5th percentile, WAP < 5th percentile or both; criterion II, HAM < 90%, WAM < 80% or both; criterion III, HAP < 5th percentile, IWH < 85% or both; and criterion IV, HAM < 90%, WHM < 85% or both. Table I shows the classification of malnutrition by each criterion.

Criterion I is based on common clinical practice that any child who falls below the 5th percentile curve for height or weight on the NCHS/CDC growth curves is considered to be
potentially malnourished. Criterion II also uses height-for-age and weight-for-age but utilizes a different expression (i.e., percent of the reference median) and cutoff points.\textsuperscript{8,9,12} Criteria III and IV use weight-for-height instead of weight-for-age to define wasting; however, two different computations of weight-for-height (IWH based on CFF Nutrition Consensus Report,\textsuperscript{14} and WHM based on Waterloo’s classification\textsuperscript{9,10} for criteria III and IV, respectively) are compared.

Statistical analyses. Of the 13,116 observations, 4% had missing measurements for height or weight or both. Approximately 0.5% of children had height or weight measurements that deviated more than 6 standard deviations from the reference mean, as indicated by the symbol “+” in Fig 1. These height and weight values are likely outliers resulting from measurement or recording errors; for example, it is highly unlikely for a 10 year-old child to be 50 cm tall, or an infant with a 80 kg weight. Therefore, these values were excluded from computations and statistical analyses.

Comparisons between categorical outcomes were assessed by chi-square contingency table methods using SAS. Agreement among the four criteria in identifying children with malnutrition was measured by the kappa statistic.\textsuperscript{22} A kappa below 0.4 was considered to be in poor agreement according to criteria described by Landis and Koch.\textsuperscript{23} Generalized additive model methods were used to estimate the percentage of patients with HAP < 5th percentile, WAP < 5th percentile, and IWH < 85% as a function of age (using a logit link) with smoothing splines having 7 degrees of freedom.\textsuperscript{24} An approximate F-test was used to obtain statistical significance of the models.\textsuperscript{24} Except for the contingency table methods, statistical and graphical analyses were performed using S-Plus statistical software (StatSci: A Division of MathSoft, Inc, Seattle, WA).

RESULTS

Patient characteristics. Of the 13,116 children maintained in the 1993 National CF Patient Registry, 52.8% were male. The majority (95.6%) were Caucasians; 3.6% were African
Americans and 0.8% were other races. Age distribution of this pediatric CF population indicated that approximately 40% of the children with CF were infants (< 1 year) or adolescents (11-18 years). These children have higher energy and nutrient requirements for growth and therefore may be at higher risk for malnutrition than children at other ages.

Growth status as assessed by height- and weight-for-age percentiles. As shown in Fig. 1, the 5th, 50th and 95th percentile curves for both height and weight in children with CF fall substantially below the corresponding NCHS/CDC percentile curves. The difference in weight is particularly pronounced at 18 years of age, with the 95th and 50th percentile curves of the CF population close to the 50th and 5th percentile curves of the NCHS/CDC reference population.

Fig. 2A summarizes the growth status of CF children as reflected by the percentage of patients categorized in the NCHS/CDC height and weight percentile channels. Overall, frequency distributions of HAP and WAP for children with CF are skewed to the left when compared to the expected distribution for the reference population, indicating subnormal growth status in children with CF. Mean (S.D.) HAP for male (n = 6605) and female (n = 5887) patients are 29.7 (27.7) and 29.5 (26.6), respectively; median HAP for male and female patients are 20.8 and 22.0, respectively; mean (S.D.) WAP for male (n = 6630) and female (n = 5904) patients are 30.5 (27.3) and 30.1 (26.6), respectively; median WAP for male and female patients are 22.3 and 21.7. Age-stratified chi-square analysis indicates no significant differences comparing males and females in the frequency distributions of HAP (p = 0.6) and WAP (p = 0.9).

According to criterion I, the occurrence of “stunting” (HAP < 5th percentile), “wasting” (WAP < 5th percentile) and the combination of “stunting and wasting” in children with CF is 22%, 20% and 13%, respectively. Another 11% of the children with CF exhibits growth faltering as indicated by HAP or WAP between the 5th and the 10th percentile. Overall, as much as one-third of the study population are below the 10th percentile and less than 25% of the children are
above the 50th percentile for HAP or WAP.

**Growth status as assessed by height- and weight-for-age Z-scores.** Fig. 2B summarizes the growth status of CF children as reflected by the percentage of patients categorized in the NCHS/CDC height and weight Z-score channels. Mean (S.D.) HAZ for male (n = 6605) and female (n = 5887) patients are -0.81 (1.17) and -0.81 (1.19), respectively; median HAZ for male and female patients are -0.81 and -0.77, respectively; mean (S.D.) WAZ for male (n = 6630) and female (n = 5904) patients are -0.74 (1.12) and -0.74 (1.14), respectively; median WAZ for male and female patients are -0.76 and -0.78, respectively. The majority of the children are in the range of zero to minus two standard deviations for HAZ (62% of the male and 63% of the female) and WAZ (63% of the male and 65% of the female). The occurrence of "stunting" (HAZ < -2), "wasting" (WAZ < -2) and the combination of "stunting and wasting" is 14%, 11% and 7%, respectively. Age-stratified chi-square analysis indicates no significant differences comparing males and females in the frequency distributions of HAZ (p = 0.7) and WAZ (p = 1.0).

**Growth status as assessed by percent ideal weight-for-height.** Growth status as reflected by the percentage of patients in each IWH category is shown in Fig. 2C. Mean (S.D.) IWH for male (n = 6582) and female (n = 5869) patients are 99.9 (13.2) and 100.3 (14.6), respectively; median IWH for male and female patients are 99.6% and 99.9%, respectively. The occurrence of "wasting" (IWH < 85%) is 10%. Another 10% of the children with CF is underweight (IWH 86-90%). No significant difference is noted when comparing males and females in the frequency distribution of IWH, p = 0.2.

**Occurrence of malnutrition as a function of age.** To examine if the occurrence of malnutrition varies with age, the percentages of patients with HAP < 5th percentile, WAP < 5th percentile and IWH < 85% as a function of age were estimated using generalized additive model
methods (Fig. 3). Approximately 40% of the infants were below the 5th percentile for height- and weight-for-age. The occurrence of malnutrition declined rapidly to 20-25% at 2 years of age but increased again at the onset of adolescence (8-10 years). During adolescence, the occurrence of stunting (HAP < 5th percentile) differed significantly between male and female CF patients. More specifically, female CF patients showed higher occurrence of stunting (28.8%) than male patients (18.8%) at 11-14 years whereas an opposite trend was observed at 15-18 years (33.8% for male and 28.4% for female). In support of this finding, chi-square analysis using 6 age strata (< 1 year, 1-3 years, 4-6 years, 8-10 years, 11-14 years and 15-18 years based on Recommended Dietary Allowances\textsuperscript{35}) demonstrated a significant gender effect on the proportion of patients with HAP < 5th percentile, \( p = 0.009 \).

Comparison of the three indicators showed that HAP < 5th percentile and WAP < 5th percentile were more sensitive than IWH < 85% as a single indicator to identify malnutrition at all ages, except for female patients during late adolescence (15-18 years). One explanation to this finding is that HAP and WAP < 5th percentile identify 11% of the patients that have a IWH > 85%, therefore, these children would be not be classified as malnourished by IWH > 85%.

Agreement among different criteria in identifying CF children with malnutrition. Table I shows the occurrence of “stunting”, “wasting” and the combination of “stunting and wasting” as determined by the four criteria in children with CF. The occurrence of malnutrition was determined separately for infants (< 1 year), adolescents (11-18 years) and for children at other ages (1-10 years) because the percentage of patients with malnutrition was much higher in infants and adolescents, as demonstrated earlier. In addition, weight-for-height ratios vary with age in adolescents, primarily due to rapid growth rates and differences in the age of onset of puberty. For this reason, WHM is not computed for males older than 11.5 years or taller than 145 cm nor for females older than 10.0 years or taller than 137 cm in the NCHS/CDC growth
references; hence criterion IV was not applied to children ages 11-18 years. Lastly, HAZ and WAZ < -2 S.D. were not used to identify malnutrition because they correspond approximately to the third percentile in the normalized NCHS/CDC growth curves, therefore they simply reflect a stricter criterion than HAP and WAP < 5th percentile.

Comparison between criterion I and II reveals the difference between the use of percentile vs. percent of reference median as indicators to identify malnutrition. For infants and adolescents, the overall occurrence of malnutrition was not significantly different (47% versus 42% in age group < 1 year, and 34% versus 38% in age group 11-18 years) by these two criteria. Kappa analysis indicated a good agreement comparing these two criteria in identifying normal versus malnourished patients (kappa = 0.60 and 0.59 for age group < 1 year and 11-18 years, respectively). However, the percentages of the malnourished children classified as “stunted”, “wasted” or “stunted and wasted” varied greatly. In fact, more than one-third of the malnourished patients were classified in different categories of malnutrition. For example, more children were classified as “stunted” and “stunted and wasted” by criterion I whereas more children were classified as “wasted” by criterion II. Similarly, discrepancies were observed when comparing between criteria I and III or between criteria II and IV to compare the difference between using weight-for-age vs. weight-for-height to identify “wasting”. Taken together, these results indicate that although the four criteria identify a similar percentages of patients with malnutrition, the occurrence of acute (“wasting”) or chronic (“stunting”) malnutrition varies significantly among the four criteria.

Growth status at diagnosis of CF. The occurrence of malnutrition at diagnosis of CF in children birth to 10 years of age was determined in two CF populations: patients diagnosed in 1993 as reported to the 1993 National CF Patient Registry, and the non-screened patients diagnosed in the Wisconsin Neonatal CF Screening Study during 1985-1994. This comparison
was of interest to us because our data from a randomized trial of early detection through neonatal screening show better anthropometric indices at diagnosis in screened patients. Table II shows the occurrence of malnutrition in these two CF populations compared to that of all patients in the 1993 National CF Patient Registry. The mean (1.2 - 1.4 years) and median (0.34 - 0.50 years) age of diagnosis were not significantly different comparing newly diagnosed CF patients from the 1993 Patient Registry to the Wisconsin non-screened patients. However, the ages of diagnosis were considerably delayed in these two CF populations compared to that of the Wisconsin screened patients (mean and median age of diagnosis: 0.25 and 0.15 year, respectively). The incidence of meconium ileus at birth appeared somewhat higher in Wisconsin compared to that of the 1993 Patient Registry but this difference was not statistically significant (p = 0.8). Overall, the occurrence of malnutrition, by all criteria, was 1.3-2.8 fold higher in newly diagnosed patients compared to all patients in the 1993 National CF Patient Registry. No significant difference (p = 0.1-0.9) was noted in the occurrence of malnutrition between the national and Wisconsin newly diagnosed patients by all criteria.

DISCUSSION

In this study, we presented comprehensive cross-sectional analysis on the growth status of children with CF by utilizing the large anthropometric database maintained in the National CF Patient Registry. We applied and compared different height and weight indicators to characterize growth and identify individuals with malnutrition in the pediatric CF population. Overall, our results confirm and extend previous findings that children with CF experience subnormal growth at all ages, as reflected by their low mean HAP and WAP (~30th percentile) and median HAP and WAP (~20th percentile) compared to the NCHS/CDC reference population. In addition, 20% of the children with CF were below the 5th percentile for HAP or WAP during the year 1993. The occurrence of "stunting" (HAP < 5th percentile), "wasting" (IWH < 85%) and the
combination of “stunting and wasting” is 20%, 10% and 2.4%, respectively. Infants (0-1 year) and adolescents (11-18 years) showed two to three fold higher occurrence of malnutrition compared to children at other ages. A significant gender difference in the occurrence of stunting during adolescence was also observed.

Our analysis demonstrated that approximately one-third of the 13,116 children with CF reported in the 1993 National CF Patient Registry were at less than the 10th percentile for HAP and WAP using NCHS/CDC references. This finding differs significantly from a previous analysis\textsuperscript{4} which reported 50% of CF patients were below the 10th percentile for HAP and WAP with median HAP and WAP of 15.3 and 10.5 percentiles, respectively, based on the 1990 registry data. This discrepancy can be explained largely by the difference in the computation of ages used to determine HAP and WAP. Specifically, age was calculated to the nearest one-hundredth of the year in the present study whereas age was rounded to the nearest year in the other study,\textsuperscript{4} a rounding error corrected in subsequent CFF annual registry reports. In addition, differences in the study population (pediatric vs. all ages) and year of registry data (1993 vs. 1990) may also contribute to the above discrepancy.

The finding that infants and adolescents with CF showed a significantly higher occurrence of malnutrition than CF children at other ages is not surprising. Several reasons may explain this phenomenon. First, it may reflect the high energy and nutrient requirements in infants and adolescents. Second, the high occurrence of malnutrition in infants could be a result of newly diagnosed, untreated CF, as supported by our finding that malnutrition is more prevalent in newly diagnosed CF patients. Third, the high occurrence of malnutrition in adolescents could be a result of their frequent pulmonary symptoms. However, it could also be reflective of their delayed onset of puberty and adolescent growth spurts during this period\textsuperscript{28,29}. Therefore, the high occurrence of malnutrition in adolescents with CF noted in our study may be overestimated, due
to the use of a non-CF reference population. In addition, our cross-sectional analysis is limited in that changes in growth patterns with age may reflect changes in disease severity over time rather than changes specific to age.

As demonstrated, the four criteria compared in our study resulted in a large discrepancy regarding classification of the "stunted", "wasted" and the combination "stunted and wasted" populations in malnourished children. For example, using percent of reference median (criterion II) results in 2-3 times more patients classified as "wasted" and 5-10 times less patients classified as "stunted" than using percentile < 5th percentile (criterion I). Because "wasting" reflects a consequence of acute malnutrition which responds to nutrition rehabilitation quickly, this population is often the first target for intervention. Our finding that classification of "stunting" and "wasting" is inconsistent with different criteria implies that it would be difficult selecting a single criterion to recommend for screening CF patients at risk for malnutrition.

From a practical standpoint, HAP < 5th percentile and WAP < 5th percentile (criterion I) are the easiest criteria to screen patients at risk for malnutrition because NCHS/CDC growth percentile charts are readily available to evaluate the patient's growth status. Use of HAM < 90% and WAM < 85% (criterion II) has the disadvantage that it may not identify children with the same degree of malnutrition due to differences in the variability of height and weight across ages. In addition, it requires an additional calculation of dividing the patient's measurement by the reference median (which is available as the 50th percentile value in the NCHS/CDC growth charts) to obtain the percent of reference median. WHM is limited because it can only be used in children less than 10 years of age and IWH is the most difficult to use because neither reference tables nor computerized program is available to determine the sex-, age- and height-specific ideal weight for this computation. Since our results demonstrated a good agreement in distinguishing the normal from the malnourished children with CF, HAP and WAP < 5th percentile represents a
practical and appropriate criterion as an initial screening tool to identify CF children at risk for malnutrition. However, questions remain whether the 5th percentile is a valid cutoff point to identify malnutrition and whether the definitions of “stunting” and “wasting” apply in children with a chronic, life-long disease such as CF. Further research linking clinical outcomes to various criteria for identifying malnutrition in CF with the use of longitudinal growth data is necessary to address these questions. In addition, other anthropometric measurements, in particular weight gain (loss) and skinfold thickness, should also be determined in conjunction with height and weight indicators to identify malnutrition.

In conclusion, our study demonstrated that the 1993 population of children with CF have subnormal growth at all ages. The occurrence of malnutrition is particularly pronounced in infants and adolescents, as well as newly diagnosed patients. It is likely that delayed diagnosis contributes significantly to the high prevalence of malnutrition in infants and newly diagnosed patients. This problem can potentially be addressed by CF neonatal screening. Although the overall occurrence of malnutrition is similar by the four criteria used in our study, further distinction between acute (“wasting”) or chronic (“stunting”) malnutrition in maldnourished patients was inconsistent among the four criteria. These data should be useful in planning new interventions aimed at reducing the occurrence of malnutrition in patients with CF.
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Figure legends

Fig. 1. Height and weight percentile curves of children with CF (dashed curves) compared to those of the NCHS/CDC reference population\textsuperscript{15,16} (solid curves). (A) height-for-age for males with CF (n = 6605), (B) height-for-age for females with CF (n = 5887), (C) weight-for-age for males (n = 6630) and (D) weight-for-age for females (n = 5904). Values with the symbol "+" represent heights and weights that deviate more than 6 S.D. from the reference median. These values are likely outliers resulting from measurement or recording errors, and therefore are excluded from computations and statistical analyses. (Cross-sectional data from National Cystic Fibrosis Patient Registry, 1993).

Fig. 2. Growth status in children with CF as indicated by frequency distributions of height-for-age and weight-for-age percentiles (A) and height-for-age and weight-for-age Z-scores (B) based on the growth reference curves developed by NCHS/CDC,\textsuperscript{15,16} and percent ideal weight-for-height (C) as recommended by the CFF Nutrition Consensus Report.\textsuperscript{14} The areas under the dashed line in (A) and (B) represent the expected distributions of height- and weight-for-age percentiles or Z-scores of the NCHS/CDC reference population. (Cross-sectional data from National Cystic Fibrosis Patient Registry, 1993).

Fig. 3. Occurrence of malnutrition by sex and age in children with CF. The percentage of patients with HAP < 5th percentile, WAP < 5th percentile and IWH < 85% as a function of age were estimated using generalized additive model methods with smooth splines having 7 degrees of freedom. (Cross-sectional data from National Cystic Fibrosis Patient Registry, 1993).
Table I. Classification and determination of malnutrition in children with CF (Cross-sectional data from the 1993 National Cystic Fibrosis Patient Registry)

<table>
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<th>Criterion II</th>
<th>Criterion III</th>
<th>Criterion IV</th>
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<td>HAP &lt; 5%, IWH ≥ 85%</td>
<td>HAM &lt; 90%, WHM ≥ 85%</td>
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<td>HAM &lt; 90%, WAM &lt; 80%</td>
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**Percent of patients with nutrition:**

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<th>&lt;1</th>
<th>1-10</th>
<th>11-18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stunted</td>
<td>0.5</td>
<td>1.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Wasted</td>
<td>26.0</td>
<td>8.0</td>
<td>25.8</td>
</tr>
<tr>
<td>Stunted &amp; wasted</td>
<td>15.7</td>
<td>3.9</td>
<td>11.5</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>42.2</td>
<td>13.7</td>
<td>38.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>&lt;1</th>
<th>1-10</th>
<th>11-18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stunted</td>
<td>27.2</td>
<td>17.7</td>
<td>21.1</td>
</tr>
<tr>
<td>Wasted</td>
<td>12.4</td>
<td>3.5</td>
<td>13.0</td>
</tr>
<tr>
<td>Stunted &amp; wasted</td>
<td>8.5</td>
<td>0.5</td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>48.0</td>
<td>21.7</td>
<td>38.0</td>
</tr>
</tbody>
</table>

$^1$HAP, height-for-age percentile; WAP, weight-for-age percentile; HAM, height-for-age percent of reference median; WAM, weight-for-age percent of reference median; IWH, percent ideal weight-for-height; WHM, weight-for-height percent of reference median. IWH is calculated according to the method described by Moore et al. (ref 13). All other height and weight indices were computed using the Epi Info program (ref 21) and based on the growth reference curves developed by NCHS/CDC (ref 15, 16).

$^2$ND, not determined because the majority of patients (89\%) had age and/or body size beyond the range of weight-for-height determinations provided by the NCHS/CDC references, i.e., WHM is not computed for males older than 11.5 years or taller than 145 cm and for females older than 10.0 years or taller than 137 cm (ref 16).
Table II. Occurrence of malnutrition at diagnosis of CF in children birth to 10 years of age

<table>
<thead>
<tr>
<th></th>
<th>1993 National CF Patient Registry (all patients)</th>
<th>1993 National CF Patient Registry (new diagnosis)</th>
<th>1985-94 Wisconsin (non-screened)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7892</td>
<td>790</td>
<td>67</td>
</tr>
<tr>
<td>Age (yr):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>5.04</td>
<td>1.41</td>
<td>1.19</td>
</tr>
<tr>
<td>median</td>
<td>5.16</td>
<td>0.50</td>
<td>0.34</td>
</tr>
<tr>
<td>Male (%)</td>
<td>52.8</td>
<td>52.2</td>
<td>53.7</td>
</tr>
<tr>
<td>MI* at birth (%)</td>
<td>22.7</td>
<td>19.0</td>
<td>26.9</td>
</tr>
</tbody>
</table>

% patients with malnutrition as defined by criteria I-IV:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Stunted</td>
<td>9.5</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>Wasted</td>
<td>4.6</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>Stunted and wasted</td>
<td>10.6</td>
<td>26.4</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>24.7</td>
<td>43.9</td>
</tr>
<tr>
<td>II</td>
<td>Stunted</td>
<td>1.7</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Wasted</td>
<td>10.0</td>
<td>22.9</td>
</tr>
<tr>
<td></td>
<td>Stunted and wasted</td>
<td>5.2</td>
<td>15.3</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>16.9</td>
<td>39.0</td>
</tr>
<tr>
<td>III</td>
<td>Stunted</td>
<td>18.7</td>
<td>27.1</td>
</tr>
<tr>
<td></td>
<td>Wasted</td>
<td>4.5</td>
<td>10.4</td>
</tr>
<tr>
<td></td>
<td>Stunted and wasted</td>
<td>1.4</td>
<td>7.2</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>24.6</td>
<td>44.7</td>
</tr>
<tr>
<td>IV</td>
<td>Stunted</td>
<td>6.2</td>
<td>13.7</td>
</tr>
<tr>
<td></td>
<td>Wasted</td>
<td>4.5</td>
<td>15.4</td>
</tr>
<tr>
<td></td>
<td>Stunted and wasted</td>
<td>0.7</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>11.4</td>
<td>31.5</td>
</tr>
</tbody>
</table>

(Continued on the next page)
(Table II continued)

1 All patients birth to 10 years of age (57% of all patients) maintained on the 1993 CF Patient Registry. Weight and height data represent the first available measurement during 1993. 5.0% or 399 patients had missing values for height or weight.

2 Patients birth to 10 years of age diagnosed in 1993. This population represents 96% of all new cases; 5.2% or 41 patients had missing values for height or weight.

3 Wisconsin CF Neonatal Screening Study (ref 26, 27). Non-screened patients were diagnosed at variable ages by standard method, e.g. symptoms or a family history of CF. Weight and height were measured during the month of CF diagnosis; 7 patients had missing values for height or weight.

4 Meconium ileus at birth.

5 See Table I for criteria to define malnutrition.