RESEARCH REPORT

On the World Health Organisation's measurement of health inequalities

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J Epidemiol Community Health 2002;**56**:177–182

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Accepted for publication 24 July 2001

Study objective: To review the World Health Organisation's methodological approach for the purpose of measuring health inequalities presented in the WHR 2000 and reference papers.
Main findings: Recommending that health inequalities be assessed by measuring interindividual differences, without regard for the distribution of health status among specific population subgroups, the approach taken by WHO does not take into account the socioeconomic dimension, is strongly influenced by the extent of socioeconomic inequalities in the population, and suffers from the health redistribution problem. Apart from the conceptual issues, the estimation procedure also has methodological problems hidden in a sophisticated statistical procedure, which is confusingly explained in one of the referred discussion papers. The results presented in the WHR 2000 are based on Demographic and Health Survey data that refer to more than 10 years ago.
Other methodological problems: The WHO's individual differences measure of health inequalities is expressed in units of survival time raised to the power of 2.5. Besides the difficulty of interpretation, the individual differences index is not a relative measure. However, the index of equality of child survival was defined as the complement of the individual differences index, as though it were a relative measure.
Neglect to the specialised literature: The WHO's index is a particular case in a family of measures that provides generalisations of the Gini coefficient. However, concerns on the adequacy and validity of this procedure for the purposes of measuring health inequalities were completely ignored.
Conclusions: The need to open up the debate with the scientific community has been recently recognised by the executive board of the WHO. In view of the new prospect, the paper concludes by raising some points that can contribute to the discussion on the measurement of health inequalities, with regard to the evaluation of the health system performance.

The inverse association between socioeconomic status (SES) and health outcomes at the individual level has been reported throughout the world. A substantial number of studies have documented strong inverse associations between SES and morbidity and mortality over time and in different countries, regardless of the measure of the socioeconomic level.[1–4]

The consistent evidence of persistent and increasing social inequalities in health has raised much interest in this issue in many countries.[5–8] Reducing health inequalities has become a central goal in the context of health policies and development of programmes to achieve a more equal share of good health.[9]

Recognising the importance of reducing the burden of illness of people at a socioeconomic disadvantage, the WHO has adopted strategies of "Health for all", focused on the reduction in health inequalities between countries and between groups within countries.[10] The importance of this topic has been emphasised over the past years in the WHO's policy agenda, and is now considered as one of the first priorities.

The WHO's concern in improving the health of the worse off and reducing health inequalities is clearly established in the World Health Report 2000 (WHR 2000) (page 26)[11]:

> "A good health system, above all, contributes to good health. But is not always satisfactory to protect or improve the average health of the population, if at the same time inequality worsens or remains high because the gain accrues disproportionately to those already enjoying better health. The health system also has the responsibility to try to reduce inequalities by preferentially improving the health of the worse-off, wherever these inequalities are caused by conditions amenable to intervention. The objective of good health is really twofold: the best attainable average level—goodness—and the smallest feasible differences among individuals and groups—fairness".

Under this perspective, the WHR 2000 promotes the monitoring of inequalities in health as a distinct dimension to assess the performance of health systems. Although the existence of a great deal of discussion on measures of health inequalities in the scientific literature,[12–15] the WHO has adopted a new approach based on a family of measures proposed by Gakidou *et al*.[16] The family is defined as a set of measures of interindividual differences (IID) in health status within a population and provides generalisations of the Gini coefficient by modification of two mathematical parameters.

The measurement of health inequalities by means of the Lorenz curve and the Gini coefficient, as first used by Le Grand and Rabin,[17] has been criticised on conceptual grounds because it fails to capture the socioeconomic dimension.[12] However, restrictions to the use of this procedure for the purposes of measuring health inequalities have been completely ignored in the WHO's approach.

Apart from the conceptual issues, the WHO's measure of inequality has other methodological problems hidden in a very sophisticated statistical procedure, which includes the

Abbreviations: SES, socioeconomic status; ECS, equality of child survival; IID, interindividual differences; DALE; disability adjusted life expectancy

Table 1 Example of the effects of population distributions by socioeconomic status on the IID index

	Area 1		Area 2	
Educational level of the mother	Probability of survival in the first four weeks	Population distribution	Probability of survival in the first four weeks	Population distribution
Illiterate	0.9278	1.2%	0.9200	0.6%
Fundamental	0.9912	46.9%	0.9921	25.0%
High school	0.9940	37.3%	0.9921	24.9%
College	0.9938	14.6%	0.9960	49.5%
Statistics	Mean=0.9919 SD=0.0071 IID (3, 0.5) = 3.19×10^{-6}		Mean=0.9936 SD=0.0061 IID (3, 0.5) = 1.84×10^{-6}	

Area 1: composed of the districts of Campo Grande and Santa Cruz; Area 2: composed of the districts of Copacabana, Botafogo and Leblon.

maximum likelihood estimation of the expected probability of death during childhood by an extended beta-binomial distribution. Besides the lack of transparency in the utilisation of such a complex methodology, the estimation procedure is based on Demographic and Health Survey (DHS) data that refer to more than 10 years ago.

Despite the recognition and appreciation of the WHO's efforts in promoting the measurement of health inequalities, our concern is on the validity of the WHO's methodological approach for the estimation of health inequalities, in view of the main goal of assessing performance of health systems. The objective of this paper is to examine the inconsistencies, problems, and limitations we have found in our review.

THE WHO'S APPROACH FOR MEASURING HEALTH INEQUALITIES

The WHO's approach is based on a family of health inequality measures proposed by Gakidou *et al*,[16] denominated as IID indices:

$$IID(\alpha,\beta) = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}|y_i - y_j|^{\alpha}}{2n^2\mu^{\beta}}$$

where "y_i is the health of individual i and y_j is the health of individual j, μ is the mean health of the population and n is the number of individuals in the population"(page 47).[16] The parameter α changes the significance attributed to differences in health status and the parameter β controls the extent to which the index is purely relative to the mean or absolute. Different measures of health inequalities are provided by modification of the parameters α and β. In the particular case of the WHR approach, the values of $\alpha=3$ and $\beta=0.5$ have been used.

CONCEPTUAL ISSUES

Recommending that health inequalities be assessed by measuring IID, without regard for differential distribution of health status among specific population subgroups, the WHO's approach fails to identify the determinants of health inequalities. As has been discussed by Carr Hill,[18] it is considered rather uninteresting to assess generalised variability in health status within a population, without regarding for systematic variations provided by the appropriate stratification of the population.

Besides, the IID index suffers from various conceptual limitations: the health redistribution problem; failure to capture the socioeconomic dimension; and influence of socioeconomic inequalities. In the following sections, we discuss these conceptual issues.

The health redistribution problem

Although the IID index is given by a complex mathematical formula, the WHO's indicator of health inequalities is simply a generalised Gini coefficient, obtained by modification of the parameters $\alpha=1$ and $\beta=1$ (which corresponds to the Gini coefficient) to the parameters $\alpha=3$ and $\beta=0.5$ (which corresponds to the WHO's index).

The Gini coefficient is a well known index used by economists to measure income inequalities. It is a relative measure and ranges from 0 (equality) to 1 (maximum inequality). The assumption behind the Gini coefficient is of redistribution of income, because equality is achieved by raising the income of the worse off at the cost of diminishing the income of the wealthiest. Similarly to the Gini coefficient, the IID index reflects individual differences in health status, which can be reduced by lowering the health status of the healthiest and increasing the health status of the sickest.

However, in the case of health inequalities, the redistribution perspective is not appropriate. Indeed, it contradicts the WHO's proposal, as stated in the Report itself (page 26).[11]

Effects of socioeconomic inequalities on the IID index

Because the IID index is a measure of IID, that is, a measure of variations in health status across individuals in a population, it depends on the distribution of the population by SES, or other confounding factors related to health.

The influence of the population socioeconomic inequalities on the IID index is illustrated with an example. In table 1, we present the probability of survival in the first four weeks of life, calculated as the complement of the neonatal mortality rate, estimated in two distinct areas of the city of Rio de Janeiro, in 2000, by years of schooling of the mother. In the first area, composed of the two poorest districts of the city (Campo Grande and Santa Cruz), the neonatal mortality rate ranges from 72.2/1000 to 6.2/1000 live births. In the second area, composed of the three wealthiest districts of Rio (Botafogo, Copacabana, and Leblon), the neonatal mortality ranges from 80.0/1000 to 4.0/1000 live births, thus showing a greater inequality in health.

However, because the socioeconomic inequality is greater in the first area, measures that are based on the IID without controlling for confounding factors will show higher values in this area. This is the case of both the standard deviation and the IID index based on the probability of survival in the first four weeks of life, as shown in table 1.

The effects of income inequality on the measurement of health inequalities by means of IID in health status can be examined mathematically. For this purpose, we considered the specific case of the relation between mortality risk and income, and examined the influence of income inequality on the variance of the mortality risk (appendix).

The mathematical model demonstrates that if we consider the existence of a log-log relation between mortality risk and income,[19] the variance of the logarithm of the mortality risk

will depend not only on the performance of the health system in diminishing the socioeconomic health inequalities but also on the extent of the income inequalities in the population.

From the purely quantitative viewpoint, it is a matter of choice whether one should or should not take into account the distribution of the population across socioeconomic groups. In the first case, the distribution of health status in the population is estimated, without regarding the distribution of health among specific population groups. In the second case, the joint distribution of both health and SES is considered.[14] However, it should be emphasised that if one considers that what is important about health inequalities is to assess the magnitude of the interindividual differences in health status, as the view taken by WHO,[11] the index of health inequalities will inevitably mirror the inequality in SES.

As has been discussed by Wagstaff *et al*,[12] whether the influence of the extent of the socioeconomic inequalities in the population on the measure of health inequality is a defect depends on what is being evaluated. Particularly, if the main goal is to assess the performance of health systems, this is clearly a restriction because the extent of inequalities in SES within the population is generally outside the domain of influence of public health policies and actions.

It should be noted that measuring health inequalities at the individual level, as recommended by WHO, is contradictory to the argument used in the Report itself, which recognises that "Health systems cannot be held responsible for influences such as the distribution of income and wealth, any more than for the impact of climate" (page 23).[11]

In addition, the considerable influence of the extent of socioeconomic inequalities on the IID index has certainly biased the cross country comparison in the WHR 2000. Rather than comparing the health system performance in diminishing health inequalities across countries, you are comparing the extent of socioeconomic inequalities within each country population.

ON THE WHO'S INDEX OF EQUALITY OF CHILD SURVIVAL (ECS)

We now focus on some mathematical and statistical problems we have found in our review. The first mathematical problem lies in the definition of the ECS index.

The WHO's index of health equality is defined as the complement of a measure of IID of child survival. The intention was to measure the distribution of DALE (disability adjusted life expectancy) across individuals, but the analysis of the distribution of DALE in each country has not been completed for the WHR 2000 (page 146).[11]

As mentioned previously, the WHO's approach for measuring health inequalities is based on the family of measures (IID (α,β)) proposed by Gakidou *et al*.[16] For the purposes of calculating an index of health inequality, the parameters α=3 and β=0.5 have been selected according to the preference of 1006 respondents to an internet-based interactive questionnaire.[20] This unusual way of choosing parameters of a statistical measure, according to preference to respondents and not according to the mathematical properties of the measure introduced by modification of the parameters, provided an index that it is very difficult to interpret. The index is not an absolute measure—like the standard deviation that can be compared to the mean—nor a relative measure—like the Gini coefficient or the coefficient of variation that do not depend on the measurement scale of survival time. The WHO's index of health inequalities is a function of the unit of measurement of survival time raised to the power of 2.5. That is, if survival time is measured in months or days, the index takes completely different values, far beyond the unity.

At this point, it should be emphasised that, only by chance, the WHO's index ranges from 0 to 1 when survival time is measured in years, as recognised in the WHR 2000 itself (page 147)[11] and not because the index is a relative measure.

Nevertheless, for the purpose of defining an index of health equality, the WHO's ECS index was defined as the complement of the IID index, using the parameters α=3.0 and β=0.5 (page 147)[11]:

$$ECS = 1 - \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}|y_i - y_j|^3}{2n^2\mu^{0.5}}$$

But it does not make sense to define an index of equality as the complement of an index of inequality if the latter is not a relative measure. Mathematically, you cannot add two quantities with distinct measurement scales: one that is independent of the units of measurement of survival time (the unity) and the other that is a function of the unit of measurement of survival time raised to the power of 2.5. For example, as for Brazil, the ECS index equals 0.762[11] (annex table 5). Now, suppose that survival time is measured in months. Then, the ECS index for Brazil would equal (−117.7). What is the meaning of such a measure of ECS?

It should be noted that this problem certainly misleads the analysis of the results corresponding to the ECS index presented in the Report[11] (annex table 5), which are being interpreted as relative measures under the hypothesis that equality is achieved when the ECS index equals 1.

ON THE PROBLEMS OF THE ECS INDEX ESTIMATION PROCEDURE

The detailed description of the methodological procedure used by WHO in the estimation of the ECS index is referred to two GPE discussion papers: references number 20 and 21 in the Report (page 151).[11] The first one has been available only three months after the publication of the WHR 2000, with a different title, though.[21] The second one has not been released yet.

Several important problems in the WHO's methodological approach have been found, which refer to: inconsistencies between the GPE discussion paper and the WHR 2000; the sources of information; relevant mathematical and statistical mistakes. Besides these problems, the paper does not fully clarify the applied statistical procedures.

In respect to the sources of information, we point out that the dataset refers to a long time ago. As stated by the authors (page 5)[21]: "For each country we used the latest year of available data from a nationally representative DHS, ranging from 1987 to 1997"... "We used a ten-year observation period starting two years prior to the interview year." So, for the 50 countries for which DHS data were available, the ECS indices were calculated in periods of time ranging from 1975–85 to 1985–95. That is, the WHR 2000 describes and compares measures of health inequalities that refer to years ranging, on the average, from 10 to 20 years ago.

Also, the methodology that has been applied to small area data has not been described either in the WHR 2000 or in the reference papers. It seems that the application to small area data has been used only to validate the methodology applied to individual (family) data (page 7).[21]

Regarding the latter argument, we point out that Brazil has 11 cities with more than one million population, including São Paulo and Rio de Janeiro. They are all Brazilian municipalities and are extremely heterogeneous. Recommending that it is appropriate to assess health inequalities across geographical regions, such as municipalities, with the underlying assumption of health homogeneity within the population, is contradictory to all of the discussion on intraurban health variations that has taken place in the recent literature. Metropolitan areas, which frequently encompass zones ranging

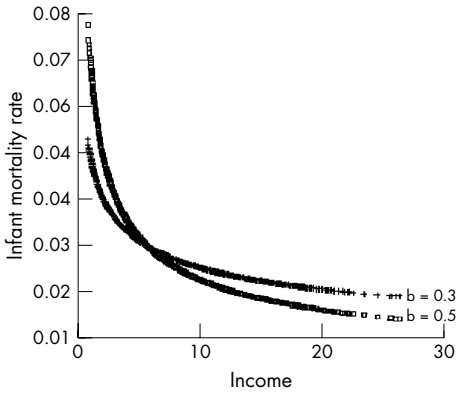

Figure 1 Example of a log-log relation between infant mortality rate and income.

from wealthy to marginal, and often pockets of poverty and slums, have peculiar health patterns known to be highly unequal.[22–24]

In the paper describing the methodological approach used in the WHR 2000,[21] mathematical and statistical concepts are presented without the traditional accuracy peculiar to those disciplines. For example, the equality equation for the estimation of π (page 6)[21]

$$\hat{\pi} = \sum_{i}^{N} Y_i / \sum_{i}^{N} n_i = \frac{1}{N} \sum_{i}^{N} (Y_i / n_i)$$

does not hold. The second expression is a typical ratio estimate of the probability of death π in cluster sampling[25] but is not equal to the first expression, which is a random sampling estimate of the probability π.

Another relevant question refers to the utilisation of the beta-binomial approximation in calculating the IID index point estimates and corresponding confidence intervals. Regarding this procedure, several points are unclear: utilisation of the beta-binomial distribution to provide IID index point estimates; estimation of the standard error of the IID index, which is necessary to the calculation of the confidence interval estimation; and the use of asymptotic normal approximations. It is important to observe that the lack of transparency in the methodology restricts the possibilities of individually reproducing the approach in each member country.

Now, concerning the covariate adjustment,[21] besides the fact that there is no description of the method of adjustment, some points deserve attention. Firstly, it is well known that many other variables, such as "previous sibling mortality", "mother's prenatal attendance", "geographical region of residence", "community environment", are known factors that can affect infant and childhood mortality[26] and could have been included in the model. Secondly, the adjustment for covariates is inconsistent with the authors' conception of a measure of health inequalities, which should be assessed by measuring health IID, without categorising a priori according to some features of specific population subgroups.[27]

DISCUSSION

Several methods are available to measure inequalities in health. The advantages and disadvantages of different approaches have been considerably discussed in the recent literature. Some are simple measures such as rate ratios or rate differences between two extreme groups.[2] Others are borrowed from the epidemiological approach in assessing differential disease risks, such as the odds ratio or the population attributable risk.[13] More sophisticated measures use the ordered nature of SES, including the slope index of inequality or other regression-based measures.[28] Some composite indices originate from adaptations of the methods used to assess income inequality, like the concentration index,[29] and some others are based on overall measures of association, such as the dissimilarity index (S Koskinen, 20th general conference of The International Union For Scientific Study Of Population, 1985).

Other authors have suggested the use of the Gini coefficient to measure inequalities in health[17 30 31] but restrictions of this procedure have been pointed out in many of the revision papers.[12 13 14]

In the full description of the WHO's methodological approach, however, concerns on the adequacy and validity of indexes based on the Gini coefficient were completely ignored. The authors did not simply disregard the restrictions cited in the literature but they increase the properties of the proposed family of measures (IID (α,β)), saying that the family "encompasses or can be used to compute every popular inequality measure used in the literature and many others..." (page 8).[21] This omission seems particularly inappropriate as all health inequality measures that are not assessed at the individual level are not particular cases in the family of IID indices. Measures like the "slope index of inequality", the "concentration index", the "population-attributable risk" are of widespread use and do not belong to the IID family.

It also became clear the disregard to the concepts and theoretical principles of the disciplines of mathematics, statistics, and epidemiology. In the absence of data for all countries, covariate adjustment procedures without underlying conceptual epidemiological models were excessively used. Moreover, regression estimated results were presented in the WHR 2000 without considering the goodness of fit of the models, as though the models were perfectly fitted to the data.

The need to establish a dialogue with the scientific community and a technical consultation process was recently recognised by the Executive Board of the WHO.[32] In view of the new prospect, we conclude this paper by raising some points that can contribute to the debate on the measurement of health inequalities.

As a starting argument, we point out that the problem we are dealing with is not only the measurement of socioeconomic inequalities in health within a population. Additionally, we have to focus on the evaluation of the health system performance in reducing health inequalities.

So, before the selection of the appropriate method in the measurement of health inequalities, we first consider the problem of the choice of the response health indicator. As the goal is the evaluation of health policies, which aim at reducing health inequalities in the population, we have to think on health indicators that are responsive to health actions as well as amenable to intervention.

Key points

- The WHO's index of health inequality is a measure of interindividual differences (IID), based on generalisations of the Gini coefficient.
- Concerns in the specialised literature on the adequacy and validity of interindividual measures of health inequalities were completely ignored.
- The IID index fails to capture the socioeconomic dimension and is influenced by the extent of socioeconomic inequalities.
- The estimation procedure is based on Demographic and Health Survey data that refer to more than 10 years ago.
- The equality of child survival index was defined as the complement of the IID index, as though it were a relative measure.

As our second point, we emphasise the importance of the social determinants of health inequalities. As has been shown in the present paper, we cannot dissociate inequality in health from inequality in socioeconomic conditions. Therefore, the first important challenge would be to define an underlying causal web able to represent the pathways linking socioeconomic factors to effects of intervenient health actions, which jointly affect the response health indicator.

Having defined a conceptual underlying model, the next step would be the selection of the method to assess the health inequalities in the population. As mentioned before, several methods are available, from the estimation of composite summary indices to the fitness of logistic regression models to describe multidimensional tables.[14] Each method has its own weaknesses and strengths, which should be discussed in view of the conceptual model.

Discussing the appropriateness of the method, the availability of data cannot be neglected. Therefore, as the third integrated step in this process, we focus on the importance of reliable and up to date data in the process of monitoring health inequalities. Conceptual models and corresponding methods are of no use if reliable data are not available and trends cannot be assessed.

In summary, discussing an approach for the purposes of the measurement of health inequalities, with regard to the assessment of the health system performance, our proposal is that you should focus on a three component strategy: proposition of a conceptual underlying model; selection of appropriate methods and summary measures; and collection of reliable and up to date data. All of the three steps should be integrated in a unique process. Dissociating any one of the components would certainly unbalance the process and would put in risk the achievement of the main objective.

APPENDIX

Effects of income inequality on the variance of mortality risk

For the purpose of mathematically examining the effects of socioeconomic inequalities on measures of dispersion of health status, we consider the specific case of the relation between income and mortality risk. This relation has been described by many authors as a continuous decreasing function with a non-constant gradient, steeper at low income levels than at high income levels.[19 33]

As suggested by Backlund *et al*,[19] the log-log model is suitable to model the relation between the relative risk of mortality (Y) and income (X):

$$\mathrm{Ln(Y)} = \mathrm{Ln(c)} - \mathrm{bLn}\frac{\mathrm{X}}{\mu}, \mathrm{b} > 0$$

or

$$\mathrm{Y} = \mathrm{c}\left(\frac{\mathrm{X}}{\mu}\right)^{-\mathrm{b}}$$

The parameter c measures the level of the mortality risk corresponding to the average value of income represented by μ. The parameter b measures the gradient of the mortality risk by income. Increasing the absolute value of b implies the increase of the gradient by income. So, the parameter b has the role of measuring the size of health inequalities across socioeconomic groups: the greater the absolute value of b, the steeper is the decreasing trend of the mortality risk and the greater is the gap of the mortality risk between poor and wealthy people.

In figure 1, we show an example of the log-log relation between mortality risk and income.

In the simulated 10 000 population, income (x) has a log normal distribution with mean =5 and standard deviation =0.5 and the infant mortality rate has a log-log relation with income, with c=0.030. In the first case, b=0.5, and in the second, b=0.3. We can see that the decreasing of b implies the decreasing of the variation of the infant mortality rate by income.

Assuming the log-log model, we can easily calculate the expected value and the variance of $Ln\ Y$:

$$\mathrm{E\,(Ln\,Y)} = \mathrm{Ln(c)}$$
$$\mathrm{Var\ (Ln\,Y)} = \mathrm{b^2\ Var\,(Ln\,X)}$$

Hence, if we consider the existence of a log-log relation between mortality risk and income, the variance of $Ln\ Y$ depends on both, the inequality of the mortality risk by income, as measured by the parameter b, and the income inequality in the population, as measured by the variance of $Ln\ X$. So, in the case of worsening the income inequality in the population, an improvement in reducing the gradient of the mortality risk (expressed by a smaller b) does not necessarily imply the reduction of the variance of the mortality risk, which could even increase.

In other words, this mathematical model says that dispersion indices of health status measured at the individual level are dependent not only on the performance of the health system in diminishing the socioeconomic health inequalities but also on the extent of the magnitude of the income inequalities in the population.

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