# Identifying New Age Patterns of Under-Five Mortality Using the Under-Five Mortality Database

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## 1 Objective of the study

This study brings new insights into the global diversity of the age pattern of under-five mortality. The novelty of our results relies on the newly-compiled Under-Five Mortality Database (U5MD) providing mortality information by detailed age groups – including daily, weekly, and monthly breakdowns. The fine granularity of these data allows the detection of age patterns as well as data quality issues that could not be seen previously in low- and middle-income countries, but also and high-income countries.

The age pattern of under-five mortality refers to variation in the risk of dying between 0 and 5 years of age. This variation reflects underlying causes of death and their changes over time as overall mortality falls. These distributional changes are relatively stable; the existence of typical trajectories in the historical experience of European countries in the 19th and 20th centuries was initially shown by Coale and Demeny (1966). In particular, Coale and Demeny (CD) identified four families of model life tables relating the level of mortality during infancy (between age 0 and 1) and childhood (between 1 and 5). In Figure 1, we illustrate this relationship between infant mortality denoted q(1y) and child mortality denoted q(1y,5y). The four families of CD models – East, North, South, West – depict trajectories (blue lines) where child mortality tends to decrease faster than infant mortality as mortality falls, but at different paces. These trajectories reflect the increasing proportion of congenital and perinatal causes of deaths concentrated at early age, while infectious diseases tend to decrease at all ages.

The CD model life tables have been used as a historical yardstick to examine the age patten of under-five mortality in low- and middle-income countries (Hill, 1995; Guillot et al., 2012). These previous systematic comparisons with empirical values showed both substantial agreement as well as systematic deviations. This is shown in Figure 1 using mortality rates obtained with full birth histories from publicly available Demographic and Health Surveys (DHS). While a majority of points from all world regions fall within the range of the CD models, most Sub-Saharan surveys display a strong tendency for child mortality to be above the model range. Epidemiological conditions specific to this world region have been invoked to explain such deviation from European patterns: specific environments characterized by a high prevalence of infectious diseases, inadequate weaning foods, and in some specific cases high prevalence of HIV/AIDS (Cantrelle and Leridon, 1971; Garenne, 1982; Pison and

Langaney, 1985; Jasseh, 2003; Guillot et al., 2012). These factors potentially contribute to increasing mortality at later ages, generating a relatively high level of q(1y,5y) vs. q(1y). However, data quality issues associated with DHS are also commonly acknowledged (Pullum and Becker, 2014). In particular, omission of neonatal deaths has been a particular subject of concern and might have contributed to producing the pattern of deviation in q(1y,5y) vs. q(1y) observed in Sub-Saharan DHS surveys.

This study aims to elucidate such deviations. Specifically, the objective of this study is to identify and validate new regional and epidemiological age patterns of under-five mortality that depart from the European and, more broadly, Western experience. To do so, we take advantage of a newly-constituted database (U5MD) to examine age patterns of under-five mortality using unconventional age groups, e.g. relating the neonatal period to the postneonatal period up to 6 months. Indeed, the U5MD includes a large set of high-quality detailed age distributions from low-, middle-, and high-income countries that allow systematic comparisons for these non-conventional age relationships.

This new understanding of the age pattern of under-five mortality is necessary to determine to what extent existing models need to be amended and expanded to take into account epidemiological specificities in low- and middle-income countries. This issue is particularly critical knowing that the CD model life tables are still widely used in these countries for the purpose of estimating infant and under-five mortality (UN IGME, 2018). As shown elsewhere (Guillot et al., 2020), a better modeling of age patterns of under-five mortality in low- and middle-income countries can help evaluate and adjust data that are subject to various types of errors (neonatal omissions, age heaping, etc.). It can also help detect specific vulnerability of children at certain ages. Our results will thus help guide health policy in low- and middle-income countries.

# 2 The Under-Five Mortality Database (U5MD)

The U5MD gathers high-quality distributions of deaths and provides mortality rates by sex for low-, middle-, and high-income countries. The U5MD includes daily and weekly age breakdowns up to 28 days of age, monthly age groups up to one year, and trimester groups for the second year. After 2 years, the database provides single year cut-off points up to 5 years.

The first component of the database includes 25 Western countries with high-quality vital registration (VR) systems covering a time period from 1841 to 2016 (1,653 country-years). We used this information as historical yardstick in order to identify deviation in low- and middle-income countries at similar levels of mortality.

As a criterion of data quality, we only selected country-years that were previously included in the Human Mortality Database (HMD). However, further investigation raises serious doubts about the quality of the early neonatal mortality data during the earlier years covered in the VR information (before WWI). Specifically, we found reversals and flattenings of the level of early neonatal mortality associated with the increase of the overall mortality. As discussed elsewhere (Guillot et al., 2020), these reversals and flattenings are clearly related to data quality problems. As a result, we removed 326 country-years for further analysis purpose.

In the present study, we compare directly the DHS to the selected VR data of the U5MD. In order to explain the deviations we find, we use the other components of the database. These other components cover a variety of high-quality data from Asia, Latin America, and Sub-Saharan Africa. They include closely scrutinized data from 12 demographic surveillance sites, 10 cohort studies, and 3 sample registration systems. They will be described in detail in the final paper.

# 3 Preliminary results and future work

Preliminary findings show that two distinct regions of the world stand out as having an age pattern of under-five mortality that strongly differs from the European/Western experience: West Africa and South Asia. In both cases, we found that, for a given level of neonatal mortality, the level of postneonatal mortality is below the range of VR data; or inversely, for a given level of postneonatal mortality, the level of neonatal mortality is above range (see Figure 2). Here, we limited the postneonatal period to 6 months to avoid any offsetting effect. In both regions, mortality remain high after 6 months due to acute exposure to infectious diseases. In sum, these regions are characterized by high levels of neonatal mortality and mortality after 6 months, vs. mortality between 28 days and 6 months. This is why this very peculiar age pattern tends to be less visible when the full postneonatal period (up to 12 months) is plotted instead (not shown).

Panel (a) of Figure 2 also shows that the rest of Sub-Saharan surveys is relatively well aligned on the VR data as far as neonatal mortality is concerned. That disproves the hypothesis that the particularly late age pattern found in that region (see Figure 1) is due to omissions of neonatal deaths. This finding supports the hypothesis that specificities of the age pattern observed in parts of Sub-Saharan Africa are real and due to true epidemiological factors. This also shows that the concerns about underestimation of neonatal mortality in DHS may not be warranted.

However, the data misreporting could also be the other way around. Recently, Helleringer et al. (2020) pointed out the risk that reporting errors in DHS-type survey data might lead to estimates of the neonatal mortality rate that are too high. The main mechanism for such outcome would be the misclassification of stillbirths as early deaths. If it were the case, the early age pattern of mortality we found in West Africa and South Asia could still be spurious. This is why, in the rest of paper, we will compare DHS estimates with the estimates of the U5MD that pertain specifically to low- and middle-income countries. As an example, in the Panel (b) of Figure 2, we plotted the estimates obtained from the Matlab Heath and Demographic Surveillance site (HDSS) in Bangladesh for the period 1966 to 2011. Matlab estimates are in total agreement with the deviation found in South Asian DHS. As a gold standard of data quality, these HDSS data included in the U5MD contribute to validate the existence of specific age pattern of under-five mortality in the region. Similar evidence in support of a specific South Asian pattern were found with the sample registration system from India (not shown). Following this comparative approach, we will examine whether deviations found in the Sub-Saharan African DHS are real or spurious.

Finally, after this analysis of the data, we will characterize the new age patterns of under-five mortality in terms of specific epidemiological patterns and classify regions and countries accordingly, using available information on causes of death and other known epidemiological factors that are related to age patterns of under-five mortality. In the conclusion, we will discuss potential avenues for expanding the scope of existing model life tables to the epidemiological realities of low- and middle-income countries.

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Figure 1: Relationship between infant q(1y) and child mortality q(1y,5y). *Note: The gray dashed lines indicate isoclines for a given level of q(5y).*

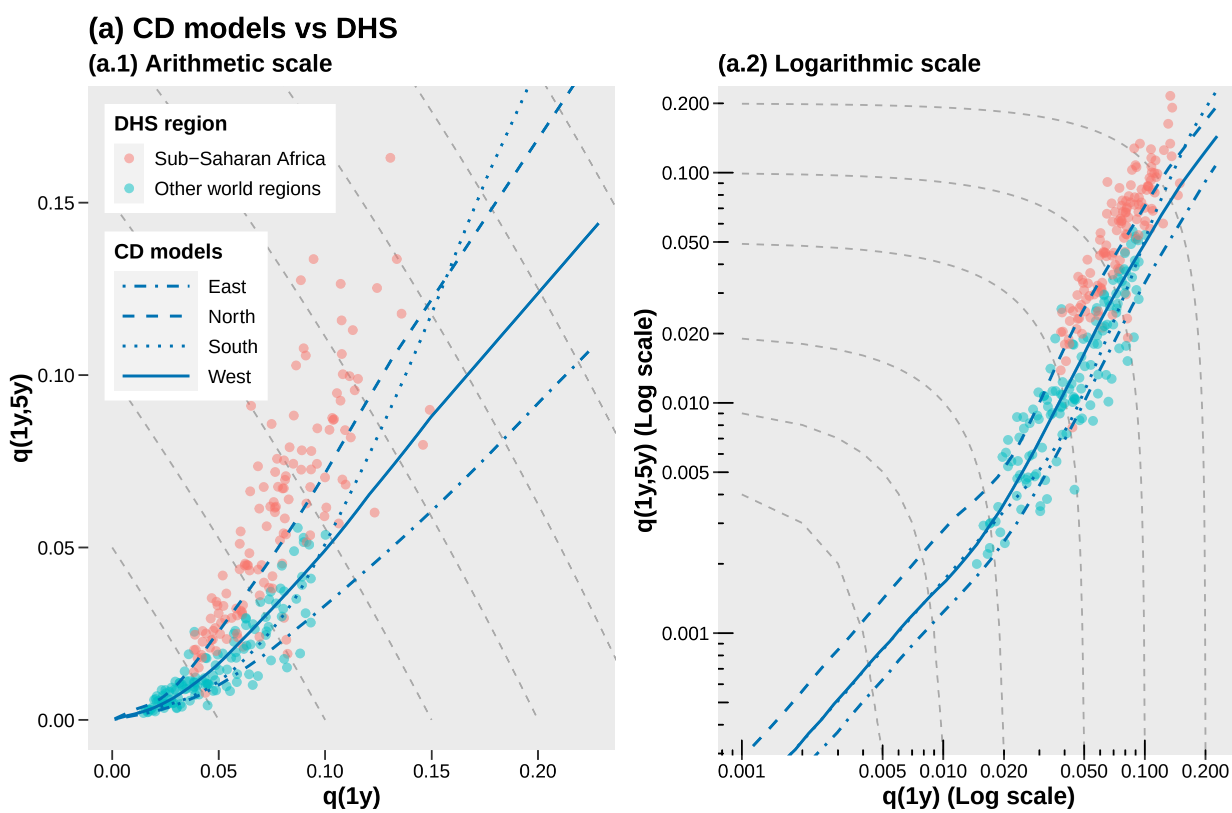

Figure 2: Relationship between neonatal q(28d) and postneonatal mortality up to 6 months q(28d,6m). *Notes: The solid line corresponds to the central prediction of the relationship based on a model derived from the VR data (Guillot et al., 2020). The dashed lines indicate isoclines for a given level of q(6m).*