Demography, social contact patterns, and SARS-CoV-2 transmission in the South West Shewa Zone of Oromia Region, Ethiopia

Introduction

Despite limited access to healthcare and relatively milder social distancing restrictions compared to those imposed in most high-income countries, COVID-19 mortality rates have been relatively low throughout Africa. As of November 5, 2020, the World Health Organization (WHO) reports 44,012 deaths out of 1,838,867 diagnosed cases in the continent, for a case-fatality ratio (CFR) of 2.4%, compared to about 3% in the rest of the world. However, SARS-CoV-2 transmission dynamics have been highly heterogeneous across different African countries in terms of timing and implemented interventions.

In sub-Saharan Africa, Ethiopia is second only to South Africa in terms of number of recorded cases and deaths, with an overall CFR of about 1.5%. The first COVID-19 case was confirmed on March 13, 2020 and, less than a month later, the Ethiopian Prime Minister declared a state of emergency in the country on April 8, 2020. Since then, borders and school closure were implemented, public institutions and firms operated at minimum capacity or under complete closure, and people were advised to stay at home. Despite these restrictions, several hundred cases have been reported in all the 12 regions of Ethiopia. The possible spread of SARS-CoV-2 in rural areas of the country is especially dangerous because of the sparse presence of well-resourced health facilities implying long travel distances for remote populations, which is an important barrier to universal access to primary care. Moreover, the healthcare workforce in Ethiopia is 5 times lower than the minimum threshold defined by the WHO for Sustainable Development Goals health targets, and far below the African average.

Recent modeling studies investigated the impact of control measures, such as self-isolation and temporary lockdowns, in a number of sub-Saharan African countries, highlighting the difficulties in defining effective, feasible and sustainable strategies for suppression or mitigation of COVID-19 epidemics. In this work, we aim to assess how demographic factors and age-specific mixing patterns can influence COVID-19 burden in Ethiopia across different geographical contexts characterized by different levels of access to healthcare.

Methods

Between November and December 2019, we conducted a survey based on individual interviews to estimate age-specific mixing patterns in four districts (*woreda*) of the South West Shewa Zone (SWSZ) of the Oromia Region, Ethiopia. About 40% of the SWSZ population is below 15 years of age and about 68% lives in remote rural settlements, 18% in rural villages, and 14% in the largest town of the area (Woliso Town, 53,065 inhabitants). The districts targeted by our study encompass a population of 449,460 inhabitants and represent the main catchment area of the St. Luke Hospital located in Woliso Town, a well-resourced health facility acting as the referral hospital for the entire Zone.

Participants were asked to recall information on the frequency, location, type of social encounters from the day preceding their interview, providing the age (or age range when exact age was unknown) and their relationship for each listed contact. A contact was defined

as an interaction between two individuals, either physical (when involving skin-to-skin contact), or non-physical (when involving a two-way conversation with five or more words in the physical presence of another person, but no skin-to-skin contact). The participants' age, sex, education and occupational status were recorded along with details on their household composition. Age-specific contact matrices were computed considering both physical and non-physical contacts.

We simulated SARS-CoV-2 spread in the different geographical contexts of the SWSZ, using an age-structured SIR compartmental model with three consecutive stages of infectiousness. The model was run separately for each geographical context, using estimates of the population age structure and of the age-specific contact matrix computed from survey data. Because school closure in all of Ethiopia was mandated much before the exponential growth of reported COVID-19 cases, we included only data on household and community contacts in the contact matrices. However, we included school contacts to estimate the theoretical SARS-CoV-2 transmission potential in the absence of a school closure mandate.

Results

A total of 938 study participants were interviewed with 43% of them living in rural remote settlements, 35% in rural villages, and 22% from urban neighborhoods. 227 participants were students, 22.9% of whom were between 5 and 9 years of age, 71.8% between 10 and 19 years, and 4.9% older. School attendance rates among the study participants aged 5-18 years was 67%, 80% and 77% in remote, rural and urban sites, respectively. The median class size ranged from 70 children per class in rural villages to 90 in remote settlements. Only 27% of our study participants reported travels outside their village in the last month; 87.3% reported they were never admitted to the local hospital.

The mean household size in remote settlements was 5.5 (95% CI: 5.3-5.7), significantly larger (Tukey test $p<0.001$) than in rural villages (4.6, 95% CI: 4.4-4.8) and in urban neighborhoods (4.4, 95%CI: 4.2-4.6), while no significant difference in the household size was found between the latter two settings (Tukey test $p=0.48$).

Overall, 5,690 non-school contacts were reported by the 938 study participants (median 6 contacts per person, range 1-26. Of these, 79.9% were physical and 43.0% involved a single social interaction during the day.

For all sites, contacts outside school were predominantly reported between family members (46.1%), neighbors (25.2%), and other relatives outside the household (13.1%), while the remaining 15.5% of contacts occurred with friends, schoolmates outside school, or other unspecified categories. Individuals with a recent history of travel outside their neighborhood did not report an increased number of contacts, except for urban residents (t-test $p=0.004$). The mean number of contacts (excluding school contacts) reported by participants was lower in rural villages (5.73, 95%CI 5.44-6.02) with respect to both urban neighborhoods (6.35, 95%CI 5.96-6.73) and remote settlements (6.19, 95%CI 5.87-6.51). In particular, the mean number of daily contacts reported by the elderly (60+ years old) was much higher in remote settlements and urban neighborhoods than in rural villages (7.7 and 5.8 vs 3.6).

Students reported 1,372 additional contacts in schools, resulting in a mean number of 6.07 (95%CI 4.98-7.16) daily physical contacts per child (median 3, range 0-50). There were limited differences in the mean number of school contacts across geographical contexts (6.31, 95%CI 4.13-8.50 in remote settlements; 5.70, 95%CI 4.19-7.21 in rural towns; 6.54, 95%CI 4.25-8.84 in urban neighborhoods).

The analysis of contacts by age clearly shows that subjects below 30 years of age tend to interact mostly with individuals of similar age (assortative mixing). The highest contact rates were found between school aged children (10-19 years), young adults (20-39 years) and between children below 10 years and their parents. However, a marked intergenerational mixing both within households and in the community was found, especially in remote settlements.

Our simulation results show that, should schools remain closed for the entire duration of the epidemic and no other interventions enacted, between 10% and 15% of the overall population would have developed respiratory symptoms or fever because of COVID-19. The fraction of critical cases (requiring mechanical ventilation and/or resulting in a fatal outcome) is estimated to be between 0.29% and 0.41% of the overall population. The highest prevalence of critical cases (between 4.2% and 5.4% on average) is expected within subjects aged 60 years or older. This age segment represents only about 5% of the total population in Ethiopia but is expected to represent 7 to 14% of symptomatic cases and 45% to 63% of all critical cases.

Remote settlements are expected to suffer a higher overall burden of critical cases (0.40% of the total population, 95%CI: 0.37-0.41%) compared to rural villages (0.32%, 95%CI: 0.30-0.35%) and urban neighborhoods (0.31%, 95%CI 0.29-0.33%). This difference is explained by a higher proportion of the elderly in the population, but also by their higher number of daily contacts and the higher intergenerational mixing compared to the other settings, which results in a higher attack rate of infections, symptomatic cases, and critical disease in this age group. Urban neighborhoods, where highest contact rates at younger ages were recorded, are expected to have the highest attack rate of infections (58.8%, 95%CI: 50.6-67.3) and symptomatic cases (13.4%, 95%CI: 11.8-15.0). However, since a large proportion of the overall number of infections (81.8%, 95%CI: 79.5-84.2) is concentrated on children and younger adults (up to 40 years of age), this does not result in a high overall proportion of critical disease. Finally, rural villages have lower attack rates among the elderly because of the significantly lower number of contacts reported by that age group in this geographical context.

Discussion

Our analysis explored the effect of demographics and social contact patterns on COVID-19 burden in the South West Shewa Zone of the Oromia region, Ethiopia. Data collected within an interview-based survey highlighted differences in demographic structure and in age-specific contacts between urban neighborhoods, rural villages, and remote settlements, and were used to inform an epidemic model simulating the transmission dynamic of SARS-CoV-2.

On the basis of the trajectory of COVID-19 cases observed in the country up to June 12, 2020, we estimated that between 3.1 and 4.0 patients per 1,000 inhabitants may experience critical disease (i.e., requiring mechanical ventilation and/or resulting in a fatal outcome) at the end of an epidemic mitigated by school closure alone. Considering the low availability and accessibility of healthcare, especially in remote and rural settlements, and the lack of intensive care units to treat critical patients, it is possible that a large fraction of those cases would result in a fatal outcome, adding up to the already high background mortality rate in the region (estimated at about 6.4 per 1,000 per year).

Considering the extreme scenario where all critical cases would result in a fatal outcome, we obtain an estimate of the infection-fatality ratio (IFR) ranging between 0.53% in urban neighborhoods and 0.76% in remote settlements. Such estimates are generally lower than the IFR estimated from serological studies for higher income countries. This difference is partially due to the younger age structure of the Ethiopian population, where only 5% of individuals are older than 60 years (compared to over 20% in most of Europe). However, by simply adjusting the age-specific IFR to the local demographics, Ghisolfi et al estimated a four-fold reduction in the overall IFR in Eastern Africa with respect to European countries, which is around 2 time lower than our estimates. In fact, our simulations not only account for the demography of the population, but also for its mixing patterns. Indeed, we found that in Ethiopia the effects of a younger population is partially compensated by high infection attack rates in the elderly, which derive from the intense intergenerational mixing and the larger number of contacts observed among the elderly. In particular, we show that these characteristics are especially marked in remote settlements, where the highest incidence of critical disease is expected to occur.

This study provides novel data on mixing patterns in rural Ethiopia and highlights the potential impact of COVID-19 epidemics in less urbanized regions of the country. We provide estimates on the potential burden of COVID-19 under the assumption of a mitigated, but not controlled epidemic. We conclude that, although the overall mortality might be generally lower in sub-Saharan Africa compared to high income settings, thanks to younger demographics, this effect may be partially offset in rural areas by higher attack rates in elderly individuals, due to high rates of intergenerational mixing. The observed contact patterns suggest that elderly individuals in remote settlements may be even more exposed to the risk of infection (and thus of critical disease), which is especially worrysome in light of the major obstacles in access to healthcare for those populations[2].