

Global burden of blinding trachoma in the year 2000: Summary of methods and data sources

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1. Introduction

Trachoma is a chronic inflammation of the conjunctiva, most commonly found amongst the most disadvantaged populations living in crowded conditions with insufficient personal and environmental hygiene. Its prevalence is disproportionately high in children and women in poor rural community. The evolution of trachoma is slow and it is characterised by an acute inflammatory stage in childhood and a cicatricial stage subsequently. Complications from trachoma such as scarring of the conjunctiva and corneal opacification appear after variable time from the acute, infective stage, often many years of disease. Cases of trachomatous blindness have been reported in AFRO, EMRO, SEARO, WPRO (aboriginal communities in Australia), and AMRO regions (PBD database at <http://www.who.int/pbd/index.htm>).

Globally trachoma is the major preventable causes of blindness¹ and in particular it is the second leading cause of blindness in developing regions.² However, the epidemiological information on incidence and prevalence of blinding trachoma at the population level has been limited: study samples are often not representative and the confidence intervals for the point estimates are usually very large. Most often the cited global estimates on prevalence were based on expert opinions and not only on sound scientific evidence.³

It was not until the first round of the GBD 1990 study the actual magnitude of burden from blinding trachoma was systemically assessed.⁴ Ranson and Evans carried out more systematic and thorough evaluation of the burden from trachoma based on the representative prevalence surveys on blinding trachoma from mid-1970s and thereafter.³ Their analysis was based on the best available scientific evidence and enhanced the understanding of the magnitude of the problem. In their analysis, the population-weighted average of available prevalence figures within a same region was applied to all countries within the region. Therefore, while blinding trachoma cases have been reported from AMRO regions (PBD database), the estimated prevalence was zero since there was no representative prevalence study in this region. On the other hand, the data used for endemic regions such as SEARO and AFRO included the prevalence estimates made in 10-20 years before the analysis and the application of the regional prevalence estimates from earlier studies would overestimate the current prevalence.

The recent estimate by Frick and colleagues basically followed the Ranson and Evans method.^{3,5} Instead of applying the point estimates, they estimated the confidence interval of a point estimate to obtain lower and upper bounds of prevalence from each study. However, the updated analysis incorporated only two population-based surveys in Lebanon (EMRO) and Tonga (WPRO) in addition to the original data after 1980 compiled by Ranson and Evans. Therefore, the extrapolated regional prevalence in sub-Saharan Africa (AFRO), India (SEARO), and other endemic regions remained the same as the previous estimate and mostly based on the relatively earlier studies. Furthermore, zero prevalence was again assigned to AMRO region. For this reason, we re-estimated the prevalence of blinding trachoma for the year 2000 based on the existing data sources and statistical modelling by taking into account the changes in socio-economic status and regional variations.

2. Case and sequelae definitions

A simplified international grading scheme developed by WHO distinguishes 5 stages of trachoma. Active trachoma includes trachomatous inflammation-follicular (TF) and trachomatous inflammation-intense (TI). These two grades of the disease are especially common in childhood; their prevalence diminishes in those over ten years old. A single active trachoma infection resolves without complications (Ref. H.Taylor, Australia, WHO coll. Centre). However, recurrent infections can lead to the third stage of trachomatous scarring (TS) in which scarring of the tarsal conjunctiva results. This manifestation is more common in those over 10 years.

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The grade known as trachomatous trichiasis (TT) may follow and may eventually lead to corneal damage (CO : Corneal Opacity) with consequent visual impairment or blindness. In this exercise, we only focus on either low vision or blindness as a disabling sequela of trachoma regardless of the type of trachomatous changes. The case definition and sequelae used for blinding trachoma are given in Table 1 below.

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Table 1. Case and sequelae definitions for blinding trachoma

Cause category	GBD 2000 Code	ICD 9 code	ICD 10 code
Trachoma	W031	076	A71

Sequelae	Definition
1. Blindness	<u>Best</u> Corrected visual acuity in the better eye of less than 3/60 due to corneal opacity as a result of trachoma.
2. Low vision	<u>Best</u> Corrected visual acuity in the better eye of less than 6/18 but better than or equal to 3/60 due to corneal opacity as a result of trachoma.

3. Methods of epidemiological estimation

3.1 Crude prevalence of blindness

In the two previous estimates,^{3,5} the study years differed significantly within the same region and the prevalence estimated 10-20 years before the analysis was included in the calculation of weighted averages of prevalence for the whole region. Since the prevalence of blinding trachoma declines along with the improvement of health and socio-economic status even without a specific trachoma control programme,⁶ the application of the regional prevalence estimates from earlier studies would overestimate the current prevalence, particularly in endemic regions such as AFRO.

Instead of compiling the prevalence estimates in different years, we modelled the prevalence as a function of GDP per capita in international dollars (based on purchasing power parity) in the study year and regional fixed effects in the form:

$$\log(\text{prevalence}) = a + \beta_1 \log(\text{GDP}) + \beta_2 \log(\text{GDP})^2 + ? (\text{dummy for WHO region}) + e$$

This allows us to capture broadly the effects of levels and trends of socio-economic development on prevalence of trachoma. We assumed that error terms are correlated within a same mortality stratum and estimated the best fit model with the population-average method because of a relatively small number of observations.

We included prevalence data used in the two previous analyses^{3,5} as well as recently published population-based studies mostly as a part of blindness survey in AFRO and EMRO regions.⁷⁻¹¹ Prevalence data used for the regression analysis are presented in Appendix 1. We excluded the countries where no trachomatous cases were reported or reported prevalence was zero to avoid the bias due to outliers and to accommodate with the global mapping prepared by the Department of Prevention of Blindness and Deafness (PBD).

3.2 Age- and sex- specific prevalence of blindness

To estimate age- and sex- specific prevalence from overall crude rate as an input to DisMod, information on the distribution of prevalent cases by age and sex in a population is required. Trachomatous blindness appears many years after the infection and thus age-distribution of cases are skewed among older age groups. We generally followed the age-distribution estimated in the previous analysis by Evans and Ranson.¹² In GBD 2000, exercise, however, age groups were further divided into 8 (0-4, 5-14, 15-29, 30-44, 45-59, 60-69, 70-79, and 80+) rather than 5 (0-4, 5-14, 15-44, 45-59, and 60+) so that more accurate estimation among middle and older age groups are possible. Therefore we adjusted the distribution of prevalence for age groups over 60 based on the available data. We further estimated conversion factor of crude prevalence rate for each age which is consistent with age distribution of actual prevalence numbers in each age group (Figure 1).

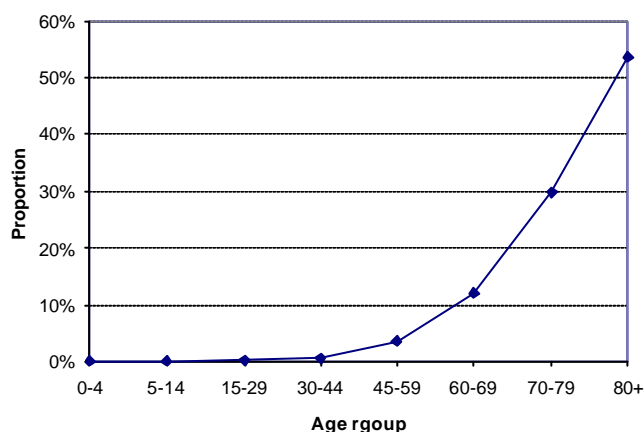


Figure 1. Age-distribution of prevalence rate

It is generally recognised that blindness prevalence tends to be higher in females than in males even after adjusting for age structure of a population.¹³ This is particularly true in the case of trachoma -- there is considerable evidence that women account for approximately 75% of trachomatous trichiasis.¹⁴ It is suggested that more interactions with children as well as limited access to care and poor status of women would account for the excess risk of exposure to trachoma.¹³ Although trachomatous trichiasis itself does not necessarily lead to blindness, it is reasonable to assume that the sex differential of trichiasis can be applied to that of trachomatous blindness among adults.

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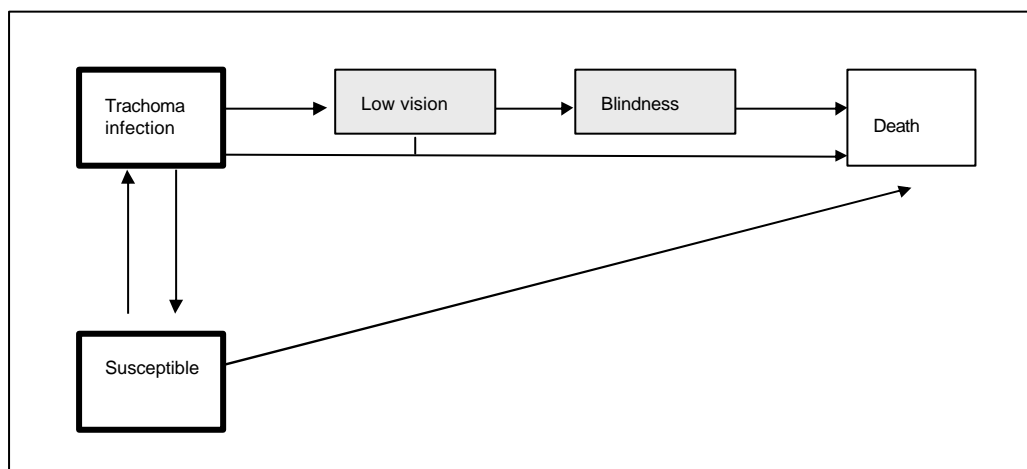
3.3 Blindness-to-low vision ratio

To estimate the burden of low vision in addition to blindness, average ratio of blindness to low vision was estimated from the surveys which report prevalence of both conditions. The two previous estimate employed slightly different ratios: 1.3 by Evans and Ranson and 1.4 by Frick and colleagues.^{5,12} The latter estimate is based on the data used by Evans and Ranson as well as three additional studies among which ratios varied substantially (0, 0.5 and 5). So we decided to use the ratio estimated by Evans and Ranson to avoid the bias due to outliers.

4. Disease model for trachoma

The model for trachoma is a simple three-box model as shown in Figure 2. Years lived with disability (YLDs) were calculated for the boxes shaded in grey. The estimated regional prevalence rates were input to DISMOD II together with the estimated remission rates and a RR for mortality. Assumptions and data sources on remission and mortality relative risk are described in the following sections.

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Years lived with disability (YLDs) were calculated for the boxes shaded in grey.

Figure 2. Trachoma disease model

4.1 Excess mortality from blindness and low vision

Studies have shown that the visually impaired are at increased risk of deaths.¹⁵ Risk of excess mortality is higher among the blind but still presents among the people with low vision. The relative risk (RR) of mortality among the blind varied from 1.5 to 4.1 deaths in developing regions.¹⁵⁻¹⁸ As Evans and Ranson claimed, the study with the largest sample size and based on WHO definition of blindness by Kirkwood and colleagues would yield the most accurate estimate for mortality RR: 2.5 for blind males and 3.8 for blind females, and 1.4 for low visioned males and 1.5 for low visioned females. On the other hand, more recent studies have suggested that there was no statistically significant differences in mortality RR between males and females after controlling for other covariates.^{15,16} Considering the lack of controlling of cofounders in earlier studies, we decided to employ the value of 2.5 for blindness and 1.5 for low vision for both sexes in the present analysis.

4.2 Remission rate

Permanent trachomatous visual impairment may be avoided if relatively cost-effective preventive or curative interventions are made early in the disease course.¹⁹ Otherwise a disabling sequela of blinding trachoma does not remit once it is established, although some relief of symptoms may be achieved through surgery in the case of trachomatous trichiasis. Therefore, remission rates were assumed to be zero for both conditions in modelling trachoma with DisMod II.

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4.3 DISMOD estimation of incidence and duration for blinding trachoma

Table 2 summarises trachoma disease model and assumptions. Table 3 compares the GBD 2000 assumptions with those used in 1990.

Table 2. Disease model assumptions

Definitions	As defined in Table 1.
Incidence/Prevalence	Prevalence was derived from both population-based surveys and epidemiological models. Internally consistent estimate of incidence was estimated by DisMod.
Remission	No remission assumed
Relative risk (RR) of mortality	Excess mortality from disabling sequelae was assumed as follows: RR=2.5 for blindness and =1.5 for low vision
Disability distribution	Blindness: 0.60 for both treated and untreated, Low vision: 0.282 for treated and 0.224 for untreated
Other assumptions	Male-to-female ratio of prevalence of blindness = 1 : 3 Blindness-to-low vision ratio = 1.3
Data	Prevalence studies from population-based blindness surveys and global mapping of reported trachoma cases compiled by the Department of Blindness Prevention (PBD)

Table 3. Comparison between GBD 1990 and GBD 2000 disease models

	GBD 1990	GBD 2000
Stages/Sequelae	Blindness and low vision as defined above.	Blindness and low vision as defined above.
Prevalence estimate	Available prevalence surveys in 1970-90	Both latest surveys and model estimates
Male-to-female prevalence ratio	1 : 1.16	1 : 1.3
Blindness-to low vision ratio	1 : 2.9	1 : 3
Incidence rates	DISMOD 1 used to estimate from prevalence rates	DISMOD 2 used to estimate from prevalence rates
Remission	0	0
Relative risk of mortality	Blindness: 2.5 (males) and 3.8 (females) Low vision: 1.4 (males) and 1.5 (females)	Blindness: 2.5 Low vision: 1.5

5. Disability weights and health state descriptions

The GBD 1990 study estimated disability weights for treated and untreated blindness and low vision as shown in Table 4.⁴ The proportion of cases treated was assumed to range from over 95% in developed regions, to around 50% in AMRO B and D, down to 5% in AFRO D and E. While disability weights for low vision were kept constant regardless of the proportion of treated, different values were assigned for treated and untreated blindness. However, this assumption is not plausible since once established there is no way to reverse trachomatous blindness.

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The Netherlands disability weights study estimated disability weights for two levels of vision loss.²⁰ The Australian Burden of Disease Study employed the same definition as in the Netherlands disability weights.¹¹ Since the definition of sequelae in the present study is slightly different from that in the studies in the Netherlands and Australia, slightly modified disability weights for low vision were used for low vision depending on the proportion of treated while disability weights for blindness was kept constant at 0.6 regardless of treatment. Further revision of disability weights will be made when data analysis of the modules on health status valuation in the on-going World Health Survey is completed.

Table 4. Disability weights for blinding trachoma

Stage/sequela	GBD 1990	Netherlands DW Study	Australian BOD Study	GBD 2000
Low vision	0.245 (treated) 0.245 (untreated)	0.17 for moderate vision loss	0.17 for moderate vision loss	0.224 (treated) 0.282 (untreated)
Blindness	0.488 (treated) 0.600 (untreated)	0.43 for severe vision loss	0.43 for severe vision loss	0.600 (treated) 0.600 (untreated)

6. Results

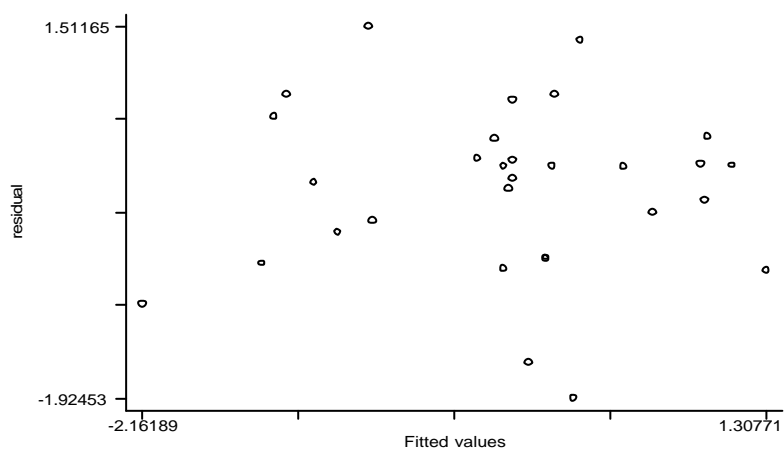
6.1 Regional prevalence

Table 5 presents the results of regression analysis in which both coefficients of both log of GDP per capita and its square (to capture non-linearity) were significant. There was no systematic deviation among error terms (Figure 3).

Table 5. Regression results

Independent variable	Estimated coefficient*
Log (GDP -PPP)	-5.72 ** (1.78)
Log (GDP -PPP) ²	0.37 ** (0.12)
Dummy for WHO region (3 for AFRO, 2 for EMRO, 1 for WPRO, and 0 for others)	0.63 ** (0.18)
Constant	19.96 ** (6.85)
R-square	0.58

* Standard errors in parentheses ** p < 0.05



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Figure 3. Scatter plot of residuals vs. predicted values

For countries where blinding cases have been reported and prevalence studies are available, both nationally reported data and specific criteria for a regression model were used to estimate prevalence of blinding trachoma. For those regions with no available prevalence of trachomatous blindness studies, prevalence rates were assumed to be similar to other selected regions, comparable in terms of level of development and population age structure. An estimate derived from a different region is more likely to be correct than the assumption that the condition does not exist in the region with no data of its own.

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Regional crude prevalence was derived from population-weighted average of estimated prevalence in each country within the region (Table 6). It was then distributed by age and sex to get an age- and sex- specific prevalence by region as one of the key inputs for DisMod.

Table 6. Data/assumptions used to estimate regional prevalence rates for blinding trachoma and estimated regional crude prevalence

		Crude prevalence per 1,000
AFRO D	8 population-based studies from the late 1980s were identified as the basis for model inputs (see Appendix 1). For the countries with known blinding trachoma cases, both survey results and model estimates were used. Zero prevalence was assigned to other countries in the region (i.e., Gabon, Liberia, and Madagascar).	1.12
AFRO E	11 population-based studies from the early 1980s were identified as the basis for model inputs (see Appendix 1). For the countries with known blinding trachoma cases, both survey results and model estimates were used. Zero prevalence was assigned to other countries in the region (i.e., Congo, Lesotho and Namibia).	1.57
AMRO A	No reported cases of blinding trachoma.	0.00
AMRO B	One population-based survey of blindness in 1986 did not identify blinding trachoma cases. ²¹ However, Brazil and Mexico are identified as the countries with known blinding trachoma. For the two countries, model estimates were used. Zero prevalence was assigned to other countries.	0.22
AMRO D	No population-based survey of blinding trachoma is available. For Guatemala blinding trachoma cases have been reported, model estimates were used. Zero prevalence was assigned to other countries in the region.	0.04
EMRO B	Two early population-based studies from Saudi Arabia ^{22,23} and one	0.54

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	recent survey from Oman ¹⁰ were used as the basis for model inputs. For the countries with known blinding trachoma cases (Iran, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, and UAE), model estimates were used. Zero prevalence was assigned to other countries in the region.	
EMRO D	Two recent population-based studies from Egypt ²⁴ and Morocco ²⁵ were used as the basis for model inputs. Model estimates were applied to all countries within the region.	1.05
EURO A	No reported cases of blinding trachoma.	0.00
EURO B1	No reported cases of blinding trachoma.	0.00
EURO B2	No reported cases of blinding trachoma.	0.00
EURO B3	No reported cases of blinding trachoma.	0.00
SEARO B	No reported cases of blinding trachoma.	0.00
SEARO D	Two early population-based studies from India ^{26,27} were used as the basis for model inputs. Model estimates were applied to all countries within the region.	0.09
WPRO A	Reported cases from Aboriginal communities in Australia ^{11,28,29} . The results of Australian BOD study ¹¹ was used for Australia. Zero prevalence was assigned to other countries in the region.	0.001
WPRO B1	Two population-based studies in China are available ^{30 31,32} . One study in Mongolia ³³ did not identify cases due to trachoma. Zero prevalence was assigned to countries other than China.	0.11
WPRO B2	Two studies from Nepal ³⁴ and Myanmar ³⁵ as the basis for model inputs. Model estimates were used for all countries in the region.	0.12
WPRO B3	Generally non blinding trachoma in the region except Tonga where population-based surveys was carried out ³⁶ . Zero prevalence was assigned to other countries in the region.	0.003

6.2 Internally consistent estimates of incidence and prevalence of trachomatous blindness and low vision by region

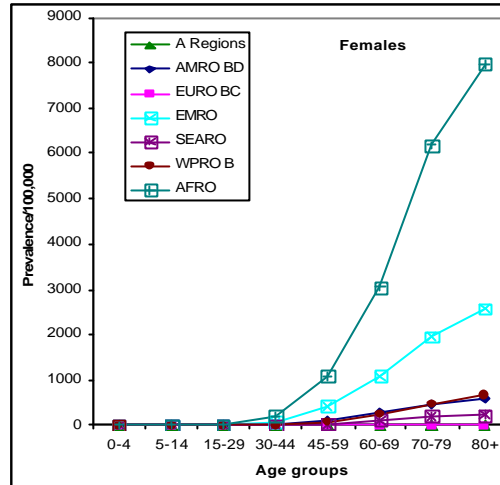
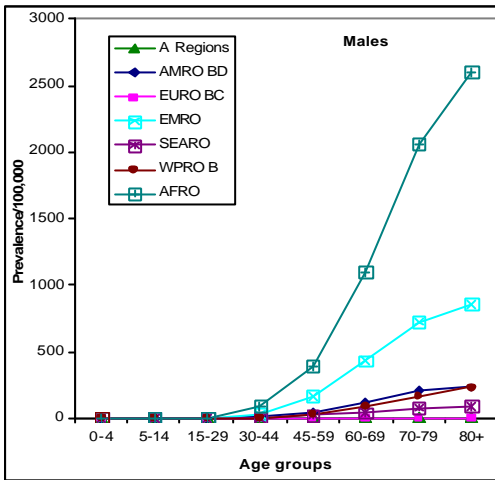
As described above, three parameters (i.e., prevalence, remission, and mortality relative risk) were used as inputs to obtain internally consistent estimates of incidence, prevalence, remission, mortality and duration. Table 7 and Figure 4 below summarise the internally consistent estimates of age-standardised incidence and prevalence by region and age-distribution of prevalence of both trachomatous blindness and low vision.

Table 7. Blinding trachoma: age-standardized incidence and prevalence rates of blindness and low vision for WHO epidemiological subregions, 2000

Subregion	Age-std. incidence per 100,000*				Age-std. prevalence per 100,000*			
	Blindness		Low vision		Blindness		Low vision	
	Males	Females	Males	Females	Males	Females	Males	Females
AFRO D	38.1	104.2	47.2	128.2	232.6	646.3	279.4	789.9
AFRO E	54.0	148.6	38.3	107.0	314.6	904.5	372.4	1031.8
AMRO A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AMRO B	3.7	7.9	3.1	7.3	30.2	78.4	37.4	91.8
AMRO D	0.5	1.2	0.4	1.0	2.6	8.2	3.9	9.8
EMRO B	12.7	33.4	9.4	24.3	78.6	181.2	99.0	245.6
EMRO D	21.7	59.5	16.8	45.0	129.1	345.1	168.4	449.7
EURO A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EURO B1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EURO B2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EURO C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEARO B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEARO D	2.0	4.8	1.6	3.9	13.1	34.5	17.3	42.7
WPRO A	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2
WPRO B1	3.2	8.4	2.6	7.1	19.8	60.5	24.3	73.9
WPRO B2	3.6	10.3	2.8	7.9	20.5	60.7	26.8	76.8
WPRO B3	0.2	0.5	0.1	0.4	0.9	2.8	1.2	3.1
World	4.3	10.9	3.9	10.0	27.5	74.9	33.5	89.1

* Age-standardized to World Standard Population.

(1) Blindness prevalence by age



(2) Low vision prevalence by age

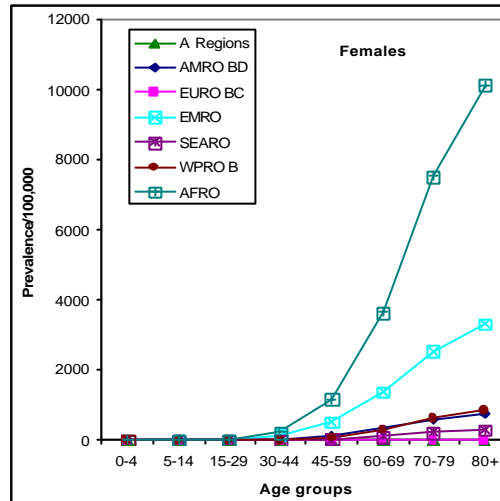
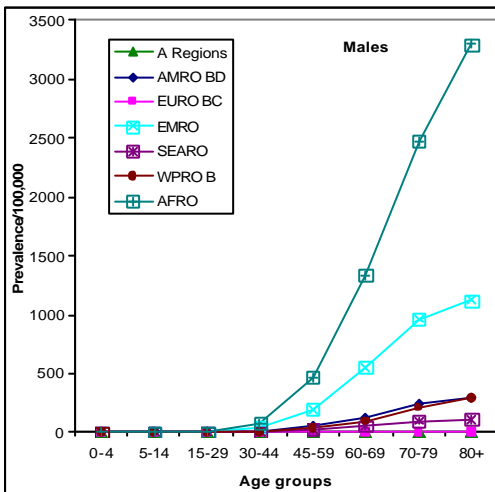


Figure 4. Blinding trachoma: prevalence rates of blindness and low vision, age group and sex, broad regions, 2000.

6.3 Global burden of blinding trachoma in 2000

General methods used for the estimation of the global burden of disease are given elsewhere. The tables and graphs below summarise the global burden of blinding trachoma estimates for the GBD 2000 and compare them with those from the GBD 1990. It should be noted that the methodology and data sources used in GBD 1990 were different from the later updates^{3,5} and GBD 2000 estimate and thus the two estimates below are not directly comparable. This is why total burden has substantially increased in the GBD 2000 revision despite the declining incidence and prevalence of blinding trachoma. GBD 2000 estimate is closer to the estimated made by Frick and colleagues⁵ but yielded lower burden due to lower estimated incidence and prevalence of blinding trachoma in the present study

Table 8. Blinding trachoma: global total YLD, YLL and DALY estimates, 1990 and 2000.

	<i>Males</i>	<i>Females</i>	<i>Persons</i>
YLD('000)			
<i>GBD1990</i>	279	745	1,024
<i>GBD2000</i>	558	1,617	2,176
YLL('000)			
<i>GBD1990</i>	0	0	0
<i>GBD2000</i>	0.3	0.1	0.4
DALY('000)			
<i>GBD1990</i>	279	745	1,024
<i>GBD2000</i>	558	1,617	2,176

Table 9. Blinding trachoma: YLD, YLL and DALY estimates for WHO subregions, 2000.

Subregion	Blindness		Low vision		Total		
	YLD/100,000		YLD/100,000		YLD	YLL	DALY
	Males	Females	Males	Females	('000)	('000)	('000)
AFRO D	55.5	157.7	30.2	90.3	558	0	558
AFRO E	67.3	188.7	35.3	103.9	669	0	669
AMRO A	0.0	0.0	0.0	0.0	0	0	0
AMRO B	11.0	33.9	6.2	16.6	151	0	151
AMRO D	0.6	2.5	0.4	1.3	2	0	2
EMRO B	25.1	50.6	13.8	32.5	84	0	84
EMRO D	35.6	103.5	20.6	61.9	152	0	152
EURO A	0.0	0.0	0.0	0.0	0	0	0
EURO B1	0.0	0.0	0.0	0.0	0	0	0
EURO B2	0.0	0.0	0.0	0.0	0	0	0
EURO C	0.0	0.0	0.0	0.0	0	0	0
SEARO B	0.0	0.0	0.0	0.0	0	0	0
SEARO D	4.2	12.2	2.5	6.5	169	0	169
WPRO A	0.0	0.0	0.0	0.1	0	0	0
WPRO B1	8.0	27.5	4.2	14.4	362	0	362
WPRO B2	5.5	19.7	3.5	11.2	28	0	28
WPRO B3	0.2	0.8	0.2	0.4	0	0	0
World	11.9	34.7	6.5	19.2	2,176	0	2,176

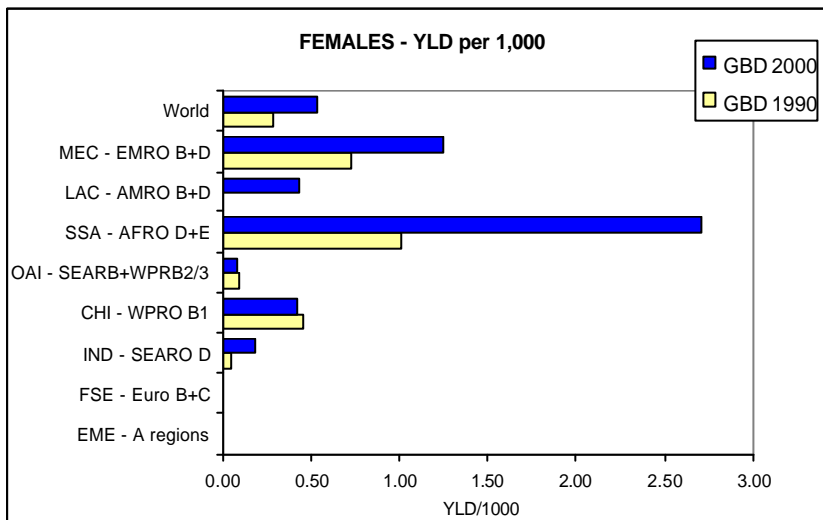
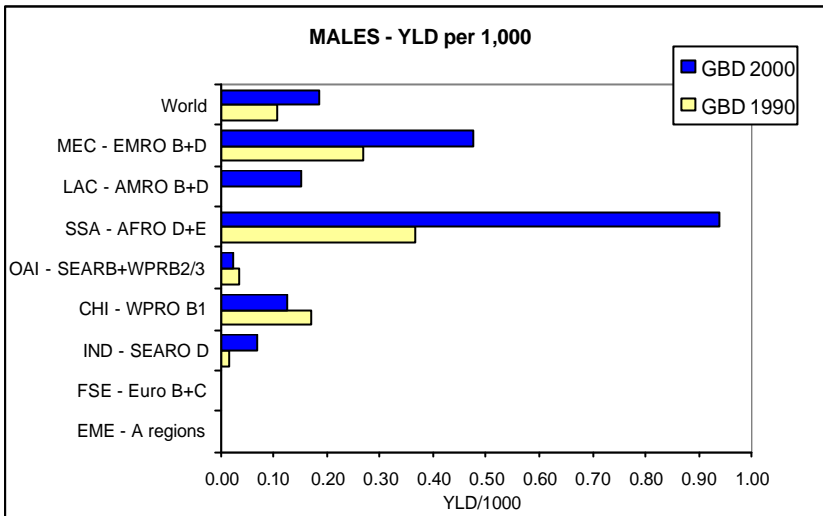


Figure 5. Blinding trachoma: YLD rates, by sex, broad regions, 1990 and 2000

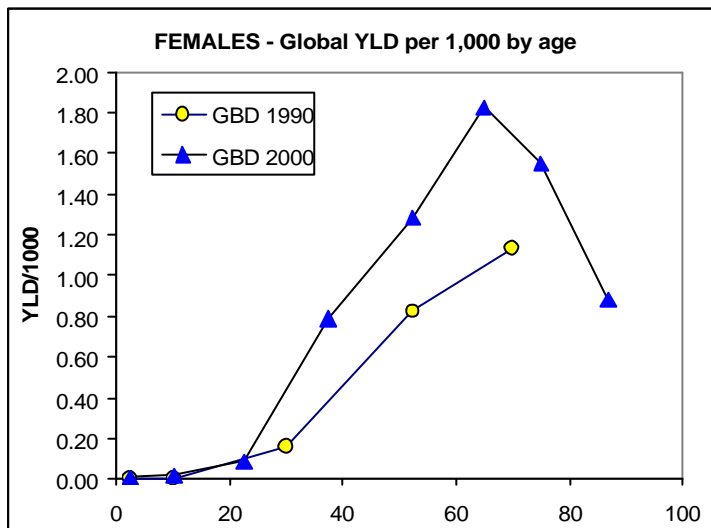
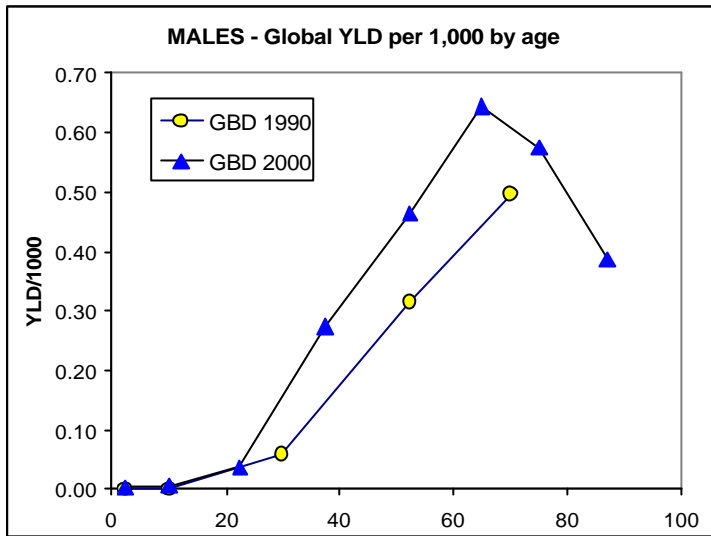


Figure 6. Blinding trachoma: YLD rates, by age and sex, 1990 and 2000

7. Uncertainty analysis

General methods for uncertainty analysis of estimates for the Global Burden of Disease 2000 are outlined elsewhere³⁷. Uncertainty analysis for the estimation of prevalence of blinding trachoma and a resulting change in healthy life expectancy (HALE) is under way and will be reported by region and for each Member State.

8. Discussion

The current estimate is based on the assumption that the prevalence of blinding trachoma declines along with the improvement of health and socio-economic status and thus the application of the regional prevalence estimates from earlier studies would bias the current prevalence.⁶ Furthermore, if no studies were available or one study did not identify the trachomatous blinding cases, the previous estimates assigned zero prevalence in the regions such as AMRO where cases have been reported.^{3,5} Under such circumstances, one approach would be to simply say that there is no evidence. The approach taken in this paper is to provide the best available evidence, even if this means extrapolating from one setting to another.

We take the advantage of using the data compiled for the two previous estimates as well as the latest population-based surveys and modelled the relationship between the prevalence of blinding trachoma and the level of socio-economic status approximated by the latest GDP-PPP from GBD 2000 database and took into account the regional variation. Both surveys data and model estimates were used for countries where cases blinding trachoma have been reported to the Department of Prevention of Blindness and Deafness (PBD).

On the other hand, there are several limitations in the present study. Firstly, the dynamics of trachoma in a community are best assessed by measuring changes in the age-specific prevalence of inflammatory trachoma: trachomatous inflammation-follicular (TF) and trachomatous inflammation-intense (TI), trachomatous scarring (TS), trachomatous trichiasis (TT), and corneal opacity (CO). The most sensitive measure is the prevalence of TF amongst children under 10 years of age, which demonstrates how widespread the infection is in the community, the proportion of children under the age of 10 with TI (how severe the disease is in the community) and the prevalence of TS (how common trachoma was in the past). The prevalence of trichiasis (TT) indicates the immediate need for corrective lid surgery in the community and the number with CO the effect of trachoma in the community in terms of visual loss. Thus, although the model fit was reasonable for the relationship between prevalence of blindness and socio-economic status, the sensitivity to the recent implementations of a trachoma control programme would not be captured properly.

Secondly, the pathway to blindness from trachoma is not specific, in the sense that the corneal opacification induced by TT may be the result of secondary infections. Therefore, if there is not enough awareness as to the endemicity of trachoma in an area, it is likely that there will be an underestimate as to the role of trachoma as a cause of blindness. On the other hand, in certain rural settings, particularly in north Africa, there are regular seasonal epidemics of conjunctivitis, which is transmitted by flies in great numbers. There is a known interaction between conjunctivitis epidemics and the increased prevalence and intensity of trachoma in such populations, but this fact may be easily overlooked by local health staff. Such variation within countries was not taken into consideration.

Despite these limitations, the present estimates are based on best available empirical data and filled the gap for regions with no population-based studies. One approach would be to simply say that there is no evidence. The approach taken in this paper is to provide the best available evidence, even if this means extrapolating from one setting to another. This approach carries additional uncertainty and this should be considered when interpreting the results.

These are version 2 estimates for the GBD 2000. Apart from the uncertainty analysis, updating estimates to reflect revisions of mortality estimates and any new or revised epidemiological data or evidence, it is not intended to undertake any major addition revision of these estimates. We welcome comments and criticisms of these draft estimates, and information on additional sources of data and evidence. Please contact Kenji Shibuya or Colin D. Mathers (EBD/GPE).

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References

1. Thylefors B. et al: Avoidable blindness. *Bull World Health Organ* 1999;77(6):453.
2. Lewallen S, Courtright P. Blindness in Africa: present situation and future needs. *Br J Ophthalmol* 2001;85(8):897-903.
3. Ranson MK, Evans TG. The global burden of trachomatous visual impairment: I. Assessing prevalence. *Int Ophthalmol* 1995;19(5):261-70.
4. Murray CJL, Lopez AD. *The Global Burden of Disease*. Cambridge, MA: Harvard University Press, 1996.
5. Frick K, Basilion E, Hanson C, et al. Estimating the burden and economic impact of trachomatous visual loss. *Ophthalmic Epidemiol* 2003;10(2):121-32.
6. Dolin PJ, Faal H, Johnson GJ, et al. Reduction of trachoma in a sub-Saharan village in absence of a disease control programme. *Lancet* 1997;349(9064):1511-2.
7. Schwartz EC, Huss R, Hopkins A, et al. Blindness and visual impairment in a region endemic for onchocerciasis in the Central African Republic. *British Journal of Ophthalmology* 1997;81(6):443-7.
8. Zerihun N, Mabey D. Blindness and low vision in Jimma Zone, Ethiopia: results of a population-based survey. *Ophthalmic Epidemiol* 1997;4(1):19-26.
9. Kortlang C, Koster JC, Coulibaly S, et al. Prevalence of blindness and visual impairment in the region of Segou, Mali. A baseline survey for a primary eye care programme. *Tropical Medicine & International Health* 1996;1(3):314-9.
10. Khandekar R, Mohammed AJ, Negrel AD, et al. The prevalence and causes of blindness in the Sultanate of Oman: the Oman Eye Study (OES). *Br J Ophthalmol* 2002;86(9):957-62.
11. Mathers C, T. V, Stevenson C. The burden of disease and injury in Australia. Canberra: Australian Institute of Health and Welfare, 1999.
12. Evans TG, Ranson MK. The global burden of trachomatous visual impairment: II. Assessing burden. *Int Ophthalmol* 1995;19(5):271-80.
13. Abou-Gareeb I, Lewallen S, Bassett K, et al. Gender and blindness: a meta-analysis of population-based prevalence surveys. *Ophthalmic Epidemiol* 2001;8(1):39-56.
14. Tabbara KF, Ross-Degnan D. Blindness in Saudi Arabia. *Jama* 1986;255(24):3378-84.
15. Taylor HR, Katala S, Munoz B, et al. Increase in mortality associated with blindness in rural Africa. *Bull World Health Organ* 1991;69(3):335-8.

16. Pion SD, Kamgno J, Demanga N, et al. Excess mortality associated with blindness in the onchocerciasis focus of the Mbam Valley, Cameroon. *Ann Trop Med Parasitol* 2002;96(2):181-9.
17. Prost A, Vaugelade J. [Excess mortality among blind persons in the West African savannah zone]. *Bull World Health Organ* 1981;59(5):773-6.
18. Kirkwood B, Smith P, Marshall T, et al. Relationships between mortality, visual acuity and microfilarial load in the area of the Onchocerciasis Control Programme. *Trans R Soc Trop Med Hyg* 1983;77(6):862-8.
19. Evans TG, Ranson MK, Kyaw TA, et al. Cost effectiveness and cost utility of preventing trachomatous visual impairment: lessons from 30 years of trachoma control in Burma. *British Journal of Ophthalmology* 1996;80(10):880-9.
20. Stouthard M, Essink-Bot M, Bonsel G, et al. Disability weights for diseases in the Netherlands. Rotterdam: Department of Public Health, Erasmus University., 1997.
21. Luna EJ, Medina NH, Oliveira MB, et al. Epidemiology of trachoma in Bebedouro State of Sao Paulo, Brazil: prevalence and risk factors. *Int J Epidemiol* 1992;21(1):169-77.
22. Tabbara KF, Ross-Degnan D. Blindness in Saudi Arabia. *British Journal of Ophthalmology* 1987;71(11):873-6.
23. Badr IA, Al-Saif AM, Al-Rajhi AA, et al. Changing patterns of visual loss in the Eastern Province, Kingdom of Saudi Arabia. *Saudi Journal of Ophthalmology* 1992;6:59-68.
24. Ezz al Arab G, Tawfik N, El Gendy R, et al. The burden of trachoma in the rural Nile Delta of Egypt: a survey of Menofiya governorate. *Br J Ophthalmol* 2001;85(12):1406-10.
25. World Health Organization. Report on the intercountry meeting for evaluating national prevention of blindness programmes. Geneva: WHO unpublished document, 1993.
26. Srivastava RN, Verma BL. An epidemiological study of blindness in an Indian rural community. *Journal of Epidemiology & Community Health* 1978;32(2):131-5.
27. Mohan M. Epidemiological studies on prevalence of trachoma and impact of the trachoma control programme in India. Unpublished document, 1989.
28. Taylor HR. The prevalence of corneal disease and cataracts in Australian aborigines in Northwestern Australia. *Aust J Ophthalmol* 1980;8(4):289-301.
29. Taylor HR. Trachoma in Australia. *Med J Aust* 2001;175(7):371-2.
30. Zhang SY. The 1987 National Epidemiological Survey of Blindness and Low Vision in China. *Chung-Hua Yen Ko Tsa Chih [Chinese Journal of Ophthalmology]* 1992;28(5):260-4.
31. Zhang SY, Zou LH, Gao YQ, et al. National epidemiological survey of blindness and low vision in China. *Chinese Medical Journal* 1992;105(7):603-8.

32. World Health Organization. Prevention of blindness: China. *Weekly Epidemiological Record* 1985;60:369-76.
33. Baasanhu J, Johnson GJ, Burendei G, et al. Prevalence and causes of blindness and visual impairment in Mongolia: a survey of populations aged 40 years and older. *Bulletin of the World Health Organization* 1994;72(5):771-6.
34. Brilliant LB, Pokhrel RP, Grasset NC, et al. Epidemiology of blindness in Nepal. *Bull World Health Organ* 1985;63(2):375-86.
35. Than KM. The model village eye health survey. Myanmar Trachoma Control and Blindness Prevention Programme. Unpublished document., 1990.
36. Newland H, Hiller J, Moll AC. Prevalence of blindness and low vision of people over 30 years in the Wenchi district, Ghana, in relation to eye care programmes. *Medical Journal of Australia* 1994;160(12):751-6.
37. Mathers CD, Stein C, Ma Fat D, et al. Global Burden of Disease 2000: Version 2 methods and results. Geneva: Global Programme on Evidence for Health policy, World Health Organization, 2002.
38. Negrel AD, Avognon Z, Minassian DC, et al. [Blindness in Benin]. *Med Trop (Mars)* 1995;55(4):409-14.
39. Wilson MR, Mansour M, Ross-Degnan D, et al. Prevalence and causes of low vision and blindness in the Extreme North Province of Cameroon, West Africa. *Ophthalmic Epidemiol* 1996;3(1):23-33.
40. Abiose A, Murdoch I, Babalola O, et al. Distribution and aetiology of blindness and visual impairment in mesoendemic onchocercal communities, Kaduna State, Nigeria. Kaduna Collaboration for Research on Onchocerciasis. *Br J Ophthalmol* 1994;78(1):8-13.
41. Dolin PJ, Faal H, Johnson GJ, et al. Trachoma in The Gambia. *Br J Ophthalmol* 1998;82(8):930-3.
42. Faal H, Minassian D, Sowa S, et al. National survey of blindness and low vision in The Gambia: results. *British Journal of Ophthalmology* 1989;73(2):82-7.
43. Balo K, Negrel DA. [Causes of blindness in Togo]. *J Fr Ophthalmol* 1989;12(4):291-5.
44. Schemann JF, Minassian CD, Negrel D. Prevalence et causes de cécité la région de Kara au Togo. *Cahier Santé* 1993;3:24-30.
45. World Health Organization. Prevalence surveys: Chad. *Weekly Epidemiological Record* 1987;43:322-3.
46. Alemayehu W, Tekle-Haimanot R, Forsgren L, et al. Causes of visual impairment in central Ethiopia. *Ethiop Med J* 1995;33(3):163-74.

47. Cerulli L, Cedrone C, Culasso F, et al. Preliminary epidemiological study on the causes of blindness in one region of Ethiopia. *Rev Int Trach Pathol Ocul Trop Subtrop Sante Publique* 1981;157-61.
48. Whitfield R, Jr., Schwab L, Bakker NJ, et al. Cataract and corneal opacity are the main causes of blindness in the Samburu tribe of Kenya. *Ophthalmic Surg* 1983;14(2):139-44.
49. Whitfield R, Schwab L, Ross-Degnan D, et al. Blindness and eye disease in Kenya: ocular status survey results from the Kenya Rural Blindness Prevention Project. *Br J Ophthalmol* 1990;74(6):333-40.
50. Bucher PJ, Ijsselmuiden CB. Prevalence and causes of blindness in the northern Transvaal. *Br J Ophthalmol* 1988;72(10):721-6.
51. Ballard RC, Sutter EE, Fotheringham P. Trachoma in a rural South African community. *Am J Trop Med Hyg* 1978;27(1 Pt 1):113-20.
52. Ballard RC, Fehler HG, Fotheringham P, et al. Trachoma in South Africa. *Soc Sci Med* 1983;17(22):1755-65.
53. Rapoza PA, West SK, Katala SJ, et al. Prevalence and causes of vision loss in central Tanzania. *International Ophthalmology* 1991;15(2):123-9.

Appendix 1

Region	Mortality stratum*	Country	Year	GDP per capita (Int'l \$)	Prevalence per 1,000	Source
Afro	D	Benin	1995	688	0.18	38
Afro	D	Cameroon	1993	1149	0.89	39
Afro	D	Mali	1994	521	2.06	9
Afro	D	Nigeria	1988	778	2.76	40
Afro	D	The Gambia	1996	947	0.2	41
Afro	D	The Gambia	1986	1100	1.19	42
Afro	D	Togo	1985	1223	0.41	43
Afro	D	Togo	1986	1216	1.07	44
Afro	E	Central Africa	1994	2564	0.99	7
Afro	E	Chad	1985	660	5.26	45
Afro	E	Ethiopia	1993	285	1.75	8
Afro	E	Ethiopia	1987	323	3.85	46
Afro	E	Ethiopia	1981	357	4.34	47
Afro	E	Kenya	1976	1363	1.3	48
Afro	E	Kenya	1987	1363	1.31	49
Afro	E	South Africa	1985	6363	0.57	50
Afro	E	South Africa	1976	6480	3.31	51
Afro	E	South Africa	1979	6447	6.1	52
Afro	E	Tanzania	1986	360	2.39	53
Emro	B	Oman	1997	10250	2.09	10
Emro	B	Saudi Arabia	1984	18485	1.6	22
Emro	B	Saudi Arabia	1990	12360	1.41	23
Emro	D	Egypt	1997	2991	1.84	24
Emro	D	Morocco	1992	3282	0.31	25
Searo	D	India	1976	619	0.3	26
Searo	D	India	1987	1863	0.04	27
Wpro	A	Australia	1977	15330	1.07	28
Wpro	A	Australia	1996	22090	1.29	11
Wpro	B	China	1983	875	0.32	32
Wpro	B	China	1987	1291	0.47	30,31
Wpro	B	Myanmar	1990	1112	0.62	35
Wpro	B	Nepal	1981	738	0.23	34
Wpro	B	Tonga	1991	3375	0.11	36

* Five mortality strata were defined in terms of quintiles of the distribution of 5q0 and 45q15 (both sexes combined). Countries with low child mortality (mostly developed and middle-income countries) were split into three: A = very low child mortality, B= low child mortality and low adult mortality, and C = low child mortality but high adult mortality. Adult mortality 45q15 was regressed on 5q0 and the regression line used to divide countries with high child mortality into high adult mortality (stratum D) and very high adult

mortality (stratum E). Stratum E includes the countries in sub-Saharan Africa where HIV/AIDS has had a very substantial impact.