Child Mortality Attributable to Two Major Risk Factors: How much of the burden is concentrated in the poor?

Majid Ezzati [1], Stephen vander Hoorn [2], Cecilia Vidal [1], Ajay Tandon [1], Angelica Sousa [3], Margaret Hogan [3], Emmanuela Gakidou [1]

1) Harvard University
2) University of Auckland
3) World Health Organization

Summary

The contributions of risk factors (e.g. undernutrition and poor water, sanitation, and hygiene) to child mortality have been extensively documented. Because of paucity of data, global and regional estimates have assumed that risks are uniformly distributed in a population and the *distributions* of the health effects of risk factors have not been studied in a comparable way across populations. In this paper, we estimate total and equity effects of exposure to two important childhood mortality risk factors – childhood underweight and poor water, sanitation, and hygiene – accounting for concentration of multiple risks and mortality in different income groups using the Demographic and Health Surveys. This analysis takes an important step in answering questions on: i) reductions in child mortality if exposure to multiple childhood risks were reduced; ii) effects of risk factor reduction on child mortality inequalities within and between countries.

Introduction

Child mortality, regularly on the agenda of public health and international development agencies, has received renewed attention as a part of the United Nation's Millennium Development Goals (MDGs) (*1, 2*). Approximately 10 million infants and children under five years of age die each year, with large variations in under-five mortality rates, and trends, across regions and countries (*1, 3*). The contributions of specific diseases (e.g. malaria or diarrhea) and risk factors (e.g. undernutrition and poor water, sanitation, and hygiene) to child mortality have also been documented in some detail in different world regions (*1, 4, 5*).

For many risk factors and childhood diseases, exposures and outcomes are simultaneously higher in some groups. For example, poor rural households in developing countries may have higher exposure to undernutrition, unsafe water and sanitation, and indoor smoke from solid fuels. Childhood mortality may be simultaneously higher in the same group both because of higher exposure to risks and due to factors such as limited access to health services (Figure 1) (*6*). Risk factor and disease correlations are important for health inequalities because concentrations of multiple risk factors for some diseases coupled with lack of access to treatment for the same diseases imply that much of childhood mortality will occur in specific countries, or specific groups within countries (*7*). In this case, universal prevention or treatment could provide larger benefits to those at highest-risk, and therefore help reduce health inequalities in addition to average benefits to the whole population (Figure 1; see also Figure 10 in (*7*)). Conversely, if intervention programs for risk factor reduction do not reach those at highest risk (see

Figure 10 in (*7*)) inequalities in health will increase (*7*). In this paper, we estimate the total effects of exposure to two important childhood mortality risk factors – childhood undernutrition as measured by low weight-for-age and poor water, sanitation, and hygiene – and their distributions in different income groups.

Methods

Estimating population attributable fractions

The contribution of a risk factor to disease or mortality relative to some alternative exposure scenario (i.e. population attributable fraction, PAF, defined as the proportional reduction in population disease or mortality that would occur if exposure to the risk factor were reduced to an alternative exposure scenario (*8, 9*)) is given by the generalized "potential impact fraction" in Equation 1. The alternative scenario used in this work is the exposure distribution that would result in the lowest population risk, referred to as the theoretical-minimum-risk exposure distribution (*4, 10*).

$$PAF = \frac{\int_{x=0}^{m} RR(x)P(x)\,dx - \int_{x=0}^{m} RR(x)P'(x)\,dx}{\int_{x=0}^{m} RR(x)P(x)\,dx} \qquad (1)$$

$RR(x)$: relative risk at exposure level x

$P(x)$: population distribution of exposure

$P'(x)$: alternative (or counterfactual) distribution of exposure

m: maximum exposure level

Risk factor exposure and hazard

Data for risk factor exposure, stratified on economic status, were from Demographic and Health Surveys, reported in an accompanying paper (*11*). Hazards of each risk factor were from systematic and comprehensive reviews and meta-analysis of epidemiological studies (Table 1). Mortality data were from the global burden of disease database (*5*). For each quintile of economic status, the relationship in Equation 1 was estimated, and the resulting PAF applied to the cause-specific mortality estimates. Estimates were made for four epidemiological subregions of the world, defined in Table 2. GBD cause-specific mortality data were divided into quintiles of economic status using the DHS distributions of all-cause mortality.

Table 1: Risk factors, exposure variables, theoretical minima, disease and injury outcomes and data sources for the risk factors considered (source: (*4*)).

Risk Factor	Exposure Variable	Theoretical-Minimum-Risk	Outcomes	Sources for Hazard Estimates
Underweight	Children < 1 standard deviation weight-for-age compared to the international reference group in 1 SD increments	Same fraction of children below 1 standard deviation weight-for-age as the international reference group; all women of childbearing age with body mass index > 20 kg/m^2	Mortality and acute morbidity from diarrhea, malaria, measles, pneumonia, and selected other infectious diseases	Childhood underweight: re-analysis of 10 cohort studies for mortality to obtain hazard in 1 SD increments, and systematic review and new meta-analysis of existing cohort studies for morbidity; maternal underweight: systematic review and meta-analysis of existing cohort studies
Unsafe water, sanitation, and hygiene	Six scenarios, ranging from regulated water and sanitation with hygiene through to no improved water supply and no improved sanitation	Absence of transmission of diarrheal disease through water, sanitation and hygiene	Diarrhea	Systematic reviews of multi-country RCTs and observational studies

Table 2: Analysis subregions.

WHO Region	Mortality stratum *	Countries with DHS	% population in 5 economic status quintiles
African Region (AFR)	**D**	Benin, Burkina Faso, Cameroon, Chad, Ghana, Guinea, Madagascar, Mali, Niger, Nigeria, Senegal.	67%, 20%, 10%, 3%, <<1%
	E	Botswana, Burundi, Central African Republic, Côte d'Ivoire, Congo, Ethiopia, Kenya, Malawi, Mozambique, Namibia, Rwanda, Uganda, United Republic of Tanzania, Zambia, Zimbabwe	71%, 14%, 9%, 5%, 1%
Region of the Americas (AMR)	**B**	Brazil, Colombia, Dominican Republic, Paraguay, Trinidad and Tobago	9%, 14%, 24%, 26%, 27%
	D	Bolivia, Guatemala, Haiti, Nicaragua, Peru	28%, 26%, 23%, 16%, 7%

* Mortality strata are based on the Global Burden of Disease 2000 reporting regions (source: (*5*)) defined as **B**: low child mortality and low adult mortality; **D**: high child mortality and high adult mortality; **E**: high child mortality and very high adult mortality.

The indicator of economic status used in this analysis is among non-monetary indices derived from socioeconomic variables and asset indicator variables. The method, described in detail elsewhere (*12*), also allows for information using socio-demographic predictors of economic status – such as education, age, and rural-urban residence – to be incorporated in the estimation process. The asset-based method is also easily adapted to construct an index of economic status that is comparable across countries by identifying a sub-set of asset indicators that become more likely to be observed to be owned at roughly the same level on an internationally comparable underlying economic status scale. These asset indicators can then be used as anchors such that the resulting economic status index using pooled cross-country data is cross-population comparable akin to a purchasing-power parity (PPP) scale, as described in detail elsewhere (*13*). The index of economic status was divided into five quintiles. Because the quintile are international quintiles (i.e. across all countries with DHS), most countries in the African region do not have significant numbers in the wealthiest quintile and some countries from the Region of the Americas have no households in the poorest quintile. Table 2 shows the distribution of the population of each region in this analysis by the five quintiles.

Results and Discussion

Figures 2 and 3 show the total number of deaths and proportions attributable to childhood underweight and poor water, sanitation, and hygiene behavior, respectively, stratified on economic status. After accounting for the fraction of population in each group, there was an inverse relationship between income level and both total number of child deaths and the proportion attributable to underweight. The two African subregions had higher mortality and higher proportions caused by undernutrition. The economic gradient of both total mortality and the proportion caused by underweight was also larger in the two African subregions than the two subregions in the Americas. This illustrates both an economic and geographical gradient in childhood undernutrition as well as other determinants of child mortality, with the two patterns interacting (i.e. children in households of similar income are at higher risk in the two African regions). These different roles for income in the various regions may reflect the prevalence of other risk factors as well as differential access to health services for case management or other childcare practices.

Unlike underweight, there were no or very small differences between income groups and regions in the proportion of childhood deaths caused by poor water, sanitation, and hygiene behavior. This pattern is because this risk factor affects a single disease end point (diarrhea) and is nearly universally a cause of large proportion (77-90%) of diarrhea, especially among children. The proportion of all childhood deaths caused by diarrhea also is fairly similar among regions or income groups. Therefore, the contribution of poor water, sanitation, and hygiene to total child mortality remains relatively unchanged. The fact that this risk factor contributed less to total child mortality in the African regions, is also partly because of cause-composition, rather than exposure patterns. In Africa, diarrhea is a smaller proportion of total child deaths because of the important role of malaria. Therefore, even with similar proportions of diarrhea attributable to this risk factor in the African and American regions, the fraction of total child deaths is smaller in Africa.

Creating analytical and empirical links between the paradigms of disease prevention and health inequalities is important because risk interventions can in principle be used to reduce health inequalities in the same way that they are used for aggregate population level benefits. At the same time, some risk interventions with aggregate population-wide benefits may increase health inequalities, because those with higher education or income, who may already have lower levels of risk, would have higher access and utilization of these interventions. The simple analysis of child mortality attributable to two major risk factors presented here illustrates that major risk factors are an important contributor to geographical or economic gradients in child mortality. At the same time, an important portion of these differences was not attributable to any *single* risk factor. Analysis of joint hazards of multiple risk factors, currently ongoing, would likely account for a larger proportion of differences in child deaths since many of these risks are likely to have economic determinants. It is however likely that at least for some diseases differences will persist and will have to overcome by better case management and health system encounters.

Figure 1: Schematic diagram to illustrate the correlation of multiple risks and disease outcome in relation to health inequalities. Suppose a population consists of two subgroups, equal in size for simplicity. One subgroup (A) has high mortality from a disease and high exposure to its risk factors. Mortality from the disease is higher in A because of both higher risk factor exposures and higher vulnerability caused by other factors that affect the same outcome, like lower access to treatment. Therefore, for subgroup A, both the fraction caused by risk factor exposure (30% = 6,000) and the total number of deaths (20,000) are higher. Another subgroup (B) has lower mortality (8,000) from the same disease and lower exposure to its risk factors (5% = 400). Removing exposure to the risk factors entirely would eliminate the fraction of deaths caused by it (right hand panels). This would in turn result in larger absolute and relative benefits for the high-exposure group (A) compared to the low-exposure one (B) – hence reducing health inequality. Even if the fractions caused by risk exposure were the same between the two groups, the absolute hazard would be higher for A. In other words, in absolute terms, A would be more vulnerable to risk.

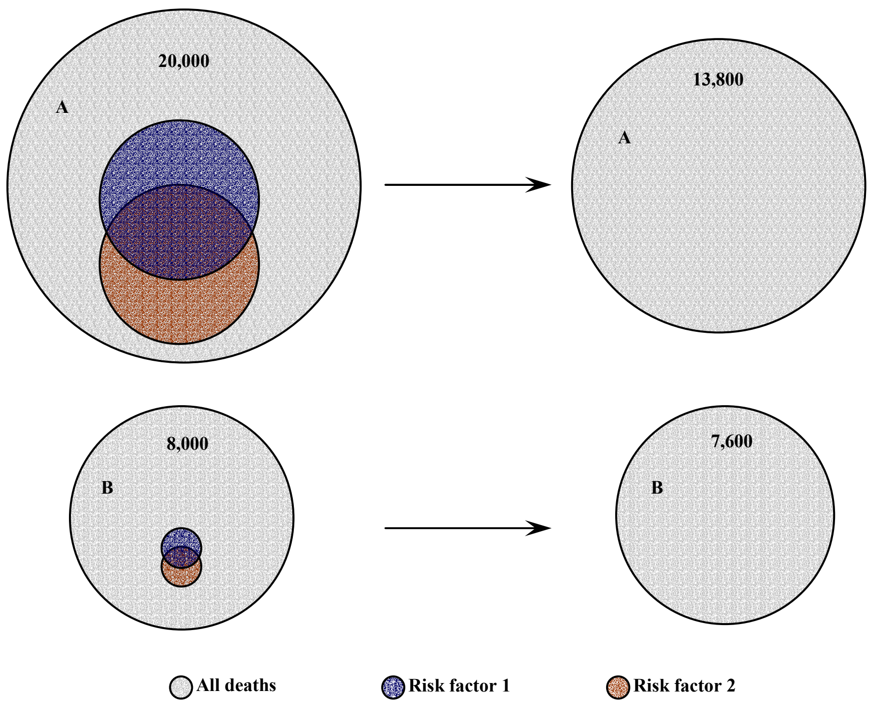
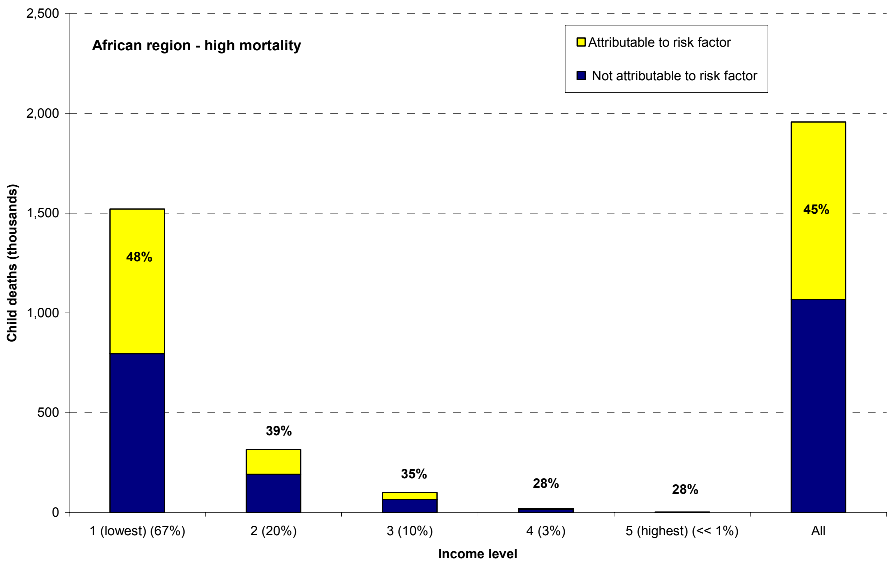
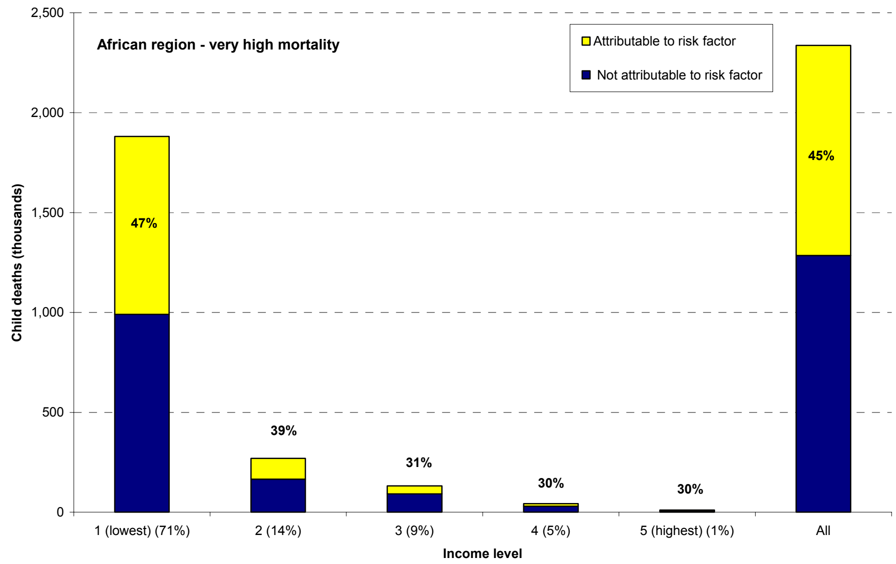
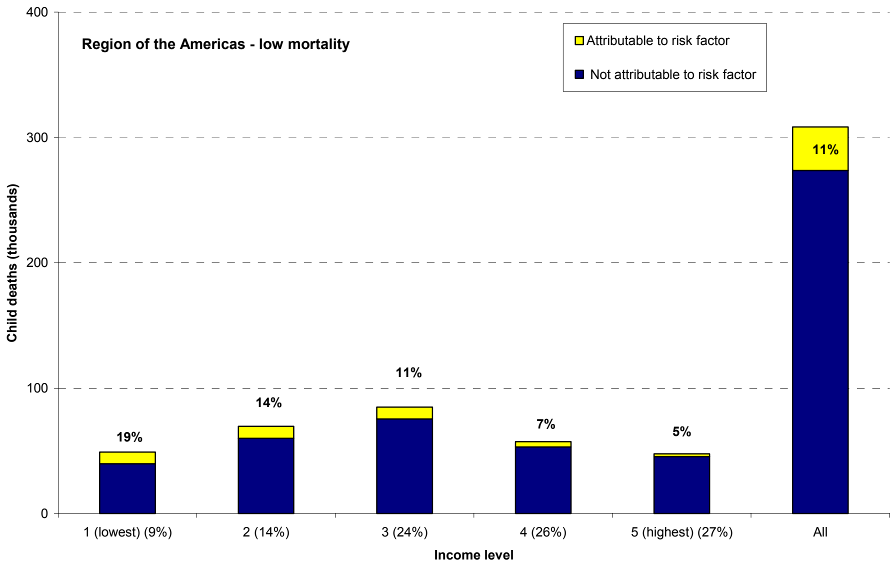


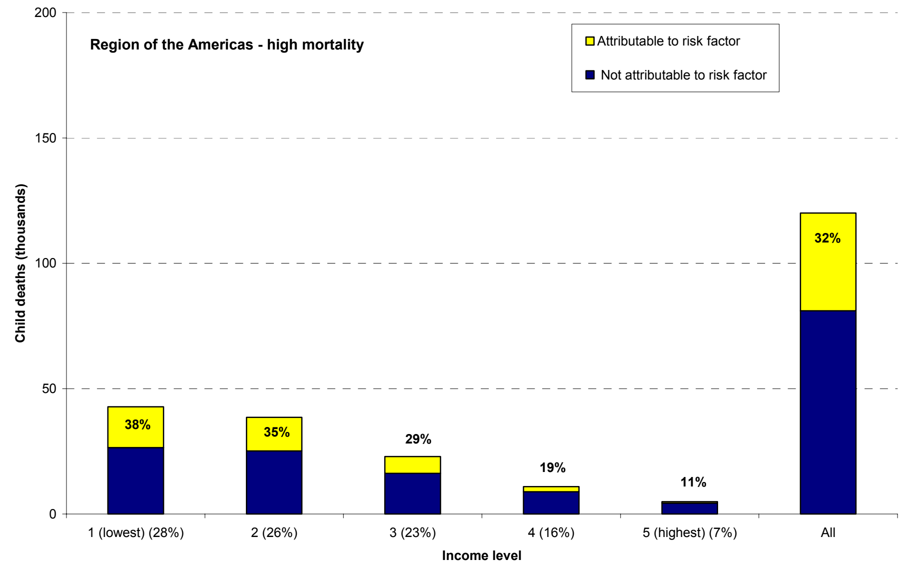
Figure 2: Proportion of child mortality attributable to childhood underweight, by income level. The percentage on each column shows the fraction of all child deaths attributable to the risk factor. The percentage next to income levels shows the proportion of population in each income group.



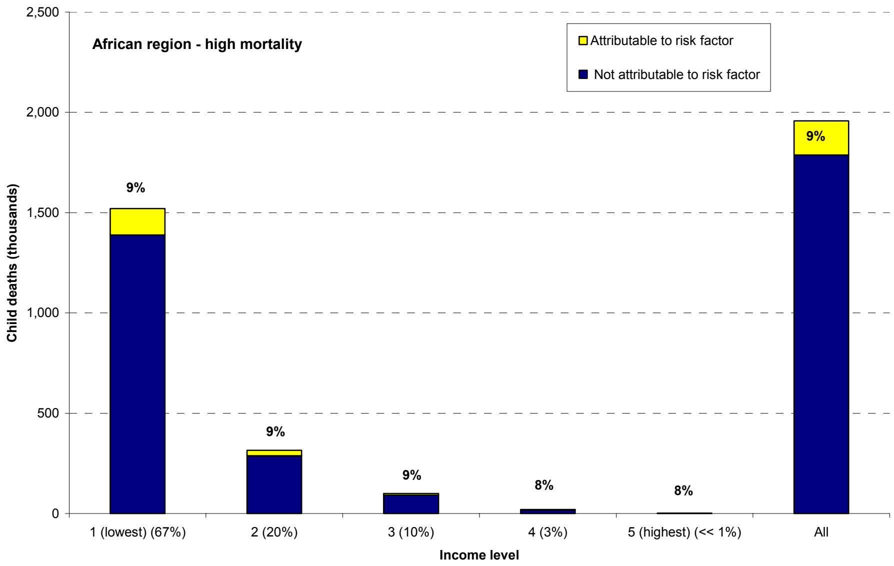


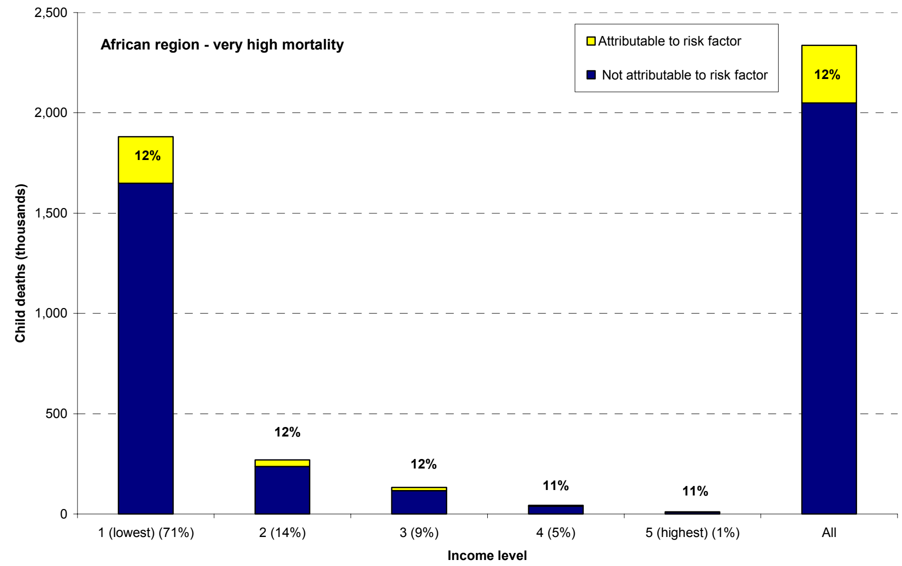


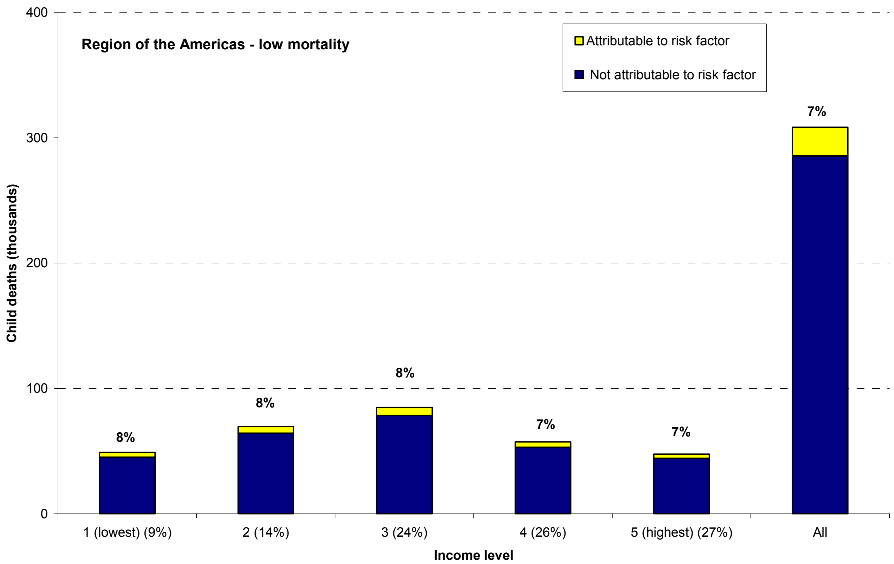
Region of the Americas - low mortality
Attributable to risk factor
Not attributable to risk factor
Child deaths (thousands)
400
300
200
100
0
19%
14%
11%
7%
5%
11%
1 (lowest) (9%)
2 (14%)
3 (24%)
4 (26%)
5 (highest) (27%)
All
Income level



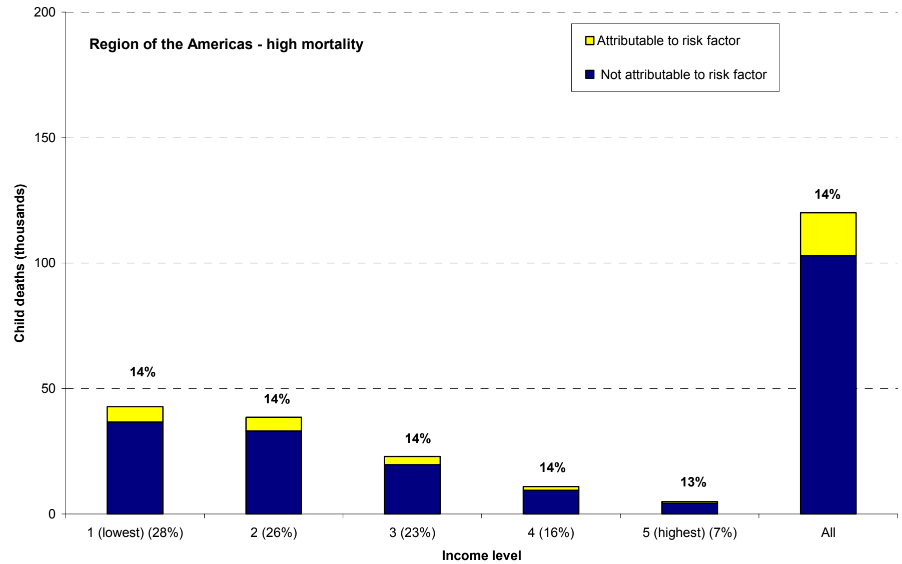
Region of the Americas - high mortality
Attributable to risk factor
Not attributable to risk factor
Child deaths (thousands)
200
150
100
50
0
38%
35%
29%
19%
11%
32%
1 (lowest) (28%)
2 (26%)
3 (23%)
4 (16%)
5 (highest) (7%)
All
Income level


African region - high mortality
Attributable to risk factor
Not attributable to risk factor
Child deaths (thousands)
2,500
2,000
1,500
1,000
500
0
9%
9%
9%
8%
8%
9%
1 (lowest) (67%)
2 (20%)
3 (10%)
4 (3%)
5 (highest) (<< 1%)
All
Income level


African region - very high mortality
Attributable to risk factor
Not attributable to risk factor
Child deaths (thousands)
2,500
2,000
1,500
1,000
500
0
12%
12%
12%
11%
11%
12%
1 (lowest) (71%)
2 (14%)
3 (9%)
4 (5%)
5 (highest) (1%)
All
Income level



Region of the Americas - low mortality
Attributable to risk factor
Not attributable to risk factor
Child deaths (thousands)
400
300
200
100
0
8%
8%
8%
7%
7%
7%
1 (lowest) (9%)
2 (14%)
3 (24%)
4 (26%)
5 (highest) (27%)
All
Income level



Region of the Americas - high mortality
Attributable to risk factor
Not attributable to risk factor
Child deaths (thousands)
200
150
100
50
0
14%
14%
14%
14%
13%
14%
1 (lowest) (28%)
2 (26%)
3 (23%)
4 (16%)
5 (highest) (7%)
All
Income level

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