

# Z-Score Anthropometric Indicators Derived from NCHS-1977, CDC-2000 and WHO-2006 in Children Under 5 Years in Central Area of Peru

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**Abstract** Objectives. To Identify and analyze the distribution of Z-scores of anthropometric indices of children between 36-60 months of age in the province of Huancayo, Peru, which were calculated based on the NCHS-1977, CDC-2000 and WHO-2006 references. Methods. We analyzed a database of 2640 children (1268 males and 1372 females) collected between 1992-2007. The Z-scores were determined using the Anthro V.3.0 and the EpiInfo 6.04. The data were divided into four chronological periods: First, 1992 with 532 data; Second, from 1993 to 1997 with 370 data; Third. From 1998 to 2002 with 494 data, and Fourth from 2003 to 2007 with 1244 data. Results. The weight-for-age, height-for-age, weight-for-height and body mass index Z-scores were different for each assessment standard. The mean±SD of the weight-for-age, height-for-age, weight-for-height and BMI Z-scores with NCHS were -0.85±0.88, -1.29±1.07, -0.04±0.84 and 0.05±1.05 respectively, with CDC the values were -0.79±0.95, -1.08±1.05, -0.12±1.00 and 0.05±0.91 and with WHO the values were -0.75±0.84, -1.40 ±1.02, 0.15±0.91 and 0.21±0.91, correspondingly. With the new WHO standard it was obtained lower Z-scores of height-for-age than with NCHS, being the farthest curve from the median. The new WHO standard would be the most accurate and realistic standard used to determine the Z-scores, because was determined in a multicentric study to world level, and it should be officially adopted for the nutritional assessment in children under 5 years.

**Keywords** Z-score, Stunting, Anthropometric Index, NCHS Standard, WHO Child Growth Standards, Central Highlands of Peru

## 1. Introduction

The simplest method to assess the nutritional status of an individual or a population is the anthropometric assessment [1] by means of calculating indices based on height, weight,

sex and exact age of the assessed individuals [2], being the weight-for-height, height-for-age, weight-for-age [3,4,5,6] and body mass index ( $\text{weight}/\text{height}^2$ ) the most used in children, which can be compared to the internationally recognized standards, as NCHS-1977 [3], CDC-2000 [8], and WHO-2006 [7,9,10,11,12]; which are different from their mean and standard deviations and resulting in different Z-scores for the same individual [13]. The NCHS and CDC standards corresponded to different population, sampling and care conditions and feeding practices, and methodological procedures [7,13,14,15]. The WHO, with the purpose to correct these deficiencies and through a multicenter study in 8500 children of different ethnic origins and from different cultural backgrounds (Brazil, Ghana, India, Norway, Oman and United States), and considering favorable socio-economic conditions to carry it out, created the new and globally valid WHO-2006 standard [7,16,17], which is being adopted in different countries and altitudinal zones.

The Z-score is widely known as the best system to analyze and present the anthropometric data, compared to other methods [14], such as percentiles or percentage of the median [5].

The Z-scores are a transformation of a normal distribution values in order to analyze its distance in relation to the mean and to express them in standard deviation units. It shows the direction and the standard deviations in which an individual value moves further from the mean. The formula used in the transformation is:  $Z = (X - \mu) / \sigma$ , where X is the observed value to transform,  $\mu$  is the mean/average of the reference population and  $\sigma$  is the standard deviation of the reference population. From the nutritional point of view the result shows the number of the standard deviations in which the individual moves away from the average population [3,18,19,20]. For population-based applications, a major advantage is that a group of Z-scores can be subjected to summary statistics such as the mean and standard deviation in order to classify the population growth rate [14]. The registered data of children all over the world show a large

homogeneity in the standard deviation of anthropometric indices, expressed as Z-score, and getting close to the unit [21], which shows that all distributions shift (Figure 1), being more appropriate to make a comparison of the total population distribution instead of considering only the prevalence below certain limit or cut-off values [22]. The Z-score shows numerically how much the data move away from normal values and it also monitors their evolution in a more accurate way [23].

**Figure 1.** Distribution of the corresponding height-for-age and weight-for-age Z-scores of chinese children, compared to the international reference data of NCHS/WHO [24].

The average Z-score has the advantage of directly describing the nutritional status of the population without having the need to turn to a subgroup of individuals below a cut-off. An average Z-score significantly lower than zero usually means that the whole distribution has shifted downward, suggesting that most or all people have been affected. Using the average Z-score as an index of severity of health and nutrition problems and results in greater awareness that, if a condition is severe, an intervention is required in the entire community, not just in children classified as "malnourished" by the cut-off criterion (25, 26).

In this research, weight-for-height, height-for-age, weight-for-age and body mass index are understood using the Z-score classification system based on the NCHS, CDC, WHO standards.

## 2. Materials and Methods

### 2.1. Population and Sampling

The study was performed in 25 of 28 districts of Huancayo province, Junín region of Peru, located between 3250-3500 MASL. The children who were assessed are 36-60 months old, born and living in the districts of study. The sample consisted of 2640 children who met the inclusion criteria: mothers who voluntarily agreed to have their children anthropometrically, assessed, children with no chronic diseases and who have no history of low birth weight or prematurity. Exclusion criteria were: children with no complete measurements, children that do not accredit date of birth and children over 60 months of age. The overall sample was divided into four chronological periods to establish trends over time: 1. Basal measurement (1992) with 532 data(20.2%);2. 1993-1997, with 370 data (14%); 3. 1998-2002, with 494 data (18.7%), and 4. 2003-2007, with 1244 data (47.1%).

### 2.2. Study Design

Benchmarking was considered for the Z-scores of weight-for-age, height-for-age, weight-for-height and body mass index (BMI), established in NCHS-1977, CDC-2000 and WHO-2006. Movement of population curves of each indicator were analyzed in respect to the references used.

### 2.3. Anthropometric Assessment

We followed the recommendations of the WHO [3,14,15]. Weight was measured using digital scales Unicef, brand SECA ( $\pm 100$ g accuracy) and height in standardized infantometers ( $\pm 1$ mm accuracy). Z- scores of weight-for-age (WAZ), height-for-age (HAZ), weight-for-height (WHZ) and body mass index (BMIZ) were determined in the EpiInfo 6.04d [27] and Anthro V.3.0 [15,28]. The date of birth was verified in the birth certificates or cards growth.

### 2.4. Data Analysis and Preparation

Z-scores were statistically analyzed using the SPSS V15, Minitab V.15 and Excel, generating summary tables of measures of central tendency and dispersion, and also Z-scores variation graphs for each benchmark used.

### 2.5. Ethical Considerations

We informed mothers about the objective of the study, its benefits and the absence of any risk associated with the participation of their children. After the assessment was made, we informed the mothers about the nutritional status of their children and they were given recommendations to improve the nutritional status of their families. The list of the children suffering from stunting was delivered to the Health Center to take the necessary provisions.

## 3. Results

### 3.1. Average of Weight/Age, Height/Age, Weight/Height and BMI Z-Scores of Children in the Central Highlands, with the NCHS-1977, CDC-2000 and WHO-2006 References He Z-Score

The average Z-score of weight-for-age, with the CDC reference averaged intermediate between those determined by NHCS and WHO references, determining the lowest average with NCHS.

**Table 1.** Measures of central tendency and dispersion of the Z-scores of weight-for-age (n = 2640)

Z-score	Min	Max	Avg	SD
Z W/A NCHS-1977	-3.06	2.40	-0.85	0.88
Z W/A CDC-2000	-4.00	2.08	-0.79	0.95
Z W/A WHO-2006	-3.19	2.14	-0.76	0.84
Z H/A NCHS-1977	-4.48	1.64	-1.29	1.07
Z HA CDC-2000	-4.16	1.75	-1.08	1.05
Z H/A WHO-2006	-4.94	1.51	-1.40	1.02
Z W/H NCHS-1977	-2.42	2.87	-0.04	0.84
Z W/H CDC-2000	-3.86	2.72	-0.12	1.00
Z W/H WHO-2006	-2.68	3.02	0.15	0.91
Z BMI NCHS-1977	-4.04	3.12	0.05	1.05
Z BMI CDC-2000	-4.04	3.12	0.05	1.05
Z BMI WHO-2006	-2.76	3.49	0.21	0.91

In the case of the Z-score of height-for-age, the average of the sample was closer to the median of the CDC, and was farthest from the median of the new WHO standard. With respect to the Z-scores of weight-for-height, the average was positive with the WHO standard, whereas with CDC and NCHS averages were negative. With regard to the BMI Z-score, it appears that with the new WHO standard average, the value is further from the median; while the other two are close to zero (Table 1, Figure 2).

### 3.2. Distribution of Weight/Age, Height/Age, Weight/Height and BMI Z-Scores of Children in the Central Highlands, Compared to the International Reference Data of NCHS and WHO

For weight-for-age Z-score, the average with NCHS was lower (-0.85) than with WHO (-0.75). With WHO we would have more accurate information and it should be used to monitor and evaluate the trend of malnutrition in different regions of the country (Figure 3).

For height-for- age, the average Z-score with NCHS was

closer to the standard median (-1.29) than with WHO (-1.40), reflecting that the stunting assessment has not been adequately determined with NCHS, and the apparent increase in the stunting prevalence is due to the fact that WHO refers to a more real mean and standard deviation, from the multicenter study (Figure 4).

For weight-for-height Z-score average with NCHS was negative (-0.04), whereas the average WHO was positive (0.15) (Figure 5). For weight-for-height Z-score average with NCHS was negative (-0.04), whereas the average WHO was positive (0.15) (Figure 5).

For BMI, the average Z-score with NCHS (0.05) was lower than with WHO (0.21) (Figure 6).

### 3.3. Distribution of Weight/Height, Height/Age, Weight/Age and BMI Z-Scores of Children in the Central Highlands, for Assessment Period with NCHS and WHO Standards

The following bar charts show the average Z scores in the 4 assessment periods (Cluster: 1. Basal-1992, 2. 1993-1997, 3. 4 1998-2002. 2003-2007. Average Z-score of weight/height, with NCHS, in 3 of the 4 periods evaluated were negative, while all were positive with WHO (Figure 7). The Z-scores of height/age were lower than WHO, with NCHS (Figure 8). The Z-scores of weight/age were slightly lower than with WHO, with NCHS (Figure 9). In the case of the Z-scores for the BMI, they were lower with NCHS than with WHO (Figure 10).

## 4. Discussion

Considering that one of the main advantages of Z-scores is that it can be subjected to summary statistics such as the mean and standard deviation [14] and that the average Z-score describes the nutritional status of the entire population [22], this study shows that in the case of weight/age average Z-scores the best value is obtained with WHO (-0.75), with the curve closer to the median of the WHO standard, while with NCHS the average population assessed moves further from that standard median (-0.85).

A different result is shown in the case of the height/age Z-score, where with the WHO standard the average Z-scores of children in the central highlands (-1.40) moves further from the WHO median and is closer to the NCHS median (-1.29). In the case of weight/height Z-score, the mean of the assessed child population moves further from the WHO median (0.15) and moves closer to the NCHS (-0.04), however it is important to note that with WHO standard, the average is positive, while with NCHS, it is negative.

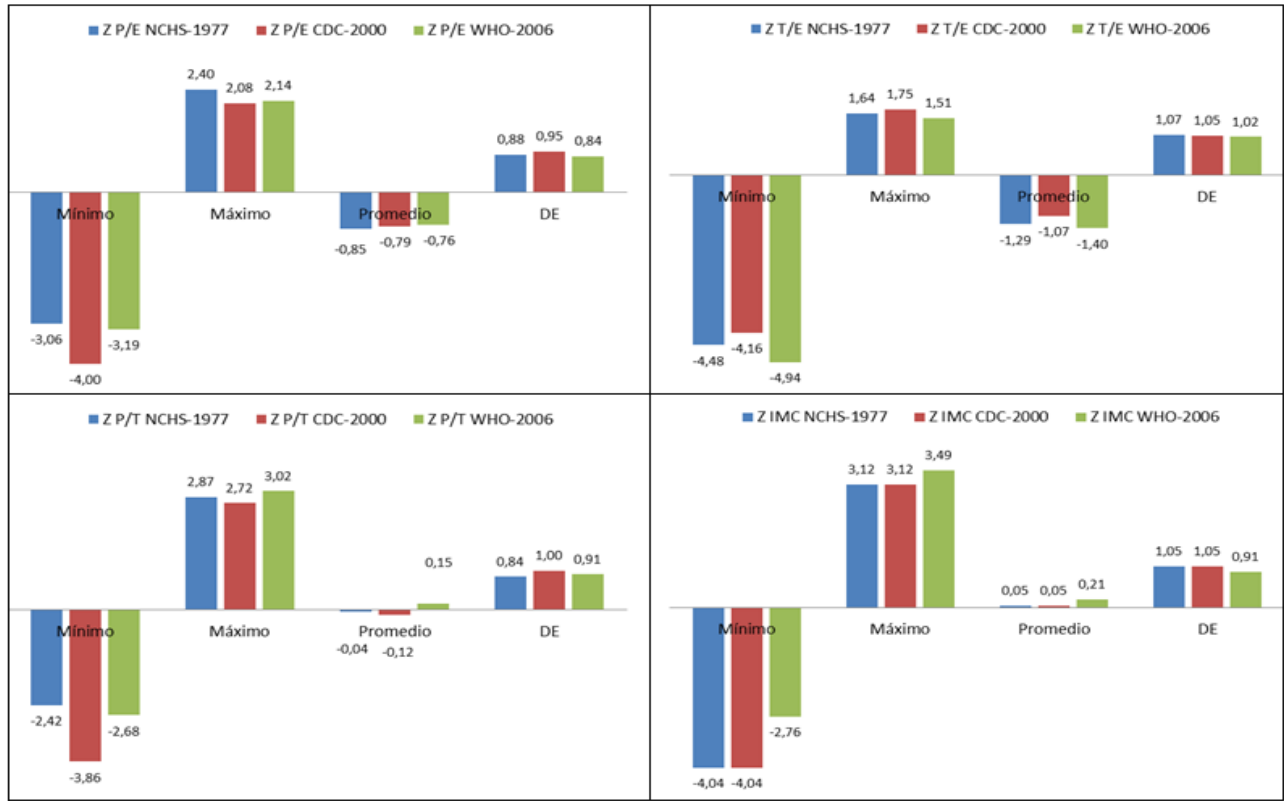


Figure 2. Minimum, maximum, average and standard deviation of weight/age, height/age, weight/height, and BMI Z-scores by standard evaluation.

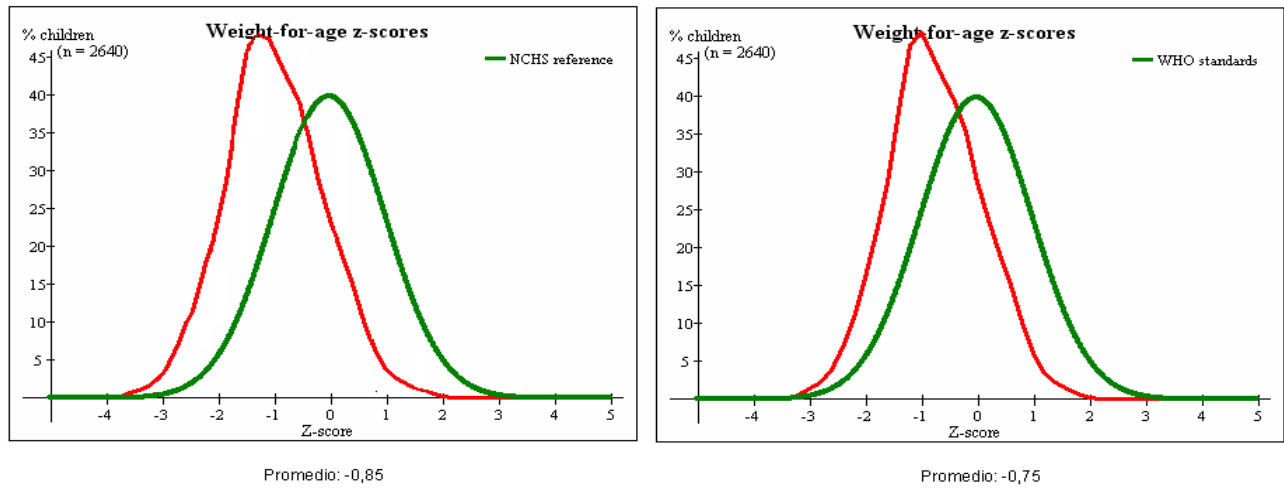
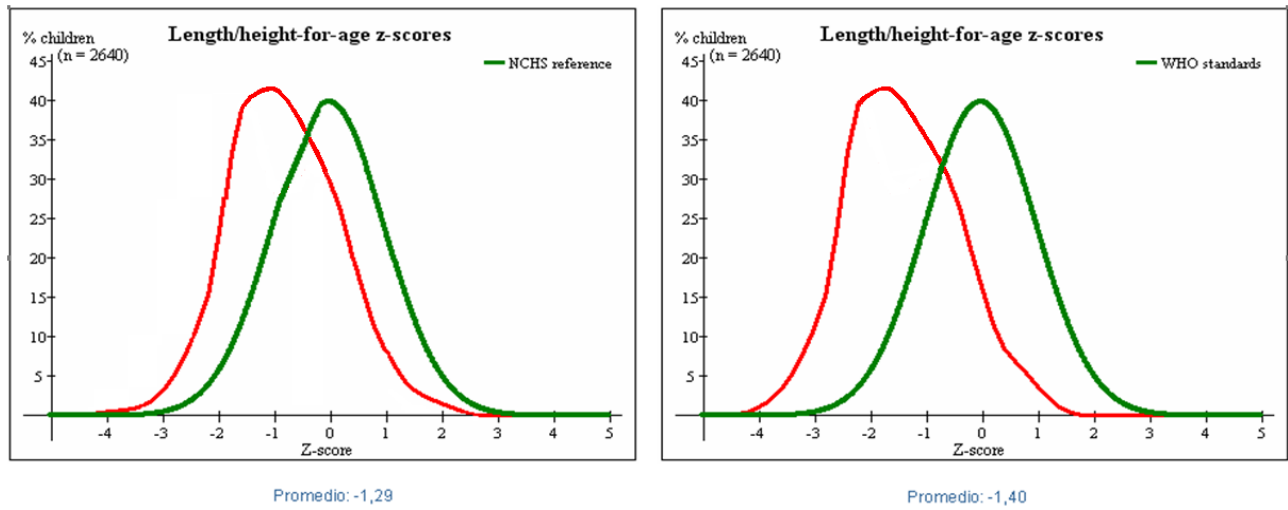
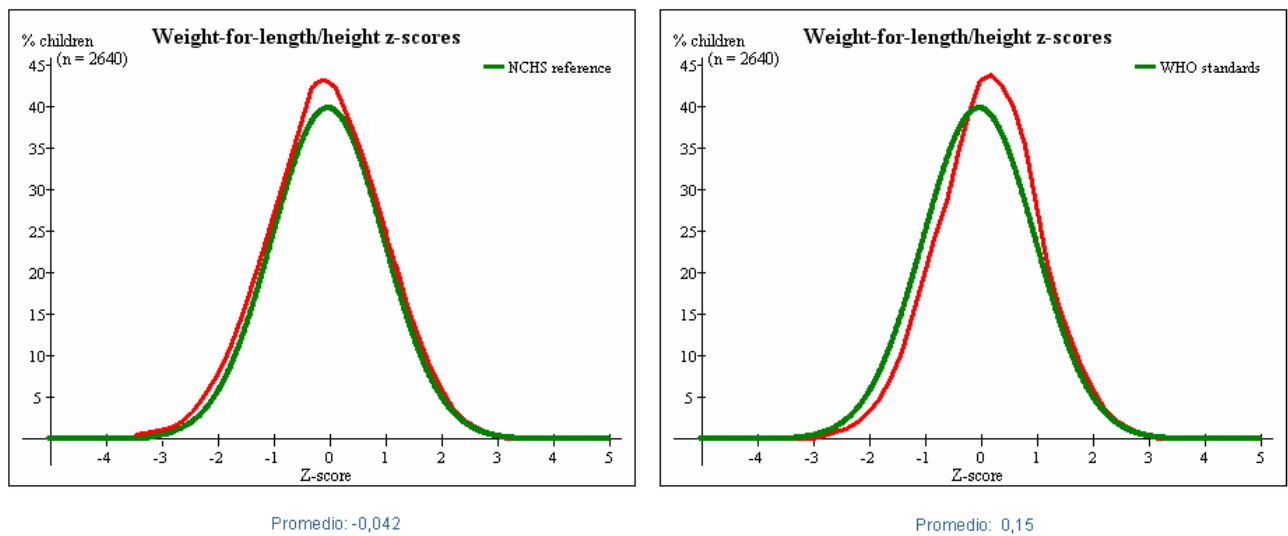


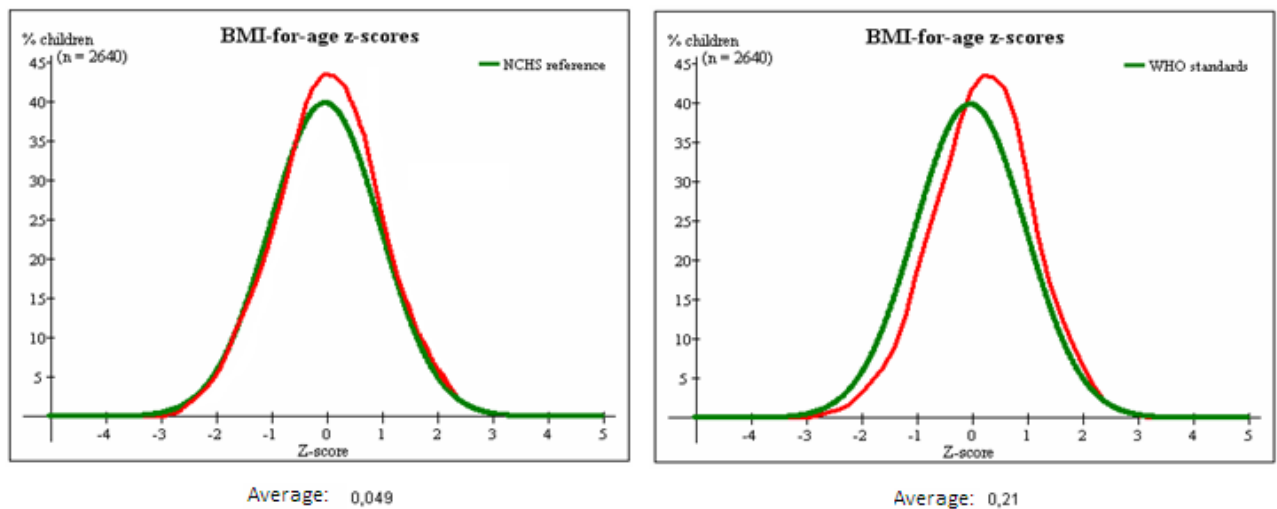
Figure 3. Distribution of the weight/age Z-score of children in the central highlands compared to international reference data NCHS-1977 and WHO-2006



**Figure 4.** Distribution of Z-score of height/age of children in the central highlands compared to international reference data NCHS-1977 and WHO-2006



**Figure 5.** Distribution of Z-score of weight/height of children in the central highlands compared to international reference data NCHS-1977 and WHO-2006



**Figure 6.** Distribution of BMI Z-score of children in the central highlands compared to international reference data NCHS-1977 and WHO-2006.

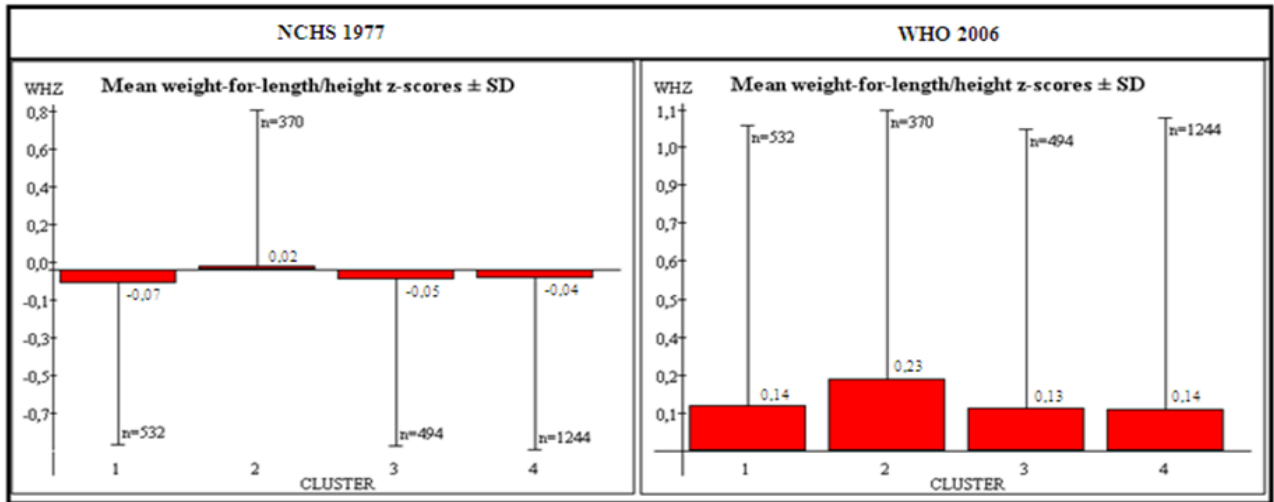


Figure 7. Bar graph of the Z-scores of weight/height for the assessment periods with NCHS-1977 and WHO-2006 standards.

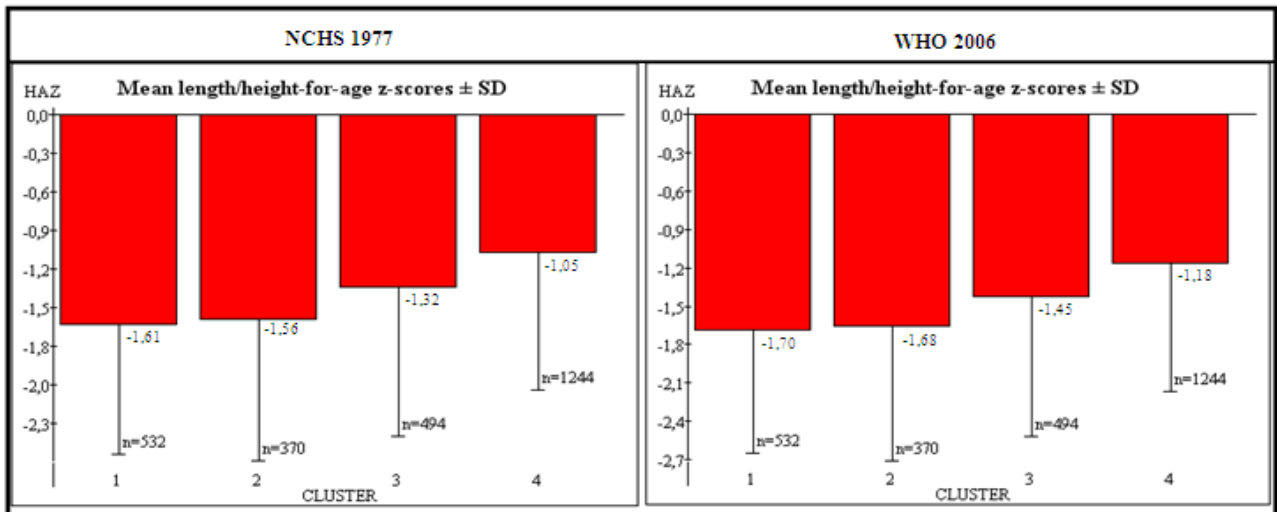


Figure 8. Bar charts of the Z-scores of height/age for assessment periods, with NCHS-1977 and WHO-2006 standards.

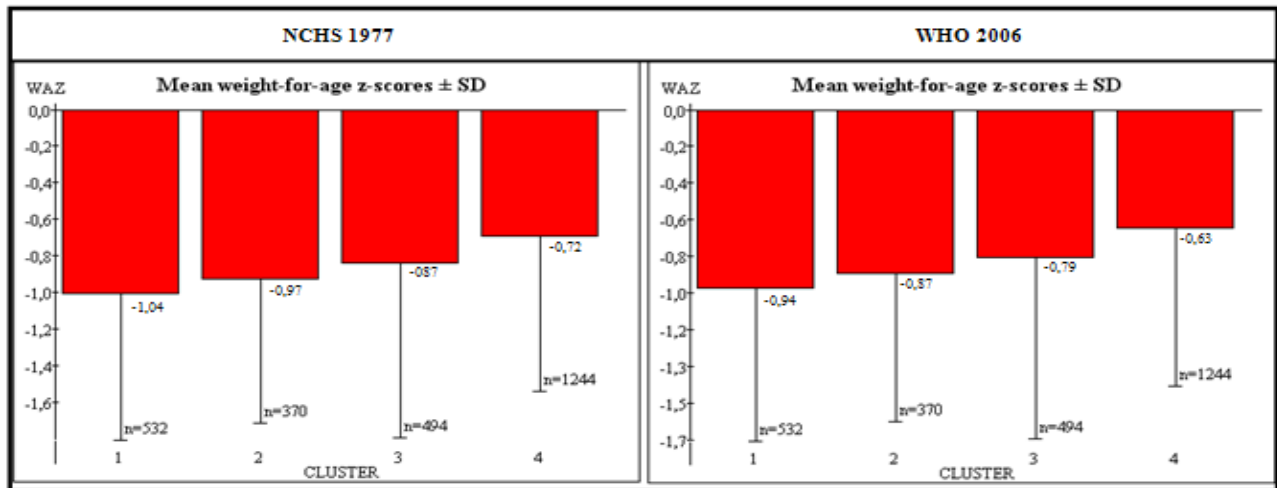
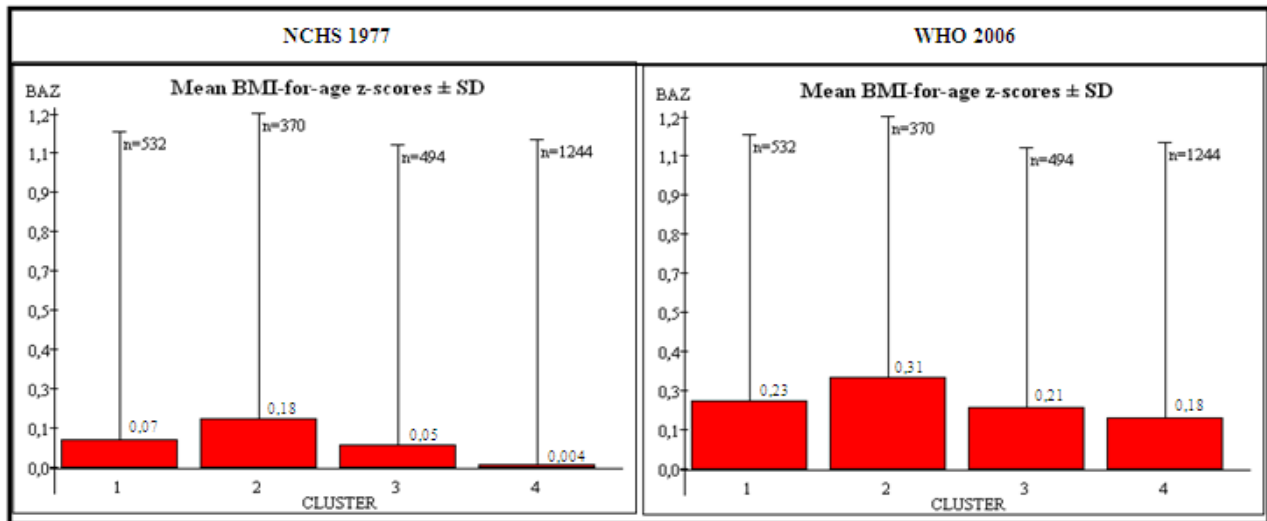


Figure 9. Bar charts of the Z-scores of weight/age for assessment periods with NCHS-1977 and WHO-2006 standards.



**Figure 10.** Bar charts of the Z-scores of BMI for assessment periods with NCHS-1977 and WHO-2006 standards.

These results support the assumptions of WHO, noting that the stunting evaluation in children under the age of 5 years with the NCHS standards was not the most appropriate, demonstrating with the multicenter study the validity of the use of new WHO pattern at the global level [16,17,26], in terms of prevalence, is equivalent to more than 5.1% in growth delay when going from NCHS standard (28.8%) to the new WHO standard (33.9%) [29], a result that is also related to the official data of the National Statistical Institute of Peru (INEI), which indicate that by 2011 the percentage of stunting in children when evaluated with NCHS (Standard used officially in Peru) was 15.2% and if used the WHO standard, prevalence would be 19.5% [30], noting that the WHO standard is considered more accurate, however the country still does not adopt it. The distributions of the Z-score of weight /age and height/age, both with NCHS and WHO, recorded averages below zero, shifting all the distributions downwards; this outcome is in line with other studies [25,26].

In the case of the weight/height Z-score, although the entire distribution is affected, the average is negative and very small with the NCHS standard (0.04), such an average moves the curve to the left; with the WHO, the average is positive (0.15) and moves the entire curve to the right. In the case of the BMI Z-score, both with NCHS and WHO averages are positive and move the curve to the right. These results agree with other authors' reports [25,26].

Using the average Z-score as an index of severity of growth retardation, with the new WHO standard it was -1.40, which shows that a high percentage of children 36-60 months in the central highlands of Peru are at risk of stunting (29.5%), have stunting (29.1%) and severe stunting (4.8%), with only 35.8% of children classified as normal and 0.8 % of children with tall stature [29]. Therefore, interventions would be required for the entire population group and not focus only in those that the current conventional criteria classify as "malnourished".

The value of the standard deviation observed in Z-score distributions is very useful for evaluating the quality of data. With the determination of age and accurate anthropometric measurements, the standard deviation of the height/age, weight/age and weight/height Z-scores should be relatively constant and close to 1.0 [26]. A standard deviation that is significantly smaller than 0.9 describes a more homogeneous distribution. If the standard deviation of the Z-scores is between 1.1 and 1.2, the distribution has a greater variability and is wider than the reference curve. Any standard deviation of Z-scores greater than 1.3 suggests inaccurate data due to error or incorrect information age. The expected ranges of the standard deviations of the Z distributions of height/age range from 1.10 to 1.30, the weight/age between 1.00 and 1.20 and weight/height between 0.85 and 1.10 [14]. In this study, the standard deviations of the height/age, weight/age and weight/height Z-scores with NCHS were 1.07, 0.88 and 0.84, while with WHO, standard deviations were 1.02, 0.84 and 0.91, values that show homogeneous distributions [14]. These findings support the importance of assessing the Z-scores mean and standard deviation [26].

The Z-scores averages were different with NCHS and WHO for each period, for example; for height/age, for 1992 (Cluster 1), the average determined with NCHS was -1.61 while with WHO was -1.70. For the period 2003-2007 (Cluster 4), with WHO, the average was 12.4 % lower than that determined with NCHS (-1.05 vs. -1.18) (Figure 8). In the case of weight/height for the period 2003-2007, with NCHS the Z-score average was 14.3% lower than with WHO (-0.72 vs. -0.63).

The variation between the Z-scores determined with NCHS and WHO would determine differences in the prevalence of global, acute and chronic malnutrition, and overweight and obesity, because even when international cut-off points will be maintained, the percentage of children considered normal or with risk or malnutrition problems will be different, as reported in a study in children under five

years of the central highlands of Peru, which when evaluated with NCHS report 24.30, 8.40 and 0.90% of stunting, underweight, and wasting, respectively, while with WHO the percentages are 29.10, 6.00 and 1.40%. Being overweight was 2.1% with NCHS and 1.90 % with WHO [29].

## 4. Conclusions

The distribution of the weight-for-age, height-for-age, weight-for-height and body mass index Z-scores in children 36-60 months of age in the central highlands of Peru were different when using NCHS-1977, CDC-2000 and WHO-2006 references, noting that all distributions are shifted either to the left or right, which allowed to describe the nutritional status of the entire population without resorting to conventionally established cut-off points. The standard deviations of the Z-scores of different anthropometric indicators were within the range reflecting homogeneity, and being close to 1.0. The new WHO- 2006 growth standard is a reliable model for widespread use in our country.

## 5. Recommendations

For the nutritional assessment of children less than five years, in addition to using the conventionally recommended cut-off points, we recommend the analysis of the averages and standard deviations of the Z distributions of different anthropometric indicators being a great help in describing the nutritional status of the entire study population. Also, in determining the Z-scores, we recommend the use of the new international standard for nutritional assessment OMS-2006, being more reliable and accurate than the NCHS-1977 or CDC-2000.

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