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 measurements on mothers of reproductive age and pre-school children. Such indices are especially useful for the purpose of planning a nutritional program in a community when there is need for a quick assessment of the relative nutritional level of individuals.

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Data Utilized

A nutritional survey in the Central American countries and in Panama was carried out by the Institute of Nutrition for Central America and Panama (INCAP) to assess nutritional problems in the population (with a view toward initiation of a nutritional program). All aspects of nutrition, including dietary intake, biochemistry, and anthropometry of mothers and children of ages 5 and below, were covered. The International Institute for the Study of Human Reproduction, Columbia University, collaborated with INCAP for a detailed study of such data. This paper reports only one aspect of analysis, based only on anthropometric data. The objective, as stated above, was to develop an index for quick assessment of the nutritional needs of the individuals by ranking them according to their nutritional scores.

Approach to the Problem

In developing an index, we have taken the view that a composite index should always be preferred over a one-variable index. A composite index is more comprehensive, as it includes more than one dimension of the growth and development of an individual and thus reflects more than one aspect of nutrition. The one-variable index is more open 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 = Observed weight as a percentage of the standard weight for that age and sex (for pre-school children only).
- P_2 = Observed height as a percentage of the standard height for that age and sex (for pre-school children only). For mothers, it was obtained by dividing the observed height by 150 cm.‡
- P_3 = Observed arm circumference as a percentage of the standard for that age (for pre-school children only). For mothers, it was obtained by taking the standard for adult females.
- P_4 = Observed mid-arm muscle circumference as a percentage of the standard for adult females.
- P_5 = Observed weight as a percentage of the sex-specific standard weight for the observed height.

* Mid-arm muscle circumference was obtained by subtracting π times skinfold thickness from arm circumference.

† The expected standards were taken from Jelliffe.[1]

‡ The choice of 150 cm is arbitrary. One could as well utilize a different height for an expected standard. The purpose was to make P_2 unitless so that it could be combined with other unitless variables. Thus, 150 cm was chosen because it was about the average height of the population of mothers in the data under study.

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_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_5), various combinations of P_1 through P_5 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_2 and P_3; P_1, P_2, and P_3; and P_1, P_2, and P_5. 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, . . .) is an eigenvector corresponding to the largest eigenvalue of the correlation matrix of variables under consideration, the nutritional score for the individual i is

§ In the first stage, an attempt was made to develop a composite index based on only P_1, P_2, and P_3. Various combinations of these three variables suggested that P_1 and P_2 should be retained. In the second stage, P_5 was combined with P_1 and P_2 to see whether the combination of P_1, P_2, and P_5 provided an index which contained more nutritional information as compared to the combination of only P_1 and P_2.

TABLE 1—Rank Correlation Coefficients between Various Indices under Examination

	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
I_1	1.000	0.727	0.638	0.850	0.912	0.925	0.940	0.996	0.607
I_2		1.000	0.404	0.821	0.612	0.902	0.803	0.729	0.016
I_3			1.000	0.809	0.868	0.585	0.771	0.641	0.469
I_4				1.000	0.918	0.904	0.972	0.853	0.303
I_5					1.000	0.836	0.953	0.911	0.615
I_6						1.000	0.949	0.936	0.335
I_7							1.000	0.940	0.441
I_8								1.000	0.609
I_9									1.000

obtained as:

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

where σ_{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 $\sum_k (b_k/\sigma_{P_k}) = 1.$

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_i. 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 = First principal component of P_2 and P_3
I_5 = First principal component of P_1 and P_3
I_6 = First principal component of P_1 and P_2
I_7 = First principal component of P_1, P_2, and P_3
I_8 = First principal component of P_1, P_2, and P_5
$I_9 = P_5$

TABLE 2—Grouping of Children

Score	Nomenclature
$(NI)_C < 83.0$	Nutritionally poor
$83.0 \leq (NI)_C \leq 97.0$	Nutritionally average
$(NI)_C > 97.0$	Nutritionally better

The matrix of rank correlation coefficients is given in Table 1. Various composite indices, namely, I_4, I_5, I_6, I_7, I_8, 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_6 and I_8.

Between I_6 and I_8, the preference would have been for I_6, because of its simplicity. But it may be noted in Table 1 that I_6 is poorly correlated with variable P_5 (the correlation is of the order of 0.335), which means that the information contained in P_5 is not adequately included in I_6. Thus, statistical and nutritional considerations suggested that I_8 would be the best choice among the available nutritional indices. This index is given by: $(NI)_C = 0.290P_1 + 0.485P_2 + 0.225P_5$, 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_5, and P_5 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_2 and P_5. This index is given by: $0.686P_2 + 0.314P_5$. 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_2 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, and P_5 or P_2 and P_5 only. The decision will be made on the reliability of the specific data.

TABLE 3—Grouping of Mothers

Score		Nomenclature
$(NI_1)_M$	$(NI_2)_M$	
$(NI_1)_M < 79.0$	$(NI_2)_M < 90.5$	Nutritionally poor
$79.0 \le (NI_1)_M \le 102.0$	$90.5 \le (NI_2)_M \le 100.5$	Nutritionally average
$(NI_1)_M > 102.0$	$(NI_2)_M > 100.5$	Nutritionally better

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_5 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_5 and P_3. The weights for combining P_5 and P_3 were obtained from principal component analysis, the methodology of which has been discussed earlier. The index is given by: $(NI_1)_M = 0.411P_5 + 0.589P_3$. 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 $(NI_1)_M$ and P_5, is of the order of 0.92. This suggests that either P_5 as defined above or $(NI_1)_M$ can be used to determine current nutritional scores for mothers. We will, however, recommend the composite index $(NI_1)_M$, 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_3 is doubtful, one may use P_5 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_2) and her mid-arm muscle circumference (P_4). 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_4 and P_2 were determined by principal component analysis. The index based on this analysis was: $(NI_2)_M = 0.7192P_2 + 0.2808P_4$. 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

* The need for developing an index of current nutrition and another index reflecting the past nutritional experience has been indicated in the section "Approach to the Problem" above.

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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