

ARI Methods and Data Sources for Africa Disease Prevalence Estimates 2020 and Age- Disease Comorbidity Risk in COVID-19 Cases

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1 Introduction

1.1 Background

The COVID-19 pandemic which gripped the world in the early onset of 2020 has come with reverting challenges both economically (due to government policy interventions) and epidemiologically (AU, 2020). The need to understand and investigate predictor variables in COVID-19 is of paramount importance. Age and Disease have been observed to be role players in COVID-19 reported, hospitalized cases, and deaths. COVID-19 seems to develop to the severity in patients who are over the ages of 60 years old and those with underlying conditions such as hypertension, diabetes, cardiovascular diseases, chronic respiratory disease, and cancer (WHO, 2020a). The need to understand the risk of these factors in COVID-19 symptoms and deaths can lead to easier identification of high-risk groups within the population and the development of strategies to mitigate the risk. Survival analysis through regression models such as the Cox pro-proportional-hazards models (Farewell, 1979) has played an important role in medical research. Allowing the understanding of the association between the survival time of patients and investigated predictor variables. Whilst the use of the Disability Adjusted Life Years (DALY) has allowed us to quantify the burden of disease comparatively within the disease and across regions (Murray & Lopez, 1996). Africa currently is the region with the highest disease burden in the world (IHME, 2017; WHO, 2020b). There is a high prevalence of HIV particularly in the Southern African region, Tuberculosis with comorbidity with HIV, Diabetes, and Hypertension. Several surveillance programs have been started internationally to monitor these diseases. Of note is the Joint United Nations Programme on HIV and AIDS, the World Health Organisation (WHO) Global TB Programme, and the WHO STEPwise approach to Surveillance (STEPS) (Glaziou et al., 2016; IDF, 2019; Saeedi et al., 2019; WHO, 2019a; UNAIDS, 2020). The need to quantify the prevalence of these diseases is of paramount importance in understanding their risk factor in COVID-19.

Studies in the United Kingdom (UK) (Bhaskaran et al., 2020; Geretti et al., 2020) and South Africa (Davies & Boule, 2020) have shown that HIV might be a risk factor to COVID-19 severity and deaths. Indeed, confirmed deaths in Africa have been largely attributed to comorbidity with HIV, Diabetes, Tuberculosis, and Hypertension (Wyk et al., 2020). The limit of time-based COVID-19 Data in Africa particularly regarding comorbidity and age led the Afrikan Research Initiative (ARI) to consider a Risk Analysis approach. The risk analysis approach that the ARI took was the use of statistical regression analysis using a non-time-based model with the estimation of disease in age groups (using disease prevalence by age) versus observed data based on COVID-19 age and disease profiles in South Africa's COVID-19 surveillance program. This approach allowed for the extension of risk factors (RF) from South Africa to other African countries through risk ratios (RR). Although ARI was able to identify the COVID-19 risk groups in African countries for the age and disease factor, the model does not associate between the survival time of COVID-19 patients and these factors.

1.2 Focus on this paper

Due to limitations in disease prevalence by age data in Africa, age, and disease risk factors were only determined for HIV, TB, Diabetes, and Hypertension. Disease prevalence by age data had to be extended to 2020 estimates based on the currently available data from the Joint United Nations Programme on HIV and AIDS, World Health Organisation (WHO) Global TB Programme, and the WHO STEPwise approach to Surveillance (STEPS). This technical paper only focused on African countries.

2 HIV Prevalence

2.1 Estimates for HIV Total Prevalence

The 2020 Estimates for HIV Total Prevalence in African countries were determined based on the generic formula given in Equation 1:

$$HIV\ prevalence, A, 2020 = Initial\ HIV\ Prevalence, A, 2020 + HIV\ Incident, A, 2020 - AIDS\ Related\ Deaths, A, 2020 \quad \text{Equation 1}$$

Where A, represents respective African countries, the *Initial HIV Prevalence, A, 2020* are the total number of HIV cases at the start of 2020, *HIV Incident, A, 2020* are the number of new HIV infection arising during the year 2020 and the *AIDS-Related Deaths, A, 2020* are the numbers of HIV/AIDS-related deaths in 2020.

2.1.1 Initial HIV Prevalence

The initial HIV Prevalence, A, 2020 was estimated based on Equation 2:

$$Initial\ HIV\ prevalence, A, 2020 = HIV\ prevalence, A, 2019 - AIDS\ Related\ Deaths, A, 2019 \quad \text{Equation 2}$$

The HIV prevalence, A, 2019 and the AIDS-Related Deaths, A, 2019 were obtained from the Estimated adults and children living with HIV 2019 and AIDS-related deaths in adults and children 2019 respectively from the UNAIDS 2019 Estimates (UNAIDS, 2020).

2.1.2 HIV Incident

The HIV Incident, A, 2020 was estimated using a population-adjusted average of the HIV Incidents from the years 2017 to 2019 based on Equation 3:

$$HIV\ Incident, A, 2020 = \frac{\sum_{2017}^{2019} \frac{HIV\ Incident, A, i}{Population, A, i}}{n} \times Population, A, 2020 \quad \text{Equation 3}$$

Where i are the years from 2017 to 2019, n is the total number of year period used, HIV Incident, A, i are the number of new HIV infection arising in those years, Population, A is the total population in respective years. Population, A data was obtained from the United Nations Department of Economic and Social Affairs World Population Prospects 2019 (United Nations Department of Economic and Social Affairs Population Division, 2019). The HIV Incident, A, i was obtained from the UNAIDS 2019 Estimates (UNAIDS, 2020).

2.1.3 HIV/AIDS-Related Deaths

The HIV/AIDS-Related Deaths, A, 2020 was estimated using a prevalence adjusted average of the Case Fatality Ratio from the years 2017 to 2019 based on Equation 3:

$$AIDS\ Related\ Deaths,\ A,\ 2020 = \frac{\sum_{2017}^{2019} t \frac{AIDS\ Related\ Deaths,\ A,\ i}{HIV\ Prevalence,\ A,\ i}}{n} \times HIV\ Prevalence,\ A,\ 2020$$

Equation 4

Where i are the years from 2017 to 2019, n is the total number of year period used, AIDS-Related Deaths, A,i are the numbers of HIV/AIDS-related deaths in those years, HIV Prevalence, A, 2020. is the total population in respective years. AIDS-Related Deaths, A,i was obtained from the United Nations Department of Economic and Social Affairs World Population Prospects 2019 (United Nations Department of Economic and Social Affairs Population Division, 2019). The HIV Incident, A,i was obtained from the UNAIDS 2019 Estimates (UNAIDS, 2020).

To determine HIV prevalence, A,2020, Equation 4 was substituted into Equation 1 to yield Equation 5:

$$HIV\ prevalence,\ A,\ 2020 = \frac{Initial\ HIV\ Prevalence,\ A,\ 2020 + HIV\ Incident,\ A,\ 2020}{(1 + \frac{\sum_{2017}^{2019} t \frac{AIDS\ Related\ Deaths,\ A,\ i}{HIV\ Prevalence,\ A,\ i}}{n})}$$

Equation 5

2.2 Estimates for HIV Prevalence by Age

2.2.1 Estimated Children Living with HIV (0-14 years)

The HIV Prevalence in Children (0-14 years) was determined using Equation 6:

$$HIV\ prevalence,\ A,\ 2020,\ 0 - 14 = \frac{HIV\ Prevalence,\ A,\ 2019,\ 0-14 + (HIV\ Prevalence,\ A,\ 2019,\ 0-14 - HIV\ Prevalence,\ A,\ 2018,\ 0-14)}{Population,\ A,\ 2020,\ 0-14}$$

Equation 6

Where HIV Prevalence, A,2018,0-14 and HIV Prevalence, A,2019,0-14 are the number of Estimated children (0-14) living with HIV Estimate in 2018 and 2019 obtained from the UNAIDS 2019 Estimates (UNAIDS, 2020). Population, A,2020,0-14 was obtained from the United Nations Department of Economic and Social Affairs World Population Prospects 2019 (United Nations Department of Economic and Social Affairs Population Division, 2019).

2.2.2 Estimated Young Adults with HIV (15-24 years)

The Estimated Young Men and Women with HIV (15-24 years) was determined using Equation 6 and Equation 7:

$$\frac{HIV\ Cases,\ A,\ 2020,\ 15 - 24,\ Men = HIV\ Prevalence,\ A,\ 2019,\ 15-24,\ Men + (HIV\ Prevalence,\ A,\ 2019,\ 15-24,\ Men - HIV\ Prevalence,\ A,\ 2018,\ 15-24,\ Men)}{100} \times Population,\ A,\ 2020,\ 15 - 24,\ Men \quad \text{Equation 6}$$

$$\frac{HIV\ Cases,\ A,\ 2020,\ 15 - 24,\ Women = HIV\ Prevalence,\ A,\ 2019,\ 15-24,\ Women + (HIV\ Prevalence,\ A,\ 2019,\ 15-24,\ Women - HIV\ Prevalence,\ A,\ 2018,\ 15-24,\ Women)}{100} \times Population,\ A,\ 2020,\ 15 - 24,\ Women \quad \text{Equation 7}$$

Where the number of HIV Young men (15-24) prevalence (%) Estimate and Young women (15-24) prevalence (%) in 2018 and 2019 were obtained from the UNAIDS 2019 Estimates (UNAIDS, 2020). The Population, A,2020,15-24, Men and Population, A,2020,15-24, Women was obtained from the United Nations Department of Economic and Social Affairs World Population Prospects 2019 (United Nations Department of Economic and Social Affairs Population Division, 2019). The HIV Prevalence in Young Adults (15-24 years) was determined by Equation 8.

$$HIV\ prevalence,\ A,\ 2020,\ 15 - 24 = \frac{HIV\ Cases,\ A,\ 2020,\ 15-24,\ Men + HIV\ Cases,\ A,\ 2020,\ 15-24,\ Women}{Population,\ A,\ 2020,\ 15-24} \quad \text{Equation 8}$$

2.2.3 Estimated Adults with HIV (25-49 years)

The Estimated Adults with HIV (15-49 years) was determined using Equation 9:

$$\frac{HIV\ Cases,\ A,\ 2020,\ 15 - 49 = HIV\ Prevalence,\ A,\ 2019,\ 15-49 + (HIV\ Prevalence,\ A,\ 2019,\ 15-49 - HIV\ Prevalence,\ A,\ 2018,\ 15-49)}{100} \times Population,\ A,\ 2020,\ 15 - 49 \quad \text{Equation 9}$$

Where the number of HIV Adult (15-49) prevalence (%) Estimate in 2018 and 2019 were obtained from the UNAIDS 2019 Estimates (UNAIDS, 2020). The Population, A,2020,15-49 was obtained from the United Nations Department of Economic and Social Affairs World Population Prospects 2019 (United Nations Department of Economic and Social Affairs Population Division, 2019). The HIV Prevalence in Adults (25-24 years) was determined by Equation 10.

$$HIV\ prevalence,\ A,\ 2020,\ 25 - 49 = \frac{HIV\ Cases,\ A,\ 2020,\ 15-49 - HIV\ Cases,\ A,\ 2020,\ 15-24,}{Population,\ A,\ 2020,\ 25-49} \quad \text{Equation 10}$$

2.2.4 Estimated Adults with HIV (Over 50 years)

The Estimated Adults with HIV (Over 50 years) was determined using Equation 11:

$$\frac{HIV\ prevalence, A, 2020, 0 - 14 = HIV\ Cases, A, 2020, Total - (HIV\ Cases, A, 2020, 0-14 + HIV\ Cases, A, 2020, 15-49)}{Population, A, 2020, Over\ 50} \quad \text{Equation 11}$$

Where the Population, A, 2020, Over 50 was obtained from the United Nations Department of Economic and Social Affairs World Population Prospects 2019 (United Nations Department of Economic and Social Affairs Population Division, 2019).

3 TB Prevalence

3.1 Estimates for TB Total Prevalence

The 2019 and 2020 Estimates for TB Total Prevalence in African countries were determined based on the generic formula given in Equation 12 and Equation 13:

$$TB\ prevalence, A, 2019 = Initial\ TB\ Prevalence, A, 2019 + TB\ Incident, A, 2019 - TB\ Mortalities, A, 2019 - TB\ Treated\ Cases, A, 2019 \quad \text{Equation 12}$$

$$TB\ prevalence, A, 2020 = Initial\ TB\ Prevalence, A, 2020 + TB\ Incident, A, 2020 - TB\ Mortalities, A, 2020 - TB\ Treated\ Cases, A, 2020 \quad \text{Equation 13}$$

Where the *Initial TB Prevalence, A, 2019* and *Initial TB Prevalence, A, 2020* are the total number of TB cases at the start of 2019 and 2020 respectively, *TB Incident, A, 2019* and *TB Incident, A, 2020* are the number of new TB infection arising during the year 2019 and 2020 respectively, the *TB Mortalities, A, 2019* and *TB Mortalities, A, 2020* are the numbers of TB related deaths in 2019 and 2020 respectively and the *TB Treated Cases, A, 2019* and *TB Treated Cases, A, 2020* are the number of TB treated cases in 2019 and 2020 respectively.

3.1.1 Initial TB Prevalence

The initial TB Prevalence, A, 2019 was estimated based on Equation 14:

$$Initial\ TB\ Cases, A, 2019 = TB\ Cases, A, 2018 - TB\ Mortalities, A, 2018 - \left(\frac{Previously\ TB\ Treated\ Cases_{2017}(\%)}{100} \times TB\ Total\ Cases, A, 2018 \right) \quad \text{Equation 14}$$

The TB Cases, A, 2018, TB Mortalities, A, 2018 and the Previously TB Treated Cases 2017/2018 (%) were obtained from the WHO Estimates of Global Burden of TB Disease (Glaziou et al., 2016; WHO, 2020c) and Global Tuberculosis Report 2019 (WHO, 2019a). The initial TB Prevalence, A, 2020 was estimated based on Equation 15:

$$Initial\ TB\ Cases, A, 2020 = TB\ Cases, A, 2019 - TB\ Mortalities, A, 2019 - \left(\frac{Previously\ TB\ Treated\ Cases_{2017}(\%)}{100} \times TB\ Total\ Cases, A, 2019 \right) \quad \text{Equation 15}$$

3.1.2 TB Incident

The TB Incident, A, 2019 was estimated using a population-adjusted average of the TB Incidents from the years 2016 to 2018 based on Equation 16:

$$TB\ Incident, A, 2019 = \frac{\sum_{2016}^{2018} iTB\ Incident, A, i}{n} \times Population, A, 2019$$

Equation 16

Where i are the years from 2016 to 2018, n is the total number of year period used, TB Incident, A, i are the number of new TB infections arising in those years, Population, A is the total population in respective years. Population, A data was obtained from the United Nations Department of Economic and Social Affairs World Population Prospects 2019 (United Nations Department of Economic and Social Affairs Population Division, 2019). The TB Incident, A, i was obtained from the WHO Estimates of Global Burden of TB Disease (Glaziou et al., 2016; WHO, 2020c) and Global Tuberculosis Report 2019 (WHO, 2019a). The TB Incident, A, 2020 was estimated using Equation 17:

$$TB\ Incident, A, 2020 = \frac{\sum_{2017}^{2019} iTB\ Incident, A, i}{n} \times Population, A, 2020$$

Equation 17

Where i are the years from 2017 to 2019, n is the total number of year period used

3.1.3 TB Treated Cases

The TB Treated Cases, A, 2019 and TB Treated Cases, A, 2020 were estimated using a prevalence adjusted average of the TB treated cases from the years 2017 to 2018 based on Equation 18 and Equation 19:

$$TB\ Treated\ Cases, A, 2019 = \frac{Previously\ TB\ Treated\ Cases\ 2017/2018\ (\%)}{TB\ Total\ Cases, A, 2019} \times TB\ Total\ Cases, A, 2019$$

Equation 18

$$TB\ Treated\ Cases, A, 2020 = \frac{Previously\ TB\ Treated\ Cases\ 2017/2018\ (\%)}{TB\ Total\ Cases, A, 2020} \times TB\ Total\ Cases, A, 2020$$

Equation 19

3.1.4 TB Mortalities

The TB Mortalities, A, 2019 and TB Mortalities, A, 2020 were estimated using Equation 20 and Equation 21 respectively:

$$TB\ Mortalities, A, 2019 = Initial\ TB\ Cases, A, 2019 + TB\ Incident, A, 2019 - TB\ Treated\ Cases, A, 2019 - TB\ Total\ Cases, A, 2019$$

Equation 20

$$TB\ Mortalities, A, 2020 = Initial\ TB\ Cases, A, 2020 + TB\ Incident, A, 2020 - TB\ Treated\ Cases, A, 2020 - TB\ Cases, A, 2020$$

Equation 21

To determine the TB prevalence, A,2019 and TB prevalence, A,2020, Equation 18 and Equation 19 were substituted into Equation 12 and Equation 13 respectively and the number of TB mortalities were estimated using a prevalence adjusted average of the TB mortalities in 2017, 2018 and 2019 as shown in Equation 22 and Equation 23:

$$TB \text{ Total Cases, A, 2019} = \frac{Initial \ TB \ Cases, A, 2019 + TB \ Incident, A, 2019}{\left(1 + \frac{\sum_{2017}^{2018} TB \ Mortalities, A, i}{\sum_{2017}^{2018} TB \ Total \ Cases, A, i} + Previously \ TB \ Treated \ Cases \ 2017/2018\right) \times n}$$

Equation 22

Where i are the years from 2017 to 2018, n is the total number of year period used.

$$TB \text{ Total Cases, A, 2020} = \frac{Initial \ TB \ Cases, A, 2020 + TB \ Incident, A, 2020}{\left(1 + \frac{\sum_{2018}^{2019} TB \ Mortalities, A, i}{\sum_{2018}^{2019} TB \ Total \ Cases, A, i} + Previously \ TB \ Treated \ Cases \ 2017/2018\right) \times n}$$

Equation 23

Where i are the years from 2018 to 2019, n is the total number of year period used.

3.2 TB Prevalence by Age

3.2.1 TB Prevalence in 0-4 Year Age Group

The TB Prevalence, A, 2020, 0-4 were estimated using Equation 24:

$$TB \ Prevalence, A, 2020, 0 - 4 = TB \ Prevalence, A, 2018, 0 - 4 \times TB \ Prevalence \ Adjustment \ Factor \left(\frac{2020}{2018}\right)$$

Equation 24

Where the TB Prevalence, A,2018,0-4 was obtained from the WHO Estimates of the Global Burden of TB Disease 2018 (WHO, 2019a). The TB Prevalence was adjusted from 2018 to 2020 using the TB Prevalence Adjustment Factor determined using Equation 25:

$$TB \ Prevalence \ Adjustment \ Factor \left(\frac{2020}{2018}\right) = \frac{TB \ Prevalence, A, 2020}{TB \ Prevalence, A, 2018}$$

Equation 25

The TB Prevalence Adjustment Factors (2020/2018) are shown in Table A. 1 in the Appendix Section.

3.2.2 TB Prevalence in 5-14 Year Age Group

The TB Prevalence, A, 2020, 5-14 were estimated using Equation 26:

$$TB \ Prevalence, A, 2020, 5 - 14 = TB \ Prevalence, A, 2018, 5 - 14 \times TB \ Prevalence \ Adjustment \ Factor \left(\frac{2020}{2018}\right)$$

Equation 26

Where the TB Prevalence, A,2018,5-14 was obtained from the WHO Estimates of the Global Burden of TB Disease 2018 (WHO, 2019a).

3.2.3 TB Prevalence in 15-24 Year Age Group

The TB Prevalence, A, 2020, 15-24 were estimated using Equation 27:

$$TB\ Prevalence,\ A,\ 2020,\ 15 - 24 = TB\ Prevalence,\ A,\ 2018,\ 15 - 24 \times TB\ Prevalence\ Adjustment\ Factor\ \left(\frac{2020}{2018}\right) \quad \text{Equation 27}$$

Where the TB Prevalence, A,2018,15-24 was obtained from the WHO Estimates of the Global Burden of TB Disease 2018 (WHO, 2019a).

3.2.4 TB Prevalence in 25-34 Year Age Group

The TB Prevalence, A, 2020, 25-34 were estimated using Equation 28:

$$TB\ Prevalence,\ A,\ 2020,\ 25 - 34 = TB\ Prevalence,\ A,\ 2018,\ 25 - 34 \times TB\ Prevalence\ Adjustment\ Factor\ \left(\frac{2020}{2018}\right) \quad \text{Equation 28}$$

Where the TB Prevalence, A,2018,25-34 was obtained from the WHO Estimates of the Global Burden of TB Disease 2018 (WHO, 2019a).

3.2.5 TB Prevalence in 35-44 Year Age Group

The TB Prevalence, A, 2020, 35-44 were estimated using Equation 29:

$$TB\ Prevalence,\ A,\ 2020,\ 35 - 44 = TB\ Prevalence,\ A,\ 2018,\ 35 - 44 \times TB\ Prevalence\ Adjustment\ Factor\ \left(\frac{2020}{2018}\right) \quad \text{Equation 29}$$

Where the TB Prevalence, A,2018,35-44 was obtained from the WHO Estimates of the Global Burden of TB Disease 2018 (WHO, 2019a).

3.2.6 TB Prevalence in 45-54 Year Age Group

The TB Prevalence, A, 2020, 45-54 were estimated using Equation 30:

$$TB\ Prevalence,\ A,\ 2020,\ 45 - 54 = TB\ Prevalence,\ A,\ 2018,\ 45 - 54 \times TB\ Prevalence\ Adjustment\ Factor\ \left(\frac{2020}{2018}\right) \quad \text{Equation 30}$$

Where the TB Prevalence, A,2018,45-54 was obtained from the WHO Estimates of the Global Burden of TB Disease 2018 (WHO, 2019a).

3.2.7 TB Prevalence in 55-64 Year Age Group

The TB Prevalence, A, 2020, 55-64 were estimated using Equation 31:

$$TB\ Prevalence,\ A,\ 2020,\ 55 - 64 = TB\ Prevalence,\ A,\ 2018,\ 55 - 64 \times TB\ Prevalence\ Adjustment\ Factor\ \left(\frac{2020}{2018}\right) \quad \text{Equation 31}$$

Where the TB Prevalence, A,2018,55-64 was obtained from the WHO Estimates of the Global Burden of TB Disease 2018 (WHO, 2019a).

3.2.8 TB Prevalence in Over 65 Year Age Group

The TB Prevalence, A, 2020, Over 65 were estimated using Equation 32:

$$TB\ Prevalence,\ A,\ 2020,\ Over\ 65 = TB\ Prevalence,\ A,\ 2018,\ Over\ 65 \times TB\ Prevalence\ Adjustment\ Factor\ \left(\frac{2020}{2018}\right) \quad \text{Equation 32}$$

Where the TB Prevalence, A,2018, Over 65 was obtained from the WHO Estimates of the Global Burden of TB Disease 2018 (WHO, 2019a).

4 Non-Communicable Diseases (NCD)-Diabetes and Hypertension

Estimation for the prevalence of Diabetes and Hypertension were developed largely based on the WHO STEPwise approach to Surveillance (STEPS) (WHO, 2020d), WHO Raised fasting blood glucose (≥ 7.0 mmol/L or on medication)(age-standardized estimate) (WHO, 2019b) and Raised blood pressure (SBP ≥ 140 OR DBP ≥ 90) (age-standardized estimate) (WHO, 2015) Data. The Afrikan Research Initiative, was granted a license and data for the WHO STEPwise approach to Surveillance (STEPS) by the WHO NCD Microdata Repository for countries shown in Table A. 2. The WHO NCD Microdata Repository as of the date of this Technical Paper did not have data for the following African countries: Nigeria, Djibouti*, Somalia, Egypt, Burundi*, Zimbabwe, Mauritius, Angola, Senegal, Tunisia, Burkina Faso and South Africa. For these African countries additional references of Diabetes and Hypertension Prevalence studies were used. The WHO STEPwise approach to Surveillance (STEPS) Data also did not have data for Diabetes and Hypertension Prevalence in Age Groups over 70 years with the exceptions of Cameroon, Eritrea, Morocco, Togo, and Uganda. Additional references which had conducted Diabetes and Hypertension Prevalence studies for Age Groups over 70 years for the non-exception African countries were used.

4 Diabetes Prevalence

4.1 Diabetes Prevalence Total

The Diabetes Total Cases were estimated based on the Diabetes prevalence from the World Bank Database (IDF, 2019; Saeedi et al., 2019) using Equation 33:

$$\text{Diabetes Total Cases, } A, 2020 = \text{Diabetes prevalence (\% of population ages 20 to 79) 2019} \times \text{Population, } A, 2020$$

Equation 33

This approach assumed that the Diabetes Total Prevalence in 2019 is equivalent to that of the Diabetes Total Prevalence in 2020.

4.2 Diabetes Prevalence by Age

To Estimate the Diabetes Prevalence by Age, the prevalence was obtained for countries stated in Table A. 2 from the WHO STEPwise approach to Surveillance (STEPS) by counting the number of “Yes” to the question: “During the past 12 months, have you ever been told by a doctor or other health worker that you have diabetes?” outlined in the WHO STEPS Instrument relative to the Number of Respondents. Diabetes Prevalence was determined for Age Groups: 20-39 years, 40-49 years, 50-59 years, 60-69 years, and over 70 years. Additional references were used to determine Diabetes Prevalence by Age for Nigeria, Djibouti*, Somalia, Egypt, Burundi*, Zimbabwe, Mauritius, Angola, Senegal, Tunisia, Burkina Faso, and South Africa. For the Diabetes Prevalence for age groups Over 70 years, the diabetes prevalence was obtained from additional references. The reference sources used for the Diabetes Prevalence by Age are shown in Table A. 3.

The Prevalence by Age from reference sources was adjusted to 2020 using Prevalence Adjustment Factors calculated based on Equation 34 and Equation 35:

$$\text{Diabetes Prevalence Adjustment Factor} = \frac{\text{Diabetes prevalence (\% of population ages 20 to 79) 2019}}{\text{Total Diabetes Prevalence (\%)-Ref}}$$

Equation 34

Where the Total Diabetes Prevalence (%) -Ref is the Diabetes Total Prevalence in the year of the reference. The Diabetes Total Prevalence in the year of the reference was obtained from the WHO Raised fasting blood glucose (≥ 7.0 mmol/L or on medication) (age-standardized estimate) Data for years before 2015 and from the reference for years after 2015.

$$\text{Diabetes Prevalence, } A, 2020, i = \text{Diabetes Prevalence, } A, \text{Ref Year, } i, \times \text{Diabetes Prevalence Adjustment Factor}$$

Equation 35

Where i are the Age Groups: 20-39 years, 40-49 years, 50-59 years, 60-69 years and over 70 years.

For some countries, no references could be sourced with the Diabetes Prevalence for age groups over 70 years. For these countries risk factor ratios were used to estimate the Diabetes Prevalence for age groups Over 70 years using Equation 36:

$$\frac{\text{Diabetes Prevalence, A, 2020, Over 70 years} = \text{Diabetes Prevalence, A, Regional Ref, Ref Year, Over 70 years}}{\text{Diabetes Prevalence, A, Regional Ref, Ref Year, 60-69 years}} \times \text{Diabetes Prevalence, A, Ref Year, Over 70 years} \quad \text{Equation 36}$$

Where Diabetes Prevalence, A, Regional Ref, Ref Year, 60-69 years and Diabetes Prevalence, A, Regional Ref, Ref Year, Over 70 years is the Diabetes Prevalence for Age Groups 60-69 years and Over 70 years respectively for a Regional Country Reference chosen based on data availability. The regional references used are shown in Table 1.

Table 1: Regional References for the determination of risk factor ratios in adjusting the Diabetes Prevalence for Age Groups 60-69 to Over 70 in Adjusted Countries

Region	Regional Reference	Adjusted Countries
Central Africa	The Democratic Republic of the Congo	Chad, Equatorial Guinea, Gabon, Sao Tome and Principe
East Africa	Eritrea	Djibouti, Somalia, Mauritius, Comoros, Kenya, and Madagascar
Southern Africa	South Africa	Lesotho
West Africa	Nigeria	Cabo Verde, Ghana, Liberia, and Togo

5 Hypertension Prevalence

5.1 Hypertension Prevalence Total

The Hypertension Total Cases were estimated based on the WHO Raised blood pressure (SBP \geq 140 OR DBP \geq 90) (age-standardized estimate) 2015 using Equation 33:

$$\text{Diabetes Total Cases, A, 2020} = \text{WHO Raised fasting blood glucose } (\geq 7.0 \text{ mmol/L or on medication}) (\text{age} - \text{standardized estimate}) 2015 (\%) \times \text{Population, A, 2020} \quad \text{Equation 37}$$

This approach assumes that the Hypertension Total Prevalence in 2015 is equivalent to that of the Hypertension Total Prevalence in 2020. Over periods of more than 3 years, the Hypertension Total Prevalence has been shown to change (Ogah & Rayner, 2013; van de Vijver et al., 2013; Bosu et al., 2019) therefore this estimation is not accurate however due to limitations in data, adjustments for Hypertension Total Prevalence Changes are difficult to estimate and apply as they might lead to further data bias and inaccuracies.

5.2 Hypertension Prevalence by Age

To Estimate the Hypertension Prevalence by Age, the prevalence was obtained for countries stated in Table A. 2 from the WHO STEPwise approach to Surveillance (STEPS) by counting the number of “Yes” to the question: “During the past 12 months have you been told by a doctor or other health worker that you have raised blood pressure or hypertension?” outlined in the WHO STEPS Instrument relative to the Number of Respondents. Hypertension

Prevalence was determined for Age Groups: 20-39 years, 40-49 years, 50-59 years, 60-69 years and over 70 years. Additional references were used to determine Hypertension Prevalence by Age for Nigeria, Djibouti*, Somalia, Egypt, Burundi*, Zimbabwe, Mauritius, Angola, Senegal, Tunisia, Burkina Faso, and South Africa. For the Hypertension Prevalence for age groups Over 70 years, the hypertension prevalence was obtained from additional references. The reference sources used for the Hypertension Prevalence by Age are shown in Table A. 4Table A. 3.

The Prevalence by Age from reference sources was adjusted to 2020 using a Prevalence Adjustment Factors calculated based on Equation 38 and Equation 39:

$$\text{Hypertension Prevalence Adjustment Factor} = \frac{\text{WHO Raised fasting blood glucose } (>=7.0 \text{ mmol/L or on medication})(\text{age-standardized estimate}) 2015 (\%)}{\text{Total Diabetes Prevalence } (\%)-\text{Ref}}$$

Equation 38

Where the Total Hypertension Prevalence (%)-Ref is the Hypertension Total Prevalence in the year of the reference. The Hypertension Total Prevalence in the year of the reference was obtained from the WHO WHO Raised fasting blood glucose (>=7.0 mmol/L or on medication)(age-standardized estimate) 2015 (%) for years before 2015 and from the reference for years after 2015.

$$\text{Hypertension Prevalence, A, 2020, } i = \text{Hypertension Prevalence, A, Ref Year, } i, \times \text{Hypertension Prevalence Adjustment Factor}$$

Equation 39

Where i are the Age Groups: 20-39 years, 40-49 years, 50-59 years, 60-69 years and over 70 years.

For some countries, no references could be sourced with the Hypertension Prevalence for age groups over 70 years. For these countries risk factor ratios were used to estimate the Hypertension Prevalence for age groups Over 70 years using Equation 40:

$$\text{Hypertension Prevalence, A, 2020, Over 70 years} = \frac{\text{Hypertension Prevalence, A, Regional Ref, Ref Year, Over 70 years}}{\text{Hypertension Prevalence, A, Regional Ref, Ref Year, 60-69 years}} \times \text{Hypertension Prevalence, A, Ref Year, Over 70 years}$$

Equation 40

Where Hypertension Prevalence, A, Regional Ref, Ref Year,60-69 years and Hypertension Prevalence, A , Regional Ref, Ref Year, Over 70 years is the Hypertension Prevalence for Age Groups 60-69 years and Over 70 years respectively for a Regional Country Reference chosen based on data availability. The regional references used are shown in Table 2.

Table 2: Regional References for the determination of risk factor ratios in adjusting the Hypertension Prevalence for Age Groups 60-69 to Over 70 in Adjusted Countries

Region	Regional Reference	Adjusted Countries
Central Africa	Democratic Republic of the Congo	Chad, Equatorial Guinea, Gabon, Sao Tome and Principe
East Africa	Eritrea	Comoros, Kenya, Madagascar, Rwanda, Seychelles
North Africa	Morocco	Tunisia, Libya, and Mauritania

Southern Africa	South Africa	Eswatini, Lesotho, Mozambique, and Namibia
West Africa	Burkina Faso	Benin, Cabo Verde, Guinea, Guinea-Bissau, Liberia, and Cote d'Ivoire

6 Risk Disease Co-morbidity with COVID-19

6.1 Risk of Disease Co-morbidity in COVID-19 Symptomatic Cases

The general approach in determining the risk of disease co-morbidity with COVID-19 in COVID-19 symptomatic cases was determined by estimating the Age profile in Reported COVID-19 Cases then using the Disease Prevalence by Age to determine the Risk of Disease Co-morbidity in COVID-19 Symptomatic Cases. This approach took the assumption that Reported COVID-19 cases are COVID-19 Symptomatic Cases. Age was defined as the number of life-years and was considered independent of disease prevalence while disease prevalence was dependent of the Age. South African COVID-19 Reported Case Data was used as a basis for extending Risk Factor (RF) calculations. The COVID-19 Reported Case Age Profile for African Countries was estimated using the Reported COVID-19 Case to Population Distribution Ratio (RCPR) observed in South Africa. The RCPR was determined by Equation 41:

$$RCPR, i = \frac{\text{Reported COVID-19 Case Age Profile, South Africa } (\%),i}{\text{Population Distribution, South Africa } (\%),i} \quad \text{Equation 41}$$

Where *i* are the Age Groups, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79 and Over 80 years. The Number cumulative cases (%) in Table 3 were used as the Reported COVID-19 Case Age Profile, South Africa for the respective Age Groups. Table 3 was obtained from the NICD COVID-19 WEEKLY EPIDEMIOLOGY BRIEF, Week 29 Report (NICD, 2020a).

Table 3: Number of COVID-19 cases by age group, South Africa, 3 March- 18 July 2020, n= 364 328 (NICD, 2020a)

Age group (years)	Number cumulative cases (n)	Number cumulative cases (%)	Population in mid-2019**, n	Population in mid-2019, %	RCPR
0-4	4292	1.2	5733946	9.76	0.12
5-9	4791	1.3	5737439	9.76	0.13
10-14	7901	2.2	5427902	9.24	0.24
15-19	12542	3.4	4660002	7.93	0.43
20-24	20112	5.5	4914186	8.36	0.66
25-29	38864	10.7	5528571	9.41	1.14
30-34	47906	13.1	5537963	9.42	1.39
35-39	48590	13.3	4571175	7.78	1.71
40-44	41394	11.4	3585408	6.10	1.87
45-49	37700	10.3	3045617	5.18	1.99
50-54	32431	8.9	2535048	4.31	2.06
55-59	25769	7.1	2192512	3.73	1.90
60-64	15629	4.3	1784476	3.04	1.42
65-69	8961	2.5	1370121	2.33	1.07

70-74	5910	1.61	949812	1.62	0.99
75-79	3861	1.1	597874	1.02	1.08
≥80	7675	2.1	602969	1.03	2.05

The Estimated Reported Case Age Profile for African Countries was then determined using Equation 42 and Equation 43. Equation 43 normalises the Estimated Reported Case Age Profile to percentage.

$$\text{Cumulative COVID – 19 Reported Cases (\% Factored), } A, i = \text{Population Distribution (\%), } A \times RCPR \quad \text{Equation 42}$$

$$\text{Cumulative COVID – 19 Reported Cases (\%), } A, i = \frac{\text{Cumulative COVID–19 Reported Cases (\% Factored), } A, i}{\text{Cumulative COVID–19 Reported Cases (\% Factored), } A, \text{Total}} \times 100 \quad \text{Equation 43}$$

Where Cumulative COVID-19 Reported Cases (% Factored), A, i and Cumulative COVID-19 Reported Cases (%), A, i are the Estimated Reported COVID-19 Case Age Profile (%) per Age Group in Country A unnormalized and normalised respectively. The Estimated Disease Prevalence in COVID-19 Reported Cases was then determined using Equation 44 and Equation 45:

$$\text{Estimated Disease Prevalance in COVID – 19 Reported Cases (n), } A, i = (\text{Cumulative COVID – 19 Reported Cases (\%), } A, i \times 100) \times \text{Disease Prevalance, } A, 2020, i \quad \text{Equation 44}$$

Where the Estimated Disease Prevalance in COVID-19 Reported Cases (n), A,i is the number of estimated Disease Comorbidity with COVID-19 per Age Groups. A basis of a population of 100 people was used. The Disease Prevalance, A,2020, i used was the Prevalance by Age for HIV, TB, Diabetes and Hypertension, respectively.

$$\text{Estimated Total Disease Prevalance in COVID – 19 Reported Cases (\%), } A = \frac{\sum \text{Estimated Disease Prevalance in COVID–19 Reported Cases (n), } A, i}{\sum \text{Cumulative COVID–19 Reported Cases (n), } A, i} \times 100 \quad \text{Equation 45}$$

For South Africa, The Age & Disease Risk Factor (RF) in Disease Comorbidity in COVID-19 Symptomatic Cases was then determined using Equation 46:

$$\text{AGE, DISEASE COVID – 19 RF, Symptoms, } SA = \frac{\text{Observed Total Disease Prevalance in COVID–19 Reported Cases (\%), } SA}{\text{Estimated Total Disease Prevalance in COVID–19 Reported Cases (\%), } SA} \times 100 \quad \text{Equation 46}$$

Where the AGE, DISEASE COVID-19 RF, Symptoms, A is the Risk of Disease Comorbidity in COVID-19 Symptomatic Cases in Country A. The observed Total Disease Prevalance in COVID-19 Reported Cases (%), SA was based on data obtained from the NICD COVID-19 SENTINEL HOSPITAL SURVEILLANCE UPDATE, Week 29 Report (NICD, 2020b).

Table 4: Reported comorbid diseases among COVID-19 admissions reporting at least one comorbid disease, South Africa, 5 March-18 July 2020, n=14 475* (NICD, 2020b).

Comorbid disease**	N	%
Hypertension	9 012	62.30%
Diabetes mellitus	7 141	49.30%

Chronic cardiac disease	1 047	7.20%
Chronic pulmonary disease/ Asthma	2 095	14.50%
Chronic renal disease	989.00	6.80%
Malignancy	264.00	1.80%
HIV	2 627	18.10%
Active tuberculosis	523.00	3.60%
Previous history of tuberculosis	1 031	7.10%

For African Countries other than South Africa a Risk Ratio (RR) had to be determined first using, using Equation 47:

$$AGE, DISEASE COVID - 19 RR Symptoms, A = \frac{Estimated Total Disease Prevalance in COVID-19 Reported Cases (\%),A}{Estimated Total Disease Prevalance in COVID-19 Reported Cases (\%),SA} \times 100 \quad \text{Equation 47}$$

Where AGE, DISEASE COVID-19 RR Symptoms, A is referred to as the Risk Ratio for the Estimated Total Disease Prevalance in COVID-19 Reported Cases in African Country A relative to that calculated for South Africa. The Age & Disease Risk Factor (RF) Disease Comorbidity in COVID-19 Symptomatic Cases in African countries was then determined by Equation 48:

$$AGE, DISEASE COVID - 19 RF, Symptoms, A = AGE, DISEASE COVID - 19 RF, Symptoms, SA \times AGE, DISEASE COVID - 19 RR Symptoms, A \quad \text{Equation 48}$$

6.2 Risk of Disease Co-morbidity in COVID-19 Severe and Critical Cases

The general approach in determining the risk of disease co-morbidity in COVID-19 Severe and Critical symptoms was determined by estimating the Age profile in Hospitalised COVID-19 Cases then using the Disease Prevalance by Age to determine the Risk of Disease Co-morbidity in COVID-19 Severe and Critical Cases. The major assumption in this approach was that hospitalised COVID-19 cases were COVID-19 cases with Severe and Critical Symptoms. South African Hospitalised COVID-19 Reported Case Data was used as a basis for extending Risk Factor (RF) calculations. The Hospitalised Case Age Profile for African Countries was estimated using the Hospitalised COVID-19 Case to Reported Case Distribution Ratio (HCRR) observed in Western Cape, South Africa. The HCRR was determined by Equation 49:

$$HCRR, i = \frac{Hospitalised COVID-19 Case Age Profile, South Africa (\%),i}{Cumulative COVID-19 Reported Cases (\%),SouthAfrica,i} \quad \text{Equation 49}$$

Where i are the Age Groups, 20-39, 40-49, 50-59, 60-69 and Over 70 years. The Hospitalised COVID-19 Case Age Profile, South Africa for the respective Age Groups. was obtained from Table 5 extracted from the NICD COVID-19 SPECIAL PUBLIC HEALTH SURVEILLANCE BULLETIN, Volume 18 Report (Davies & Boule, 2020).

Table 5: Age Characteristics of Hospitalized COVID-19 cases diagnosed in the public ≥20 years of age, Western Cape, South Africa, 1 March-4 June 2020, n=2462* (Davies & Boule, 2020).

Characteristics	COVID-19 not deceased n=1999, n	COVID-19 not deceased n=1999, %	COVID-19 deceased n=463, n	COVID-19 deceased n=463, %	COVID-19 Admitted n=2462, n	COVID-19 Admitted n=2462, %	HCRR
20-39 years	675	34	35	8	710.00	28.84	0.690
40-49 years	416	21	47	10	463.00	18.81	0.825
50-59 years	426	21	122	26	548.00	22.26	1.352
60-69 years	271	14	139	30	410.00	16.65	2.467
≥70 years	211	11	120	26	331.00	13.44	3.361

The Estimated Hospitalised Case Age Profile for African Countries was then determined using Equation 50 and Equation 51. Equation 51 normalises the Estimated Reported Case Age Profile to percentage.

$$\frac{\text{Cumulative COVID-19 Hospitalised Cases (\% Factored), } A, i}{\text{Cumulative COVID-19 Reported Cases (\%), } A, i} \times \text{HCRR} \quad \text{Equation 50}$$

$$\frac{\text{Cumulative COVID-19 Hospitalised Cases (\%), } A, i}{\frac{\text{Cumulative COVID-19 Hospitalised Cases (\% Factored), } A, i}{\text{Cumulative COVID-19 Hospitalised Cases (\% Factored), } A, \text{Total}}} \times 100 \quad \text{Equation 51}$$

Where Cumulative COVID-19 Hospitalised Cases (% Factored), A, i and Cumulative COVID-19 Hospitalised Cases (%), A, i are the Estimated Hospitalised COVID-19 Case Age Profile (%) per Age Group in Country A unnormalized and normalised respectively. The Estimated Disease Prevalence in COVID-19 Hospitalised Cases was then determined using Equation 52 and Equation 53:

$$\frac{\text{Estimated Disease Prevalence in COVID-19 Hospitalised Cases (n), } A, i}{(\text{Cumulative COVID-19 Hospitalised Cases (\%), } A, i \times 100)} \times \text{Disease Prevalence, } A, 2020, i \quad \text{Equation 52}$$

Where the Estimated Disease Prevalence in COVID-19 Hospitalised Cases (n), A, i is the number of estimated Disease Comorbidity with COVID-19 per Age Groups. A basis of a population of 100 people was used. The Disease Prevalence, A, 2020, i used was the Prevalence by Age for HIV, TB, Diabetes and Hypertension, respectively.

$$\frac{\text{Estimated Total Disease Prevalence in COVID-19 Hospitalised Cases (\%), } A}{\frac{\sum \text{Estimated Disease Prevalence in COVID-19 Hospitalised Cases (n), } A, i}{\sum \text{Cumulative COVID-19 Hospitalised Cases (n), } A, i}} \times 100 \quad \text{Equation 53}$$

For South Africa, The Age & Disease Risk Factor (RF) in Disease Co-morbidity in COVID-19 Severe and Critical Cases was then determined using Equation 54:

$$\frac{\text{AGE, DISEASE COVID-19 RF, Severe \& Critical Symptoms, } SA}{\frac{\text{Observed Total Disease Prevalence in COVID-19 Hospitalised Cases (\%), } SA}{\text{Estimated Total Disease Prevalence in COVID-19 Hospitalised Cases (\%), } SA}} \times 100 \quad \text{Equation 54}$$

Where the AGE, DISEASE COVID-19 RF, Symptoms, A is the Risk of Disease Comorbidity in COVID-19 Severe and Critical Symptoms in Country A. The observed Total Disease Prevalence in COVID-19 Hospitalised Cases (%), SA was based Table 6 on obtained from the NICD COVID-19 SPECIAL PUBLIC HEALTH SURVEILLANCE BULLETIN, Volume 18 Report (Davies & Boulle, 2020).

Table 6: Reported comorbid diseases among COVID-19 admissions reporting at least one comorbid disease, Western Cape, South Africa, 1 March-4 June 2020, n=2462* (Davies & Boulle, 2020).

Disease	COVID-19 Hospitalised Cases (n)	COVID-19 Hospitalised Cases (%)
Diabetes	948	38.5
Hypertension	896	36.4
chronic kidney disease	168	6.8
chronic pulmonary disease / asthma	302	12.3
TB	291	11.8
HIV	920	37.4
Total	2462	

For African Countries other than South Africa a Risk Ratio (RR) had to be determined first using, using Equation 55:

$$AGE, DISEASE COVID - 19 RR Severe \& Critical Symptoms, A = \frac{Estimated Total Disease Prevalance in COVID-19 Hospitalised Cases (\%),A}{Estimated Total Disease Prevalance in COVID-19 Hospitalised Cases (\%),SA} \times 100 \quad \text{Equation 55}$$

Where AGE, DISEASE COVID-19 RR Symptoms, A is referred to as the Risk Ratio for the Estimated Total Disease Prevalance in COVID-19 Hospitalised Cases in African Country A relative to that calculated for South Africa. The Age & Disease Risk Factor (RF) in Disease Comorbidity in COVID-19 Sever and Critical Cases in African countries was then determined by Equation 56:

$$AGE, DISEASE COVID - 19 RF, Severe \& Critical Symptoms, A = \frac{AGE, DISEASE COVID - 19 RF, Severe \& Critical Symptoms, SA}{AGE, DISEASE COVID - 19 RR Severe \& Critical Symptoms, A} \quad \text{Equation 56}$$

6.3 Risk of Disease Co-morbidity in COVID-19 Deaths

The general approach in determining the risk of disease co-morbidity in COVID-19 Deaths was determined by estimating the Age profile in COVID-19 Death Cases then using the Disease Prevalance by Age to determine the Risk of Disease Co-morbidity in COVID-19 Deaths. South African COVID-19 Reported Deaths from Observed Data was used as a basis for extending Risk Factor (RF) calculations. The COVID-19 Death Age Profile for African Countries was estimated using the COVID-19 Deaths to Reported Case Distribution Ratio (DCRR) observed in Western Cape, South Africa. The DCRR was determined by Equation 57:

$$DCRR, i = \frac{COVID-19 \text{ Death Case Age Profile, South Africa } (\%), i}{Cumulative \text{ COVID-19 Reported Cases } (\%), South Africa, i} \quad \text{Equation 57}$$

Where i are the Age Groups, 20-39, 40-49, 50-59, 60-69 and Over 70 years. The COVID-19 Deaths Case Age Profile, South Africa for the respective Age Groups. was obtained from Table 7 extracted from the NICD COVID-19 SPECIAL PUBLIC HEALTH SURVEILLANCE BULLETIN, Volume 18 Report (Davies & Boulle, 2020).

Table 7: Age Characteristics of COVID-19 Deaths cases diagnosed in the public ≥20 years of age, Western Cape, South Africa, 1 March-4 June 2020, n=532* (Davies & Boulle, 2020).

Characteristics	COVID-19 deceased n=532, n	COVID-19 deceased n=532, %	Cumulative COVID-19 Reported Cases* (%)	DCRR
20-39 years	36.00	7.00	41.8	0.17
40-49 years	54.00	10.00	22.8	0.44
50-59 years	146.00	27.00	16.5	1.64
60-69 years	157.00	30.00	6.7	4.45
≥70 years	139.00	26.00	4.0	6.50

The Estimated COVID-19 Death Age Profile for African Countries was then determined using Equation 58 and Equation 59. Equation 59 normalises the Estimated COVID-19 Death Age Profile to percentage.

$$Cumulative \text{ COVID-19 Deaths } (\% \text{ Factored}), A, i = \frac{Cumulative \text{ COVID-19 Deaths } (\% \text{ Factored}), A, i}{Cumulative \text{ COVID-19 Reported Cases } (\%), A, i} \times DCRR \quad \text{Equation 58}$$

$$Cumulative \text{ COVID-19 Deaths } (\%), A, i = \frac{Cumulative \text{ COVID-19 Deaths } (\% \text{ Factored}), A, i}{Cumulative \text{ COVID-19 Reported Cases } (\%), A, Total} \times 100 \quad \text{Equation 59}$$

Where Cumulative COVID-19 Deaths (% Factored), A, i and Cumulative COVID-19 Deaths (%), A, i are the Estimated COVID-19 Deaths Age Profile (%) per Age Group in Country A unnormalized and normalised respectively. The Estimated Disease Prevalence in COVID-19 Deaths was then determined using Equation 60 and Equation 61:

$$Estimated \text{ Disease Prevalence in COVID-19 Deaths } (n), A, i = \frac{Cumulative \text{ COVID-19 Deaths } (\%), A, i \times 100}{Equation 60} \times Disease \text{ Prevalence, A, 2020, } i$$

Where the Estimated Disease Prevalence in COVID-19 Deaths (n), A, i is the number of estimated Disease Comorbidity in COVID-19 Deaths per Age Groups. A basis of a population of 100 people was used. The Disease Prevalence, A, 2020, i used was the Prevalence by Age for HIV, TB, Diabetes and Hypertension, respectively.

$$Estimated \text{ Total Disease Prevalence in COVID-19 Deaths } (\%), A = \frac{\sum Estimated \text{ Disease Prevalence in COVID-19 Deaths } (n), A, i}{\sum Cumulative \text{ COVID-19 Deaths } (n), A, i} \times 100 \quad \text{Equation 61}$$

For South Africa, The Age & Disease Risk Factor (RF) in COVID-19 Deaths was then determined using Equation 62:

$$AGE, DISEASE COVID - 19 RF, COVID - 19 Deaths, SA = \frac{Estimated Total Disease Prevalance in COVID-19 Deaths (\%), SA}{Observerd Total Disease Prevalence in COVID-19 Deaths (\%), SA} \times 100 \quad \text{Equation 62}$$

Where the AGE, DISEASE COVID-19 RF, Symptoms, A is the Risk of Disease Comorbidity in COVID-19 Deaths in Country A. The observed Total Disease Prevalence in COVID-19 Deaths (%), SA was based on Table 8 obtained from the NICD COVID-19 SPECIAL PUBLIC HEALTH SURVEILLANCE BULLETIN, Volume 18 Report (Davies & Boulle, 2020).

Table 8: Reported comorbid diseases among COVID-19 Deaths with at least one comorbid disease, Western Cape, South Africa, 1 March-4 June 2020, n=532* (Davies & Boulle, 2020).

Disease	COVID-19 deceased n=532, n	COVID-19 deceased n=532, %
Diabetes	293	55.1
Hypertension	251	47.2
chronic kidney disease	79	14.8
chronic pulmonary disease / asthma	61	11.5
TB	17	3.2
HIV	86	16.2
Total	532	

For African Countries other than South Africa a Risk Ratio (RR) had to be determined first using, using Equation 63:

$$AGE, DISEASE COVID - 19 RR COVID - 19 Deaths, A = \frac{Estimated Total Disease Prevalance in COVID-19 Deaths (\%), A}{Estimated Total Disease Prevalence in COVID-19 Deaths (\%), SA} \times 100 \quad \text{Equation 63}$$

Where AGE, DISEASE COVID-19 RR Symptoms, A is referred to as the Risk Ratio for the Estimated Total Disease Prevalence in COVID-19 Deaths in African Country A relative to that calculated for South Africa. The Age & Disease Risk Factor (RF) in Disease Comorbidity in COVID-19 Deaths in African countries was then determined by Equation 64:

$$AGE, DISEASE COVID - 19 RF, COVID - 19 Deaths, A = AGE, DISEASE COVID - 19 RF, COVID - 19 Deaths, SA \times AGE, DISEASE COVID - 19 RR COVID - 19 Deaths, A \quad \text{Equation 64}$$

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Appendix

Table A. 1: TB Prevalence Adjustment Factor for the years 2018 to 2020.

Country	TB Prevalence Adjustment factor (2020/2018)
Algeria	1.10
Angola	0.82
Benin	1.10
Botswana	1.03
Burkina Faso	0.99
Burundi	0.89
Cabo Verde	1.52
Cameroon	1.05
Central African Republic	0.62
Chad	0.89
Comoros	0.77
Congo	0.82
Cote d'Ivoire	0.71
Democratic People's Republic of Korea	1.73
Djibouti	1.54
Egypt	1.07
Equatorial Guinea	0.30
Eritrea	0.65
Eswatini	1.23
Ethiopia	0.85
Gabon	0.70
Gambia	0.65
Ghana	0.79
Guinea	0.69
Guinea-Bissau	0.72
Kenya	0.82
Lesotho	0.94
Liberia	0.84
Libya	1.02
Madagascar	1.07
Malawi	1.16
Mali	1.04
Mauritania	0.65
Mauritius	1.72
Morocco	1.08
Mozambique	0.57
Namibia	0.93
Niger	0.92
Nigeria	0.74

Rwanda	1.17
Sahrawi Arab Democratic Republic (Western Sahara)	
Sao Tome and Principe	0.43
Senegal	1.11
Seychelles	1.44
Sierra Leone	0.94
Somalia	0.44
South Africa	1.17
South Sudan	1.12
Sudan	1.10
United Republic of Tanzania	1.07
Togo	1.65
Tunisia	0.75
Uganda	0.63
Zambia	0.86
Zimbabwe	1.13

Table A. 2: List of Countries with ARI obtained data licence for WHO STEPwise approach to Surveillance (STEPS)
Data from the WHO NCD Microdata Repository

Country	Region	Year	Reference
Cameroon	Central Africa	2003	WHO STEPS
Eritrea	East Africa	2010	WHO STEPS
Morocco	North Africa	2017	WHO STEPS
Togo	West Africa	2011	WHO STEPS
Uganda	East Africa	2014	WHO STEPS
Ethiopia	East Africa	2006	WHO STEPS
Sierra Leone	West Africa	2009	WHO STEPS
Mali	West Africa	2007	WHO STEPS
Algeria	North Africa	2017	WHO STEPS
Niger	West Africa	2007	WHO STEPS
United Republic of Tanzania	East Africa	2012	WHO STEPS
Gambia	West Africa	2010	WHO STEPS
Democratic Republic of the Congo	Central Africa	2004	WHO STEPS
Central African Republic*	Central Africa	2008	WHO STEPS
Congo*	Central Africa	2004	WHO STEPS
Malawi	Southern Africa	2017	WHO STEPS
Ghana	West Africa	2006	WHO STEPS
Botswana	Southern Africa	2014	WHO STEPS
South Sudan*	East Africa	2016	WHO STEPS
Sudan	East Africa	2016	WHO STEPS
Zambia	Southern Africa	2017	WHO STEPS
Benin	West Africa	2 015	WHO STEPS
Cabo Verde	West Africa	2007	WHO STEPS

Guinea	West Africa	2009	WHO STEPS
Guinea-Bissau*	West Africa	2009	WHO STEPS
Liberia	West Africa	2011	WHO STEPS
Chad	Central Africa	2011	WHO STEPS
Equatorial Guinea*	Central Africa	2008	WHO STEPS
Gabon	Central Africa	2009	WHO STEPS
Sao Tome and Principe	Central Africa	2008	WHO STEPS
Comoros	East Africa	2005	WHO STEPS
Kenya	East Africa	2015	WHO STEPS
Madagascar	East Africa	2005	WHO STEPS
Rwanda	East Africa	2013	WHO STEPS
Seychelles	East Africa	2004	WHO STEPS
Libya	North Africa	2009	WHO STEPS
Mauritania	North Africa	2006	WHO STEPS
Eswatini	Southern Africa	2014	WHO STEPS
Lesotho	Southern Africa	2012	WHO STEPS
Mozambique	Southern Africa	2005	WHO STEPS
Namibia	Southern Africa	2005	WHO STEPS
Côte d'Ivoire	West Africa	2005	WHO STEPS

Table A. 3: Reference Sources and Prevalence Adjustment Factors used in the calculation of the Diabetes Total Prevalence and Diabetes Prevalence by Age

Country	Year	References	Total Diabetes Prevalence (%) - Ref 1	Prevalence Adjustment Factor - Ref 1	Total Diabetes Prevalence (%) - Ref 2	Prevalence Adjustment Factor - Ref 2
Algeria	2017 , 2018	WHO STEPS; (Bachir Cherif et al., 2018)	12.4	0.54	6.70	1.00
Angola	2012 , 2018	(Evaristo-Neto, Foss-Freitas & Foss, 2012; Pedro, Brito & Barros, 2018)	7.7	0.58	4.50	1.00

Benin	2015	WHO STEPS, (Amoussou-Guenou et al., 2015)	7.2	0.14	6.70	0.15
Botswana	2014 , 2018	WHO STEPS, (Rwegerera et al., 2019)	8.6	0.67	5.80	1.00
Burkina Faso	2020	(Poda et al., 2020)	7.3	1.00		
Burundi*	2013 , 2018	WHO STEPS, (Ndabarora et al., 2018)	4	1.28	5.10	1.00
Cabo Verde	2007 , 2017	WHO STEPS, Nigeria Ratio	7.7	0.31	2.40	1.00
Cameroon	2003	WHO STEPS	5.3	1.13		
Central African Republic*	2008	WHO STEPS	6.4	0.94		
Chad	2011 , 2017	WHO STEPS, DRC Ratio	6.5	0.92	6.00	1.00
Comoros	2005 , 2010	WHO STEPS, Eritrea Ratio	6.4	1.92	12.30	1.00
Congo*	2004	WHO STEPS, (Mawaw et al., 2017)	6.2	0.97	6.00	1.00

Cote d'Ivoire	2005	WHO STEPS; (Agbre-Yace et al., 2016)	0.4	6.00	0.40	6.00
Democratic Republic of the Congo	2004	WHO STEPS, (Mawaw et al., 2017)	4.6	1.30	6.00	1.00
Djibouti*	2019	(Ahmed et al., 2019), Eritrea Ratio	5.1	1.00	5.10	1.00
Egypt	2012 ; 2018	(Ministry Of Health and Population, 2012; Assaad Khalil et al., 2018)	17.9	0.96	16.90	1.02
Equatorial Guinea*	2008 , 2017	WHO STEPS, DRC Ratio	7.9	0.76	6.00	1.00
Eritrea	2010	WHO STEPS	5	1.02		
Eswatini	2014 , 2020	WHO STEPS, (Gbadamosi & Tlou, 2020)	9.7	0.46	4.50	1.00
Ethiopia	2006 , 2018	WHO STEPS; (Aynalem & Zeleke, 2018)	4.5	0.96	4.30	1.00
Gabon	2009 , 2017	WHO STEPS, DRC Ratio	9.2	0.65	6.00	1.00

Gambia	2010 , 1996	WHO STEPS; (Ntyonga- Pono & Nguemby- Mbina, 1996)	7.8	0.24	5.20	0.37
Ghana	2006 , 2017	WHO STEPS, Nigeria Ratio	5.8	0.43	2.50	1.00
Guinea	2009	WHO STEPS	5.7	0.42		
Guinea- Bissau*	2009 , 2020	WHO STEPS, (Byberg et al., 2020)	6.4	0.38		
Kenya	2015 , 2010	WHO STEPS, Eritrea Ratio	6	0.52	1.90	1.63
Lesotho	2012 , 2011	WHO STEPS, (Stats SA, 2011; Ministry of Health Lesotho, 2014)	8.4	0.54	8.20	0.55
Liberia	2011 , 2017	WHO STEPS, Nigeria Ratio	7.1	0.34	2.40	1.00
Libya	2009 , 2017	WHO STEPS, (Altajori & Elshrek, 2017)	14.4	0.71	10.20	1.00
Madagascar	2005 , 2010	WHO STEPS, Eritrea Ratio	4.7	0.96	4.50	1.00

Malawi	2017 , 2018	WHO STEPS, (Price et al., 2018)	6.3	0.71		
Mali	2007 , 1987	WHO STEPS, (Fisch et al., 1987)	6	0.40	2.80	0.86
Mauritania	2006 , 2013	WHO STEPS, (Meiloud et al., 2013)	7.8	0.91	8.80	0.81
Mauritius	2012 , 2010	(Magliano et al., 2012), Eritrea Ratio	12.7	1.73	22.00	1.00
Morocco	2017	WHO STEPS	13.7	0.51		
Mozambique	2005 , 2011	WHO STEPS, (Stats SA, 2011)	5.4	0.61	6.00	0.55
Namibia	2013 , 2011	(Stats SA, 2011; The Namibia Ministry of Health and Social Services, 2014)	7.3	0.62	7.00	0.64
Niger	2007	WHO STEPS	4.9	0.49		
Nigeria	2017	(Adeloye et al., 2017)	6.2	0.50		
Rwanda	2013 , 2018	WHO STEPS, (Ndabarora et al., 2018)	4.3	1.19	5.10	1.00

Sahrawi Arab Democratic Republic (Western Sahara)						
Sao Tome and Principe	2008 , 2017	WHO STEPS, DRC Ratio	7.5	0.32	2.40	1.00
Senegal	2015	(Seck et al., 2015)	7.4	0.32		
Seychelles	2004 , 2007	WHO STEPS, (Faeh et al., 2007)	9	1.37	9.30	1.32
Sierra Leone	2009 , 2017	WHO STEPS, (Sundufu, Bockarie & Jacobsen, 2017)	6.1	0.39	6.90	0.35
Somalia	2019 , 2010	(Ahmed et al., 2019), Eritrea Ratio	5.1	1.00	5.10	1.00
South Africa	2011	(Stats SA, 2011)	10.8	1.18		
South Sudan*	2016 , 2017	WHO STEPS, (Eliadarous, 2017)	8.9	1.15	10.20	1.00
Sudan	2016 , 2017	WHO STEPS, (Eliadarous, 2017)	8.9	2.48	22.10	1.00
Tanzania	2012 , 2014	WHO STEPS, (Ruhembe, Moshia & Nyaruhucha , 2014)	5.9	0.97	6.10	0.93
Togo	2011 , 2017	WHO STEPS, Nigeria Ratio	6.7	0.36	2.40	1.00

Tunisia	2015	(Saidi et al., 2015)	10.2	0.83		
Uganda	2014, 2020	WHO STEPS, (Asiimwe, Mauti & Kiconco, 2020)	4.6	0.54	2.50	1.00
Zambia	2017, 2016	WHO STEPS, (Bailey et al., 2016)	6.6	0.68	3.50	1.29
Zimbabwe	2005	(The Zimbabwe Ministry of Health & Child Welfare, 2005)	7.1	0.25		

Table A. 4: Reference Sources and Prevalence Adjustment Factors used in the calculation of the Hypertension Total Prevalence and Hypertension Prevalence by Age

Country	Year Ref	References	Total Hypertension Prevalence (%) - Ref 1	Prevalence Adjustment Factor - Ref 1	Total Hypertension Prevalence (%) - Ref 2	Prevalence Adjustment Factor - Ref 2
Algeria	2017, 2006	WHO STEPS, (Khedda et al., 2006)	25.1	1.00	28.6	0.88
Angola	2016; 2018	(Paquissi et al., 2016; Pedro, Brito & Barros, 2018)	29.7	1.00	29.7	1.00
Benin	2015, 2017	WHO STEPS, Burkina Faso Ratio	27.7	1.00	27.7	1.00
Botswana	2014, 2015	WHO STEPS, (Tshitenge & Mabuza, 2015)	29.8	0.99	32	0.93
Burkina Faso	2017, 2016	(Kabore & Lazar, 2016; Soubeiga	32.6	1.00	59	0.55

		et al., 2017)				
Burundi*	2020, 2017	(Iradukunda et al., 2020), DRC Ratio	29.2	1.00	29.2	1.00
Cote d'Ivoire	2005, 2019	WHO STEPS; (Sackou et al., 2019)	21.7	1.25	21.7	1.25
Cabo Verde	2007, 2017	WHO STEPS, Burkina Faso Ratio	32	0.92	29.5	1.00
Cameroon	2003	WHO STEPS	27.8	0.89		
Central African Republic*	2008, 2017	WHO STEPS, (Pilleron et al., 2017)	31.4	0.99	61.1	0.51
Chad	2011, 2017	WHO STEPS, DRC Ratio	32.5	1.01	32.9	1.00
Comoros	2005, 2010	WHO STEPS, Eritrea Ratio	26.9	1.04	27.4	1.02
Congo*	2004, 2017	WHO STEPS, (Pilleron et al., 2017)	28.5	0.92	26.2	1.00
Democratic Republic of the Congo	2004, 2017	WHO STEPS, (Mawaw et al., 2017)	29	0.98	18.2	1.57
Djibouti*	2019, 2018	(Seifu et al., 2017; Ahmed et al., 2019)	26.8	1.00	26.8	1.00
Egypt	1995	(Ibrahim et al., 1995)	28.2	0.89	28.2	0.89
Equatorial Guinea*	2008, 2017	WHO STEPS, DRC Ratio	28.7	0.99	28.4	1.00
Eritrea	2010	WHO STEPS	28.6	1.02		
Eswatini	2014, 2011	WHO STEPS, South Africa Ratio	29.8	1.00	29.8	1.00
Ethiopia	2006, 2017	WHO STEPS, (Asresahe	28.6	1.06	28.3	1.07

		gn, Tadesse & Beyene, 2017)				
Gabon	2009, 2017	WHO STEPS, DRC Ratio	27.5	0.93	25.5	1.00
Gambia	2010, 2017	WHO STEPS, (Jobe et al., 2017)	30.2	0.96	18.3	1.59
Ghana	2006, 2017	WHO STEPS, (Incoom et al., 2017)	26.2	0.90	39.4	0.60
Guinea	2009, 2016	WHO STEPS, Burkina Faso Ratio	30.3	1.00	30.3	1.00
Guinea- Bissau*	2009, 2016	WHO STEPS, Burkina Faso Ratio	31.2	0.97	30.3	1.00
Kenya	2015, 2010	WHO STEPS, Eritrea Ratio	26.7	1.00	26.4	1.01
Lesotho	2012, 2011	WHO STEPS, South Africa Ratio	29	1.00	29	1.00
Liberia	2011, 2016	WHO STEPS, Burkina Faso Ratio	29	0.98	28.3	1.00
Libya	2009, 2017	WHO STEPS, Morocco Ratio	25.9	0.92	23.7	1.00
Madagasc ar	2005, 2010	WHO STEPS, Eritrea Ratio	28.1	1.00	28.1	1.00
Malawi	2017, 2018	WHO STEPS, (Price et al., 2018)	28.9	1.00	28.9	1.00
Mali	2007, 2013	WHO STEPS, (Bâ et al., 2018)	32.5	1.00	24.7	1.32
Mauritania	2006, 2017	WHO STEPS,	34.3	0.92	31.7	1.00

		Morocco Ratio				
Mauritius	1991, 2018	(Nan et al., 1991; Kowlessur et al., 2018)	27.8	0.90	25	1.00
Morocco	2017	WHO STEPS	26.1	1.00		
Mozambique	2005, 2011	WHO STEPS, South Africa Ratio	28.7	1.01	29	1.00
Namibia	2005, 2011	WHO STEPS, South Africa Ratio	30.2	0.94	29.3	0.97
Niger	2007, 2018	WHO STEPS, (Ezejimofor et al., 2018)	33.3	1.00	33.4	1.00
Nigeria	2015	(Adeloye et al., 2015)	24.3	0.98	24.3	0.98
Rwanda	2013, 2010	WHO STEPS, Eritrea Ratio	26.7	1.00	26.6	1.00
Sao Tome and Principe	2008, 2017	WHO STEPS, DRC Ratio	28.1	0.92	25.8	1.00
Senegal	2013; 2016	(Pessinaba et al., 2013; Macia, Gueye & Duboz, 2016)	30.6	0.99	24.7	1.22
Seychelles	2004, 2010	WHO STEPS, Eritrea Ratio	25.7	0.91	24.4	0.96
Sierra Leone	2009, 2014	WHO STEPS, (Awad et al., 2014)	31.3	0.97	46.2	0.66
Somalia	2019, 2016	(Seifu et al., 2017; Ahmed et al., 2019)(Ahmed et al,	32.9	1.00	13.3	2.47

		2019); (Seifu et al, 2016)				
South Africa	2011	(Stats SA, 2011)	26.9	1.00		
South Sudan*	2016, 2013	WHO STEPS, (Wake & Mazinda, 2013)	30.2	1.00	19.3	1.56
Sudan	2016, 2013	WHO STEPS, (Wake & Mazinda, 2013)	30.2	1.00	30.1	1.00
Togo	2011	WHO STEPS	29.4	0.98		
Tunisia	2012, 2017	(Romdhan e et al., 2012) Morocco Ratio	24.1	0.96	23.2	1.00
Uganda	2014	WHO STEPS	27.1	1.01		
United Republic of Tanzania	2012, 2015	WHO STEPS, (Guwatudd e et al., 2015)	27.2	1.00	25.9	1.05
Western Sahara						
Zambia	2017, 2015	WHO STEPS, (Yan et al., 2015)	27.1	1.00	23.1	1.17
Zimbabwe	2005	(The Zimbabwe Ministry of Health & Child Welfare, 2005)	29.1	0.97		