COMPARATIVE ANALYSIS OF SOME ANTHROPOMETRIC MEASUREMENTS[1]

Giovanni Acciari,[2] James C. Eckroad,[4] Luis F. Fajardo,[2] Ramiro Muñoz,[3] Ruth de Mercado,[2] Alberto Pradilla,[3] Gloria Quintero,[3] Betty de Ramírez,[3] Fanny Victoria,[2] Dean H. Wilson.[4]

Proyecto de Nutrición Universitario, Universidad del Valle, Apartado Aéreo 2188, Cali, Colombia.

SUMMARY

The main objective of this work is to determine what anthropometric method to use under field conditions, given the kind of malnutrition to be detected.

In the first part of the work some criteria and procedures are given by which to compare the field perfomance characteristics (i.e. transportability, facility of use, etc.), of the most commonly used instruments. Then we extrapolate these characteristics to the respective methods like weight for age, weight for height, height for age, etc. In the second part we present a correlation matrix among the various methods and analyze it in order to associate with each method a specific typology of malnutrition.

INTRODUCTION

The methodology currently used to assess the nutritional status of individuals can be grouped under three categories:

1. Comparing the nutrient intake with the nutrient requirements according to age, sex and physiological state. This method can be used for all individuals in

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population groups. The problem of the assessment of actual nutrient requirements remains unsolved.

2. Biochemical tests involving the analysis of total protein and serum albumin, urine, excretion of creatinine, creatinine/hydroxiproline, index, etc. Although such procedures assess the nutritional status, their implementation under field conditions is difficult.
3. Anthropometric measurements that detect deviations of growth as related to given standards. As growth occurs only in children and adolescents, anthropometric measurements can only be used for individuals of this age groups. Anthropometric measurements have been used in this project to assess the nutritional status of the communities under investigation.

The anthropometric measures analyzed here are mid-arm circumference/age, head circumference/age, weight for age, height for age, and weight for height.

The objetive is to analyze these anthropometric measures with respect to accuracy, sensitivity, specificity, cost and optimum performance under field condition.

The relation between deviation of growth and malnutrition is not specific, because other diseases could alter the patterns of growth in the same direction as malnutrition. There are two kinds of deviations of growth that anthropometric measures may detect; one is related to age, and the other to body proportions.

It is assumed that a given child may present either acute (wasting), chronic (stunting) malnutrition, or both (global malnutrition).

Acute malnutrition is defined as a deficit of the child's weight with respect to the ideal weight for his/her height. Ideal weight is defined as the mean value of weight for a given height of children from a "normal reference" population.

$$P(T) = \frac{\text{Actual weight of child (in kg.)}}{\text{Standard weight for actual height of child}}$$

The standard deviation (SD) of this variable for normal population for all age categories between 0-6 years is 0.1

(10%). The P(T) value of 1-SD = 0.9 is the limit value used to detect malnutrition. P(T) values $\leq$ 0.9 indicate acute malnutrition, and represent actual deficit either of calories or proteins or both.

Chronic malnutrition is defined as a deficit of the height of the child with respect to the ideal (standard) height for his/her actual age. Ideal height is defined as the mean value of height for a given age of children from a "normal reference" population.

$$T(E) = \frac{\text{Actual height of child (in cm.)}}{\text{Standard height for actual age of child}}$$

The standard deviation of this variable for a normal population is 0.05 (5%). The T(E) value of 1-SD = 0.95 is the limit value below which chronic malnutrition is being detected. Chronic malnutrition represents the actual effect on the growth of the child of one or several episods of acute malnutrition suffered in the past. Essentially, this indicates a variable grade of deficit of height with respect to age.

Global Malnutrition. This term is used here to represent one single indicator for either acute or chronic malnutrition, or both occuring simultaneously in the same individual. One approximation for the quantification of global malnutrition is the use of the product of the variables P(T) and T(E). That is:

$$P(T(E)) = P(T) \times T(E)$$

Because the two variables have different standard deviations, their relative influence should be "homogenized". This is done by making the SD of the two variables about the same. As already noted, the SD of the variable P(T) is twice the SD of variable T(E).

Hence, by using the relation

$$P(T(E)) = (0.5\ P(T) + 0.5)\ T(E)$$

the interval for the variable P(T) of acute malnutrition is reduced and both variables P(T) and T(E) have the same SD of 0.05.

MATERIALS AND METHODS

Data from two surveys involving 800 preschool children (0-6 years old) from urban and rural populations were used for the analysis. For each child the following data were collected: age, height, weight, sex, mid-arm circumference, head circumference and elbow circumference.

The measurements were analyzed by comparing them with the reference values for 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 5 different communities in the Cauca state. These were mainly of black or mestizo origin.

The selection of the two groups is not directed to decide as to which tipe of malnutrition (acute-chronic) to measure for a given circumstance but at the selection of what method to use, once the decisión to measure acute or chronic malnutrition is made.

The instruments used for anthropometric measurements were the following:

- for age 24-72 months; weighing scale, Detecto brand, with reading in kg. Maximum reading: 125 kg. maximum differencial reading: 1 kg.
- For age 0-23 months; Spring dynamometer, Chatillon brand, with reading in kilos and pounds. Maximum reading: 15 kilos; maximum differential reading: 100 gr.
- For all ages: infant meter for height measurement, home made, with a fixed strip on a wooden board. Reading in millimeters, maximum reading: 150 mm.; minimum differential reading: 1 mm.
- for all ages: flexible meter, local brand, to measure head arm, and elbow circumference. Maximum reading: 150 mm.; minimum differential reading: 1 mm.

RESULTS AND DISCUSSION

A. Performance Characteristics.

Several factors may influence the decision as to what anthropometric method to use when assessing malnutrition. For the purpose of this discussion the following criteria are used: accuracy, sensitivity, specificity, cost and degree of difficulty for implementation under field conditions.

To facilitate the trade-off between these factors in deciding what methodology to use, it was necessary to analyze the characteristics of the instrument for each method, and for the method per se.

The instruments studied were weighing scales, infant meter, arm tape, head tape, and age, for the performance of the following parameters:

1. Standard deviation (of the measurement) SD*
2. Percent error (error%)

$$= \frac{\text{Standard deviation}}{\text{mean value of the range of the instrument reading}}$$

3. Field performance: degree of simplicity in the use of the instrument
4. Transportability: how easy is to handle and transport the instrument.
5. Durability: refers to the half life of the instrument under normal field conditions.
6. Cost: refers to the cost of the instrument.
7. Time: refers to the time, spent in the use of the instrumental for performing the activity for which it has been designed.

The standard deviation includes both the random error and the systematic error due to the instrument. The standard

* If the same measurement (f.e. height measurement) is taken on the same child several times, the experimental values present a statistical distribution whose dispersion around the mean value is measured by the standard deviation SD.

deviation was calculated by performing the anthropometric measures several times on the same group of children.

For the per cent error calculation, the range of reading refers to the maximal variation obtained with the instrument when measuring normal children 0-6 years old.

For the other variables, an ordinal scale between 0-10 was constructed, where the 0 corresponds to the optimal behavior and 10 to worst performance. For example, for age, the value of "0" means no cost; field performance values of 4 for the infant meter and 2 for the weighing scale mean that under

TABLE 1

PERFORMANCE OF THE INSTRUMENTS FOR THE ANTHROPOLOGICAL ANÁLYSIS OF MALNUTRICION

Instrument	Units	Standard deviation	Error Percent	Field Performance	Transport ability	Durability	Cost	Time
Arm Tape	cms.	0.28	0.02	1	1	2	1	1
Head Tape	cms.	0.22	0.005	2	1	2	1	2
Infant meter	cms.	0.65	0.08	4	4	3	2	3
Weighing scale	kg	0.5	0.05	2	2	4	3	4
Age	months	0.5	0.014	1	0	0	0	1

field conditions it is easier to work with the weighing scale than with the infant meter.

Table 1 summarizes the performance of the instruments for both urban and rural settings.

It can be seen in column 3, Table 1, that the instrument with the least standard deviation is the head tape, while the measures taken with the infant meter have the greates SD. It is important to recall that these observations refer to the communities we have studied. In other communities the age may have the greatest standard deviation, due probably to cultural or other characteristics.

Once the instrument performance is defined, attention must be directed to method's performance; again a series of characteristics inherent in each method can be analyzed in conjunction with some of the characteristics of the instruments used to carry out the measurements.

The anthropometric measurements to be analyzed are expressed as the relation between the actual measure to the value of such measure relative to a child considered as well nourished. Besides the variables P(T), T(E), P(T(E)) already defined, the following anthropometric measurements are considered:

$$CB(E) = \frac{\text{mid arm circumference (cm.)}}{\text{standard mid arm circumference for actual age}}$$

$$CC(E) = \frac{\text{head circumference (cm.)}}{\text{standard head circumference for actual age}}$$

$$P(E) = \frac{\text{actual weight (kg.)}}{\text{standard weight for actual age}}$$

Appendix A describes the mathematical procedure for the calculation of all the columns of Table 2.

The values for the variables: field performance, transportability, durability, cost and time refer to the instruments used, not to the method per se. The values are in an ordinal scale.

Table 2, demostrates that variables CB(E) and CC(E) have the best performance characteristics for all the methods studied.

It is interesting to note the way in which the measurement errors propagate from the instruments to the method. Suppose that the SD for height measurement is 0.65 cms. and that for weight is 0.5 kg.; the percent error of the method height-weight, as a result of the two prevoius standard deviations is around 9%. As the coefficient of variation for the variable P(T) for a population of normal children 0-6 years is 10%, the specificity and sensitivity of the weight for height measure may be seriously affected around the value of P(T)

B. Correlation Analysis

= 0.9, i.e., the limit between the two categories of well nourished and malnourished children.

TABLE 2

PERFOMANCE CHARACTERISTICS OF ALL METHODS

Method	SD	Percent error	Field Perfor-mance	Transport-ability	Durability	Cost	Time
CB(E)	0.02	0.02	1	1	1	2	1
CC(E)	0.007	0.007	1	1	2	1	2
P(T)	0.09	0.09	5	5	5	4	5
T(E)	0.03	0.03	4	4	3	2	3
P(E)	0.06	0.06	2	3	4	3	4
P(T(E))	0.95	0.95	6	6	6	4	4

In order to study the relations between the different anthropometric methods, a regression and correlation analysis was performed for the two samples treated as a single population.

Column 1, Table 3, shows that variable P(E) correlates significantly with both P(T) and T(E). In other words, variable P(E) tends to detect both acute and chronic malnutrition. Again, since variable P(E) has a high correlation with variable P(T(E)), it may be concluded that variable P(E) is a measure of global malnutrition. The question is: What is

TABLE 3

CORRELATION COEFFICIENTS OF SOME ANTHROPOMETRIC MEASURES

	P(E)	P(T)	T(E)	P(T(E))	CB(E)	CC(E)
P(E)	1					
P(T)	R = 0.6* (F = 591)					
T(E)	R = 0.7 (F = 0922)	R = NS*** F = NS				
P(T(E))	R = 0.96 (F = 5878)	—	—			
CB(E)	R = 0.62 (F = 593)	R = 0.47 (F = 195)	R = 0.4 (F = 131)	R = 0.68 (F = 816)		
CC(E)	R = 0.45 (F = 198)	R = 0.22 (F = 113)	R = 0.42 (F = 161)	R = 0.47 (F = 215)	R = 0.37 (F = 127)	
CO(E)**					R = 0.97 (F = 8515)	

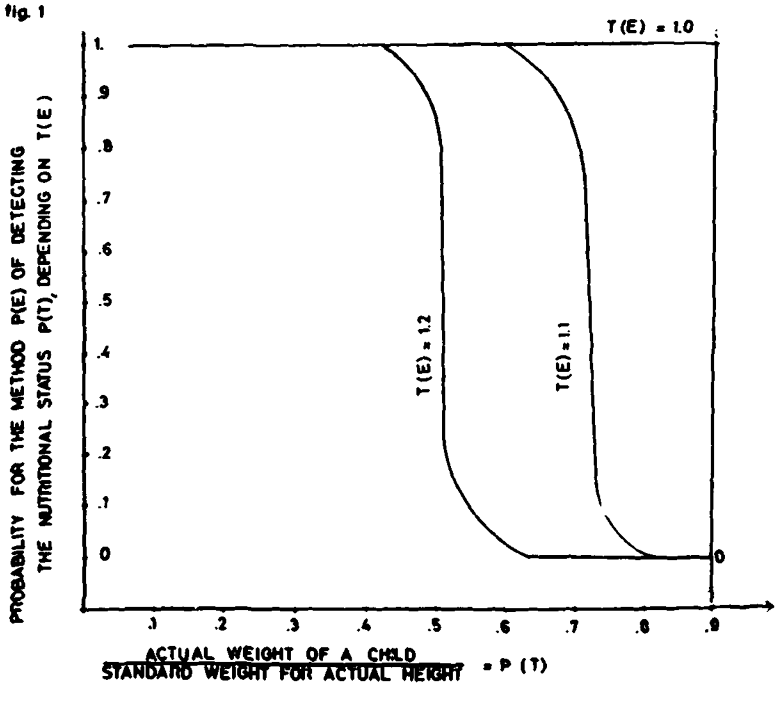
*R = Correlation coefficient
F = Snedecor's (Fisher) ratio of the regression line; values are rounded
** = Elbow circumference for age
*** = Not statistically significant.

the sensitivity and specificity* of the weight for age (Gómez' classification) measure?

On the basis of the strength of association between P(E) and P(T(E)), it can be said that:

1. for a child with both acute and chronic malnutrition, the probability of the Gómez' method (P(E)) to detect such a child as malnourished, is 100%. If $P(T)<0.9$ and $T(E)<0.95$, then the product P(T(E)) lies below the limit for detection of malnutrtion by the Gómez' method;
2. for a child with either acute or chronic malnutrition,

fig. 1



In this context, sensitivity is related to the probability of the Gómez method of detecting a case of acute and/or chronic malnutrition; specificity is related to the probability of detecting as well nourished a child with normal weight for height and height for age.

the probability for the Gómez method (P(E)) to detect him as malnourished, depends on the values of both variables P(T) and T(E) and not only on the value of variable which classified the child as malnourished. Fig. 1 shows this relationship.

For example, if T(E) $= 1.1$ the probability for the method of Gómez to detect malnutrition is 1 only if the variable P(T) is $\leqslant 0.65$. That is conceivable in a very severe case of acute malnutrition. On the other hand if a child has mild acute malnutrition ($0.8 \leqslant P(T) \leqslant 0.9$), and his height with respect to age T(E) is $\geqslant 1.1$, then the product P(T) x T(E) will tend to be high. In this case, the probability for this child to be detected as malnourished by Gómez' classification (i.e., P(E) is very low.

In conclusion the sensitivity of the Gómez' method is low when gigantism is associated with acute malnutrition. For the sample analyzed it was found that the Gómez method does not detect as malnourished 15% of the cases of acute malnutrition and 14% of the cases of chronic malnutrition.

For a child classified as well nourished by his weight for height and height for age, with both value of P(T) and T(E) near the lower limit of 0.9 and 0.95, there is a high probability for such a child to be classified as malnourished according to the Gómez method, as the P(T(E)) value tends to be low. For the sample of this study 10% of the well nourished children were classified as malnourished by the Gómez method. Never-the-less, as a method that detects at risk children, this low specificity may be considered as an advantage rather than a defect.

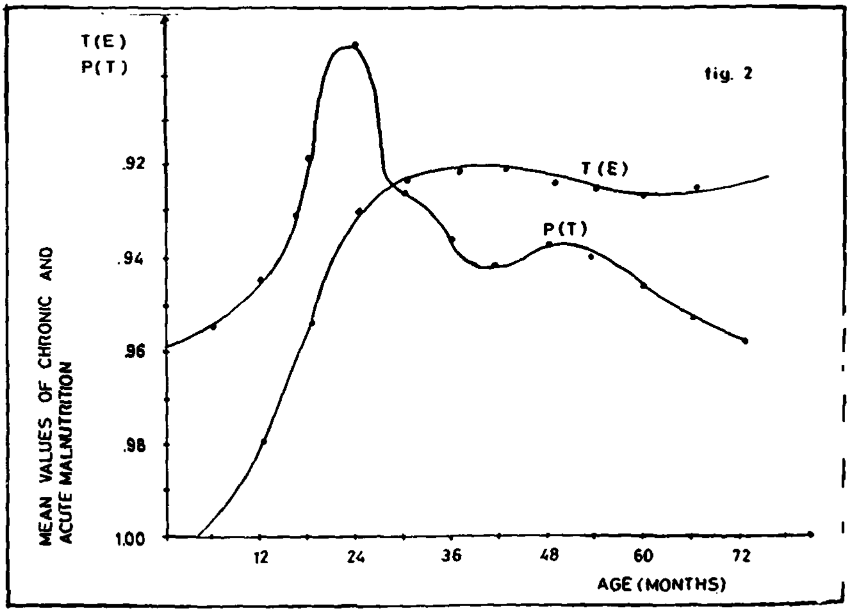
From the observation of columns 1 to 5 and row 5 and 6 of Table III it is possible to suggest:

1. mid arm circumference CB(E) is better associated with global malnutrition than head circumference (CC(E));
2. head circumference CC(E) have high association with chronic malnutrition; while mid-arm circumference correlates better with acute malnutrition.

Because CB(E) correlates with both T(E) and P(T), it is a poor indicator of either acute or chronic malnutrition.

The surprisingly poor association between T(E) and P(T) can be explained with a chronologic perspective of the occurrence of malnutrion in the studied population. Figure 2 shows the mean value of variables P(T) and T(E) for the differents age groups.

It can be seen that acute malnutrition tends to rise during the first two year and then decline, while chronic malnutrition takes a longer time to appear; it may be said to follow a monotonic curve. Under these conditions, a close association between chronic and acute malnutrition can not be expected.



CONCLUSION

From an analysis of the instruments and methods used for anthropometric evaluation of the state of nutrition of individuals it was concluded that mid-arm circumference and head circumference have the smallest instrumental error and the best characteristics of field performance in opposition to the weight for age methods. These have instrumental errors comparable in magnitude to the standard deviation of their distribution for normal populations.

From the regression and correlation analysis for the different anthropometric methods it was concluded that:

1. The Gómez' method (P(E)) of comparing weight for age, tends to detect cases of acute and chronic malnutrition, but loses sensitivity in the cases of acute malnutrition associated with taller-for-age children.
2. Mid-arm circumference and elbow (CO(E)) circumference are measures of global malnutrition, head circumference is a measure of chronic malnutrition.

RESUMEN

Análisis Comparativo de Mediciones Antropométricas

Este trabajo tiene como objetivo principal proporcionar información y criterios de decisión para quien tenga que escoger instrumentos y métodos para trabajo de campo.

En la primera parte del artículo se sugiere un procedimiento para comparar las características de los instrumentos y para extrapolar a las características de los métodos antropométricos. Se concluye que los métodos de perímetro braquial y craneal tienen menor incertidumbre o imprecisión de medición, mientras que el método peso-talla tiene una imprecisión de lectura comparable con la desviación típica de la distribución normal de peso por talla para niños pre-escolares. Además esa imprecisión se acentúa en los rangos de edad más bajos. En la segunda parte se analiza una matriz de correlación para asociar cada método específico (peso-talla, peso-edad, perímetro braquial, perímetro de codo etc.) con una de las tres definiciones de desnutrición: crónica, aguda, global. Las conclusiones más importants son las siguientes:

1. **El método peso-edad es una medida de desnutrición global.**
2. **Si un niño presenta al mismo tiempo una deficiencia de peso por talla y de talla por edad, la probabilidad que el método de Gómez detecte una deficiencia de peso por edad es muy alta; pero el método de Gómez pierde sensibilidad en casos de desnutrición aguda asociada con gigantismo y desnutrición crónica asociada con obesidad.**
3. **Hay una alta correlación entre el perímetro braquial y de codo y ambas medidas podrían ser usadas como medidas de desnutrición global, si las características de especificidad y sensibilidad son adecuadas a los requerimientos del estudio.**

   Se quiere recalcar en fin que es importante definir al comienzo qué se desea medir. Una vez decidido, debe escogerse el método apropiado para ello, teniendo en cuenta por cada método sus características. Los métodos clásicos de peso-talla, peso-edad, talla-edad, tienen teóricamente una alta especificidad y sensibilidad, más los errores de medida en los instrumentos usados

(medidas de peso y talla) pueden afectar seriamente esas características. Los métodos "prácticos" de circunferencia de brazo, codo, etc., tienen muchas ventajas de uso como rapidez de medición, transportabilidad y también presentan errores de medida inferiores a los métodos clásicos, más los valores de correlación encontrados hacen sospechar que el límite teóricos de sensibilidad y especificidad que se puede alcanzar con estos métodos es limitado. Dependiendo del peso que se le de a cada una de estas características se debe escoger el método y los instrumentos.

APPENDIX A

Each anthropometric method was defined to have a relation of the type

$$Z = X/Xo(Y) \qquad 1)$$

then:

$$dz = \frac{\partial z}{\partial x}dx + \frac{\partial z}{\partial xo}dxo \qquad 2)$$

where ∂ is the symbol for partial derivative; we know that foa large n it is possible to put:

$$SD(Z) = \sqrt{\sum^{n} (dz)^2 /n} \qquad 3)$$

when S.D. stands for standard deviation.

Squaring both members of 2), summing up and dividing by n we have:

$$\frac{\Sigma(dz)^2}{n} = \frac{1}{n}\sum^{n}\left(\frac{\partial z}{\partial x}dx + \frac{\partial z}{\partial xo}dxo\right)^2 = \left(\frac{\partial z}{\partial x}\right)^2 \sum^{n}\frac{(dx)^2}{n} + \left(\frac{\partial z}{\partial xo}\right)^2 \sum^{n}\frac{(dxo)^2}{n} + \frac{2}{n}\sum^{n}\frac{\partial z}{\partial x}\frac{\partial z}{\partial xo}dx\,dxo \qquad 4)$$

If we assume that the errors in the measurements of X and Xo are independents i.e.

$$\sum^{n} \frac{\partial z}{\partial x} \frac{\partial z}{\partial xo} \, dx \, dxo \simeq 0 \qquad 5)$$

Therefore we have for equation 4) (using definition 3)

$$SD\,(Z)^2 \simeq \left(\frac{\partial z}{\partial x}\right)^2 SD^2\,(X) + \left(\frac{\partial z}{\partial xo}\right)^2 SD^2\,(Xo) \qquad 6)$$

Calculating the derivative of 1) we have

$$\frac{\partial z}{\partial x} = \frac{1}{Xo(Y)} \; ; \; \frac{\partial z}{\partial xo} = -\frac{X}{X^2o(Y)} \simeq -\frac{1}{Xo(Y)} \qquad 7)$$

Substituing 7) into 6) we have:

$$SD(Z) = \frac{1}{Xo} \sqrt{SD^2(X) + SD^2(Xo)} \qquad 8)$$

Because Xo = Xo(Y) it is possible to put:

$$SD(Xo) = f'(Y) \;\; SD(Y) \simeq \frac{\Delta Xo}{\Delta Y} \; SD(Y) \qquad 9)$$

where:

$f'(X)$ is the first derivative of Xo with respect to Y

Δ Xo is the maximal interval of variation of Xo

Δ Y is the maximal interval of variation of Y

Substituing 9) into 8) we have:

$$SD(Z) = \frac{1}{Xo} \sqrt{SD^2(X) + \frac{\Delta Xo}{\Delta Y} SD^2(Y)} \qquad 10)$$

which is the formula used in the calculations.

For the variable P(T(E)) we have

$$Z = Z_1 \times Z_2 \quad SD(Z) = \sqrt{SD^2(Z_1) + SD^2(Z_2)} \qquad 11)$$

where Z_1 and Z^2 refer to the variables P(T) and T(E).

From formula 10) it is possible to observe how the S.D. varies with the age of the child.

If for example the method of weight by age is used, the factor $\frac{1}{Xo}$ (which represents in this case the reciprocal of standard weight for age) is small for children of 5-6 years old because Xo is high, but it tends to increase as age decreases so that if Xo = 4.000 grs. for a 1 month old child and Xo = 20.000 grams for a 70 months old child, the uncertanty is five times higher in the measurement of the small child than in the other. Therefore, special care should be used in the anthropometric measurement of children less than 1 year.

For the calculation of the percent error the following relation was used:

% error = $SD/\bar{Z}$ where $\bar{Z}$ is the mean value of the variable Z for the population under study.

In the case of the characteristics of instruments such as field performance, transportability, time and durability, the following formula was used:

Z = integer part of $(0.5 + \sqrt{X^2 + Y^2})$ where X, Y are the numeric values for the characteristics of the instruments and Z is the characteristic of the method.

For example, for the method P(T), and for the characteristics field performance we have:

Field performance of weighing scale = 2

Field performance of infant meter = 4

Field performance of P(T) =

integer part of $(0.5 + \sqrt{2^2 + 4^2}) =$

Integer part of (0.5 + 4.48) = 4

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