Comparison of the use of body mass index percentiles and percentage of ideal body weight to screen for malnutrition in children with cystic fibrosis

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ABSTRACT

Background: The Cystic Fibrosis Foundation (CFF) recommends using the percentage of ideal body weight (%IBW_CFF) and body mass index percentiles (BMIp) to assess weight-for-height status and to screen for malnutrition.

Objective: The objective was to examine the agreement and discrepancy between the use of %IBW_CFF and BMIp for screening malnutrition.

Design: Data from 13,021 children reported to the 2000 CFF Patient Registry were analyzed.

Results: In children of average stature (ie, height-for-age between the 25th and 75th percentiles) and aged <10 y, %IBW_CFF corresponded closely to BMIp, and the prevalence of underweight estimated by %IBW_CFF < 90% was similar to that by BMIp < 15th percentile. However, in children with short stature (ie, height-for-age < 25th percentile), %IBW_CFF underestimated the weight-for-height status than did BMIp, whereas the opposite trend was observed in children with tall stature (ie, height-for-age > 75th percentile). Such discrepancies averaged 8–12 percentage points when BMIp was reexpressed to the same unit and scale as %IBW_CFF. Consequently, the prevalence of underweight estimated by %IBW_CFF < 90% was significantly lower (7.3%) than that estimated by BMIp < 15th percentile (10.7%) in children with short stature, whereas the opposite trend was found in children with tall stature (3.5% and 14.4%, respectively). Additional analyses showed that BMIp was more sensitive to, and had stronger associations with, the percentage of predicted forced expiratory volume in 1 s.

Conclusion: Compared with BMIp, %IBW_CFF underestimated the severity of malnutrition in children with short stature and overestimated the severity of malnutrition in children with tall stature.


KEY WORDS Cystic fibrosis, malnutrition, anthropometry, growth, weight-for-height, percentage of ideal body weight, body mass index, lung function, children

INTRODUCTION

Assessment of the relative proportion of weight for height and its application in identifying the prevalence of underweight or overweight are widely used in both clinical and public health settings (1–8). One common approach for estimating the weight-for-height proportion is to express body weight as a percentage of an “ideal weight for that stature.” However, various methods are used to define ideal weight for a given stature, including the median weight-for-age (9), median weight-for-height (2), and median weight-for-height adjusted for age (4, 5). In a study by Wright et al (10), the number of children classified as malnourished and the degree of undernutrition were found to vary substantially when different weight-for-height indexes were used. Similar findings were reported in other studies (5, 11).

In children with cystic fibrosis (CF), the CF Foundation (CFF) Nutrition Consensus Committee (12) recommends the use of percentage of ideal body weight [%IBW_CFF; calculated by the Moore method (5)] to assess weight-for-height proportion, based on findings from observational studies linking percentage of IBW and prognosis (13–16). However, according to a study by Poutie et al (17), only 20% of the 44 CF centers in the United Kingdom routinely calculated %IBW_CFF at each clinic visit. The limited use of %IBW_CFF in routine clinical settings applicable to the CF population can be explained by several factors. First, calculation of %IBW_CFF requires several steps; hence, it is relatively time consuming. Second, accurate calculation of %IBW_CFF by hand is difficult because the ideal weight used in this method is generally determined by ways of visual estimation. As a result, large interindividual and intraindividual variation is common, making %IBW_CFF values unreliable (17). Third, no readily available clinical resource tracks %IBW_CFF over time, making longitudinal monitoring difficult.

With the availability of body mass index percentile (BMIp) charts as part of the new growth charts (18), the CFF Nutrition Consensus Committee also recommends using BMIp to assess weight-for-height proportion (12). In a study by Cole (6), BMI was shown to be superior to other weight-for-height indexes for controlling the effect of sex, height, and age on weight. In addition, the use of BMIp as a screening tool to identify both overweight and underweight in children was also validated recently (8).

In view of the abovementioned observations, we conducted the present study to examine the agreement and discrepancy.
between the use of %IBW_{CFF} and BMI_{p} for screening malnutrition and to determine whether %IBW_{CFF} or BMI_{p} has stronger association with lung disease indexes in children with CF.

SUBJECTS AND METHODS

Study population

The CFF Patient Registry documents the diagnosis and annual follow-up evaluations of patients with CF who are seen at accredited centers in the United States, as described in detail elsewhere. CFF Registry data reported in the year 2000 were used. Among the 22,303 patients documented in the registry, 13,280 were children aged 2–20 y. Children aged <2 y were excluded from the present study because BMI references are not available in the 2000 Centers for Disease Control and Prevention (CDC) growth charts (18). Of the 13,280 observations, 0.4% (n = 57 observations) had heights or weights less than zero and another 1.5% (202 observations) had height or weight or BMI measurements that deviated >4 SD from the reference mean. These height and weight values were likely outliers resulting from measurement or recording errors and were excluded. The remaining 13,021 children were included in the present study.

Computation of ideal body weight recommended by the Cystic Fibrosis Foundation

The steps involved in calculating %IBW_{CFF} by hand for an individual child with CF are as follows:

1) Obtain the child’s sex, age, height, and weight.
2) Plot the child’s height on the growth chart and determine his or her height-for-age percentile.
3) Determine the weight that corresponds to the same percentile ranking as the child’s height-for-age. (This is his or her ideal weight.)
4) Divide the actual weight of the child by his or her ideal weight and multiply that value by 100%.

These steps are illustrated in an example here and in Figure 1A. For example, a 10-y-old boy with a height of 147.0 cm and a weight of 30.0 kg would be in the 90th percentile for height-for-age. His ideal weight = 90th percentile value of weight at age 10 y = 42.0 kg and his %IBW_{CFF} = (actual weight/ideal weight) × 100% = (30/42) × 100% = 71.4%.

In the present study, %IBW_{CFF} calculations were performed in a computerized program in SAS (SAS Institute Inc, Cary, NC) by using the reference values downloaded from the CDC’s website for the new growth charts (Internet: http://www.cdc.gov/growthcharts).

Comparison between ideal body weight recommended by Cystic Fibrosis Foundation and body mass index percentile

Because %IBW_{CFF} and BMI_{p} are calculated by different methods and also expressed in different units (ie, percentage in %IBW_{CFF} and percentile in BMI_{p}) and scales (ie, 100% is optimal in %IBW_{CFF} and 50th percentile is optimal in BMI_{p}), direct comparison between the values of %IBW_{CFF} and BMI_{p} are difficult. There are 2 fundamental differences in the derivation of %IBW_{CFF} and BMI_{p}. First, the ideal weight for a given stature is defined differently, as shown in Figure 1 and Figure 2. In %IBW_{CFF}, the ideal weight for a given stature is assumed to be the weight value that corresponds to the same percentile ranking as the child’s height-for-age (eg, ideal weight corresponding to 42.0 kg in the example illustrated in Figure 1A). In other words, the child with an ideal weight for his or her stature should have height-for-age and weight-for-age at exactly the same percentile ranking. In BMI_{p}, the ideal weight for a given stature is assumed to be the weight value that corresponds to the 50th percentile of BMI at that age (eg, ideal BMI corresponding to 16.6 in the example illustrated in Figure 1B, which is equivalent to assigning ideal weight to be 16.6 × 1.47 = 35.9 kg). Second, deviation from the actual status to the ideal status is expressed differently. In %IBW_{CFF}, this deviation is expressed as a percentage relative to the ideal value, whereas in BMI_{p}, this deviation is expressed in percentile ranking.

To facilitate the numerical comparisons between %IBW_{CFF} and BMI_{p}, we reexpressed BMI_{p} into the percentage unit with 100% being optimal. For instance, in the example illustrated in Figure 1, a 10-y-old boy with height of 147.0 cm and weight of 30.0 kg has a %IBW_{CFF} of 71.4% and a BMI_{p} at the 3rd percentile. To reexpress his BMI_{p}, his absolute BMI is divided by the median value of BMI at his age obtained from CDC’s BMI chart, ie, 13.9/16.6 × 100 = 83.7%. This calculation is equivalent to dividing his actual weight by the ideal weight derived from the BMI_{p} method, ie, 30/35.9 = 83.6%. Therefore, the reexpressed BMI_{p} is referred to as %IBW_{BMI_{p}}, as shown in Figure 3 and throughout this report.

Criteria of malnutrition by ideal body weight recommended by Cystic Fibrosis Foundation and body mass index percentile

The criterion of %IBW_{CFF} < 90% recommended by CFF Pediatric Nutrition Consensus Report (12) was used to identify malnutrition. Alternatively, BMI_{p} < 15th percentile was chosen as an equivalent indicator for malnutrition and compared with %IBW_{CFF} < 90%. The cutoff value of 15th percentile for BMI_{p} was chosen on the basis of the study by Waterlow et al (2) that 10% below the median corresponded approximately to 1 SD below the median, which translated to approximately the 15th percentile in normalized distribution. In addition, we found that among children with average stature in which the ideal weights obtained from the BMI_{p} and the %IBW_{CFF} methods were similar, 15th percentile BMI_{p} corresponded more closely to 90% IBW_{CFF} than 10th percentile BMI_{p} at most ages. This similarity is clearly demonstrated in the middle 2 panels of Figure 4, in which the percentages of patients with BMI_{p} < 15th percentile (ie, the black dotted lines) are closer to those with %IBW_{CFF} < 90% (ie, the black solid lines) than those with BMI_{p} < 10th percentile (ie, the gray lines) at most ages.
FIGURE 1. An example illustrating the calculations of ideal body weight recommended by the Cystic Fibrosis Foundation (%IBW_{CFF}) (A) and body mass index percentiles (BMIp) (B). To calculate %IBW_{CFF}, plot the child’s actual height (ie, 147 cm) on the height-for-age growth chart from the Center for Disease Control and Prevention (CDC), estimate his height-for-age percentile (ie, 90th percentile), estimate his ideal weight by using the weight value corresponding to the 90th percentile point (ie, 42.0 kg), then divide his actual weight by the ideal weight and multiply by 100% (ie, 71.4%). To estimate BMIp, calculate the child’s BMI (ie, 13.9), plot his BMI on CDC’s BMI-for-age growth chart, then estimate the percentile ranking (ie, 3rd percentile).
Association of ideal body weight recommended by Cystic Fibrosis Foundation and body mass index percentile with lung disease status

The lung function indicator forced expiratory volume in 1 s (FEV₁) was used to assess whether %IBW_{CF} or BMIp has stronger association with lung disease status in children with CF. FEV₁ was expressed as a percentage of predicted values according to the Dockery equations [found in Wang et al (19)]. For this analysis, only patients who were aged >6 y and had lung function measurements were included (n = 9,770).

Statistical analysis

SAS (version 8.2) and R (Internet: http://www.r-project.org) statistical software programs were used to perform statistical analyses. All statistical analyses were performed separately for each sex or stratified by sex because of the well-documented sex gap in growth status and clinical outcomes between male and female patients with CF (15, 20, 21).

Paired t test was conducted to test the difference between the ideal weights calculated by the %IBW_{CF} and the BMIp methods. Comparisons among categorical outcomes were assessed by chi-square contingency table methods. Agreement between the 2 criteria in identifying children with malnutrition, as presented in Figure 5, was assessed by the κ statistic (22). A κ < 0.4 was considered to be in poor agreement according to Landis and Koch (23). A locally weighted scatter plot smoother (the LOESS function in R) was used to estimate trends in relation to age in Figures 2–4.

For the analyses comparing the relative strengths of associations between %IBW_{CF} and BMIp and lung disease outcomes presented in Figure 6, multiple regression analyses (by using the PROC GLM procedure in SAS) were performed by using the following model: percentage of predicted FEV₁ = β₀ + β₁(%IBW_{CF} or BMIp) + β₂(age in y). The scales and units of %IBW_{CF} and BMIp were adjusted such that β₀ represents the estimated value of percentage of predicted FEV₁ at optimal nutritional status (ie, %IBW_{CF} = 100% or BMIp = 50th percentile) and β₁ represents the estimated change of percentage of predicted FEV₁ for every unit change in the nutritional index (ie, a 10% change in %IBW_{CF} or a 1 SD change in BMIp). More specifically, for %IBW_{CF}, the model percentage of predicted FEV₁ = β₀ + β₁[(%IBW_{CF} − 100)/10] + β₂(age in y) was fitted; thus, β₀ represents the estimated value of percentage of predicted FEV₁ when %IBW_{CF} is at 100% and β₁ represents the estimated change of percentage of predicted FEV₁ for every 10% change in %IBW_{CF}. For BMIp, the model percentage of predicted FEV₁ = β₀ + β₁(BMIp reexpressed as Z score) + β₂(age in y) was fitted. It should be noted that BMIp and BMI Z score are
mathematically interchangeable on the basis of the properties of normal distribution, e.g., BMIp of 15th, 50th, and 85th percentiles are equivalent to BMI Z scores of \(-1, 0, \) and 1, respectively. Therefore in this model, \( \beta_0 \) represents the estimated value of percentage of predicted FEV\(_1\) when BMI Z score is 0 (equivalent to BMIp of 50th percentile) and \( \beta_1 \) represents the estimated change of percentage of predicted FEV\(_1\) for every 1 SD change in BMIp. Age was included as a continuous covariate in all models to adjust for its influence on percentage of predicted FEV\(_1\).

RESULTS

Comparison between ideal body weight recommended by the Cystic Fibrosis Foundation and body mass index percentile

Initial analyses were performed to compare whether the ideal weight for a given stature obtained by the \%IBW\(_{\text{CFF}}\) was similar to that obtained by the BMIp method. Because the ideal weight for a given stature depends on sex, age, and stature, results from these analyses are presented by sex, age, and stature. As shown in Figure 2, in children with CF of average stature (i.e., height-for-age between the 25th and 75th percentiles), the ideal weights obtained by the \%IBW\(_{\text{CFF}}\) method were nearly identical to those obtained by the BMIp method up to age 12 y. However, in children with CF of short stature (i.e., height-for-age < 25th percentile), the ideal weights obtained by the \%IBW\(_{\text{CFF}}\) method were significantly lower than those obtained by the BMIp method \((P < 0.0001)\). In contrast, in children with CF of tall stature (i.e., height-for-age > 75th percentile), the ideal weights obtained by the \%IBW\(_{\text{CFF}}\) method were significantly higher than those obtained by the BMIp method \((P < 0.0001)\). The discrepancy in the value of ideal weight between the \%IBW\(_{\text{CFF}}\) and the BMIp methods increases with age and increases as the children’s stature deviates from the 50th percentile point. In addition, this discrepancy was significantly greater in girls than in boys \((P < 0.0001)\).

As a result of the aforementioned discrepancy in ideal weight, the relative percentage of actual weight to ideal weight also differed between the \%IBW\(_{\text{CFF}}\) and BMIp methods. This difference is clearly demonstrated in Figure 3. In children with CF of average stature, \%IBW\(_{\text{CFF}}\) and \%IBW\(_{\text{BMIp}}\) patterns were similar at all ages, although such small differences remained statistically significant \((P < 0.0001)\). However, in children with CF of short stature, \%IBW\(_{\text{CFF}}\) was substantially lower than \%IBW\(_{\text{BMIp}}\) at all ages by an average of 8.1 percentage points \((P < 0.0001)\). This finding implies that, in children with shorter than average stature, nutritional status would always appear better when \%IBW\(_{\text{CFF}}\) is used than when \%IBW\(_{\text{BMIp}}\) is used. In contrast, in children with CF of tall stature, \%IBW\(_{\text{CFF}}\) was substantially lower than
%IBW_{BMIp} at all ages by an average of 11.9 percentage points ($P < 0.0001$). This finding implies that, in children with taller than average stature, nutritional status would always appear worse when %IBW_{CFF} is used than when %IBW_{BMIp} is used.

Further comparison between %IBW_{BMIp} and BMIp reveals the difference between using the percentage unit compared with the percentile unit to quantify the deviation from actual to ideal weights. In Figure 3, the plotting range of 90–110% in the percentage unit is equivalent to the range of the 15th–85th percentile in the percentile unit, as described in Subjects and Methods. This relation was verified by the nearly overlapping lines of %IBW_{BMIp} and BMIp up to age 10 y in children with average stature and up to age 5–10 y in children with short or tall stature (Figure 3). However, in children aged >10 y, discrepancy between %IBW_{BMIp} and BMIp was apparent and was particularly noticeable in children with short stature. This observation indicates that, in children aged >10 y, the relation of 10% below the median corresponding approximately to 1 SD below the median no longer holds.

Prevalence of malnutrition as indicated by ideal body weight recommended by the Cystic Fibrosis Foundation (%IBW_{CFF} < 90%) or body mass index percentile (BMIp < 15th percentile) is shown in Figure 4. In children with CF of average stature, the prevalence of malnutrition estimated by %IBW_{CFF} < 90% was similar to that estimated by BMIp < 15th percentile method at all ages ($P = 0.34$). However, in children with CF of short stature, the prevalence of malnutrition identified by %IBW_{CFF} < 90% was significantly lower at all ages by an average of 10 percentage points compared with that identified by BMIp < 15th percentile ($P < 0.0001$). The opposite trend, and greater differences (with an average of 33 percentage points), was observed in children with CF with tall stature ($P < 0.0001$). To summarize, the prevalence of underweight estimated by %IBW_{CFF} < 90% was significantly lower (ie, 7.3%) than that estimated by BMIp < 15th percentile (ie, 25.7%) in children with short stature, whereas the opposite trend was found in children with tall stature (47.7% with %IBW_{CFF} < 90% and 14.4% with BMIp < 15th percentile).
The agreement between using %IBW CFF < 90% and BMIp < 15th percentile for identifying malnutrition was further assessed by the \( \kappa \) statistics. In children with average stature, >90% of children were consistently classified by both criteria, and \( \kappa \) statistics indicated good agreement (Figure 5). However, large discrepancy between using %IBW CFF < 90% and BMIp < 15th percentile for identifying malnutrition was found when the children’s stature deviated from the median.

Association of ideal body weight recommended by the Cystic Fibrosis Foundation and body mass index percentile to percentage of forced expiratory volume in 1 s

As shown in Figure 6, in children with CF of average stature, the values of \( \beta_0 \) were similar between the %IBW CFF model and the BMIp model for both sexes. However, the BMIp model had a significantly larger \( \beta_1 \) (slope) than the %IBW CFF model, \( P < 0.0001 \). This observation indicated that BMIp was more sensitive to changes in percentage of predicted FEV\(_1\) than %IBW CFF. The BMIp model also had larger \( R^2 \) than the %IBW CFF model, indicating that BMIp had stronger association to percentage of predicted FEV\(_1\) than %IBW CFF.

In children with short or tall stature, differences in the values of \( \beta_0 \) were noted. Specifically, in children with short stature, the %IBW CFF model had smaller \( \beta_0 \) than the BMIp model, whereas the opposite trend was observed in children with tall stature. Nevertheless, both \( \beta_1 \) and \( R^2 \) were consistently larger in the BMIp models than the %IBW CFF models, indicating that BMIp had stronger associations to percentage of predicted FEV\(_1\) than %IBW CFF.
%IBW\textsubscript{CFF}. Finally, it should be commented on that \(\kappa\) statistics showed that the agreement between %IBW\textsubscript{CFF} \(< 90\%\) and BMI\textsubscript{p} \(< 15\%\) percentile as criterion for malnutrition was similar between children aged \(< 6\) y (who did not have lung function data) and children aged \(\geq 6\) y (who had lung function data) in children with short or average stature. In children with tall stature, the agreement between these 2 indicators was better in children aged \(< 6\) y compared with children aged \(\geq 6\) y.

DISCUSSION

In this report, we presented comprehensive analyses to compare 2 weight-for-height indexes that are commonly recommended for screening malnutrition in children with CF. Our results demonstrated a good agreement between these 2 indexes, namely, %IBW\textsubscript{CFF} and BMI\textsubscript{p}, among prepubertal children (ie, aged \(< 10\) y) who had average stature (ie, height-for-age between the 25th and 75th percentiles). However, in older children and children with shorter or taller than average stature, significant discrepancy was found between %IBW\textsubscript{CFF} and BMI\textsubscript{p}. Specifically, when compared with BMI\textsubscript{p}, %IBW\textsubscript{CFF} underestimates the severity of malnutrition in children with short stature and overestimates the severity of malnutrition in children with tall stature. This discrepancy increases with age and also increases as the children’s stature deviates from the median value.

The discrepancy between %IBW\textsubscript{CFF} and BMI\textsubscript{p} as a malnutrition index is primarily due to their differences in defining the ideal weight for a given age and stature. As described previously, in the %IBW\textsubscript{CFF} method, the ideal weight for a given age and
stature is assumed to be the weight value that corresponds to the same percentile ranking as the child’s height-for-age (5). This assumption can be valid in children with average stature, as evidenced by the observation from the reference population of CDC’s growth charts (18) that children with both height and weight at the 50th percentile values have weight-for-height or BMI or both values that fall around the 50th percentile during prepubertal period. However, the same assumption is likely not valid in children with short or tall stature, because the amount of weight gain per increment of height gain, and vice versa, is not constant as the stature deviates from the median. This is evidenced by the observation from the reference population of CDC’s growth charts (18) that children with both height and weight values at the 90th percentiles have weight-for-height or BMI or both values that fall substantially greater than the 50th percentile point (ie, around the 80th percentile). However, children with both height and weight values at the 10th percentile have weight-for-height or BMI or both values that fall substantially lower than the 50th percentile point (ie, around the 25th percentile). These observations explain why ideal weights calculated by the %IBW\textsubscript{CFF} method are substantially greater than those calculated by the BMI\textsubscript{p} method in children with tall stature, whereas the opposite results are obtained in children with short stature. Alternatively, in the BMI\textsubscript{p} method, the ideal weight for a given age and stature is assumed to be the weight value that corresponds to the median BMI at that age. Although the validity of this approach to estimate ideal weight remains to be proven, the ideal weight estimated by this method is directly derived from several observed reference populations representative of the US population (18).

In addition to differences in defining ideal weights, differences in expressing the deviation from the actual to the ideal stature also contributed to the discrepancy between %IBW\textsubscript{CFF} and BMI\textsubscript{p} in identifying malnutrition. In the %IBW\textsubscript{CFF} method, the deviation is expressed as a percentage relative to the ideal value. This method of standardizing measurements to reference values has a major drawback in that a given percentage of reference does not correspond to the same SD score across age (2, 24). Furthermore, the original intent of percentage of reference categories was to approximate decrements in SD scores (2). Therefore, classification based on SD score is preferable. In the BMI\textsubscript{p} method, deviation from the actual to the ideal stature is expressed in the percentile system, which is mathematically interchangeable with the SD score system when the reference curves were normalized, as in the case of CDC’s growth charts (18). Therefore, the percentile or the SD score system is preferable to the percentage of reference system in expressing the deviation between the actual and the ideal stature.

Besides the aforementioned considerations about the definition of ideal weights and the statistical properties of the indexes, our finding that BMI\textsubscript{p} is more sensitive to, and has a stronger association with, the lung function parameter percentage of predicted FEV\textsubscript{1} in the subgroup of children with CF aged >6 y provide further evidence to support the use of BMI\textsubscript{p} in favor of %IBW\textsubscript{CFF} as a screening tool for malnutrition in children with CF. However, it should be noted that, despite BMI\textsubscript{p} < 15th percentile was used to compare with %IBW\textsubscript{CFF} < 90% in the present study, it does not imply that the 15th rather than the 10th percentile (as recommended by the CFF Pediatric Nutrition Consensus Report (12)) should be used to define nutrition failure. As explained in “Subjects and Methods,” the rationale for using BMI < 15th percentile to compare with %IBW < 90% was primarily because, among children with average stature in which the ideal weights obtained from the BMI\textsubscript{p} and the %IBW\textsubscript{CFF} methods were similar, the 15th percentile BMI\textsubscript{p} corresponded more closely to 90% of %IBW\textsubscript{CFF} than the 10th percentile BMI\textsubscript{p}. However, to define nutrition failure by using the BMI\textsubscript{p} index, one should choose the cutoff based on its relation to functional outcomes and not based on how close it corresponds to 90% of %IBW\textsubscript{CFF}. One potential functional outcome that might be considered is how BMI\textsubscript{p} influences lung function in children with CF. Although previous observational studies reported that BMI was correlated to percentage of predicted FEV\textsubscript{1} (25), quantitative relations were not clearly defined. Our cross-sectional regression analyses between BMI\textsubscript{p} and percentage of predicted FEV\textsubscript{1} enabled us to identify potential BMI\textsubscript{p} cutoffs to define nutrition failure that would be expected to affect lung function. For example, what BMI\textsubscript{p} is needed to maintain percentage of FEV\textsubscript{1} > 80%, which is a value indicative of mild lung disease? The basis of our results, for children with CF aged 7 y, a BMI\textsubscript{p} of 6th percentile for boys and 9th percentile for girls is needed to maintain percentage of FEV\textsubscript{1} > 80%. Higher BMI\textsubscript{p} cutoffs were found for older children because percentage of FEV\textsubscript{1} worsens with age (eg, BMI\textsubscript{p} > 28th and BMI\textsubscript{p} > 43rd percentiles for 15-y-old boys and girls, respectively) and among children with shorter than average stature. Because no single BMI cutoff value can be applied to all children with CF but the lowest cutoff from our results is close to the 10th percentile value, BMI < 10th percentile appears to be a justifiable indicator for defining nutrition failure that is likely to influence lung function in children with CF.

From a practical standpoint, the readily available BMI\textsubscript{p} charts from the new CDC growth charts offer an additional advantage for screening malnutrition in routine clinical settings. Furthermore, BMI is the one most commonly recommended and widely used anthropometric index for screening overweight and underweight in the adult population. This enables continuous monitoring of nutritional status more easily when transitioning from pediatric into adult care. However, calculation of %IBW\textsubscript{CFF} by hand is time consuming, prone to estimation errors, and difficult for longitudinal tracking.

In summary, findings from the present study led us to conclude that, among children with average stature (ie, height between the 25th and 75th percentiles), %IBW\textsubscript{CFF} and BMI\textsubscript{p} yields similar estimates of ideal weights and good agreement in classifying malnutrition. However, among children with short stature (ie, height < 25th percentile), %IBW\textsubscript{CFF} underestimates the severity of malnutrition when compared with BMI\textsubscript{p}. Among children with tall stature (ie, height > 75th percentile), %IBW\textsubscript{CFF} overestimates the severity of malnutrition when compared with BMI\textsubscript{p}. Considering the practical advantages of BMI\textsubscript{p}, ie, ease of calculation and readily available BMI charts for longitudinal monitoring, we recommend using BMI\textsubscript{p} rather than %IBW\textsubscript{CFF} to assess weight-for-height status. Nevertheless, it should be emphasized that the optimal use of the BMI\textsubscript{p} chart in a child with CF is to determine whether his or her weight is in an appropriate range for his or her stature, and that BMI\textsubscript{p} should not be used as the single indicator for screening malnutrition but used in combination with height-for-age percentile and other biochemical and clinical indexes to screen for malnutrition in children with CF.
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