Adolescent Mortality in Low- and Middle-Income Countries

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Introduction

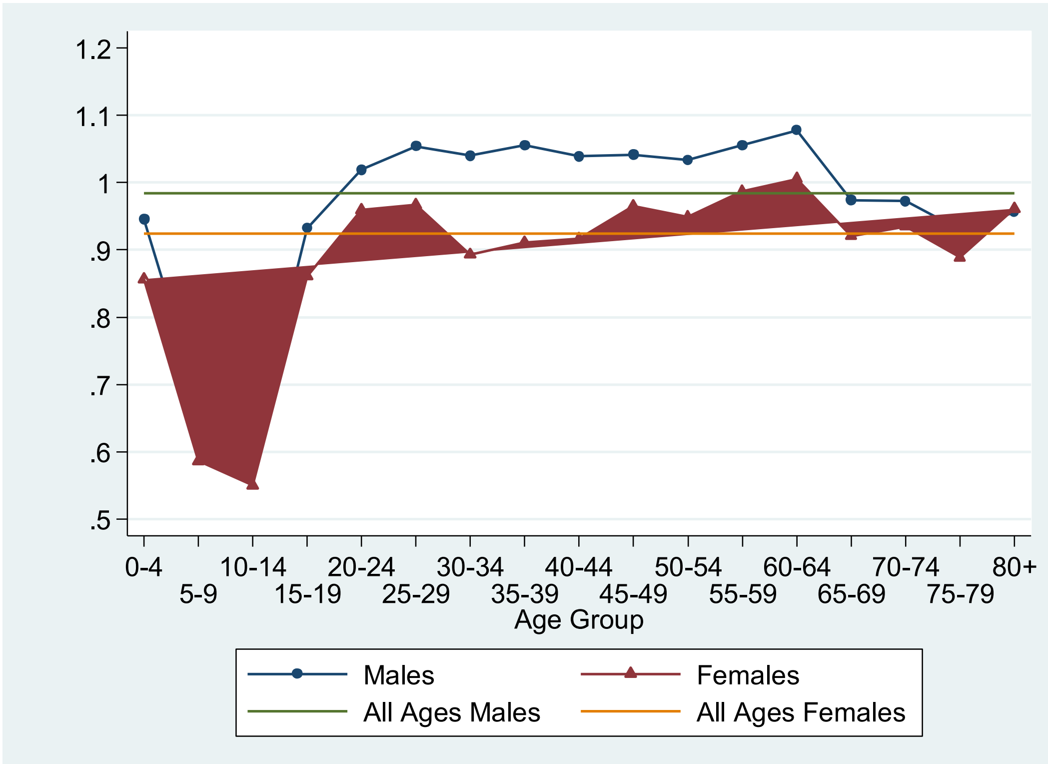
Under-5 mortality, and some of its components such as neonatal mortality, in low- and middle-income countries have drawn the attention of the public health and development communities for over a decade, with the probability of dying by age 5 being the primary yardstick for measuring progress towards the fourth MDG. The second age range of interest has become mortality between the ages of 15 and 60, measured by the probability of dying between those two ages. This has left two age ranges relatively neglected: mortality above the age of 60, and mortality between the ages of 5 and 15. There are practical reasons for limited emphasis on mortality above age 60: measuring such mortality in populations with substantial age misreporting is essentially impossible. Even measurement systems such as demographic surveillance systems with complete recording of births and deaths will provide biased estimates of old age mortality as long as the ages of the living and the dead are misreported, even if they are misreported by the same amount. The age range 5 to 14, on the other hand, is amenable to measurement, but has perhaps been neglected because it is the age range during which human mortality risks reach their minimum. This paper reviews evidence on mortality in this age range, with a focus on populations in low- and middle-income countries.

Existing Estimates of Mortality Between Ages 5 and 15

Two recent publications have presented estimates of mortality by age and sex for the world, regions and countries. Wang et al. (2012) published the mortality estimates underlying the Global Burden of Disease Study 2010, and the United Nations Population Division (2013) released the 2012 revision of World Population Prospects. Direct comparisons are not possible because the two studies present information on deaths by age and sex for time periods defined in different ways: Wang et al. present estimates for 1970, 1990 and 2010, whereas the UN Population Division estimates are for 1995-2000, 2000-2005 and 2005-2010. To make comparisons easier, we have approximated numbers of deaths by age group in 2010 for the UN Population Division series by first calculating average annual numbers for the two most recent periods, then calculating age- and sex-specific annual rates of change, and finally using those rates of change to extrapolate to 2010. Figure 1 shows ratios of numbers of deaths by sex and 5-year age groups in 2010 from the GBD exercise to those estimated from the UN Population Division numbers.

The horizontal lines in Figure 1 show the GBD:UNPD ratios for total male and female deaths. The total number of male deaths is very similar between the two exercises, but the total number of GBD female deaths is about 8% lower than the UNPD number. On an age-specific basis, however, the differences are more marked, particularly between the ages of interest here, namely 5 to 15. At these ages, the GBD numbers of deaths are between 30% and 40% lower than the UNPD numbers for males, and between 40% and 45% lower for females. These differences arise almost entirely for low- and middle-income countries, for which different estimation approaches are used. In high-income countries, data come from largely accurate reporting of deaths by age from civil registration systems, and no estimation is required.

Figure 1: Ratios of Deaths by Sex and 5-Year Age Groups in 2010: GBD Study and UNPD 2012 Revision



The large relative differences between numbers of deaths reported by these two exercises as occurring between ages 5 and 15 is surprising, given that it is an age range with a very substantial amount of empirical data available for low- and middle-income countries, as described below. The differences result from different estimation approaches. The GBD estimates are derived from a relational model life table system which is fitted to the probability of dying by age 5 and the probability of dying between the ages of 15 and 60, with a mortality standard being adopted from reliable data for the population being studied. The UNPD approach is also country-specific, and is hard to summarize adequately, but in the absence of reliable country data uses a different system of model life tables.

In this paper we analyze data on mortality between the ages of 5 and 15 from a large number of nationally-representative household surveys in an attempt to determine which numbers are closer to reality.

Data

The data we use come from the full birth histories collected by the Demographic and Health Surveys (DHS) program. DHS's conduct interviews with (almost always) nationally-representative samples of women of reproductive age; sample sizes range from about 3,000 to 100,000 women. A full birth history collects information from women (in some settings ever-married women) about the sex and date of each of her live births, whether the child is still alive, and if not the age at which the child died. Such data permit the location of child deaths and child exposure to risk by age in calendar time, and thus permit the calculation of age-specific mortality rates (deaths per person year of exposure) for specified time periods. These data have been used widely for studies of mortality under the age of 5, for example estimating national and sub-national levels and trends in under-5 mortality and its components, and for exploring differentials in early child mortality (refs). However, the data also provide a basis (albeit with smaller sample numbers of deaths and thus larger sampling errors) for calculating mortality risks between the ages of 5 and 15 using the same methodology. However, there has been no systematic use of the data to explore mortality after the age of 5. We use data from 194 DHS's covering 84 countries from all six World Bank low- and middle-income regions to estimate mortality between 5 and 15 by sex.

Methods

We use full birth history data to calculate period mortality rates for narrow age ranges for the 10 complete calendar years before each survey. For under-5 mortality, we use the Stata routine U5MR to calculate from each survey mortality rates by sex for months of age, convert them into probabilities of dying from the beginning to the end of each month, and then chain together the corresponding probabilities of surviving to estimate sex-specific probabilities of dying between birth and age 5 (U5MR). Following the methodology described in Hill et al. (Hill et al., 1997), the U5MR routine calculates age-period event-exposure mortality rates for chosen periods and age intervals of one month. The combination of date of birth in century-months (CMC) and age at death in CMC is used to locate deaths in particular 12-month periods except for deaths in the first month of life. To deal with ambiguity regarding the month of death for data recorded as CMC for births and age at death recorded in months (from 1 month to 23 months) and then year (2 years and higher), a pseudo-random number between 0 and 1 is added at the beginning and end of the period. Exposure time in a particular month of age and 12-month period is based upon the proportion of a month that each child spends in each cell of the Lexis Diagram. The events and exposure by month of age and reference period are summed for a given age, and event-exposure rates are calculated for each month of age by dividing the events by the exposure. They are then converted into probabilities of dying using the standard life table relationship, chaining together survivorship ratios to obtain probabilities of dying as follows:

$$_nq_x = 1 - \prod_{y=x}^{x+n-1} \left(1 - {_1q_y}\right)$$

From age 5 to 14, we calculate mortality rates by sex and single years of age, convert them into probabilities of dying for each year, and then chain together the corresponding survivorship probabilities to estimate sex-specific probabilities of dying between 5 and 10 ($_5q_5$) and 10 and 15 ($_5q_{10}$).

By World Bank region, we then compare graphically (by sex) the relationships of the probabilities of dying ${}_5q_5$ and ${}_5q_{10}$ to U5MR, and to the corresponding relationships in standard model life tables (the four families of Coale-Demeny (1983) model life tables).

To compute numbers of deaths at each age range in 1990 and 2010 by sex and region, we model the relationship between each ${}_nq_x$ and the corresponding ${}_5q_0$ using OLS regression of the form

$$\ln\left({}_5 q_x^{i,j}\right) = \alpha_x^{i,j} + \beta_x^{i,j} \ln {}_5 q_0^{i,j} \qquad (1)$$

where *x* is for ages 5 or 10, *i* is World Bank region and *j* is sex. World Bank estimates of ${}_5q_0$ by sex and region for 1990 and 2011 are then used with the regression model parameter estimates to obtain estimates of ${}_5q_x$ by sex and region. The ${}_5q_x$'s are then converted into age-specific mortality estimates ${}_5M_x$ using the expression ${}_5M_x = {}_5q_x/(5 - 2.5*{}_5q_x)$, which are then applied to UN Population Division estimates of the populations by sex in 1990 and 2010 to obtain numbers of deaths by age group, sex, region and year.

Results

Graphs of the relationships between ${}_nq_x$ and ${}_5q_0$ by sex and region are shown in Appendix 1. As will be seen, there is very considerable scatter in the relationships. Even though each estimate uses a 10-year reference period, there is substantial sampling error in the estimates of ${}_5q_x$ and ${}_5q_0$, especially in countries with small surveys, low fertility, or low mortality. However, some general relationships are clear. In the Coale-Demeny model life tables, ${}_5q_5$ and ${}_5q_{10}$ relative to ${}_5q_0$ tend to be high in the "North" family of tables, and low in the "South" and "East" families, with the "West" family falling in between. The survey observations tend to be close to the "West" or "North" patterns, indicating high mortality between ages 5 and 15 relative to mortality from birth to age 5; East Asia and the Pacific, South Asia and sub-Saharan Africa (with particularly notable scatter in the latter case) being particularly high; The relationships for Europe and Central Asia, Latin America and the Caribbean, and the Middle East and North Africa regions tend to be more middle of the road, and closer to the "West" family. In general, though, the mortality risks between 5 and 15 relative to ${}_5q_0$ seem to be similar to, or higher than, the historical patterns underlying the Coale-Demeny models.

Table 1 shows the region- and sex-specific estimates of ${}_5q_x$ obtained from the regression models summarized in equation (1); World Bank estimates of under-5 mortality rates or ${}_5q_0$'s are shown for comparison. On average, the 5-year probabilities of dying from age 5 to 15 are one-tenth or less of the probability of dying between birth and age 5, but mortality between 5 and 10 is closer to 20 percent of U5MR in East Asia and the Pacific, South Asia and sub-Saharan Africa. Probabilities of dying are much higher in sub-Saharan Africa than in other regions, and are higher for children aged 5 to 9 than for children aged 10 to 14, particularly in 1990. For both age ranges, risks decline from 1990 to 2010, but the declines are faster for the age range 5-9 than for 10-14. Females generally have an advantage, except at ages 5-9 in South Asia (1990 and 2010) and at ages 10-14 in East Asia and Pacific (1990 only).

Table 1: Estimated Conditional Probabilities of Dying per 1,000 by Age Group, Sex, Year and World Bank Region

Year	Sex	Age	World Bank Region						Total, Low- and Middle-Income
			East Asia & Pacific	Europe & Central Asia	Latin America & Caribbean	Middle East - North Africa	South Asia	Sub-Saharan Africa	
1990	Males	0-4	57.8	51.9	57.4	72.4	115.8	186.4	96.9
		5-9	11.0	3.6	6.2	5.0	19.2	35.6	9.4
		10-14	5.6	2.8	4.8	6.4	9.8	17.0	6.2
	Females	0-4	53.0	43.2	48.1	68.1	121.6	168.5	93.0
		5-9	10.9	2.1	5.1	6.7	19.8	30.8	9.8
		10-14	6.7	1.7	4.1	4.8	7.8	15.7	5.6
2010	Males	0-4	23.1	24.0	24.3	34.8	63.1	118.2	57.6
		5-9	7.0	2.5	2.1	2.5	10.2	22.0	5.6
		10-14	4.5	2.4	2.1	3.7	5.8	12.6	4.2
	Females	0-4	20.9	19.5	20.2	31.1	65.4	106.6	55.0
		5-9	4.1	1.0	2.0	2.6	12.1	19.8	5.2
		10-14	3.5	1.4	2.0	1.6	5.8	11.7	3.1

Sources: Probabilities of dying between birth and age 5 are from World Bank; those for ages 5 to 20 are authors' calculations

Table 2 shows the number of deaths in 1990 and 2010 by age group, sex, and World Bank region. Three regions – East Asia and Pacific, South Asia, and sub-Saharan Africa – account for a large majority of total deaths between the ages of 5 and 15 (91% of 2.4 million in 1990, and 94% of 1.8 million in 2010). South Asia has the largest number of deaths in 1990, but is overtaken by a substantial margin by sub-Saharan Africa in 2010. Female deaths are generally fewer than male deaths, except for South Asia in 2010.

Table 2: Estimated Annual Numbers of Deaths in 1990 and 2010 by Age Group, Sex and World Bank Region

Year	Sex	Age	World Bank Region						Total, Low- and Middle-Income
			East Asia & Pacific	Europe & Central Asia	Latin America & Caribbean	Middle East - North Africa	South Asia	Sub-Saharan Africa	
1990	Males	0-4	1,175.2	200.5	338.0	280.4	2,187.2	2,037.9	6,219.2
		5-9	198.6	13.1	34.0	19.3	296.8	292.0	853.8
		10-14	94.7	9.6	24.1	21.0	134.6	117.5	401.4
		Total, 5-14	293.3	22.8	58.1	40.3	431.4	409.4	1,255.2
	Females	0-4	983.6	158.4	270.7	250.6	2,153.4	1,777.3	5,594.0
		5-9	186.2	7.6	27.1	24.6	286.1	248.2	779.8
		10-14	107.5	5.7	20.1	15.1	100.3	106.9	355.5
		Total, 5-14	293.6	13.2	47.2	39.7	386.5	355.1	1,135.3
2010	Males	0-4	326.9	71.0	112.6	134.4	1,175.3	1,799.2	3,619.4
		5-9	113.3	6.4	11.6	10.1	181.4	282.6	605.4
		10-14	78.4	6.3	11.5	14.1	101.9	140.2	352.4
		Total, 5-14	191.7	12.7	23.1	24.2	283.2	422.9	957.8
	Females	0-4	260.4	54.2	89.3	114.3	1,134.6	1,566.0	3,218.9
		5-9	57.7	2.6	10.8	10.1	199.0	248.5	528.6
		10-14	53.8	3.5	10.8	5.7	94.7	127.7	296.2
		Total, 5-14	111.5	6.0	21.5	15.9	293.7	376.2	824.8

Sources: Deaths under age 5 are from World Bank; those from 5 to 19 are from age-specific mortality rates calculated by authors applied to population estimates from UN Population Division 2010 World Population Prospects.

Table 3 compares numbers of deaths from this exercise by sex, age group and country-group to the estimates available from the GBD-2010 and UN 2012 Revision. The comparison between our results and GBD is only made at the global level for 2010, whereas the comparison with UN estimates is between UN estimates for annual average numbers of deaths 2005-2010 at the global level, for less-developed countries, and for sub-Saharan Africa with our estimates for 2010; since numbers of deaths are falling over time, the UN estimates should be somewhat larger than the 2010 estimates.

Table 3: Comparison of Numbers of Deaths around 2010: GBD-2010, UNPD and Our Estimates (‘000)

Geography	GBD 2010		UNPD 2012 Revision		This Study	
	Male	Female	Male	Female	Male	Female
World	450	367	726	675	N/A	N/A
Less-Developed Regions	N/A	N/A	712	666	958	825
Sub-Saharan Africa	N/A	N/A	373	378	423	376

As indicated in Figure 1, at the global level the GBD 2010 numbers are much smaller than the UNPD estimates, which are an average for 2005-2010 rather than for 2010 specifically. The estimates in this study are larger again: for "Less-Developed Regions" as a whole, by some 30%, and for sub-Saharan Africa by about 6%.

Discussion

It is clear from this analysis that mortality in low- and middle-income countries is not negligible, and is probably higher (relative to under-5 mortality) than historical patterns, at least in East Asia and the Pacific, South Asia and sub-Saharan Africa. In 2010 on the basis of this analysis there were about 1.8 million deaths between the ages of 5 and 15 in what the UN defines as "Less Developed Regions (LDR)". Our estimates are higher than the UNPD's 2012 revision by a large amount for all LDR's, and slightly for sub-Saharan Africa alone. The reason for these discrepancies needs further investigation. In the interim, using the UNPD estimates is probably an appropriate approximation.

The results in this paper are based on birth histories collected from women of reproductive age at the time of each survey, and on events and exposure in the 10 years before each survey. These limits have implications for the mortality measures. Consider for example children aged 14 at time 10 years before a survey; they were born nearly 25 years before the survey, and must have been born to women early in their reproductive years (before age 25), and have been of low birth order by comparison with a random sample of births at that time. There are thus potential selection issues involved in using birth history data as a basis for mortality estimates for older children. If the children reported on have above average mortality risks, we will tend to over-estimate mortality and deaths for older ages. However, it seems somewhat unlikely that age of mother or parity effects continue to be major factors in mortality risk after the age of five.

Another issue is recall lapse. It is possible that women tend to omit births that occurred long before a survey, and it is also possible that such omission may be greater for children who have died than for children who have survived. Such error would probably lead to an under-estimate of risk relative to children under age 5. However, recent work for the Interagency Group on Mortality Estimation has indicated that recall lapse has no detectable effect on estimates of under-5 mortality up to 25 years before a survey, so any effect is likely to be very small.

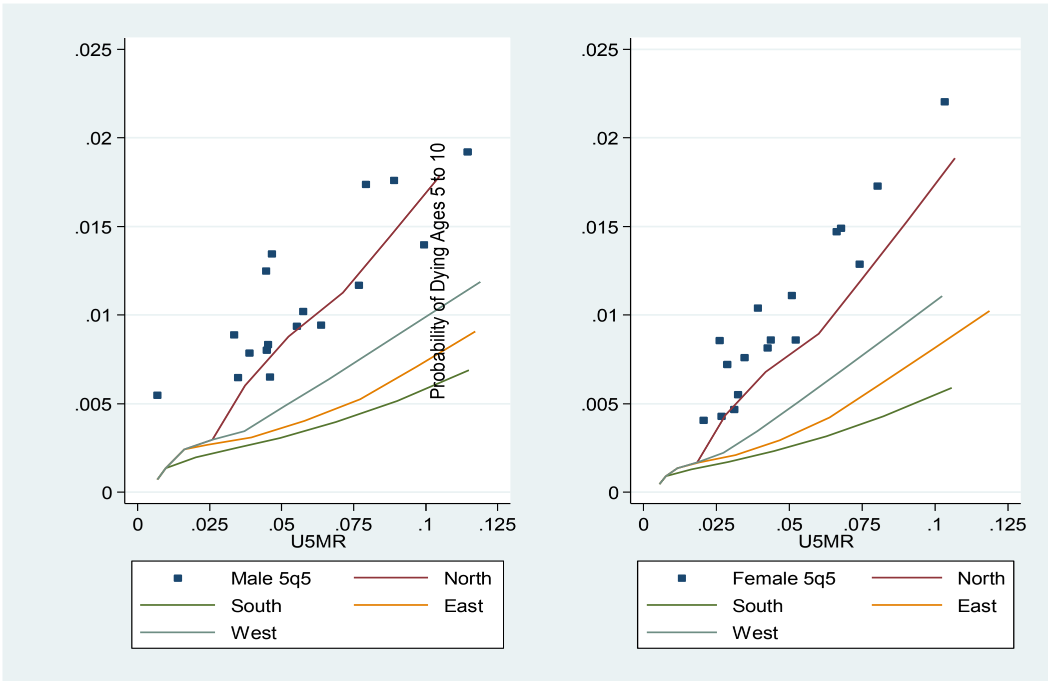
All the results reported in this paper are derived from sample surveys, with the result that both the dependent and the independent variables used to fit model (1) have sampling errors associated with them. There is thus potential for bias, though no clear indication of which direction it might be in.

References

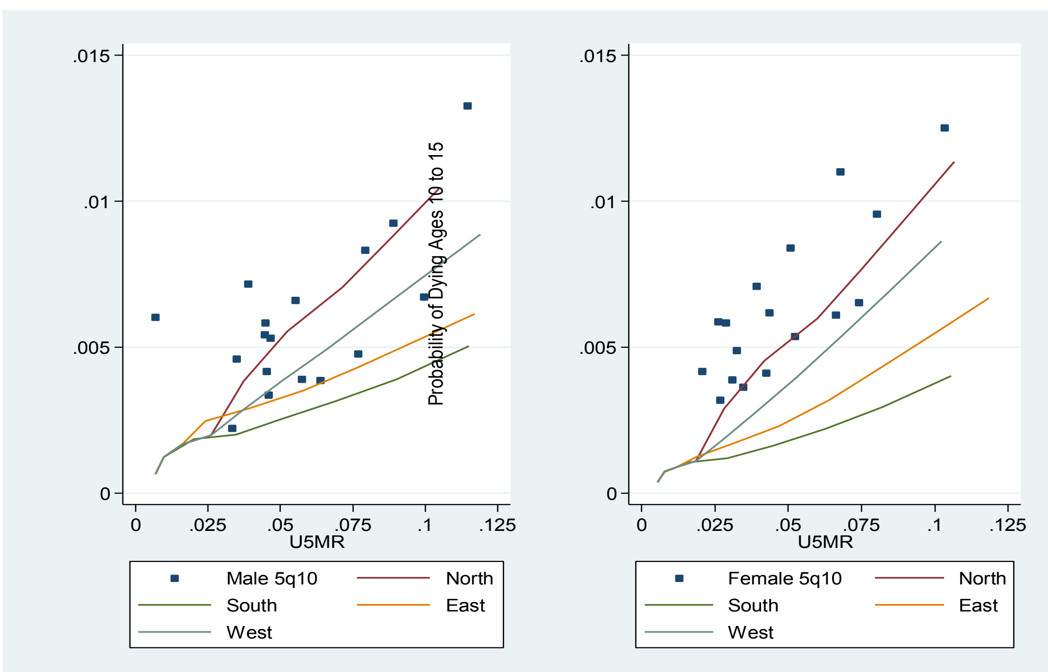
<< To come >>

Appendix 1: Observations vs. Coale-Demeny Model Patterns

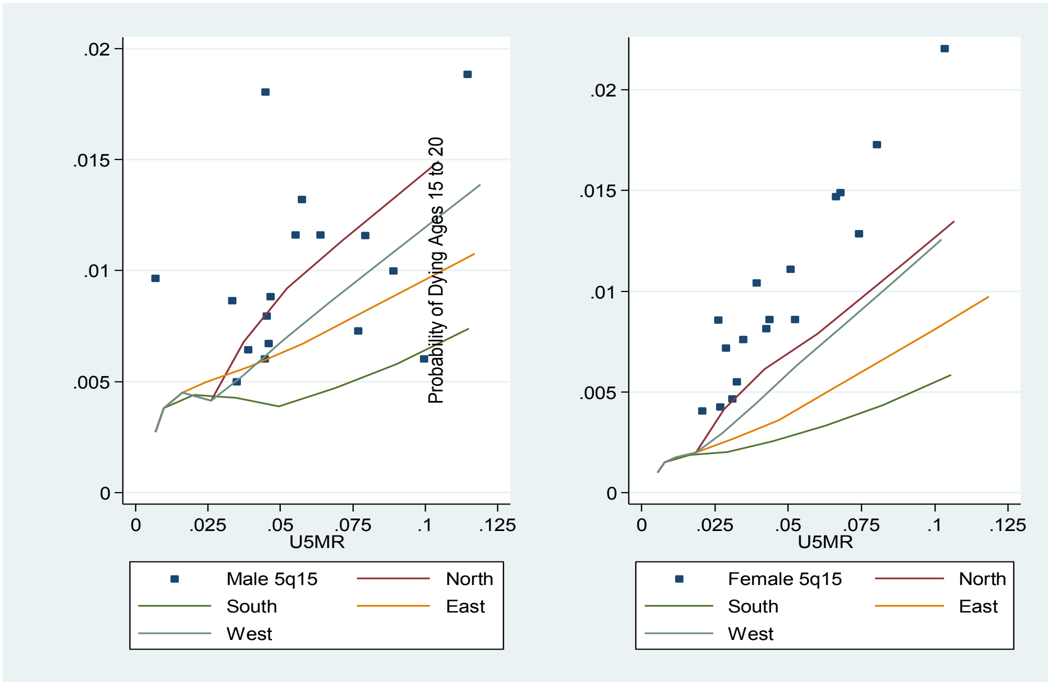
East Asia and Pacific $_5q_5$



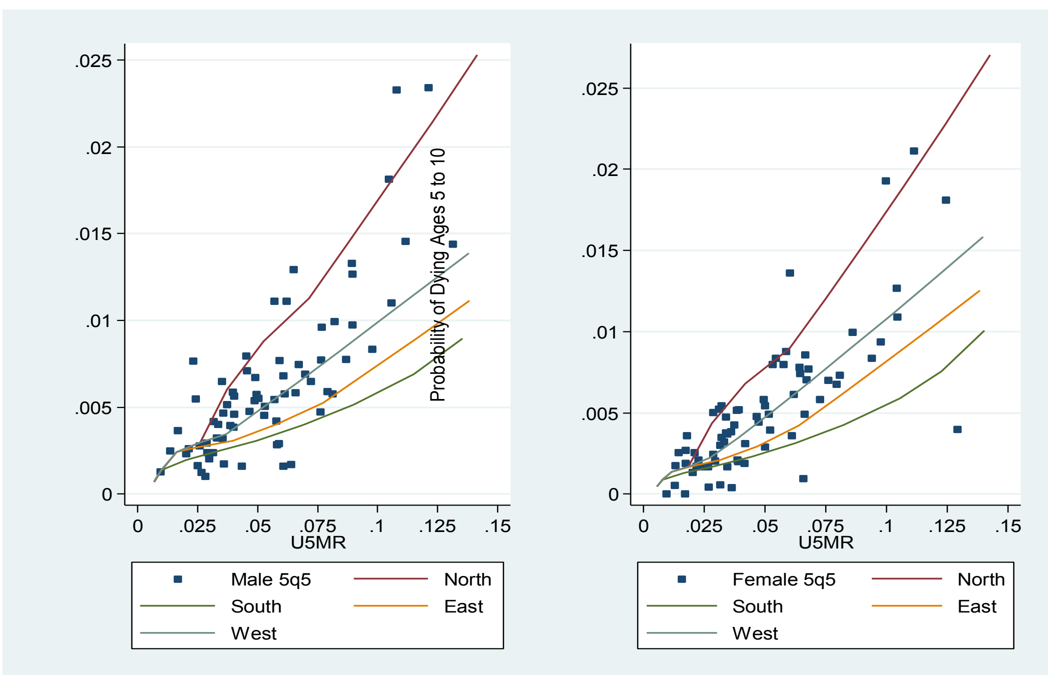
East Asia and Pacific $_5q_{10}$



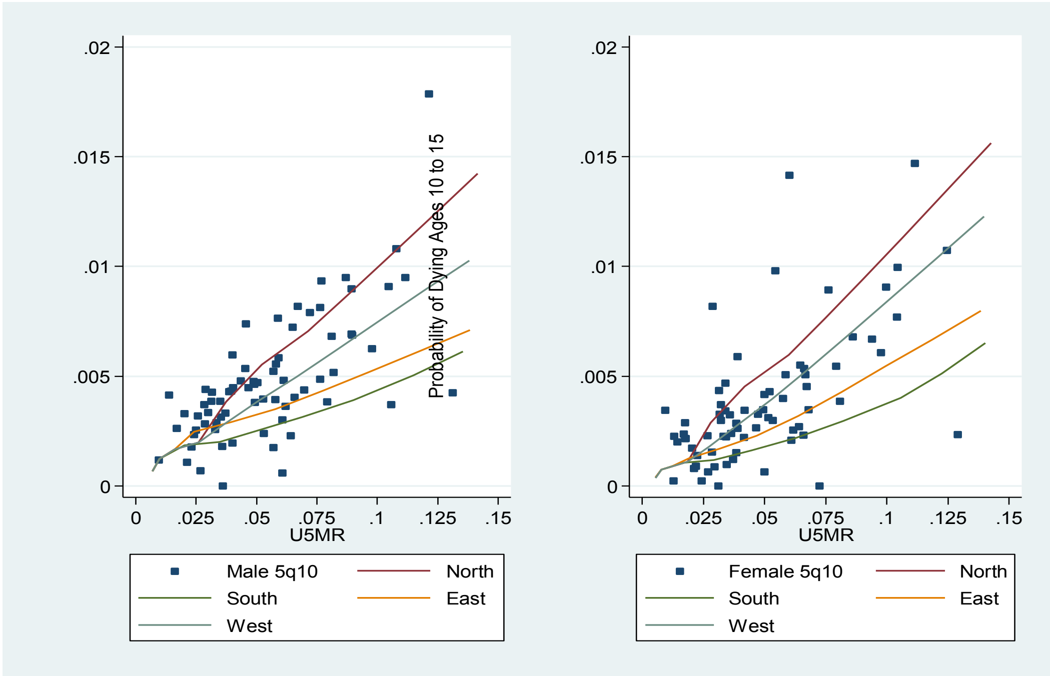
East Asia and Pacific $_5q_{15}$



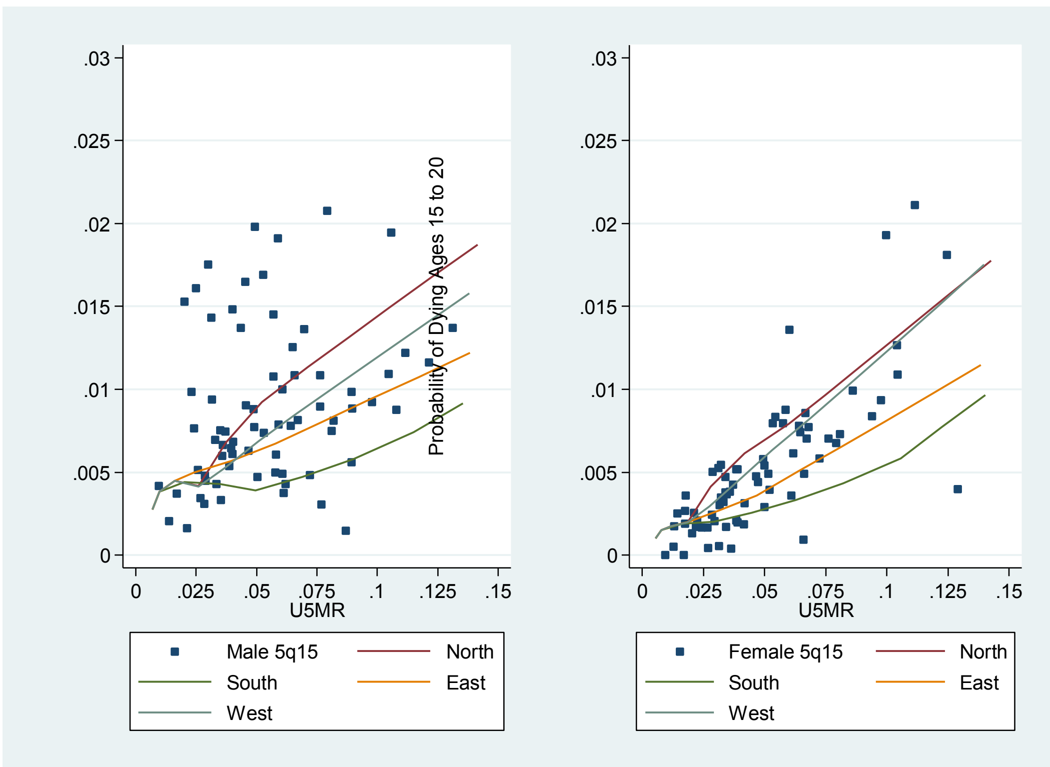
Europe, Central Asia, Latin America and Caribbean, Middle East and North Africa $_5q_5$



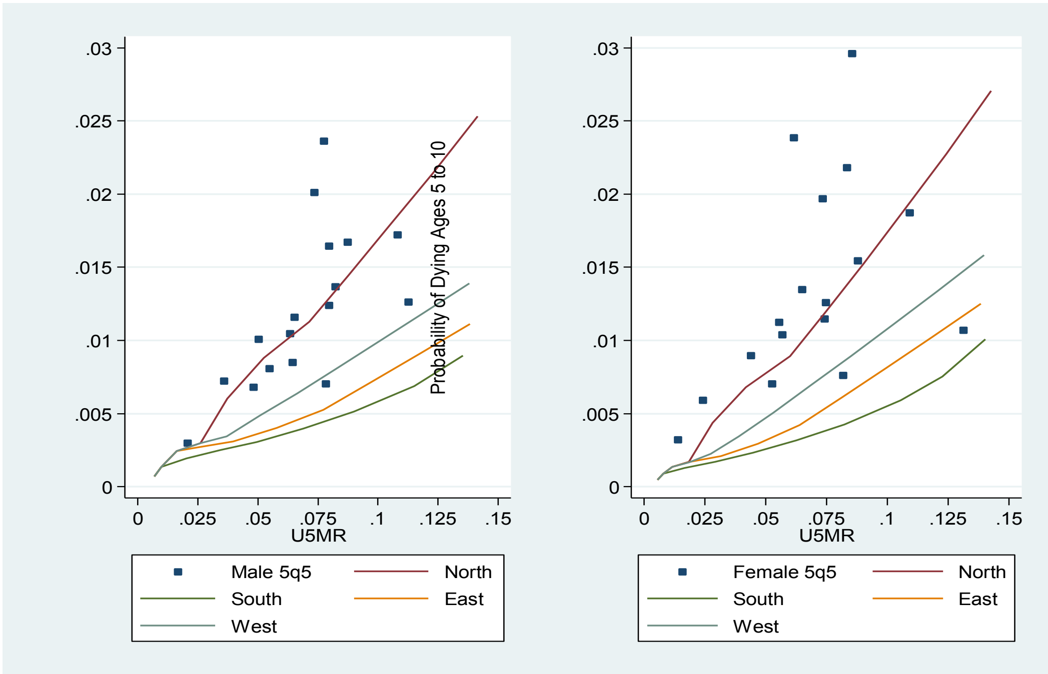
Europe, Central Asia, Latin America and Caribbean, Middle East and North Africa $_5q_{10}$



Europe, Central Asia, Latin America and Caribbean, Middle East and North Africa $_5q_{15}$



South Asia $_5q_5$



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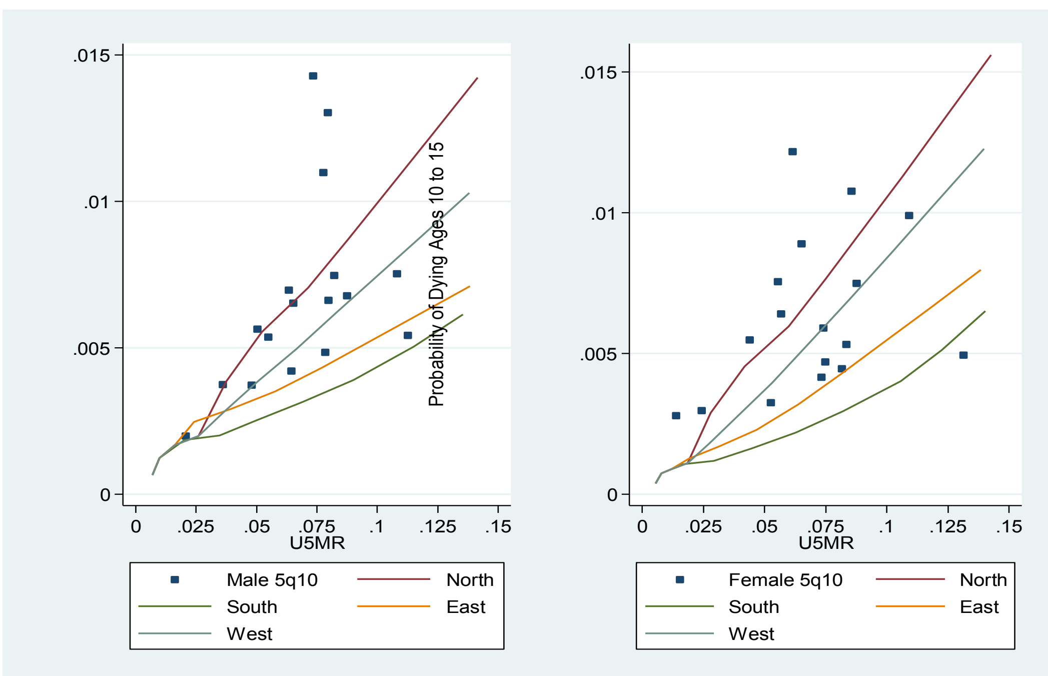

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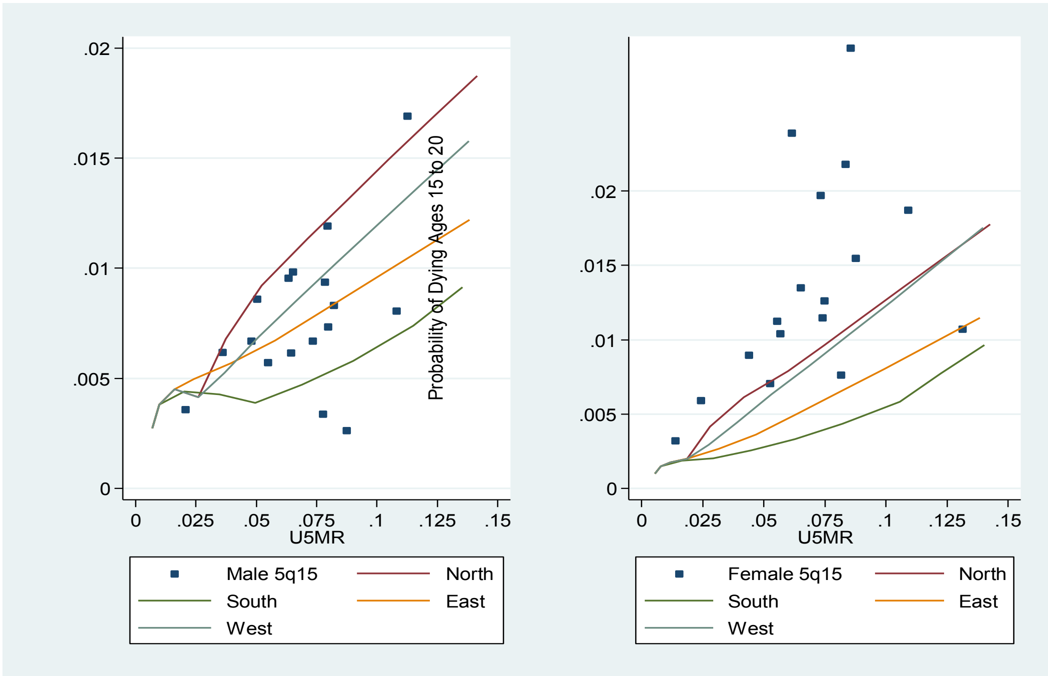
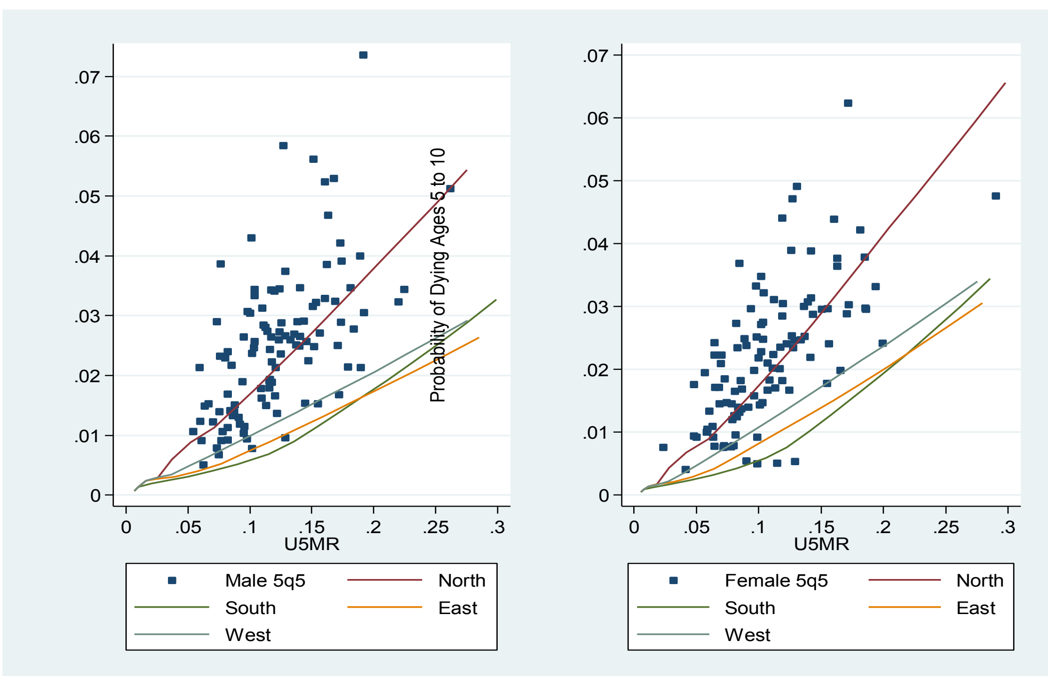
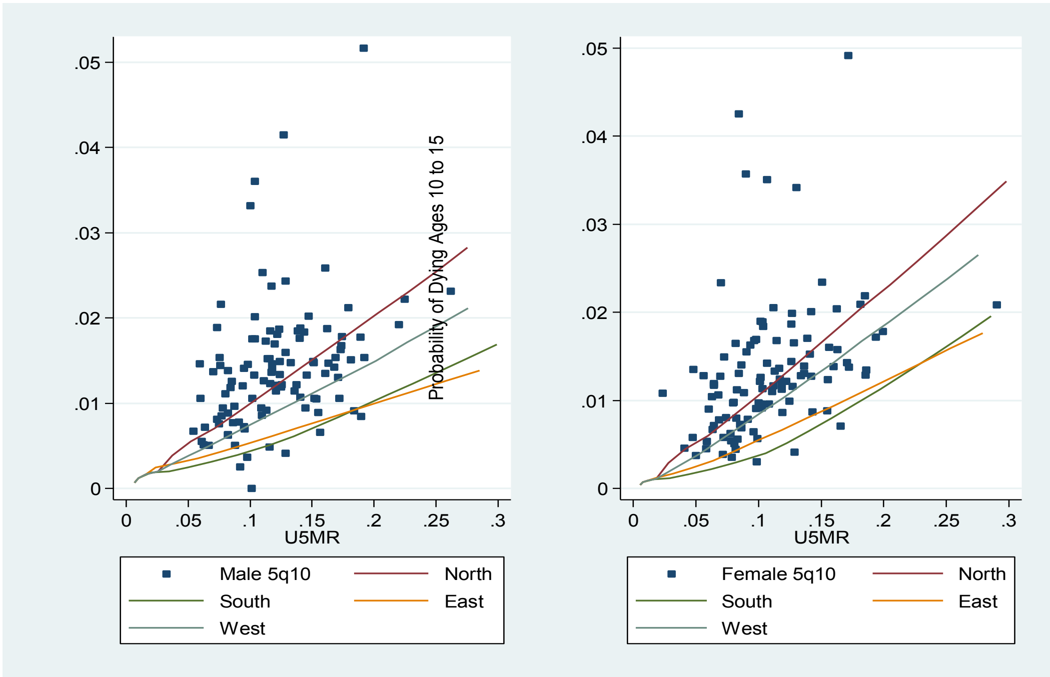


Sub-Saharan Africa $_5q_5$



Sub-Saharan Africa $_5q_{10}$



Sub-Saharan Africa $_5q_{15}$