Developing Indices of Nutritional Level from Anthropometric Measurements on Women and Young Children

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The development of an index of nutritional level using data which incorporate both past and current nutritional experience is discussed.

Introduction

Three types of information—anthropometric measurements, biochemistry, and dietary intake—are utilized to assess the nutritional levels of individuals. While the reliability of the first source may be acceptable in field survey conditions, the reliability of the other two sources is doubtful unless the field staff has received a good deal of training and is strictly supervised. Also, most of the dietary and biochemical data are affected by the current nutritional status; anthropometric measurements, on the other hand, reflect both current and past nutritional experience by including variables related to growth and development. For example, while the current weight of an adult is affected by both past and current nutritional experience, height, within the genetic range of the individual, is a reflection of past nutritional experience.

This paper discusses an approach for developing an index of nutritional level from anthropometric measure-
to the hazards of loss of information or inaccuracies in recording at various stages of data handling. In addition, a temporary variation in the normal condition of an individual affects the related measurements and therefore is likely to give an incomplete nutritional picture if assessed through only one variable.

Since several anthropometric measurements were chosen in this study, their different combinations led to different composite indices. The selection of the "best" index was based on statistical and nutritional considerations which are discussed below.

Some anthropometric measurements on mothers of reproductive age are more a reflection of their past nutritional experience, while others reflect their current status. Therefore, separate indices were developed for assessing the past and current nutritional experience. Such may be the need in a study of the relationship of fertility and nutrition—while longitudinal fertility performance may be affected by past nutritional experience, the outcome of the current birth is dependent on the mother's current nutritional status. A simple index for pre-school children was developed that is more stable and less affected by day-to-day experiences.

Methodology

A. Choice of Variables

The anthropometric measurements—weight, height, arm circumference, and mid-arm muscle circumference— are denoted algebraically by \( X_1 \) to \( X_4 \), respectively. In order to develop a composite index, it was necessary to make these raw measurements unitless (independent of the units of measurement) so that they could be combined. For this purpose, observed measurements were converted to percentages by relating them to expected standards for the particular age and sex.† For example, the weight of a 9-month-old male child was related to the standard weight as given by Jelliffe.¹ Thus, new variables \( P \) were formed from the initial variables \( X \) by relating them to the expected standards, i.e., \( P_i = X_i / [X_i(S)] \times 100 \) when \( X_i \) is the observed value and \( X_i(S) \) is the expected standard taken from Jelliffe. New variables thus obtained were as follows:

\[
P_1 = \frac{\text{Observed weight}}{\text{expected weight}} \times 100
\]

\[
P_2 = \frac{\text{Observed height}}{\text{expected height}} \times 100
\]

\[
P_3 = \frac{\text{Observed arm circumference}}{\text{expected arm circumference}} \times 100
\]

the standard for that age (for pre-school children only). For mothers, it was obtained by taking the standard for adult females.

\[
P_4 = \frac{\text{Observed mid-arm muscle circumference}}{\text{expected mid-arm muscle circumference}} \times 100
\]

\[
P_5 = \frac{\text{Observed weight}}{\text{sex-specific standard weight}} \times 100
\]

B. Age Groupings

Since growth and development patterns of children differ in the early periods of life, the children were grouped into three broad age groups for the purpose of developing the nutritional index: (1) those below 6 months of age, (2) those between 6 and 24 months, and (3) those between 25 and 60 months.

No attempt is made to discuss the nutritional index of children below 6 months of age. Nutrition of children of this age has several variants which are difficult to control. One index which is generally used is weight of the child.

C.1. Nutritional Index for Pre-School Children 6 to 24 Months and 25 to 60 Months

Each child in the INCAP study had a multivariate observation represented by a vector \( (P_1, P_2, P_3, P_4, P_5) \). In search for the best composite index of nutrition (which retains most of the information available in \( P_1, P_2, P_3, \) and \( P_4 \)), various combinations of \( P \) through \( P_4 \) were considered through principal component analysis. The first principal component was taken as a nutritional index based on the measurements in the combination. (Geometrically, this index is a linear combination of the variables which covers the maximum variance in the sample scatter configuration. The BMD Manual of Computer Programs,² prepared by the University of California at Los Angeles, was used to derive the principal components.)

The following combinations were considered: \( P_1 \) and \( P_2; P_1 \) and \( P_3; P_1 \) and \( P_4; P_1, P_2, \) and \( P_3; P_1, P_2, \) and \( P_4; P_1, P_3, \) and \( P_4; \) and \( P_2, P_3, \) and \( P_4. \)

It was found that the linear combination of these variables for children 6 to 24 months old and 25 to 60 months old was the same and hence for the rest of the study these two groups were taken together and one index was developed for the total group.

Statistically, the first principal component is obtained by obtaining the weights from the eigenvector corresponding to the largest eigenvalue of the correlation matrix of the multivariate observations. The nutritional score of an individual then is obtained by a product of the vector of standardized variables and the eigenvector. That is, if \( (b_1, b_2, \ldots) \) is an eigenvector corresponding to the largest eigenvalue of the correlation matrix of variables under consideration, the nutritional score for the individual \( i \) is

\[
\text{Nutritional score for } i = \sum b_i P_i
\]

In the first stage, an attempt was made to develop a composite index based on only \( P_1, P_2, \) and \( P_4. \) Various combinations of these three variables suggested that \( P_1 \) and \( P_2 \) should be retained. In the second stage, \( P_4 \) was combined with \( P_1 \) and \( P_2 \) to see whether the combination of \( P_1, P_2, \) and \( P_4, \) provided an index which contained more nutritional information as compared to the combination of only \( P_1 \) and \( P_2. \)
obtained as:

\[ b_1 \left( P_{i1} - \overline{P}_1 \right) / \sigma_{P_1} + b_2 \left( P_{i2} - \overline{P}_2 \right) / \sigma_{P_2} + \cdots + b_k \left( P_{ik} - \overline{P}_k \right) / \sigma_{P_k} + \cdots \]

where \( \sigma_{P_k} \) is the standard deviation for variable \( P_k \). \( P_{ik} \) is the observed measurements (as derived for this study) and \( \overline{P}_k \) is the mean measurement for the population. Two modifications were done to derive scores for this analysis:

1. The scores were approximated as:

\[ (b_1 / \sigma_{P_1}) P_{i1} + (b_2 / \sigma_{P_2}) P_{i2} + \cdots + (b_k / \sigma_{P_k}) P_{ik} + \cdots \]

and

2. \( (b_1 / \sigma_{P_1}, b_2 / \sigma_{P_2}, \cdots) \) were so chosen that \( \sum (b_k / \sigma_{P_k}) = 1 \).

These two modifications were advantageous in that a child whose anthropometric measurements were the same as the expected standards used to convert \( X \) to \( P \) would score 100. Thus scores above or below 100 would indicate the nutritional position of a specific child relative to the expected standard.

C.2. Choice of the "Best" Index for Pre-School Children

The statistical technique adopted here provides a number of nutritional indices based on various combinations of variables \( P_k \). The nutritional information in these variables was utilized to choose the "best." The best index is the one which contains most of the nutritional information available in different anthropometric measurements and indices. The operational meaning of this definition is that the ranking of individuals in a population on the basis of the best index should be highly correlated with the ranking assigned by other nutritional indices. In an attempt to study various indices on this yardstick, the population of children age 6 to 60 months in the INCAP study was ranked by the following nutritional indices:

\[ I_1 = P_1 \]
\[ I_2 = P_2 \]
\[ I_3 = P_3 \]
\[ I_4 = \text{First principal component of } P_1 \text{ and } P_2 \]
\[ I_5 = \text{First principal component of } P_1 \text{ and } P_3 \]

| TABLE 1—Rank Correlation Coefficients between Various Indices under Examination |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
|                             | \( l_1 \)                  | \( l_2 \)                  | \( l_3 \)                  | \( l_4 \)                  | \( l_5 \)                  | \( l_6 \)                  | \( l_7 \)                  | \( l_8 \)                  |
| \( l_1 \)                   | 1.000                      | 0.727                      | 0.638                      | 0.850                      | 0.912                      | 0.925                      | 0.940                      | 0.996                      | 0.607                      |
| \( l_2 \)                   | 1.000                      | 0.404                      | 0.821                      | 0.612                      | 0.902                      | 0.803                      | 0.729                      | 0.016                      |                           |
| \( l_3 \)                   | 1.000                      | 0.809                      | 0.868                      | 0.585                      | 0.771                      | 0.641                      | 0.469                      |                           |                           |
| \( l_4 \)                   | 1.000                      | 0.918                      | 0.904                      | 0.972                      | 0.853                      | 0.303                      |                           |                           |                           |
| \( l_5 \)                   | 1.000                      | 0.836                      | 0.953                      | 0.911                      | 0.615                      |                           |                           |                           |                           |
| \( l_6 \)                   | 1.000                      | 0.949                      | 0.936                      | 0.335                      |                           |                           |                           |                           |                           |
| \( l_7 \)                   | 1.000                      | 0.940                      | 0.441                      |                           |                           |                           |                           |                           |                           |
| \( l_8 \)                   | 1.000                      | 0.609                      |                           |                           |                           |                           |                           |                           |                           |

<table>
<thead>
<tr>
<th>TABLE 2—Grouping of Children</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
</tr>
<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td>( (N)_C &lt; 83.0 )</td>
</tr>
<tr>
<td>( 83.0 \leq (N)_C \leq 97.0 )</td>
</tr>
<tr>
<td>( (N)_C &gt; 97.0 )</td>
</tr>
</tbody>
</table>

The matrix of rank correlation coefficients is given in Table 1. Various composite indices, namely, \( I_1, I_2, I_3, I_4, I_5, \) show high correlation coefficients among themselves and with various other nutritional indices. In this situation, those involving \( P_3 \) (observed arm circumference as a percentage of the standard for that age) will be less desirable because of the general scarcity of this information and the relatively lower accuracy (compared to \( P_1 \) and \( P_2 \)) of its measurement (it varies according to the place on the arm that is measured). This leaves the choice between \( I_4 \) and \( I_5 \).

Between \( I_4 \) and \( I_5 \), the preference would have been for \( I_5 \), because of its simplicity. But it may be noted in Table 1 that \( I_5 \) is poorly correlated with variable \( P_3 \) (the correlation is of the order of 0.335), which means that the information contained in \( P_3 \) is not adequately included in \( I_5 \). Thus, statistical and nutritional considerations suggested that \( I_5 \) would be the best choice among the available nutritional indices. This index is given by: \( (N)_C = 0.290P_1 + 0.485P_2 + 0.225P_3 \), where the subscript \( C \) stands for pre-school children age 6 to 60 months. Since the above index is based on \( P_1, P_2, \) and \( P_3, \) and \( P_3 \) contains information on weight related to height, weight is doubly represented in this equation. In order to check whether it would be adequate to cover it only once, another index was developed from \( P_4 \) and \( P_5 \). This index is given by: \( 0.686P_4 + 0.314P_5 \). When children in the INCAP study were ranked on the basis of these two indices ((1) based on \( P_1, P_2, \) and \( P_5, \) and (2) based on \( P_4 \) and \( P_5 \)), a rank correlation coefficient was found to be 0.995, indicating that the rankings closely agreed. Thus it is immaterial whether the index is based on \( P_1, P_2, \) or \( P_4 \) only. The decision will be made on the reliability of the specific data.

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**TABLE 3—Grouping of Mothers**

<table>
<thead>
<tr>
<th>Score</th>
<th>Nomenclature</th>
</tr>
</thead>
<tbody>
<tr>
<td>((\text{NI})_M) (&lt; 79.0)</td>
<td>Nutritionally poor</td>
</tr>
<tr>
<td>(79.0 \leq (\text{NI})_M) (&lt; 102.0)</td>
<td>Nutritionally average</td>
</tr>
<tr>
<td>((\text{NI})_M) (&gt; 102.0)</td>
<td>Nutritionally better</td>
</tr>
</tbody>
</table>

**C.3. Other Uses of the Nutritional Index**

The basic use of this index will be to assign nutritional scores to individuals in a population and rank them by their nutritional status. Such ranked array can be utilized to group individuals in a few nutritional categories. While making such use of the index, it should be realized that some individuals are likely to be misclassified. However, in field survey conditions these types of misclassification will always occur unless each individual is thoroughly examined by a professional. Even then, different professionals are likely to classify individuals differently.

It is suggested that, after the nutritional scores of individuals in a population have been determined, the mean and standard deviation of the scores should be determined. One standard deviation around the mean can be taken as a cutoff point for nutritional categorization into three groups. On this basis, the child population in the INCAP study was grouped into the categories given in Table 2. It may be stressed that the three categories, “poor,” “average,” and “better,” are a relative ranking of the population in the community under consideration. It is possible that what is relatively poor in one community may be nutritionally good by accepted nutritional standards, or that what is relatively better may be nutritionally bad. The idea here is of distribution of individuals relative to the total community.

This index can also be utilized in assessing the impact of a nutritional program by calculating means and standard deviations after the program is launched and comparing them with the values before the program. A change in the statistical characteristics of distribution of the scores of children on this index will be an indicator of impact.

**D.1. Nutritional Index for Mothers**

Nutritionists have utilized \(P_3\) as a nutritional index for mothers. This index measures nutritional status by comparing the mother’s weight with the standard for her height and thus provides a reflection of her current nutritional status. To this score, we added a weighted score of the mother’s arm circumference in order to develop a composite index of the mother’s current nutritional status.* This was done in view of a rank correlation of the order of 0.6 in the ranking of the mothers in the INCAP study on the basis of \(P_3\) and \(P_5\). The weights for combining \(P_3\) and \(P_5\) were obtained from principal component analysis, the methodology of which has been discussed earlier. The index is given by: \((\text{NI})_M = 0.411P_3 + 0.589P_5\). Subscript \(M\) stands for mothers and subscript 1 for the current nutritional index.

The rank correlation coefficient of mothers in the INCAP study, when ranked on the basis of \((\text{NI})_M\) and \(P_5\), is of the order of 0.92. This suggests that either \(P_5\) as defined above or \((\text{NI})_M\) can be used to determine current nutritional scores for mothers. We will, however, recommend the composite index \((\text{NI})_M\), which is based on two measurements and would be less affected by errors in one of them. On the other hand, if the accuracy of \(P_5\) is doubtful, one may use \(P_3\) alone.

In view of the need for a nutritional index for the past nutritional experience of the mother, another index was developed by utilizing information on the height of the mother \((P_4)\) and her mid-arm muscle circumference \((P_5)\). The measurement of height was suggested by the importance it assumed in the index for children, which was reported earlier. The coefficients for a linear combination of \(P_3\) and \(P_5\) were determined by principal component analysis. The index based on this analysis was: \((\text{NI}_1)_M = 0.7192P_3 + 0.2808P_5\). These two indices were to be used to define the nutritional status of the mother. In order to study how well these indices were related, data from the INCAP study were utilized to rank women on the basis of these two indices. Not unexpectedly, it was found that significant correlation existed between the ranks assigned by the two indices \((0.5)\), but the magnitude of the correlation will suggest that one has to be selective of the index in the context of the situation for which it is being used.

**D.2. Grouping Mothers into Nutritional Categories**

As in the case of children, this index may also be used to group mothers in a field survey situation into three categories (“nutritionally poor,” “nutritionally average,” and “nutritionally better”) by choosing the cutoff point of one standard deviation around the mean value. In the case of the INCAP data, the groups are given in Table 3.

**Recommendations**

In the light of the experience gained from the above data, the following recommendations are made:

- In aiming for the advantages inherent in a composite index, if all of the required anthropometric data are available, one should go through all of the steps for (1) determining the important variables which should form the composite index, and (2) developing the index based on them. My belief is that the choice of the important variables will not change but the
coefficients for the composite index are likely to change.

* For the nutritional categorization of a population under field survey conditions (where an ideal situation of examining every member of the population does not exist), the developed index can be used for determining the scores for the population under study. A cutoff point of one standard deviation around the mean score is suggested for grouping the population into "poor," "average," and "better." One should not overlook the limitations of this grouping.

* The present study reveals that information should be collected on age, weight, and height for children and on weight, height, arm circumference, and skinfold thickness for mothers, in any nutritional study.

* For the choice of mothers' nutritional scores, the situation under consideration should determine whether the index should assess the current nutritional status or the past nutritional experience.

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REFERENCES


AAHDS CONFERENCE ON HEALTH INFORMATION

The American Association of Health Data Systems will hold its annual Conference on Health Information November 20–21, 1975, at the Crown Center Hotel, Kansas City, MO.

The Conference will cover a wide range of topics of vital importance to individuals involved in health data, such as:

* The National Health Planning and Resources Act of 1974 (P.L. 93–641)
* Confidentiality—OPSR, BQA, and SSA Policies
* The Cooperative Health Statistics System, NCHS
* Ambulatory Care—Federal Activities and Data Systems
* PSRO Data Requirements and Financing.

The Conference has been approved for eight Continuing Education hours by the American Medical Record Association. For more information, contact: The American Association of Health Data Systems, 875 North Michigan Avenue, Chicago, IL 60611, telephone (312) 337-6465.

The deadline for registration is November 10. Cost of registration, which includes reception and luncheon, is $50 for AAHDS members, $75 for nonmembers.