SCREENING FOR MALNUTRITION WITH ARM CIRCUMFERENCE

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SUMMARY

The opinions on the perfomance characteristics of the mid arm circumference as anthropometric measurement for malnutrition screening are quite contradictory. In this paper we analyze the specificity and sensitivity of the arm tape under different conditions and conclude that the design of the tape characteristics should aim at an instrument which can satisfy specific needs instead of a general purpose one. We also give some measurements for the practical design of the instrument.

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INTRODUCTION

Anthropometric measurements are the most widely used methodology for the assessment of the nutritional status of individuals.

Some of them are sensitive ,accurate and specific*, but their implementation under rough field conditions are impracticable and prohibitively costly, particularly when used for mass screening.

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* The meaning of these terms in this contex will be explained later.

It is for these reasons that the search for an anthropometric measure for the assessment of nutritional status, that takes into account the characteristics of sensitivity and specificity with good field performance and low cost has priority in our research endeavors. Mid arm circumference for age appears to fulfill the requirement of low cost and good field performance. The objetive of the present study, then, is to analyze the sensitivity and specificity of mid arm circumference in assessing malnutrition, i.e., weight for age, weight for height and height for age.

According to Waterlow-Ruthishauser (1) we can distinguish three different kinds of malnutrition: acute, chronic and global. The first one refers to a deficit of child's weight with respect to the standard weight for his/her height and is denoted by P(T). The second refers to a deficit of child's height with respect to the standard height for his/her age and is denoted by T(E). Global malnutrition is defined as the product P(T) x T(E); as this quantity has been shown to have a very high correlation with the Gómez' method (or with methods which measure deficit of child's weight with respect to the standard weight for age), this last method is used as a measurement of global malnutrition and is denoted by P(E).

MATERIALS AND METHODS

Data from two surveys involving 800 preschool children (0-6 years old) from urban and rural populations were used for this analysis. For each child the following data were collected: age, height, weight, sex, mid arm circumference and elbow circumference. The measurements were analyzed by comparing them with the reference or standard values of the Colombian population (derived from measurements of children of high income families from Bogotá).

Children for the urban survey were selected from nurseries and outpatients clinics in Cali, and were mainly whites. Children for the rural survey were randomly selected from different communities in the Cauca state. These were mainly of black or mestizo origin. As no significant difference was found between the two groups of children, the results are presented in an aggregate form.

RESULTS AND DISCUSION

The reason why the Gómez' method was used as global malnutrition indicator is explained in a previus work of the same authors.* In the same work it was shown that, since mid arm circumference statistically correlates with P(T) and T(E), it can be considered as a useful measure of global malnutrition. The high correlacton found between mid arms circumference and elbow circumference also allow to extend the results of mid arm circumference to elbow circumference.

Under these conditions it can be assumed that the Gómez classification is the standard methodology with which to compare the arm circumference measurement. The correlation found between the two methods was approximately 0.6. Since this value is not too high, the tape can be expected to present some nutritional diagnostic errors with respect to the Gómez method. This assumption is examined within the context of the following null hypothesis:

"A generic child is wellnourished, according to the Gómez' method". The possible lack of agreement between the Gómez' and arm circumference methods can be the result of two different conditions:

a. Gómez' method classifies as malnourished a child which by the tape** is classified as wellnourished. If we asume that Gómez' method is the correct one the tape can present in this case an error that we can call of type 2 as we are accepting the null hypothesis. The probability of an error of this type is related to the sensitivity of the instrument.

b. Gómez' method classifies as wellnourished a child which tape classifies as malnourished. As we are rejecting the nul hypothesis, which is correct, we can call it error type 1. The probability of an error of

** From now on the word tape will be used as synonymous of mid arm circumference measurement instrument.

this type is related to the specificity of the instrument. The probability of these two errors for a given tape depends, of course, on where, along the tape's range, the limiting value are set for identifying the different status of nutrition. Suppose for example, that all the children less than 6 years old with arm circumference less than 6 centimeters are defined as malnourished: in this case the per cent of malnutrition according to the tape will be quite low. Thus, the probability of type 2 error will be high and that of type 1 will be low. The contrary happens when the limit is too high.

Without limiting the generality of this analysis, it is assumed here that a tape is designed with only one limit X in order to separate the cases of malnutrition from the others.

If for a generic tape the following quantities, are defined:

E1 = probability of type 1 error;
1 - E1 = specifity of the method;
E2 = probability of type 2 error;
1 - E2 = sensitivity of the method;
ET = probability of an error, irrespective if 1 or 2;
T = malnutrition rate of a population defined as the per cent of preschool children malnourished, defined as grade I, II, or III according to Gómez;
C = confidence level of the tape, defined as the per cent of cases of a children population for which the Gómez and tape diagnosis coincide.

It is shown in Appendix A, paragraph A1 that:

i) If the limit X of a generic tape is changed in order to reduce type 2 error, type 1 error increases and viceversa; i.e., if sensitivity (specificity) increases, specificity (sensitivity) must decrease.
ii) The confidence level C of a tape is maximum for

* From now on the word tape will be used as synonymous of mid arm circumference measurement instrument.

that value of X which makes the total error ET minimum;

iii) As limit X varies within its allowed range, errors E1, E2, ET describe 3 curves E1(X), E2(X), ET(X) which intersect one another at the same point Xo.

The probability value that the three curves assume at the point of intersection Xo is a rough measurement of the lack of correlation between the variable P(E) relative to the Gómez' method and the variable:

$$CB(E) = \frac{\text{actual arm circumference of child}}{\text{standard arm circumference according to the age and sex of the child}}$$

i.e., the lower on the vertical axis is the intersection point, the higher is the correlation between the two variables (See Appendix A, paragraph 2). As the actual value of the arm circumference is determined not only by nutritional status of a child but also by its level of physiological growth which is related to age, the possible errors of a tape can be reduced by narrowing the range of age for which the tape is valid. In this way, we limit the effect of the growth on the observed variations of the arm circumference. The question is "for a fixed range of age, which is the limiting value X which makes the total error ET minimum and the confidence level of a tape maximum?" As a matter of fact the confidence level of a tape depends on the malnutrition rate (unless E1 = E2) of the community, as shown in Appendix A. This implies that it is not possible to design a tape with a fixed confidence level unless specificity and sensitivity have the same probability value. Figures * 3 and 4 show how for malnutrition rates of T = 30% and T = 60% the total error varies for the same range of age. What we want to point out here is that, if it is necessary to design a tape to be used in different communities, it is not always possible to use the maximum level of confidence as a performance criterion. On the other hand, it

* For this and the other figures (Fig. 1 to Fig. 9) we want to point out the cuantitative value of the curves presented, as this one is more related to the specific conditions of the experimental work.

can be shown that the probability of errors type 1 and 2 is independent of malnutrition rate T because of the way in which they are defined. Therefore under practical situations it seems advisable to design the performance characteristics

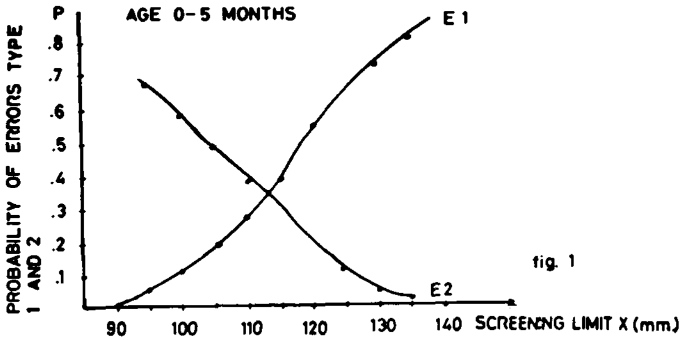


fig. 1

Figure 1 and 2: ASYMPTOTIC TREND OF ERRORS* (TYPE 1 AND 2) AS THE LIMIT X OF THE TAPE IS INCREASED. THE LIMIT X SEPARATES CASES OF MALNUTRITION FROM NORMAL ONES. E1 AND E2 ARE CALCULATED ACCORDING TO THE WEIGHT FOR AGE METHOD WHERE A DEFICIT ≤ 0.90 INDICATES MALNUTRITION. THE CONTINUOUS LINES HAVE BEEN FITTED TO EXPERIMENTAL VALUES (DOTS).

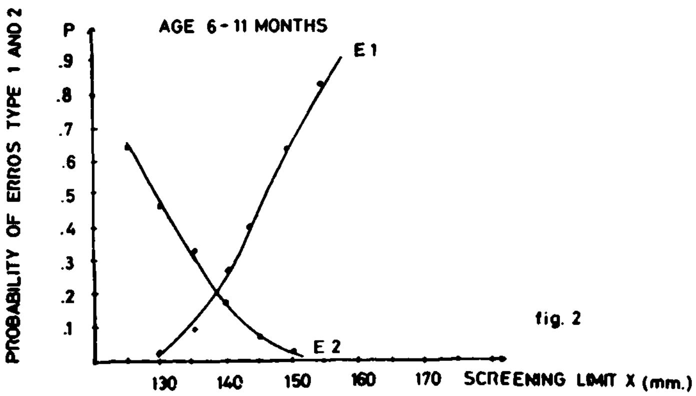


fig. 2

FOR THE DEFINITION OF E1 AND E2 RELATIVE TO. Fig. 2 TO Fig. 9 SEE APPENDIX A

of a tape not as a function of the maximum confidence level desired, but as a function of the maximum value of probability for type 1 and 2 errors which can be accepted.

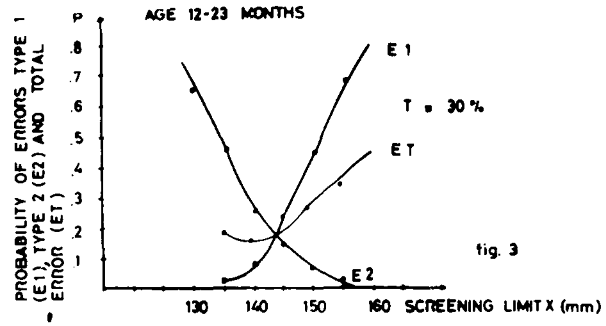
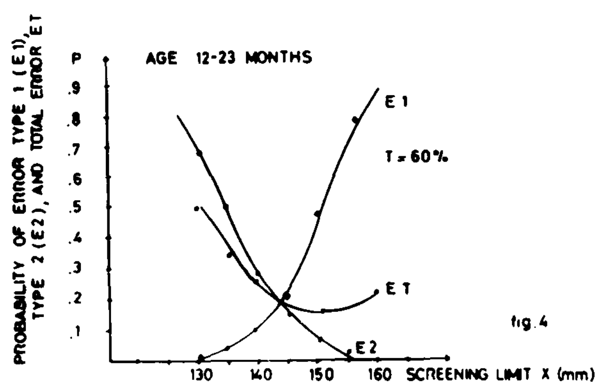


Figure 3 and 4: THESE FIGURES SHOW HOW THE CURVE OF THE TOTAL ERROR* (ET) CHANGES AS THE MALNUTRITION RATE T OF A POPULATION CHANGES FROM 30% TO 60%; E1 AND E2 CONSERVE THE SAME TREND. ERRORS E1 AND E2 ARE CALCULATED ACCORDING TO THE WEIGHT FOR AGE METHOD WHERE A DEFICIT ≤ 0.90 INDICATES MALNUTRITION



*FOR THE DEFINITION OF TOTAL ERROR ET RELATIVE TO Fig 4 AND Fig 5, SEE APPENDIX A

There are two possibilities for reducing type 1 or type 2 errors:

i) to change the limit X which separates the cases of malnutrition from the others. In this case it is necessary to look for an acceptable trade-off between the two types of errors. Recall that type 1 error tends to increase exponentially as type 2 decreases asymptotically. Of course, this trade-off can affect significantly the total costs and benefits of a social project;

ii) to reduce the age limits for which a tape is valid. Here too, it is necessary to find out a compromise between the feasibility of using a large number of tapes and the size of type 2 error. Furthermore, reducing the range of age for which the tape is valid, can hardly make errors type 1 or 2 negligible.

It has been shown here that the tape is affected by two kinds of errors and that it is almost impossible to design a tape for which both errors are negligible at the same time. It is important therefore to know: "when a community has malnourished children of grade I, II, III as well as normal ones, which one of these categories is more affected by tape's errors"? Figure 9 shows the probability of errors 1 and 2 as a function of the Gómez' variable P(E), for a tape designed to give the same weight to both errors. It is apparent from this figure that, the probability of type 2 error is high for children with grade I malnourishment ($0.75 \leq P(E) < 0.9$) and quite low for cases of grade III malnourishment (P(E) 0.6). That is, the sensitivity of the tape increases with the severity of malnutrition. Also the two curves, relative to the probability of type 1 and 2 errors, are quite symmetric with respect to $P(E) = 0.9$.

Since two different kinds of malnutrition (chronic and acute malnutrition) are defined and it is assumed that the Gómez' method can detect global malnutrition, it is possible to propose the hypothesis that the tape is able to detect only one kind of malnutrition. (i.e., the acute). Therefore, the tape and the Gómez method tend to show better agreement only when a child presents a specific kind of malnutrition. Figures 7 and 8 clarify this point. Figure 8 shows the graph of type 1 and 2 errors of a tape with respect to Height (P(T)) method. Figure 7 presents the same kind of graph with respect to Height - Age (T(E)) method. The point of the intersection P_e in Figure 7 is shifted to the right (and upward) of the point P_g of Figure 5, which is the same figure but relative to the Gómez method. This displacement is not observed for the point P_f of Figure 8. This means that, if we design a tape to detect global malnutrition, type 2 error that the instrument can make tends to be more associated with chronic rather than acute malnutrition. The contrary happens for type 1 error. This conclusion is evident if it is considered that type 2 error is prevalent to the left and type 1 error to the right of the point of intersection in Figures 1 to 8. Yet there is a non negligible probability of type 2 error for cases of acute malnutrition and type 1 error for cases of chronic malnutrition. According to recent studies acute malnutrition seems to be prevalent in the first years of life while chronic malnutrition becomes more important later. Type 2 error can therefore be more serious for the range 0-2 years rather than for the remaining range of ages. Yet the relative importance of the two kinds of errors, i.e., the tradeoff between specificity and sensitivity, should be decided consistently with the objectives of the anthropometric measurements. For example, if the objective of the nutritional study is to detect malnutrition at community level, (i.e., to detect malnourished communities) both kinds of erros can have the same weight. But if it is necessay to detect malnourished families o individuals, error type 2 can become more serious and more care should be taken in reducing type 2 rather than type 1 error. If the objective is to evaluate the effects of a nutritional intervention, or to detect a change in nutritional status, both errors tend to have the same weight, be it at community, family or individual level.

CONCLUSIONS

From the comparative analysis among arm circumference and other anthropometric measurements, we can draw the following conclusions:

a. the tape can be classified as a method for detecting global malnutrition;
b. the tape is more sensitive in cases of acute rather than chronic malnutrition, and in cases of severe rather than mild malnutrition;
c. the tape is of limited validity when used to detect individual cases of malnutrition (i.e., to detect malnourished children) because of the lack of a high

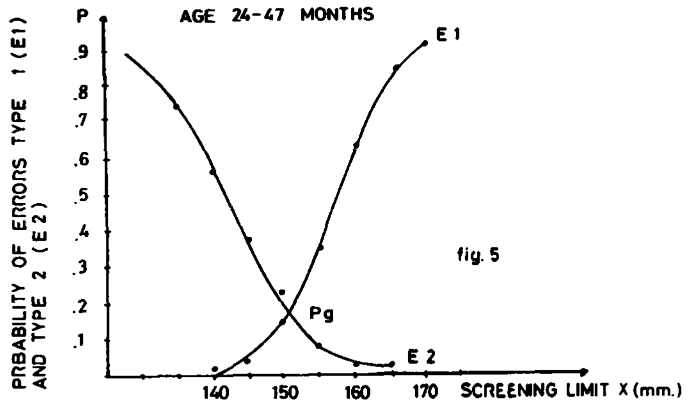
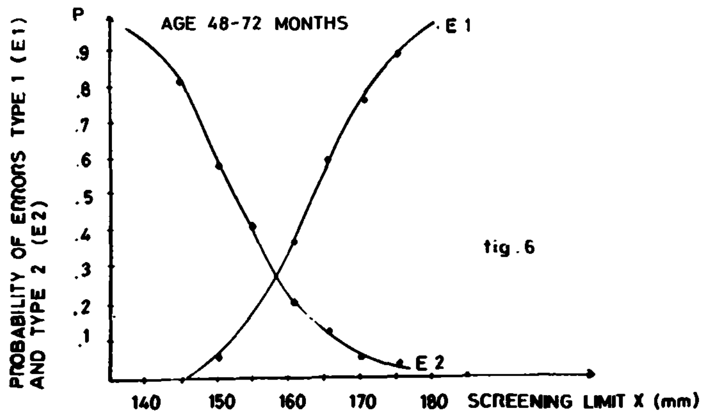


Figure 5 and 6: ASYMPTOTIC TREND OF ERRORS (TYPE 1 AND 2) AS THE LIMIT X OF THE TAPE IS INCREASED. THE LIMIT X SEPARATES CASES OF MALNUTRITION FROM NORMAL ONES. E1 AND E2 ARE CALCULATED ACCORDING TO THE WEIGHT FOR AGE METHOD WHERE A DEFICIT ≤ 0.90 INDICATES MALNUTRITION. THE CONTINUOUS LINES HAVE BEEN FITTED TO EXPERIMENTAL VALUES (DOTS). Pg is the intersection point.



level of specificity and sensitivity;

d. the tape can show better performance in cases of an aggregate diagnosis of a population. Since its sensitivity to detect children with grade II and III of malnutrition is acceptable in many cases, it is possible to make inference on the aggregate nutritional status of the children's population in a community given the per cent of grade II and grade III malnutrition cases;

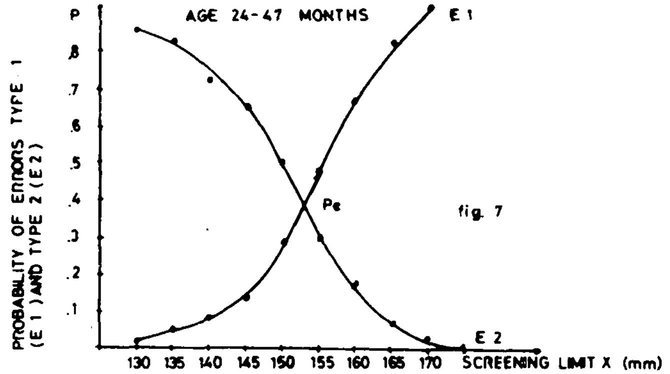


Figure 7 : ASYMPTOTIC TREND OF ERRORS (TYPE 1 AND 2) AS THE LIMIT X OF THE TAPE IS INCREASED. THIS LIMIT SEPARATES CASES OF MALNUTRITION FROM NORMAL ONES. ERRORS E1 AND E2 ARE CALCULATED WITH RESPECT TO THE HEIGHT FOR AGE METHOD WHERE A DEFICIT ≤ 0.95 IS ASSUMED TO INDICATE CHRONIC MALNUTRITION. Pe IS THE INTERSECTION POINT.

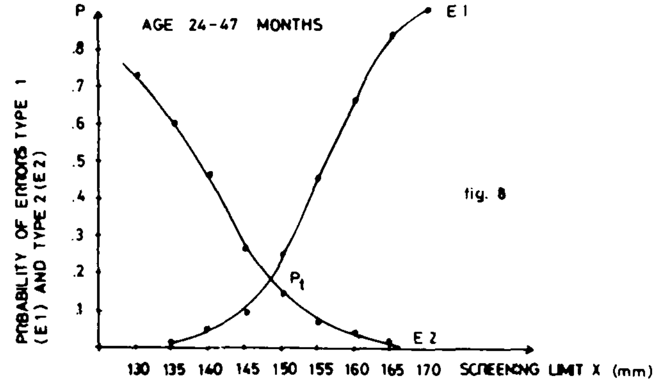
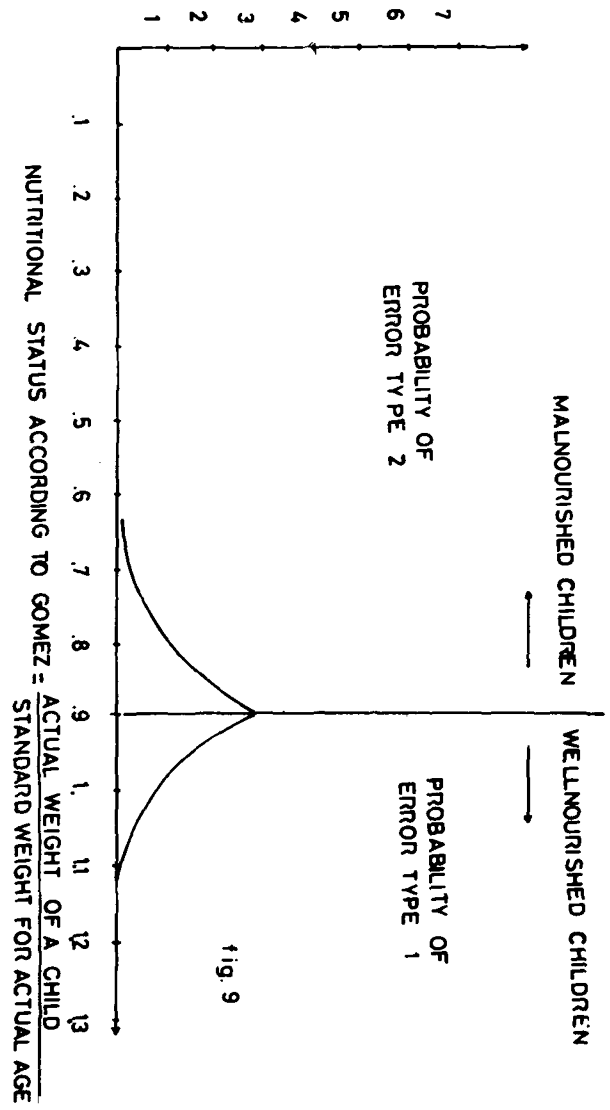


Figure 8. ASYMPTOTIC TREND OF ERRORS (TYPE 1 AND 2) AS THE LIMIT X OF THE TAPE IS INCREASED. THIS LIMIT SEPARATES CASES OF MALNUTRITION FROM NORMAL ONES ERRORS E 1 AND E2 ARE CALCULATED WITH RESPECT TO THE WEIGHT FOR HEIGHT METHOD WHERE A DEFICIT ≤ 0.90 IS ASSUMED TO INDICATE ACUTE MALNUTRITION. P_t IS THE INTERSECTION POINT

e. the tape can be useful also in making an approximate and rapid evaluation of nutritional programs at community level, since these kinds of programs, if effective, tend to reduce the prevalence of the most severe cases of malnutrition which are easily detected by the tape;

f. the criteria which should direct the design of a tape should be related to the degree of specificity and fig. 9 PROBABILITY OF ERRORS TYPE 1 AND 2 AS A FUNCTION OF THE WEIGHT FOR AGE DEFICIT FOR A TAPE DESIGNED TO GIVE EQUAL WEIGHT TO BOTH ERRORS



sensitivity allowed rather than to the confidence level desired;

g. the tape is appropriate when an instrument with a given sensitivity is needed, no matter its specificity or viceversa.

RESUMEN

La Circunferencia Braquial como Medida del Estado Nutricional

El uso de la circunferencia de brazo cómo medida antropométrica para detectar malnutrición presenta características de facilidad de uso, rapidez en la medida y bajo costo; por lo tanto podría ser una medida útil para el diagnóstico de comunidades. El presente trabajo analiza la medida en sus características de especificidad, sensibilidad y confiabilidad encontrando que la confiabilidad es generalmente limitada y la sensibilidad y especificidad varían con el diseño del instrumento.

Como conclusión se quiere hacer énfasis en la necesidad de subordinar el uso de la cinta y posiblemente el diseño de la misma a los objetivos específicos del estudio antropométrico que se quiere realizar.

APENDIX A

A1. Let us define:

N : the total number of children 0 to 6 years old

N_1 : number of children classified as malnourished weight for age method (Gómez' method)

N_2 : number of children classified as normal by the by the weight for age method (Gómez' method

$n_1(x)$: number of normal children by Gómez' and malnourished by the arm tape (with a prefixed limit x of the tape)

$n_2(x)$: number of malnourished children by Gómez' which are classified as normal by the arm tape (with prefixed limit x of the tape)

For a large N:

$$E_1(x) = \frac{n_1(x)}{N_1}$$ = Probability for error type 1; it is assumed that E_1 is a monotonic function of x;

$n_2(x)$

$$n_2(x) = \frac{\quad}{N_2}$$ = probability error type 2; its assumed that E_2 is a monotonic function of x;

$$\frac{N_2}{N} = T = \text{ malnutrition rate}$$

$$ET(x) = \frac{n_1(x) + n_2(x)}{N_1 + N_2} = \frac{n_1(x) + n_2(x)}{N} = \frac{N_1 x E_1) + N_2 x E_2)}{N}$$

$= (1\text{-}T)\ E_1 + TE_2 = T(E_2\text{-}E_1) + E_1$ = probability of total error;

$C(x) = 1 - ET(x)$ = confidence level of the tape

According to these definitions, we have:

a. $0 \leqslant E1, E2, ET, C, T, \leqslant 1$

b. $\lim_{x \to 0} E1(x) = 0$; $\lim_{x \to \infty} E1(x) = 1$

c. $\lim_{x \to 0} E2(x) = 1$; $\lim_{x \to \infty} E2(x) = 0$

d. $\lim_{x \to 0} ET(x) = 1$; $\lim_{x \to \infty} ET(x) = 1$

e. $\lim_{x \to 0} C(x) = 0$; $\lim_{x \to \infty} C(x) = 0$

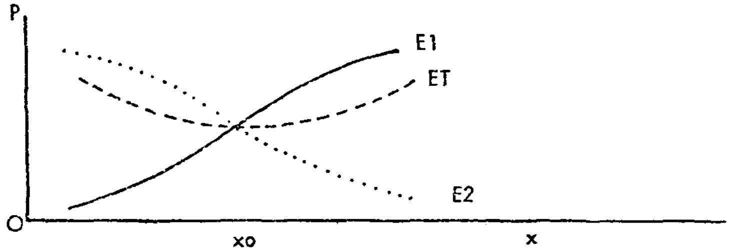
f. given an $x = xo$ such that $= E1(xo) = E2(xo)$ and $n_1(xo) = \frac{n_2(xo)}{N_2} . N_1$, we have that

$$ET(xo) = \frac{n_1(xo) + n_2(xo)}{N}$$

$$= \frac{n_2(xo)\ (N_1 + N_2)}{N_2 N} = E2(xo) = E1(o)$$

* The following methodology for the definition of E1 and E2 uses the weight for ages as a reference method but it can be done also for chronic and acute malnutrition as reference methods: Just substitute the expression "weigbt for age" with "weight for height" or "height for age". This has been done in Fig. 7 and Fig. 8.

g. given the assumption of a monotonic E1 and E2 and the characteristics b, c, d, f, the function E1(x), E2(x), ET(x), will have the following graph:



A2. Supposing that the coefficient of correlation between P(E) and CB(E) is 1; then, given a unique relation between the two variables, there will be a point xo in the tape corresponding to the limit value of P(E) = 0.9; in that case E1(xo) = E2(xo) = 0.

On the other hand, if we assume that the coefficient of correlation is zero, then, for any point on the tape that is chosen as limit x, the probability of a correct diagnosis is equal to the probability of a wrong one.

In this case, E1(x) = E2(x) = 0.5.

For cases where the correlation coefficient lies between 0 and 1, the intersect point of the three curves will be between 0 and 0.5.

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