Migrant health worker deaths during Covid-19: a methodological exploration and initial estimates

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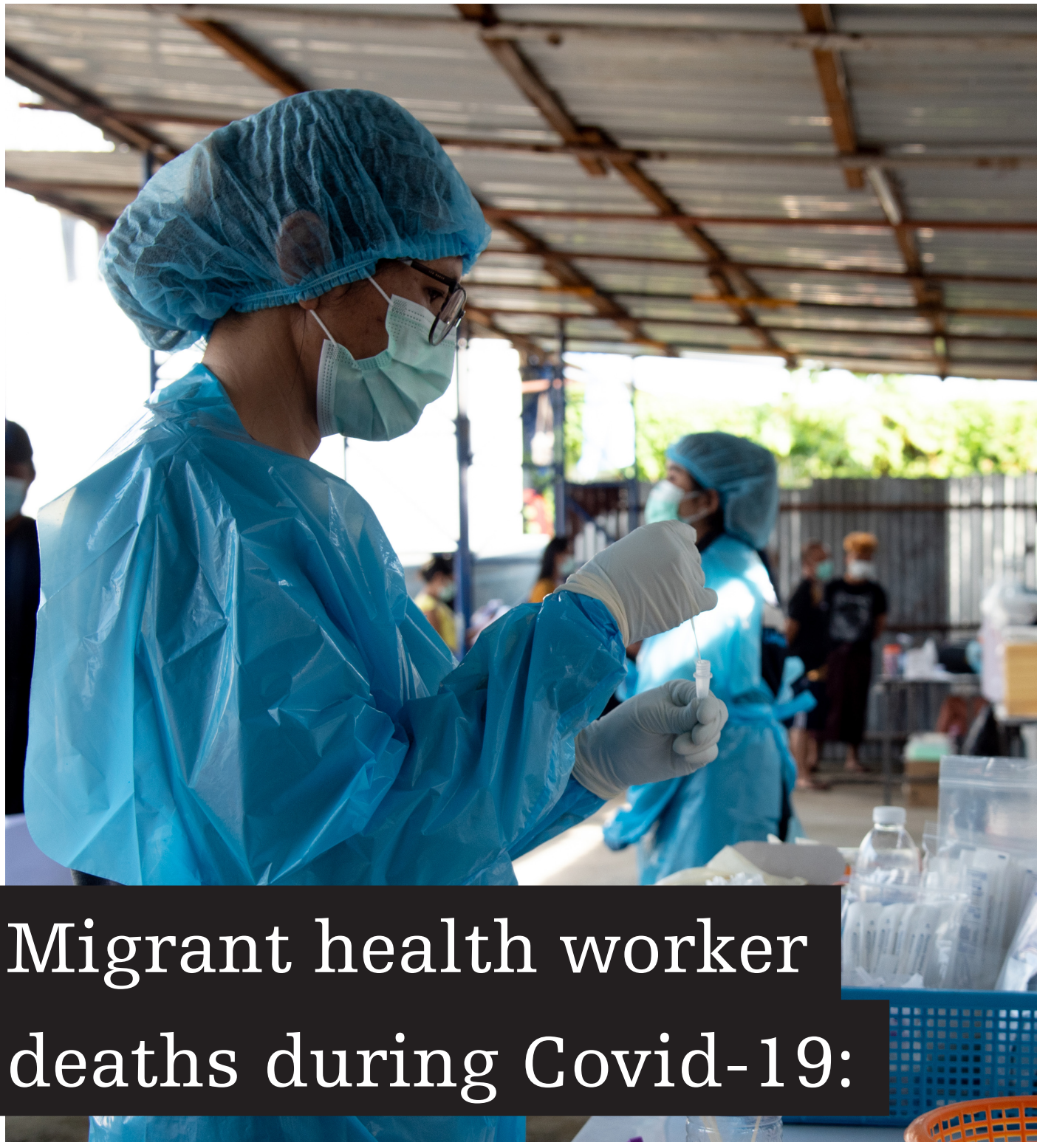

Migrant health worker deaths during Covid-19:

A METHODOLOGICAL EXPLORATION AND INITIAL ESTIMATES

Sarah Tipping, Vicky Murphy, Nicola Yeates, Carlos Montoro, Gihan Ismail and Nashwa Ismail

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COVID-19 sample collection at a migrant workers' campsite in Bang Sue,Bangkok 31st October 2021 /WHO/Ploy Phutpheng

ABSTRACT

Migrants comprise a significant proportion of health workforces that have long been recognised as being at high risk of experiencing adverse outcomes from contracting Covid-19. However, there is a paucity of high-quality research data on the risks of such outcomes faced by migrant health workers compared with non-migrant workers. This paper explores the available data around Covid-19 deaths, health workers, and migration and develops a methodology to estimate how many migrant health workers died due to Covid-19. It presents preliminary assessments of the numbers of such workers based on statistical data from four trial countries chosen for their differences in terms of proportions of foreign-born health workers and development contexts – India, Mexico, Nigeria and the UK. We identify the age-sex standardised approach as the best-available one for this enumerative task. However, the paper identifies the lack of robust data needed to confidently quantify the relative differences in risk of death faced by migrant health workers compared with their non-migrant colleagues. We reaffirm the World Health Organization's advocacy of standardised measurement and reporting of Covid-19 impacts, and, on the basis of this research, extend its recommendations to improve data on the health workforce to enable disaggregation by sex, age, ethnicity, occupation, health status, migration status, country of origin and whether employed in public or private health care delivery, and to institute better data systems with greater capacity for collecting and analysing disaggregated data. Such advances would go a long way to redressing the near-invisibility of migrant health workers (and migrants more generally) in Covid-19 impact studies and to improving their working conditions.

Key words: migrant; foreign-born; nurses; doctors; Covid-19; health workforce; health services; mortality; India; Mexico; Nigeria; United Kingdom; methodology; data quality

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LIST OF ABBREVIATIONS AND ACRONYMS

APS	Annual population survey
CI	Credibility interval
CSV	Comma-separate value
FIND	Foundation for Innovative New Diagnostics
GDP	Gross domestic product
HDI	Human Development Index
HIV	Human immunodeficiency virus
HDI	Human Development Index
ILO	International Labour Organization
IOM	International Organization for Migration
ISIC	International Standard of Industrial Classification
ISO	International Organization for Standardization
JHCSSE	Johns Hopkins Centre for Systems Science and Engineering
LFS	Labour Force Survey
NHWA	National Health Worker Account
ONS	Office for National Statistics (UK)
OECD	Organization for Economic Cooperation and Development
OU	The Open University
OWID	Our World in Data
PPE	Personal protection equipment
PSI	Public Services International
RMSE	Root mean square error
UK	The United Kingdom of Great Britain and Northern Ireland
UN	United Nations
WB	World Bank
WHO	World Health Organization

Introduction

1.1 WHAT IS KNOWN ABOUT THE RISKS OF CONTRACTING AND DYING FROM COVID-19 AMONG MIGRANT MEMBERS OF THE HEALTH WORKFORCE?

Health and social care workers providing care directly to patients have long been recognised as being at high risk of contracting infectious diseases. Covid-19 is no different. From an early stage in the pandemic, health workers' very high risks of contracting Covid-19 and of experiencing adverse outcomes, including death, have been the focus of attention (Amnesty International, 2020; Bandyopadhyay, Baticulon, Kadhum et al., 2020; Kursumovic et al., 2020; Nguyen et al., 2020; Salazar de Pablo, 2020). Early evidence of the scale and severity of these harms, coupled with a lack of robust data and systematic methodology for enumerating health and care workforce deaths, was a key driver of the World Health Organisation's (WHO's) call for *all* deaths of health and social care workers from Covid-19 to be counted. Using officially-reported Covid-19 deaths data, it estimated that 80,000 - 180,000 deaths of such workers occurred from Covid-19 between January 2020 and May 2021, with a central population-based estimate of 155,500 deaths. This estimate was, it cautioned, a likely significant under-count of the actual death toll (WHO, 2021).

From the perspective of mid-2022, the significance of migration status (as distinct from ethnicity or 'race') in shaping the incidence and distribution of Covid-19 infections, hospitalisations and mortality has received relatively little attention (Ettia et al., 2021; Hayward et al., 2021; Oliva-Arocas et al, 2022). Significant gaps in knowledge remain about the impacts of Covid-19 as they have played out within and between countries and regions of the world. Characteristic blind spots in Covid-19 research are illustrated by WHO and International Organization for Migration (IOM) studies. The WHO (2021) research did not distinguish between health and care workers who died from Covid-19 by migrant status, while the IOM's study on the impacts of Covid-19 on migrants (Guadagno, 2020) barely mentioned the health and social care sector, even though one in three international migrants work in the health sector around the world (WHO, 2006).

More widely, such studies as have been undertaken on migrants in general identify a high risk of contracting and dying from Covid-19 (Alahmad et al., 2021; European Centre for Disease Prevention and Control, 2021; Gosselin et al., 2021; Hamadah et al, 2020; Hayward, et al. 2021; Horner et al., 2021; Jaljaa et al., 2022; Kjøllesdal and Magnusson, 2021; Koh, 2020; Kumar et al., 2021; Nwaru et al., 2022; Obinna, 2021). Although many of these studies include health and social care sector workers, research studies dedicated to specifying Covid-19 outcomes for migrants working in the health and social care sector are, lamentably, few and far between. They tend to be small-scale, limited to clinical occupations, and focus on a single country (Dinakarpandian et al., 2021; Kursumovic et al., 2020; Nazareno, 2021; Pillinger, Gencianos and Yeates, 2021a; Rostila et al., 2021). Both of Jaljaa et al.'s (2022) otherwise large-scale study of 53 countries in the WHO's European region and Camacho-Servin et al.'s (2021) study attended only to the incidence of Covid-19 and not the outcomes of infection. The latter makes just one passing reference to migrants among Covid-19-infected health workers in Mexico City between 2020 and 2021[1].

1 Camacho-Servin et al. (2021) make a single reference to migrant health workers by pointing out that they accounted for 1 % of the total number of infections (n=199) affecting a total of 17,000 health workers in Mexico City. No indication is given of how many of the infected 284 health workers who died were migrants.

The first multinational study to estimate numbers of migrant health workers who had died due to Covid-19 infection was jointly conducted between The Open University (OU) and Public Services International (PSI). This estimated that as many as 36,000 migrant health and social care workers had died (Pillinger, Gencianos and Yeates, 2021a). They indicated a higher risk of serious infection and death faced by migrant health workers due to their concentration in frontline patient-facing roles combined with exposure to high numbers of infected patients in an institutional context marked by failures to provide adequate personal protective equipment (PPE) and social protection to those workers (Pillinger, Gencianos and Yeates, 2021a; 2021b; 2021c).

Indeed, migrant health workers are not always fully protected by high quality (uncontaminated) PPE or vaccination, and may be among the 3 in 5 non-vaccinated health workers worldwide, a hypothesis supported by small-scale qualitative studies that corroborate the link between occupation, practice settings, and Covid-19 infection and death (Amnesty International, 2020; International Council of Nurses, 2020, 2021). Indeed, exposure to occupational health hazards is very high for all employees in the health industry (Joseph and Joseph, 2016), especially among international migrants for whom work-related ill health and injury are relatively common (Hargreaves et al., 2019). Certainly, 40% of the sample in Dinarkarpandian et al.'s study of deaths among Covid-19-infected health workers worked in primary care, and nurses comprise 32% of all health worker Covid-19 deaths in the USA (The Guardian and Kaiser Health Network, 2020)). Mental health nurses and general practitioners were also at greater risk (Bandyopadhyay, Baticulon and Kadhum et al., 2020), as were those involved in airway management and administering certain procedures (e.g. tracheal intubation (Kursumovic et al., 2020)). The combined effects of exclusion from and discrimination within health care, communication challenges, and poorer housing, environmental and working conditions also play a role (IOM, 2022; Koh, 2020; Jaljaa et al., 2022). In short, the 'migrant mortality advantage' that Aldridge et al. (2018) discerned for certain groups of migrants in high-income countries compared with the general population in those countries may be significantly eroded (and even reversed) when it comes to Covid-19. This would be consistent with their (pre-Covid) findings that international migrants in high-income countries had increased mortality due to infectious diseases (notably, viral hepatitis, tuberculosis, and HIV) and external causes of deaths (assault and events of undetermined intent) compared with the general population (Aldridge et al., 2018).

The studies to date pose three high-level empirical questions:

1. **How many migrant health workers have died from/with Covid-19?**
2. **Do migrant members of the health workforce experience a higher risk of infection and death than non-migrant members?**
3. **Do these risks vary between countries?**

This paper is a first step in answering these questions. It explores the available data around Covid-19 deaths, health workers, and migration to assess whether it is possible to estimate how many migrant health workers died due to Covid-19. It presents preliminary assessments of the numbers of such workers, based on data from four trial countries chosen for their difference in proportions of foreign-born health workers and their development context.

1.2 METHODS TO ESTIMATE THE NUMBER OF COVID-19 DEATHS AMONG MIGRANT HEALTH WORKERS

Two approaches were considered: an estimate based on overall death rates and an estimate based on deaths standardised by age and sex. These two approaches align closely to those used by the WHO when estimating the number of health and care workers who died due to Covid-19 (WHO, 2021).

These two potential methods were trialled on four countries to better understand the data limitations. Further approaches are discussed briefly in this paper but rejected for the present as the data required to make the estimates were not widely available.

1.3 THE FOUR TRIAL COUNTRIES

The four countries selected for the trial estimates were: India, Mexico, Nigeria and The United Kingdom. These countries were purposefully selected to give a mix of higher- and lower-income countries, including countries outside the Organization for Economic Cooperation and Development (OECD), that covered a range of contexts. The aim was to also include countries with lower levels of immigration alongside those with higher levels, countries with very different reported Covid-19 rates, and countries with different data availability about health workers. Finally, the four countries also represented a mix of countries that have produced high-quality and low-quality data on mortality historically (Phillips et al., 2014). This mix of different factors made it possible to review the impact of data availability on potential methods for estimating the number of Covid-19 deaths among migrant health workers. This includes, for example, the need to impute the proportion of foreign-born health workers for a large number of countries and difficulties finding figures on the age and sex distribution of Covid-19 deaths.

1.4 TERMINOLOGY

In this analysis migrant health workers are defined as health workers who were born in a country different to the one where they are currently working. The National Health Worker Account (NHWA) data provides figures on foreign-born health workers that were used in the estimation. There is an alternative definition based on the country in which the individual trained. Foreign-trained health workers are individuals who underwent professional training in a country other than the one where they are currently working. In many countries, the numbers of foreign-born health workers will be very similar to the numbers of foreign-trained health workers. However, some smaller countries do not have strong national medical schools or training facilities and send their nationals abroad for training. Other countries train a large number of individuals specifically to work abroad. The number of foreign-born workers therefore better captures the number of international migrants in health care. Some literature uses the term international medical graduate. This is a US term for physicians (doctors) who underwent professional training outside North America (USA or Canada). It is broadly equivalent to a foreign-trained health worker. Hereon, the term ‘foreign-born’ is used rather than ‘migrant’ as this reflects the definition used by the NHWA for their figures.

1.5 STRUCTURE OF THIS PAPER

Section 2 describes what data was required for the estimates and how it was sourced. Section 3 describes how the number of Covid-19 deaths among migrant health care workers was estimated and provides estimates for the four trial countries. Finally, Section 4 discusses the pros and cons of the different approaches to estimation and the completeness and format of the data available, including what additional data sources would be required to improve the estimates.

Section 2 Data requirements and data sources

A review was carried out to assess the availability and quality of the information required to estimate the number Covid-19 deaths among foreign-born health workers. For each country, information was needed on the number of foreign-born health workers, the number of Covid-19 deaths, and the overall population size. In addition to overall numbers, the information needed to be available by age and sex.

Not all pieces of information were available for all countries: for some countries data were almost entirely missing, while for others there were gaps in the information available, or it was only available through a mix of official and non-official sources. In the following sections the different pieces of information required for the estimates are examined in turn and issues around missing data are discussed in more detail.

2.1 WORLDWIDE DATA ON MIGRANT HEALTH WORKERS

There is no single, global source of complete information on foreign-born health workers. Different data sources have been drawn on to provide estimates of foreign-born health workers.

a. National Healthcare Workforce Accounts

The NHWA[2] is an extensive data source on health workers. These data have been used as a starting point in the estimation of Covid-19 deaths for foreign-born health workers. The dataset contains information on the number of medical doctors, nursing professionals, midwifery professionals, dentists and pharmacists per country and includes breakdowns by age and by sex (but not by age within sex). The NHWA also includes the proportion of foreign-born and foreign-trained doctors, nurses and midwives. However, this information is not included for dentists and pharmacists. These two occupational groups were consequently not included in the estimation.

Whilst the NHWA is a useful and valuable data source, the available data are not complete for all countries. The proportion of countries with missing data increases when looking at breakdowns by age, and rises further when looking at the proportion of foreign-born and foreign-trained health workers. For example, 192 countries had information on the total number of medical doctors in their country. Of these, 128 countries had information on the sex of those doctors, 119 had information on their age distribution, and 72 had figures on the proportion of foreign-born doctors. A similar pattern is seen for nursing professionals and midwives[3]. Furthermore, the recency of the information available varies, with the most up-to-date information for some countries being from more than ten years ago.

Different groups may also be updated at different times; hence for the same country, the date of the most recent nurse figures and the date of the most recent doctor figures may differ. The recency of information such as age, sex and proportion of foreign-born health workers also varies, both across and within occupational group. For the estimates contained in this paper, the most recent figures available at the time were used and notes were made of the dates.

2 The National Health Worker Accounts data is collated by the WHO and contains processed data extracts of the national reporting in the National Health Workforce Accounts data platform. Complementing the national reporting, additional sources such as the National Census, Labour Force Surveys and key administrative national and regional sources are also employed. The data can be accessed at:https://apps.who.int/nhwaportal/

3 NHWA data: countries with medical doctors, latest year, downloaded 15 March 2022. The corresponding figures for nurses are 192 countries with information on total numbers, 144 with sex, 127 with age, and 100 with data on foreign-born nurses. Figures for midwives contain the most missing data: of the 169 countries with information on total numbers, 97 had data with sex, 81 with age, and 49 with foreign-born. NHWA, data accessed 15 March 2022

The NHWA also does not contain information on the age and sex distribution of foreign-born health workers, only for health workers overall. To the authors' knowledge, there are no global data sources containing this specific information. Due to this lack of data, in calculations, an assumption was made that the age and sex distributions for foreign-born health workers were the same as the overall health worker distributions. This assumption was made in the absence of any alternative figures but clearly will not hold true for many countries. This issue is discussed further in Appendix E.

The NHWA uses the following age bands in their data tables: less than 25 years, 25-34 years, 35-44 years, 45-54 years, 55-64 years, 65 years and over. When creating corresponding age breaks for other data, such as population figures and Covid-19 deaths, it was necessary to establish upper and lower age cut-offs. The middle age bands (25-34 years and 35-44 years) were also collapsed into a single, wider age band to reflect the fact that other data sources did not provide figures at the same level of granularity. A balance was struck between making the most of the detail available and ensuring consistency between different data sources. The following age bands were therefore used in the remainder of the analysis: 15-25 years, 25-44 years, 45-54 years, 55-64 years, 65-69 years.

The figures on the NHWA were also not broken down by age within sex, hence an assumption was made that the age distribution for each sex matched that of the overall distribution. Whilst this was unlikely to be the case (for instance, younger cohorts of doctors are less likely to be male dominated and maternity leave will have an impact on the age profile of female workers) there were no other global sources of information available to draw on.

b. International Labour Organization employment figures

The gaps in the NHWA meant other data sources were also reviewed and their usefulness considered. Data from the International Labour Organization (ILO) was used to obtain a fuller picture of health workers. The ILO data included figures on the overall human health and social work sector, and figures for health occupations (specifically, health professionals and health associate professionals). These data were reviewed to assess whether they could be included in the estimation to provide estimates of the number of Covid-19 deaths among the wider foreign-born health workforce, outside the specific occupations of medical doctors, nurses, and midwives.

The ILO holds a set of modelled estimates and actual figures on the number of workers in the human health and social work sector (ISIC Q)[4]. These show the total number of persons of working age whose main activity, either in paid work or self-employment, was based in the human health care and social work sector, thereby covering a wider range of workers than the NHWA. These figures are available for most countries split by age and sex. The most recent available figures are for 2020.

The ILO also contains data on occupation by sex (but not by age) using ISCO-08 occupation codes to identify health professionals (code 22) and health associate professionals (code 32)[5]. These figures were reviewed but not used in the estimation. These occupation codes are based on skill level, rather than sector of employment. They were rejected for this estimation exercise as they cover a wider workforce than the NHWA figures, such as paramedical professionals, traditional and complementary medical practitioners, and veterinary professionals. In other words, the data included groups that were outside the scope of this project.

4 ISIC is the International Standard Industrial Classification of All Economic Activities. Sector Q covers the provision of health and social work activities. This includes a wide range of activities, starting from health care provided by trained medical professionals in hospitals and other facilities, over residential care activities that still involve a degree of health care activities to social work activities without any involvement of health care professionals. https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf (accessed 22 June 2022)

5 ISCO-08 is the International Standard Classification of Occupations 2008. Category 22 covers health professionals who conduct research; improve or develop concepts, theories and operational methods; and apply scientific knowledge relating to medicine, nursing, dentistry, veterinary medicine, pharmacy, and promotion of health. Category 32 covers health associate professionals who perform technical and practical tasks to support diagnosis and treatment of illness, disease, injuries and impairments in humans and animals, and to support implementation of health care. It should be noted that a number of professions considered to be a part of the health workforce are not classified in either Category 22 or 32. These would include, but are not restricted to, addiction counsellors, biomedical engineers, and clinical psychologists. The ISCO categories are based on tasks and skill level. As such, the health professional categories include veterinary professionals and veterinary associate professionals. https://isco-ilo.netlify.app/en/isco-08/ (accessed 22 June 2022).

Neither of these ILO data sets contain information on the number of foreign-born health workers. Any estimates of the number of foreign-born health workers would need to draw on information on the proportion of foreign-born doctors, nurses and midwives from the NHWA. This makes the assumption that the proportion of foreign-born workers in the overall human health and social work sector will be similar to that for combined doctors, nurses and midwives. Whilst this assumption is unlikely to be true, it is made in the absence of any other globally-available figures.

c. Combined data

Combining the NHWA and ILO datasets resulted in four sets of figures on health workers: three covering the three different healthcare occupations taken from the NHWA, and a fourth covering workers in the human health and social work sector taken from the ILO. For each of these figures there was a corresponding age and sex distribution. For medical doctors, nursing professionals and midwifery professionals these figures were taken directly from the NHWA. Figures for the human health and social work sector were taken from the ILO[6]. Whilst it was not necessary for any of the four trial countries, in the absence of any other available data, one option would be to use the ILO figures on workforce distributions by sex and age to impute the distributions for countries that were missing this information in the NHWA. The information was collated for the four trial countries and is given in Tables A.1-A.4 in Appendix A.

d. Modelling missing data on the proportion of foreign-born health workers

The proportion of foreign-born doctors, nursing professionals, and midwives in the NHWA was missing for a number of countries (of the 192 countries in the dataset, 62% were missing any information on the proportion of foreign-born doctors, 49% on nurses, and 72% on midwives). This piece of information was a key input when estimating the number of Covid-19 deaths among foreign-born health workers; estimating the number of Covid-19 deaths is difficult and meaningless without knowing the overall population of foreign-born health workers.

Statistical models were assessed for their ability to impute this missing information successfully. Three measures were modelled: the proportion of foreign-born doctors, the proportion of foreign-born nurses, and the proportion of foreign-born midwives, with separate models (or sets of models) used to estimate each measure. The models summarise the relationships between a range of country characteristics[7] and the three measures. This relationship was then used to predict the proportion of foreign-born doctors/nurses/midwives in countries where the information was missing.

The imputed proportions of foreign-born doctors, nurses, and midwives produced by the models were used in the absence of a reported value from the NHWA or another robust, national alternative. Specifically, among the four trial countries, modelled estimates were used for the proportion of foreign-born doctors, nurses and midwives in India, foreign-born nurses in Mexico, and foreign-born midwives in Nigeria. A fuller explanation of the modelling, a full list of the measures included in the model and the model outputs are given in Appendix B.

There were also no reported figures from the NHWA for the UK. Instead figures on the proportion of foreign-born health workers were taken from the Office for National Statistics (ONS)[8]. These figures came from a large-scale nationally representative sample and were therefore sufficiently robust to use

6 It should be noted that the age groups used for the ILO are wider than those used for the NHWA, namely 15-24 years, 25-54, 55-64, 65 and over. For consistency with the NHWA, the cases in the 25-54 year age group were split into two smaller groups (25-44 years and 45-54 years). Where the information was available, this reallocation reflected the profile of that country's combined doctor, nurse and midwife age profile from the NHWA. Elsewhere, the global profile could be used.

7 Taken from the World Bank, ILO and the United Nations (UN). These include, but were not limited to: GDP; the GDP spend on healthcare; population size; the proportion of the population aged 15 years and under; the proportion aged 65 years and over; net migration; the proportion of working-age population who were migrants; the proportion of the working population working in the health care sector, and information on the number of doctors and nurses per 1,000 people.

8 Office for National Statistics – Annual Population Survey 3-year pooled dataset 2016-18.

in place of the modelled estimates. These figures suggest 29.0% of doctors, 17.5% nurses, and 7.5% of midwives are foreign-born. The same source also provides figures for the overall human health and social work sector, suggesting 22.3% of health workers are foreign-born.

The figures reported in the NHWA are rounded to one decimal place. The reported proportion of foreign-born midwives in Nigeria is 0.0% when rounded in this fashion, reflecting the fact that the number of foreign-born midwives in Nigeria is very low. However, if this rounded figure was used to calculate the number of foreign-born midwives in Nigeria, the result would be an estimate of zero. For that reason, the modelled figure of 0.004% has been used instead, rounding the estimate to one significant figure instead of one decimal place. This reflects the fact that whilst the number of foreign-born midwives in Nigeria is very low, the true figure is unlikely to be zero.

In addition to the estimated proportion of foreign-born doctors, nurses and midwives, an overall proportion of foreign-born health workers was also generated that could be used for the sector-level estimates for workers in the human health and social work sector. As mentioned, the number of foreign-born workers in the human health and social work sector is not available from the ILO. The overall estimate was therefore based on the combined proportion of foreign-born doctors, nurses and midwives from the NHWA. This combined proportion drew on reported figures from the NHWA where available, and alternative estimates and modelled figures elsewhere. The exception to this was the UK, where an overall proportion of foreign-born workers in the human health and social work sector was taken from the Annual Population Survey.

2.2 WORLDWIDE DATA SOURCES ON COVID-19 MORTALITY

Worldwide data on Covid-19 deaths includes figures that have been officially reported to the WHO by different countries and estimates of excess deaths produced by various academics and research organisations.

a. Officially-reported mortality counts related to Covid-19

Data related to mortality were limited to those deaths recorded until 31 December 2021. As data for this study were collected from March 2022, this allowed a three-month period for any deaths that occurred prior to this cut-off date to be included in official figures. Other studies have highlighted that a lag in official reporting of deaths can be an issue in obtaining an accurate estimate of official recent deaths (Wang et al., 2022). The three-month buffer period therefore minimised the chances that any official death counts would increase after the end of the study for the period of interest.

The official Covid-19 mortality figures for each country were obtained from the WHO's Covid-19 dashboard[9]. These figures were used as a base for the estimated number of Covid-19 deaths among foreign-born health workers. The total number of reported Covid-19 deaths in the period up to 31 December 2021 for the four trial countries were: 481,080 in India; 303,408 in Mexico; 3,030 in Nigeria, and 149,790 in the UK.

Other studies which have used mortality figures for calculations have tended to use data from the Johns Hopkins' Center for Systems Science and Engineering (JHCSSE). The JHCSSE combine multiple data sources, including the figures from the WHO Covid-19 dashboard, to produce what could be considered a more robust estimate of COVID mortality than the official figures reported to the WHO alone. However, as the difference in these counts was less than one percent larger than the WHO reported figures for the majority of countries, this difference was considered minimal and the WHO data represented the more conservative set of estimates. As discussed below, a second

9 WHO reported deaths from https://covid19.who.int/data. Downloaded 19 May 2022

set of estimates, based on estimated excess deaths, were generated, providing an alternative, non-conservative set of estimates for foreign-born health worker deaths.

b. Distribution of Covid-19 mortality by sex and age

A requirement for calculating representative estimates of foreign-born health worker Covid-19 deaths is distributions of deaths by sex and age. Information on this distribution was not available from the primary WHO Covid-19 dashboard. However, in line with groups such as Globalhealth 50/50[10], the WHO Covid-19 Detailed Surveillance Data Dashboard[11] was used where possible to obtain disaggregated information on Covid-19 and Covid-19-related deaths by sex and age. The latter WHO dashboard combines data from case report forms, daily and weekly counts reported to the WHO, Our World In Data (OWID), the Foundation for Innovative New Diagnostics (FIND), and official public websites to produce a dataset that includes various breakdowns of the data. Nevertheless, despite its increased detail compared to the WHO Covid-19 dashboard, the data contained some issues around data quality: for example, some records were incomplete and there were internal inconsistencies (such as the sum of male and female death counts not equalling the total for all sexes). As such, this dataset was considered to be a large sample that was appropriate for estimating sex and age proportions of Covid-19-related deaths, but unsuitable for obtaining an overall count of deaths. The WHO Covid-19 Detailed Surveillance Data Dashboard was used for estimating the mortality distribution by age and sex in Mexico and the UK. Data sources used to estimate distributions of age and sex in India and Nigeria are discussed below.

c. Additional country-specific data sources on Covid-19 mortality

The worldwide data sources described above contained data for many countries and were a key source of information that had been quality-checked to some degree. However, these data sources were not complete for all countries. Country-specific sources were used to fill the gaps for the trial countries where necessary. These resources ranged from official sources to data collected by academics and journalists. A similar exercise would be needed to supplement the data in countries not included in this trial. The following sources were used:

- **India**: Data on the age and sex distribution of Covid-19 deaths in India was taken from Covid19india.org. Covid19india.org was a website run by volunteers until October 2021. The team of volunteers curated and verified data on India and Covid-19 from several sources. The website included raw data on both age and gender; however, a large proportion of information remains missing. The age and sex data covers the period 1 April 2020 to 31 October 2021, containing data on 124,742 recorded deaths. Demographic information was available for 35,744 of those individuals.

- **Nigeria**: Data on Nigerian deaths by age and sex were taken from an academic article that had investigated a COVID testing lab in Lagos and provided an open access dataset[12]. It should be noted that the sample size in this study was limited (data was included on 73 deaths), but it was the only source of data on deaths in Nigeria by sex that could be identified by the authors.

- **Mexico, UK**: No additional data sources were used. The estimates in these countries were entirely based on deaths data taken from the WHO.

Table 1 shows the reported total Covid-19 deaths for the four trial countries in the period up to 31

10 https://globalhealth5050.org/the-sex-gender-and-Covid-19-project/ (accessed 23 June 2022)

11 https://app.powerbi.com/view?r=eyJrIjoiYWRiZWVkNWUtNmM0Ni00MDAwLTljYWMtN2EwNTM3YjQzYmRmIiwidCI6ImY2MTBjMGI3LWJkMjQtNGIzOS04MTBiLTNkYzI4MGFmYjU5MCIsImMiOjh9 (accessed 31 July 2022)

12 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0248281#sec013. This contained a dataset for 2,184 confirmed COVID-19 patients: 73 deaths with recorded age/sex (Osibogun et al., 2021).

December 2021 and how this is redistributed by age and sex using either the detailed surveillance dashboard (in the case of Mexico and the UK) or using country-specific data (in the case of India and Nigeria). These figures were used to produce the age-sex standardised estimates of the number of Covid-19 deaths for foreign-born health workers.

Table 1 Covid-19 reported deaths in the period up to 31 December 2021 for the four trial countries, redistributed by age and sex

	India	Mexico	Nigeria	UK
Female, 0-14 years	525	239	0	29
Female, 15- 25 years	1,252	1,084	0	96
Female, 25-44 years	12,288	11,172	166	1,074
Female, 45-54 years	21,481	16,988	42	2,080
Female, 55-64 years	39,556	27,250	125	4,177
Female, 65-69 years	24,455	16,609	249	3,626
Female, 70 years or more	88,641	42,916	125	56,621
Male, 0-14 years	673	264	0	28
Male, 15-25 years	1,440	1,534	83	143
Male, 25-44 years	23,190	22,215	208	1,567
Male, 45-54 years	40,296	30,714	706	3,424
Male, 55-64 years	67,309	43,705	623	7,275
Male, 65-69 years	41,669	24,974	166	6,124
Male, 70 years or more	118,305	63,744	540	63,527
Total reported deaths	**481,080**	**303,408**	**3,030**	**149,790**

Sources: Total WHO reported deaths for period up to 31 December 2021, redistributed using information on age/sex from three sources: https://data.covid19india.org/ (India); https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0248281#sec013 (Nigeria), and the WHO COVID-19 Detailed Surveillance Data Dashboard (Mexico and UK).

d. Excess death estimates

Instead of considering the official death count, an alternative approach to estimating the impact of Covid-19 is to estimate the excess mortality associated with Covid-19. 'Excess mortality' is defined as the difference between the total number of deaths from all causes and the number of deaths that would have been expected in the absence of the pandemic. Several groups have attempted to estimate the 'true' death count of Covid-19 using this approach. This task is not trivial. Delays in the reporting of routine mortality data by countries to the WHO, sometimes by a year or more, and differences in the reporting capacity and completeness of the information provided means all-cause mortality data is missing in many countries and needs to be estimated using statistical models. As a result, the estimated number of excess deaths varies between different groups' models, owing to the

variations in the methodology used to estimate both the baseline count of expected deaths and the missing all-cause mortality data in countries that have not reported any deaths during 2020 and 2021. Despite the differences in methodology, each group estimated the death toll from Covid-19 to be substantially higher than the reported figures, as discussed below.

It should be noted that each of these estimates comes with a great deal of uncertainty, given the large amount of missing data and the quality issues around some of the available data. These issues include the low registration of deaths in some countries due to poor civil registration infrastructures and weak administrative capacity, and delays in reporting. However, the estimates are useful in that they give an alternative estimate of the full death total due to the pandemic that goes beyond the number of confirmed deaths.

One group that has modelled the number of excess deaths due to Covid-19 is Wang et al. (2022), who published a set of peer-reviewed estimates in *The Lancet.* They employed sophisticated statistical methods, utilising six different models, to produce their set of estimates. In the case of India, additional data sources were used to increase the accuracy of the team's calculations. Wang et al. estimated that between 1 January 2020 and 31 December 2021 the number of global excess deaths reached 18.2 million (with a 95% certainty (confidence) interval (CI) of 17.7-19.6 million). This was far higher than the confirmed, reported number of 5.94 million for the same period. A different approach was taken by *The Economist*[13]. They produced estimates for 223 countries and regions of the world using advanced statistical techniques. A global figure was calculated of 17.7 million excess deaths (with a 95% CI of 12.2-20.8 million) for the period between 1 January 2020 and 27 December 2021. A further set of peer-reviewed estimates were produced by Karlinsky and Kobak (2021). Whilst their initial article was published in June 2021, six months before the 31 December 2021, updated estimates up until this date were available from their Github repository. Karlinsky and Kobak modelled excess deaths in 103 countries and territories, estimating that the number of deaths due to Covid-19 was at least 1.4 times higher than reported, with the actual number likely to be even higher as data from more than 100 countries were not included in their database. A major difference between the estimates produced by Wang and those by *The Economist* and by Karlinsky and Kobak were the latter's exclusion of both India and Nigeria; both teams felt they lacked the data required to produce accurate estimates for these countries.

In addition to the above sources, the WHO produced their own estimates of the excess mortality associated with Covid-19. The WHO had been tracking global excess mortality as the pandemic had evolved and published a set of figures showing excess mortality, by country and globally, for the period 1 January 2020 to 31 December 2021[14]. Unlike the other figures on excess deaths, the WHO released a set of preliminary figures broken down by age and sex. The research team built models using data from countries with national monthly data to predict all-cause mortality in countries where these data were unavailable[15]. Additional modelling was used in countries where only sub-national data were available to model regional values, based on the assumptions that the distribution of deaths across regions remained constant over time. The final models indicate that global excess mortality in the period January 2020 - December 2021 was 14.9 million (with a 95% credibility interval of 13.3-16.6 million). The estimated excess deaths were, on average, 2.75 times higher than the number of reported Covid-19 deaths reported globally over this period.

The WHO included both India and Nigeria in their estimation, although some issues have been flagged

13 https://www.economist.com/graphic-detail/coronavirus-excess-deaths-tracker Detail about the modelling can be found here: https://github.com/TheEconomist/covid-19-the-economist-global-excess-deaths-model (both accessed 23 June 2022)
14 https://www.who.int/data/stories/global-excess-deaths-associated-with-covid-19-january-2020-december-2021 (accessed 23 June 2022)
15 More details on the modelling can be found here: https://www.who.int/publications/m/item/methods-for-estimating-the-excess-mortality-associatedwith-the-covid-19-pandemic (accessed 23 June 2022)

regarding the data in India[16].

These WHO excess deaths were used in the estimation to give an alternative, non-conservative estimate of Covid-19 deaths for foreign-born health workers in each of the trial countries. The availability of preliminary figures broken down by age and sex meant the WHO figures could be used in an age-sex standardised estimate, making these estimates preferable to those produced by other sources. The figures used are presented in Table 2 below.

Table 2 WHO figures for excess deaths for 2020 and 2021 for the four trial countries

	India	Mexico	Nigeria	UK
Female, 0-14 years	0	-1,117	0	44
Female, 15- 25 years	0	-745	0	30
Female, 25-44 years	85,485	18,931	1,660	1,888
Female, 45-54 years	186,233	29,397	10,348	3,285
Female, 55-64 years	411,640	49,477	21,520	6,549
Female, 65-69 years	273,293	29,809	14,036	4,370
Female, 70 years or more	1,069,762	101,515	33,216	43,462
Male, 0-14 years	0	-1,484	0	326
Male, 15-25 years	0	-990	0	217
Male, 25-44 years	121,429	39,237	-974	3,783
Male, 45-54 years	295,226	60,412	14,181	6,966
Male, 55-64 years	594,975	91,743	28,611	13,775
Male, 65-69 years	379,524	52,403	17,914	8,701
Male, 70 years or more	1,323,326	157,633	45,923	55,501
Total excess deaths	**4,740,891**	**626,219**	**186,434**	**148,896**

Source: WHO Excess deaths for 2020 and 2021. Note: for an explanation of minus values, see below.

The minus values correspond to age groups where the excess deaths were lower than expected. The impact of lockdowns and Covid-19 restrictions reduced the death rates from other causes for groups that were less likely to suffer high rates of Covid-19 mortality. In the estimation, the total number of excess deaths for these groups is set to zero in order to redistribute the total number of excess deaths by age and therefore calculate age-specific crude mortality rates.

Whilst all estimates of excess deaths contain uncertainty, this uncertainty increases substantially

16 Technical notes for India: "These estimates may not be regarded as the national statistics officially produced by India due to differences arising from the data and methods used by WHO. The information from the Civil Registration System in India for 2020 was made publicly available by the Registrar General of India on 3 May 2022 in a report at: https://crsorgi.gov.in/annual-report.html. The newly published information in the report is being carefully examined and will be taken into consideration in revisions of the estimates." See https://www.who.int/data/stories/global-excess-deaths-associated-with-covid-19-january-2020-december-2021 (accessed 23 June 2022)

where the source data are poor. According to the vital statistics performance index (Phillips et al., 2014), the mortality data produced by India and Nigeria is in general less robust because a lower proportion of deaths in these countries are registered. For instance, it is estimated that only 10% of deaths in Nigeria are formally reported (Makinde et al., 2020). It can be seen from Tables 1 and 2 that the excess deaths in these countries are much higher than the reported estimates, unlike the UK, which has a high vital statistics performance index and where the reported and excess deaths are of a similar magnitude. The large discrepancies between the reported deaths and estimated excess deaths in both Nigeria and India are likely in part due to genuine under-reporting of confirmed Covid-19 deaths. However, the lack of high-quality data on which to base statistical models means that there is also greater uncertainty about the accuracy of any estimates produced.

Information on the data cleaning process for the mortality figures is given in Appendix H.

e. Population estimates

The final input for the estimates was information on the overall population of each country. A set of figures broken down by age and sex was also required for the age-sex standardised estimates. These figures are available from the World Bank[17] and updated annually for most countries. The published age bands were combined to make them consistent with the age bands used by the NHWA and ILO. Population estimates from 2020 were used in the estimation as these were the closest to the time period covered by the pandemic. These estimate the total population in India to be 1,380,004,385, in Mexico to be 128,932,753, in Nigeria to be 206,139,587, and the UK to be 67,081,000. Population estimates for the four trial countries broken down by age and sex are given in Appendix C.

17 https://databank.worldbank.org/source/population-estimates-and-projections (accessed 05 July 2022)

Section 3 Estimating the number of Covid-19 deaths among foreign-born health workers

This section describes how the number of Covid-19 deaths among foreign-born health workers was estimated. Two main approaches were considered: an estimate based on overall death rates (the 'basic estimate'), and an estimate based on deaths standardised by age and sex.

3.1 THE BASIC ESTIMATE

The 'basic estimate' is basic because it uses only three pieces of information to generate an estimate of the number of Covid-19 deaths for foreign-born health workers. These are: the overall population estimate, the overall number of Covid-19 deaths, and the overall number of foreign-born health workers. This latter input was based on the reported number of health workers and the reported (or imputed, where the reported figure is missing) proportion of foreign-born health workers.

The first step was to calculate a crude mortality rate based on the total reported number of Covid-19 deaths divided by that country's population. These are shown in Table 3. Hence for India the figure was 481,080 divided by 1,380,004,385 then multiplied by 100 to get 0.035%. Mexico has the highest crude mortality rate for reported Covid-19 deaths of the four trial countries at 0.24%. Nigeria has the lowest at 0.001%. The reported death rate from Covid-19 in Mexico was therefore 160 times higher than the death rate in Nigeria.

Table 3 Crude Mortality Rates for reported Covid-19 deaths for the four trial countries

	Total population	Total reported deaths	CMR for reported deaths
India	1,380,004,385	481,080	0.035%
Mexico	128,932,753	303,408	0.235%
Nigeria	206,139,587	3,030	0.001%
UK	67,081,000	149,790	0.223%

Sources: The population estimates are taken from the World Bank (2020). Covid-19 deaths are the total number of deaths reported to the WHO up to 31 December 2021.

The second step was to estimate the number of foreign-born health workers by multiplying the proportion of foreign-born workers by the total number of health workers for specific health worker groups (these figures are shown in Appendix Table B.4).

The final step was to multiply the crude mortality rate with the number of foreign-born health workers. As a comparison, the crude mortality rate was also applied to the total number of health workers in each group to get the estimated total number of health worker deaths. Table 4 contains basic estimates for reported Covid-19 deaths of foreign-born doctors, nurses, midwives, and workers in the health sector for each of the four trial countries.

Table 4 Basic estimates of reported Covid-19 deaths for foreign-born health workers and all health workers for the period up to 31 December 2021

	Covid-19 deaths for foreign-born workers per health care group				Total Covid-19 deaths per health care group			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
India	1	7	0	11	354	841	293	2,049
Mexico	8	16	0	57	728	848	0	3,779
Nigeria	0	0	0	0	1	3	2	17
UK	132	222	6	2,273	455	1,269	73	10,193

Among the four trial countries, the number of estimated foreign-born workers in the human health and social work sector who died from Covid-19, based on Covid-19 deaths reported to the WHO, is highest in the UK at 2,273 deaths, with a 95% credibility interval (CI) of 1,986 to 2,579 (more information about credibility intervals and intervals for all estimates is given in Appendix G). This is followed by Mexico (57 deaths, CI: 31-85), India (11, CI: 4-18) and Nigeria (0, CI: 0-0). These differences are reflected within each of the health worker groups, for example, the number of Covid-19 deaths among foreign-born doctors, nurses and midwives are each highest in the UK. There are no recorded Mexican midwife deaths due to the low reported number of midwives with formal qualifications in NHWA (33 in total).

The UK also has the highest number of estimated Covid-19 deaths for health workers overall at 10,193 (CI: 9,670-10,717), compared to 2,049 (CI: 1,941-2,156) in India, 3,779 (CI: 3,670-3,888) in Mexico and 17 (CI: 14-21) in Nigeria, again shown in Table 4.

The disparities in deaths occur for a number of reasons. A key factor is differences in the level of reporting of Covid-19 deaths. The low number in some countries is likely caused by under-reporting rather than low actual deaths. The administrative capacity of the trial countries varies widely, as did their ability to test for Covid-19, and as a result there were inconsistencies in the rigour with which Covid-19 deaths were recorded and registered, leading to some degree of under-reporting. This is reflected in the crude mortality rates for each country, shown in Table 3 above.

These differences are exacerbated by differences in the size and composition of the health workforce. Whilst India has the largest health workforce of the four trial countries in absolute terms, the UK health workforce is proportionally large when compared to the size of the UK population (as an illustration, the size of the UK human health and social work sector corresponds to 6.8% of the UK total population, the figure for Mexico is 1.3%, for India is 0.4% and Nigeria is 0.6%). The UK also has a higher proportion of health workers who are foreign-born, as reflected in a larger proportion of the deaths among health workers. Of the four trial countries, the UK is the only country that is a major recruiter of health workers, which has a major impact of the composition of health workforce relevant to this study. As discussed in the Introduction, it is not clear whether the increased presence of foreign-born workers in the UK health system acts as an additional risk or a protective factor.

A second set of estimates was generated using estimates of excess deaths due to Covid-19 to avoid some of the differences between countries in reporting Covid-19 deaths. These estimates followed the same approach as before, but the crude mortality rate was based on the estimated number of excess deaths due to Covid-19 rather than the number officially reported to the WHO.

Table 5 Crude mortality rates for excess Covid-19 deaths for the four trial countries

	Total population	Total excess deaths	Crude mortality rate for excess deaths
India	1,380,004,385	4,740,891	0.34%
Mexico	128,932,753	626,219	0.49%
Nigeria	206,139,587	186,434	0.09%
UK	67,081,000	148,896	0.22%

Sources: The population estimates are taken from the World Bank (2020). Total estimated excess Covid-19 deaths for 2020 and 2021 are taken from the WHO

The crude mortality rate for excess deaths is higher than the crude mortality rate for reported deaths as the number of excess deaths generally exceeds the number of reported deaths in each trial country. The crude mortality rate based on excess deaths was 0.49% in India, 0.34% in Mexico, 0.22% in UK (unchanged) and 0.09% in Nigeria. The estimated excess number of Covid-19 deaths among foreign-born health workers based on these revised crude mortality rates are given in Table 6 below.

Table 6 Basic estimates of excess Covid-19 deaths for foreign-born health workers and all health workers for the period up to 31 December 2021

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
India	10	66	1	106	3,485	8,288	2,890	20,189
Mexico	17	33	0	119	1,503	1,750	0	7,799
Nigeria	3	1	0	13	67	163	109	1,073
UK	131	221	5	2,260	453	1,261	73	10,133

The estimated number of excess deaths due to Covid-19 is higher than the number of reported Covid-19 deaths for India, Mexico and Nigeria. The estimated number of deaths among foreign-born health workers for these countries is higher as a result. For the UK, the number of reported and estimated excess Covid-19 deaths is very similar.

The UK again has the highest number of estimated Covid-19 deaths for foreign-born workers in the human health and social work sector at 2,260 (CI: 1,837-2,659), followed by Mexico (119, CI: 64-174), India (106, CI: 33-224) and Nigeria (13, CI: 0-42). However, when using excess deaths, India now has the highest number of Covid-19 deaths among health workers overall at 20,189 (CI: 13,987-27,503), compared to 10,103 (CI: 8,947-11,047) in the UK, 7,779 (CI: 7,579-7,932) in Mexico and 1,073 (CI: 12-2,230) in Nigeria. This is because the crude mortality rates in India and Mexico using estimated excess deaths are higher than when reported deaths are used. Hence India, which has the largest health workforce of the four trial countries, has the highest number of Covid-19 deaths among health workers, whilst the UK, which has the largest number of foreign-born health workers, has the highest number of deaths for foreign-born workers.

It should be noted that these basic estimates over-estimate the number of Covid-19 deaths among foreign-born health workers (and health workers generally). This over-estimation occurs as the crude mortality rate includes deaths for individuals aged 70 years and over - an age group which made up the bulk of Covid-19 deaths but is not well-represented in the working-age population of health workers. The crude death rate used in the estimate is therefore higher than the death rate for the working age population is expected to be. The estimate was subsequently improved by including information on age and sex. The basic estimate should therefore only be used when input information by age and sex is not available.

In order to demonstrate the steps required to make the calculation, the basic estimate for doctors using data from Mexico is reproduced in Appendix D.

3.2 THE AGE-SEX STANDARDISED ESTIMATE

The age-sex standardised estimate uses the same approach as the basic estimate (applying a crude mortality rate to the number of health care workers) but does so within age and sex sub-groups. This addresses the fact that the working age population will have a lower mortality rate than the overall population, resulting in a more accurate estimate. It also accounts for the age and sex profile of different health occupations (nurses and midwives tend to be female, doctors are more likely to be male, and the gender profile of Covid-19 deaths under the age-sex standardised estimate reflects this whilst also accounting for the fact men were more likely to die from Covid-19). As before, two estimates were calculated, one using reported Covid-19 death rates and a second using estimated excess deaths.

Table 7 contains the age-sex standardised estimates for reported Covid-19 deaths for foreign-born doctors, nurses, midwives, and workers in the health care sector, for each of the four trial countries. The table contains the overall numbers. The numbers of reported Covid-19 deaths for foreign-born health workers by age and sex are given in Appendix E.

Table 7 Age-sex standardised estimates of reported Covid-19 deaths for foreign-born health workers and all health workers for the period up to 31 December 2021

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
India	1	3	0	8	375	334	184	1,532
Mexico	11	14	0	56	1,012	725	0	3,711
Nigeria	0	0	0	0	2	4	2	34
UK	28	48	1	511	95	276	12	2,293

The estimated number of deaths is lower than for the basic estimates as the crude mortality rates excluded people aged 70 and over, which is where a high proportion of Covid-19 deaths occurred in the general population.

As with the basic estimates, the number of Covid-19 deaths among foreign-born health workers is highest in the UK with 511 (CI: 447, 580) deaths, compared to 56 (CI: 30, 84) in Mexico, 8 (CI: 3, 13) in India and none (CI: 0, 1) in Nigeria. Again, this pattern is true for all groups of health workers; for each group of health workers the estimated number of reported Covid-19 deaths of foreign-born health workers is highest in the UK. This is due to the UK having a higher proportion of health workers who are foreign-born.

The estimated number of Covid-19 deaths for overall health workers is highest in Mexico (the basic estimate of reported Covid-19 deaths among all health workers was highest in the UK). The reported Covid-19 deaths in the UK were more heavily skewed by age than those in Mexico. When the deaths for individuals aged 70 years and over are removed, the crude mortality rates in each of the remaining

age groups in the UK were lower than the corresponding rates in Mexico, leading to lower estimated deaths in the UK (these age-specific crude mortality rates are shown in Table E.1 in Appendix E).

The age-sex standardised estimates also have the advantage of providing estimates of Covid-19 deaths for health workers, both foreign-born and overall health workers, by age and gender. These estimates indicate more male health workers than female died of Covid-19 in India, Nigeria and Mexico, whereas the reverse is true in the UK (with the exception of UK doctors, who constitute a male-dominated profession in the UK). This reflects the age/sex structure of the health workforce in these countries (men make up 26% of human health and social work sector in UK, compared to 48% in India, 35% in Mexico and 46% in Nigeria) and the fact that men are more likely to die from Covid-19. These figures are given in Appendix E.

As before, the estimation is repeated using the estimated number of excess Covid-19 deaths in place of the reported estimates. The number of estimated excess Covid-19 deaths among foreign-born health workers and all health workers for the same time period is shown in Table 8 below. The crude mortality rates using estimated excess deaths by age and sex for the four trial countries are given in Appendix E.

Table 8 Age-sex standardised estimates of reported Covid-19 deaths for foreign-born health workers and all health workers for the period up to 31 December 2021

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
India	9	22	0	66	3,002	2,784	1,524	12,494
Mexico	22	25	0	106	1,957	1,310	0	6,984
Nigeria	4	2	0	24	85	268	172	1,903
UK	51	78	1	849	174	445	19	3,809

The estimated number of excess Covid-19 deaths for foreign-born health workers is highest in the UK with 849 (CI: 691-999) deaths in the overall human health and social work sector, compared to 106 (CI: 57-156) in Mexico, 66 (CI: 21 -139) in India and 24 (CI: 0-75) in Nigeria. This same pattern is seen within each health occupation – the number of deaths is highest for UK foreign-born doctors, nurses, and midwives.

Whilst the UK basic estimates using reported deaths were very similar to the UK basic estimates using excess deaths, this is not true for the age-sex standardised estimates. The age-sex standardised estimate using excess deaths is notably higher than the age-sex standardised estimate using excess deaths (the excess Covid-19 deaths estimate for foreign-born workers in the human health and social work sector is 849, whereas the corresponding reported estimate is 511). This is due to the age-sex distribution of the excess deaths being 'younger'; the excess deaths have a higher proportion of the deaths distributed among the younger age groups. This increases the crude mortality rate among the working age population.

The estimated number of Covid-19 deaths among foreign-born health workers in Mexico has doubled, whilst those in India are eight times higher and those in Nigeria over fifty times higher. This reflects the relative differences between reported and estimated excess deaths from Covid-19 for the overall populations of 15-69-year-olds in these countries.

The sex split seen above is still in evidence when using the estimated excess deaths; with a higher death toll among male health workers in India, Mexico and Nigeria, and for doctors in the UK. This can be seen in Appendix E.

By way of demonstration, the calculation used to produce the estimates for doctors is again reproduced in Appendix F using data from Mexico.

3.3 VALIDATING THE ESTIMATES

Some external data was sought with which to validate the estimates of foreign-born health workers. Whilst it was not possible to find figures specific to foreign-born health workers, some figures are available for health workers more generally that could be used as a check for the methodology.

The ONS-produced figures on the number of deaths registered between 9 March 2020 and 28 February 2022 among health and social care workers (those aged 20 to 64 years) that involved Covid-19[18] were available for England and Wales only. They showed that there were 2,129 deaths registered in this period in total for workers in health and social care. 710 of these were male and 1,419 were female. The UK age-sex standardised estimates of Covid-19 deaths in the period up to 31 December 2021 among all workers in the human health and social work sector was 2,293, with 790 of those deaths male and 1,503 female. Whilst there are differences in the scope of these two estimates (the time periods are different and the ONS figures exclude Scotland and Northern Ireland), the similarities between the two sets of figures are reassuring, particularly regarding the gender split.

No other suitable data were available for validating the estimates.

18 https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/14379deathsinvolvingcoronaviruscovid19amonghealthandsocialcareworkersthoseaged20to64yearsenglandandwalesdeathsregistered9march2020to28february2022 (accessed 14 July 2022)

Section 4 Discussion and future data requirements

This section contains a discussion of the pros and cons of the different approaches considered for the estimation and a discussion of the completeness and format of the data available, including what additional data sources would be required to improve the estimates.

4.1 DISCUSSION OF APPROACH TAKEN

The primary purpose of this analysis was to assess the data availability to generate estimates of the number of Covid-19 deaths among foreign-born health workers, to identify methods that could be used to generate estimates based on the available data, and to trial the methodology on four countries.

The aim was to identify an approach or set of approaches that could be applied across the four trial countries in a relatively uniform manner. The selected approaches could then be applied with some confidence to countries other than the four trial countries. The alternative, to create bespoke approaches for each of the different trial countries based on the national data available, would have had less application beyond the four trial countries. After due consideration, a compromise of these aims was reached, where the method of calculation was standardised for all countries, but the source of input data required to make the calculation varied according to availability.

Two approaches were identified: a basic approach and an age-sex standardised approach. The basic estimate is based on a crude mortality rate generated from the total number of Covid-19 deaths. It has the advantage of being simple to calculate as it requires less input information: the total number of Covid-19 deaths, the total population, and the total number of foreign-born health workers. The disadvantage of the basic estimate is that it includes deaths for individuals aged 70 years old and over in the calculation. This age group makes up the bulk of Covid-19 deaths but is generally outside the working age population. The crude death rate used in the estimate is therefore higher than the expected death rate for the working age population.

The age-sex standardised estimates are an improvement on the basic estimates. They address the fact that the working age population will have a lower mortality rate than the overall population and differences in mortality rates by sex. However, the necessary data on Covid-19 deaths, figures on foreign-born health workers, and population counts disaggregated by age and sex is collected less routinely and is not always available. This improved approach is therefore not an option for all countries.

4.2 FLAWS OF THE AGE-SEX STANDARDISED APPROACH

Whilst the age-sex standardised estimate is an improvement on the basic estimate, it still has flaws. It was not possible to obtain global data on the age and gender profile of foreign-born health workers. Some evidence from the UK suggests foreign-born health workers have a different age profile to

UK-born health workers[19], however, this will vary by country. In light of these circumstances, the team had to assume the age and sex profile of foreign-born health workers was the same as all health workers.

There were also issues around the availability of disaggregated data on deaths. A lack of formal information meant alternative sources were sought. For example, the profile for Nigeria was based on an academic study with a small sample size. Estimates based on small sample sizes are less robust and may be biased. In addition, any systematic differences in the collection of age and sex (for instance, if age and sex are more likely to be collected for deaths in specific circumstances, such as care homes or hospitals) may cause bias and result in the profile of reported deaths being skewed. This may be more likely if the data come from an unofficial source.

The estimates use the proportion of foreign-born health workers as an input. As a consequence, the proportion of estimated deaths among health workers that is attributable to foreign-born health workers is the same as the proportion of health workers who are foreign-born, since the latter was used to estimate the former. The estimates therefore assume foreign-born health workers have the same risk of death as other health workers, who have the same risk of death as the general population. The estimates also assume the same risk is experienced by different occupations within the health sector even though it is unlikely that the risks faced will in practice be equal[20]. There is some evidence, such as the small-scale studies by Dinakarpandian et al. (2021) and Kursumovic et al. (2020), that Covid-19 deaths of foreign-born health workers are over-represented among those of the health workforce. However, these disproportionate risks could not be factored into our estimation because the data required to include them was not available. Country-level data that quantified the relative differences (i.e. showed *how much* larger the risk was for the different groups) would be needed to adjust the estimate.

In short, there are a number of differences in the risks faced by foreign-born health workers, other health workers, and the wider population. These variations in risk are complex and intertwined – and they are not yet well understood. Without having the data to be able to unpick the impacts of different risk factors, it is not possible to make adjustments to the expected mortality rates. The result is a default to using crude mortality rates for the estimates.

4.3 ESTIMATING THE NUMBER OF FOREIGN-BORN HEALTH WORKERS

The estimates rely on data about the number of foreign-born health workers. This piece of information was a key input when estimating the number of Covid-19 deaths among foreign-born health workers. This information was difficult to source outside the NHWA, particularly for countries with low rates of foreign-born workers. Whilst the UK was missing data on the NHWA, alternative robust national-level data were available. In the absence of this data, the missing information was predicted using a statistical model.

There is potential to improve this estimate, through trying different approaches to the modelling. Time constraints meant only one approach (regression analysis using a generalised linear model) was tried. Other methods may produce more accurate estimates. A wider set of countries could also be included in the trial – these countries could be selected specifically due to the availability of national-level data that could be used to validate the estimates. Time constraints of this project meant this could not be attempted outside the four trial countries.

19 Figures from the Office for National Statistics Annual Population Survey (3-year pooled dataset 2016-18) shows that UK-born health workers are more likely to be at both the younger and older end of the age distribution, with a third of foreign-born health workers aged 35-44 years, compared to 23% of UK-born health workers.

20 Some data suggest doctors have a lower risk than nurses. See Roblez-Perez et al. (2021).

4.4 ALTERNATIVE APPROACHES

In its Working Paper examining the impact of Covid-19 on health and care workers (WHO, 2021), the WHO used data on infection rates to produce an estimate of the number of Covid-19 related deaths in the health and social care sector. A similar approach in this project was ruled out due to data considerations. Data on infection rates rely on testing and are impacted by the availability of testing, government policies around testing (both among health workers and in the general population), how those tests were recorded, and the type of tests used. These differences in testing approaches makes the relationship between infections and death rates less consistent – a stricter testing regime would make the death rate look lower, since a larger proportion of less serious cases would be identified. The opposite – only testing cases in specific settings, such as hospitals, where cases are more severe – makes the death rate of Covid-19 cases appear higher. This means it is difficult to convert the number of infections within a country to potential deaths. Information on infection rates tends to be released at country-level and cover the general population, meaning infection and death rates are skewed by the inclusion of older, more vulnerable groups that would not form part of the health workforce.

The relationship is further complicated by some strains of Covid-19 being more deadly than others, and by differences in the availability and uptake of vaccinations, as well as in the availability of that information for health workers. Vaccination programmes were generally rolled out to older, more vulnerable groups first, meaning figures on overall vaccination rates are not a good indication of vaccination rates among health workers generally, even less for foreign-born health workers. This means information on the probability of infection and death among the immunised population cannot be readily applied to the younger, generally less vulnerable, health workforce.

This lack of data is also the reason why methods used by various teams to estimate excess mortality due to Covid-19 cannot at this point be replicated and used to estimate deaths among foreign-born health workers (or indeed, all health workers). There are differences in the approaches used by different teams, but they all rely on estimating actual and excess mortality, using trend data for infections, deaths and vaccination rates to generate estimates by building models using weekly or monthly data. Such data are available at population level at best, but not for health workers or for the foreign-born population. As a result, the chosen approach was to use the final, published estimates of excess deaths (by age and sex) and calculate what proportion of those deaths were foreign-born health workers, rather than estimate the proportion of foreign-born health workers' actual and excess deaths at the earlier, modelling stage. There was little benefit to doing so as, unlike the information on infections and deaths, the proportion of foreign-born health workers in the population was not updated regularly.

4.5 DISCUSSION OF DATA FORMATS AND DATA RECOMMENDATIONS FOR THE FUTURE

There were some data issues that made the analysis far less straightforward than it initially appeared. These include the use of standard country code across global datasets, the age breaks used to present data, and the format in which the data exists. Specifically:

- ISO standards exist for country codes, but these are not used consistently. There are three separate ISO standards: two letter, three letter, country number. The three-letter codes are the most recent version. The team identified inconsistencies even between the two WHO dashboards and recommend that databases of international data should use the three-letter code.

- No standard 'buckets' exist for age. The age bands used to present figures on Covid-19 deaths are different from those used to present figures on health care workers. This meant some manipulation was needed to make the two sets of information more comparable.

- Care needs to be taken with the programmes used to store data as errors can easily be introduced. For example, programmes may interpret 6-10 as 10 June or 6 October, rather than an age range as intended in this data. This issue needs to be flagged to data users.

- Comma-separated value (CSV) formats with raw data should ideally be available.

- Raw CSVs should be produced in long formats, where each row represents a complete data set for one entry. The UK's ONS tends to have multiple tables split over tabs in Excel, making it less easy to process with programmes such as R or Stata.

The WHO has advocated a standardised measurement and reporting of the range and severity of impacts not just by sector, but by occupation for both health and care workforces (WHO, 2021: 3). We strongly concur with this recommendation. However, it does not go far enough. There is a fundamental need for better data to guide effective policy and practice and improve working conditions of all of the health workforce. Additionally, then, this research highlights the need for:

- Better data on the health workforce that enables disaggregation by sex, age, ethnicity, occupation, migration status, country of origin, health status (such as the presence of co-morbidities; also, vaccinations) and whether employed in delivering public or private health care. This would help identify and quantify different levels of relative risk among health workforces and between countries.

- Better data systems with greater capacity for collecting and analysing disaggregated data. Crucially, this includes increased capacity to encourage better reporting from health facilities (e.g. a centralised database for reporting) and from workers, their families and/or their representatives (e.g. an online confidential reporting tool).

- Further studies into the risks of death experienced by foreign-born health workers. Where suitable administrative data are not available, this could involve surveying a selection of health institutions, designed to act as a representative cross-section of health workplaces within each country, and collecting information on the number of deaths – overall and from Covid-19 – of all health workers along with information on their migrant status, health status, age, sex and occupation and whether they are involved in public or private health care services delivery.

- Further studies of Covid-19 deaths (and other impacts) among foreign-trained and -born health workers. Our study has focused on foreign-born health workers, and developing a methodology for estimating the number of Covid-19 deaths among this population. It has been vital to look at a small number of countries in the first instance, but there is significant scope to scale-up this research to encompass many more countries and increase the comparative content. Our research suggests there is some overlap between countries that are high recipients of foreign-born health workers and countries with better data availability, specifically those with data that is available disaggregated by age and sex. There would be some merit in generating a 'near' global estimate of deaths of foreign-born health workers by generating age-sex estimates for all countries with data available, since this will include the bulk of countries that recruit large numbers of health workers, and therefore include the bulk of foreign-born health workers.

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APPENDICES

APPENDIX A COUNTS OF HEALTH WORKERS FOR THE FOUR TRIAL COUNTRIES

Table A.1 Data on health workers in India from the NHWA and ILO

	Doctors[1]	Nurses[1]	Midwives[1]	Human Health and Social Work Sector[2]
Total	**1,0145,38**	**2,412,621**	**841,279**	**5,876,718**
Female, less than 25 years	0.5%	12.0%	1.9%	7.1%
Female, 25-44 years	8.5%	57.7%	43.1%	32.0%
Female, 45-54 years	3.2%	14.8%	24.6%	10.4%
Female, 55-64 years	1.4%	2.6%	3.5%	2.7%
Female, 65 years or more	0.6%	1.0%	0.8%	0.3%
Male, less than 25 years	2.9%	1.6%	0.7%	4.8%
Male, 25-44 years	51.6%	7.8%	15.2%	25.8%
Male, 45-54 years	19.2%	2.0%	8.7%	9.7%
Male, 55-64 years	8.7%	0.4%	1.2%	5.3%
Male, 65 years or more	3.4%	0.1%	0.3%	1.9%
Female, less than 25 years	4,898	289,360	16,164	414,511
Female, 25-44 years	86,583	1,391,481	362,454	1,881,787
Female, 45-54 years	32,270	357,445	207,028	610,123
Female, 55-64 years	14,551	63,830	29,220	159,440
Female, 65 years or more	5,763	23,404	6,839	15,559
Male, less than 25 years	29,596	39,085	5,709	281,946
Male, 25-44 years	523,155	187,953	128,012	1,517,208
Male, 45-54 years	194,986	48,281	73,118	572,056
Male, 55-64 years	87,918	8,622	10,320	310,515
Male, 65 years or more	34,819	3,161	2,415	113,573

1.Taken from NHWA. Totals for doctors and nurses from 2020. Totals for midwives from 2017. Age distribution for nurses and midwives from 2004. Age distribution for doctors from 2009.
2.Totals are based on ILO actual estimates (2020) for ISIC sector Q (Human Health and Social Work Activities). ILO provides age/sex distributions for these figures but does not split the 25-54 age band. This has been split using the weighted average from NHWATable A.2 Data on health workers in Mexico from the NHWA and ILO.

Table A.2 Data on health workers in Mexico from the NHWA and ILO

	Doctors[1]	Nurses[1]	Midwives[1]	Human Health and Social Work Sector[2]
Total	**309,414**	**360,210**	**33**	**1,605,748**
Female, less than 25 years	0.0%	1.6%	0.0%	6.3%
Female, 25-44 years	22.6%	47.5%	97.0%	34.4%
Female, 45-54 years	9.9%	22.5%	0.0%	15.9%
Female, 55-64 years	10.0%	10.8%	3.0%	7.1%
Female, 65 years or more	1.5%	2.5%	0.0%	1.3%
Male, less than 25 years	0.0%	0.3%	0.0%	3.0%
Male, 25-44 years	28.9%	8.4%	0.0%	17.0%
Male, 45-54 years	12.6%	4.0%	0.0%	7.6%
Male, 55-64 years	12.7%	1.9%	0.0%	5.2%
Male, 65 years or more	1.9%	0.5%	0.0%	2.0%
Female, less than 25 years	0	5,811	0	100,789
Female, 25-44 years	69,884	170,952	32	552,802
Female, 45-54 years	30,532	81,042	0	256,066
Female, 55-64 years	30,803	38,839	1	114,375
Female, 65 years or more	4,614	9,175	0	21,467
Male, less than 25 years	0	1,033	0	48,821
Male, 25-44 years	89,305	30,405	0	273,411
Male, 45-54 years	39,017	14,414	0	122,033
Male, 55-64 years	39,364	6,908	0	84,171
Male, 65 years or more	5,896	1,632	0	31,814

1.Taken from NHWA. Totals for 2019. Doctor's age distribution for 2017, nurse age distribution for 2019 and midwife age distributions for 2010. Figures for midwives include those with formal qualifications only.
2.Totals are based on ILO actual estimates (2021) for ISIC sector Q (Human Health and Social Work Activities). ILO provides age/sex distributions for these figures but does not split the 25-54 age band. This has been split using the weighted average from NHWA.

Table A.3 Data on health workers in Nigeria from the NHWA and ILO

	Doctors[1]	Nurses[1]	Midwives[1]	Human Health and Social Work Sector[2]
Total	**74,543**	**180,709**	**120,870**	**1,185,924**
Female, less than 25 years	0.5%	1.6%	1.8%	6.4%
Female, 25-44 years	43.1%	52.6%	60.4%	33.0%
Female, 45-54 years	16.0%	15.7%	18.0%	10.4%
Female, 55-64 years	3.9%	15.4%	17.6%	4.0%
Female, 65 years or more	2.0%	1.9%	2.2%	0.4%
Male, less than 25 years	0.2%	0.2%	0.0%	2.2%
Male, 25-44 years	22.8%	7.7%	0.0%	25.8%
Male, 45-54 years	8.4%	2.3%	0.0%	8.7%
Male, 55-64 years	2.1%	2.3%	0.0%	4.2%
Male, 65 years or more	1.0%	0.3%	0.0%	4.9%
Female, less than 25 years	341	2,839	2,178	75,636
Female, 25-44 years	32,127	95,115	72,958	391,291
Female, 45-54 years	11,895	28,392	21,778	123,892
Female, 55-64 years	2,925	27,762	21,294	47,673
Female, 65 years or more	1,463	3,470	2,662	4,365
Male, less than 25 years	181	417	0	26,346
Male, 25-44 years	16,997	13,962	0	305,863
Male, 45-54 years	6,293	4,168	0	103,351
Male, 55-64 years	1,548	4,075	0	49,710
Male, 65 years or more	774	509	0	57,797

1. Taken from NHWA. Totals for doctors are 2018. Totals for nurses and midwives 2019. Doctor and nurse age distribution for 2013. Midwives in NHWA are all female but age distribution is missing: have assumed age distribution is the same as nurses.
2. Totals are based on ILO actual estimates (2019) for ISIC sector Q (Human Health and Social Work Activities). ILO provides age/sex distributions for these figures but does not split the 25-54 age band. This has been split using the weighted average for doctors, nurses and midwives from NHWA (2013 for doctors and nurses; midwives assumed to be all female with same age distribution as nurses).

Table A.4 Data on health workers in the UK from the NHWA and ILO

	Doctors[1]	Nurses[1]	Midwives[1]	Human Health and Social Work Sector[2]
Total	**203,907**	**568,158**	**32,839**	**4,564,990**
Female, less than 25 years	0.0%	2.8%	5.9%	5.3%
Female, 25-44 years	30.8%	39.6%	51.9%	34.7%
Female, 45-54 years	11.2%	25.4%	23.7%	19.3%
Female, 55-64 years	6.0%	18.4%	16.8%	15.3%
Female, 65 years or more	1.0%	2.3%	1.3%	2.2%
Male, less than 25 years	0.0%	0.4%	0.0%	1.2%
Male, 25-44 years	32.0%	5.1%	0.2%	11.6%
Male, 45-54 years	11.7%	3.3%	0.1%	5.4%
Male, 55-64 years	6.2%	2.4%	0.1%	4.2%
Male, 65 years or more	1.1%	0.3%	0.0%	0.9%
Female, less than 25 years	0	16,125	1,932	240,048
Female, 25-44 years	62,746	225,240	17,058	1,583,618
Female, 45-54 years	22,880	144,113	7,792	881,209
Female, 55-64 years	12,190	104,810	5,533	697,861
Female, 65 years or more	2,098	13,101	426	98,583
Male, less than 25 years	0	2,075	6	53,627
Male, 25-44 years	65,307	28,981	51	527,351
Male, 45-54 years	23,814	18,543	23	247,435
Male, 55-64 years	12,687	13,486	17	193,019
Male, 65 years or more	2,184	1,686	1	42,239

1. Taken from NHWA. Totals for 2020. Doctor's age distribution for 2020. Nurse and midwife age distributions for 2019.
2. Totals are based on ILO modelled estimates (2019) for ISIC sector Q (Human Health and Social Work Activities). Age distribution is taken from annual population surveys; 2019.

APPENDIX B IMPUTING MISSING INFORMATION ON THE PROPORTION OF FOREIGN-BORN HEALTH WORKERS IN A COUNTRY

The proportion of foreign-born doctors, nursing professionals, and midwives in the NHWA was missing for a number of countries (of 192 countries in the dataset, 62% were missing any information on the proportion of foreign-born doctors, 49% on nurses, and 72% on midwives).

An investigation was made into whether this missing information could be successfully imputed using a statistical model. A statistical model will create a relationship between various inputs and an outcome of interest. For example, in this case, the outcome of interest would be the proportion of foreign-born doctors, whereas inputs that might be connected to this number could be a country's gross domestic product (GDP) or net migration figures. As data on the proportion of foreign-born doctors were available for 48% of countries, the model was trained using these data to assess the most accurate way to predict the proportion of foreign-born doctors. This relationship between inputs and the outcome of interest was then used to make predictions for countries where the data is missing. A generalized linear model with a logit link and the binomial family was used to predict the missing data. This type of model is appropriate when the outcome variable (the characteristic being predicted) is a proportion (in this case, the proportion of foreign-born workers). It ensures the predicted values fall between zero (no foreign-born workers) and one (100% foreign-born workers), unlike other approaches that may allow values to be predicted that fall outside this range.

Three outcome variables were modelled: the proportion of foreign-born doctors; the proportion of foreign-born nurses; and the proportion of foreign-born midwives, with separate models (or sets of models) used to estimate each outcome.

A range of data from the World Bank, ILO and UN was used as predictor variables in the models. These include the country's GDP, the proportion of GDP spend on healthcare, population size, population growth, the proportion of the population aged 15 years and under, the proportion aged 65 years and over, the country's urban population, the country's value in the Human Development Index, net migration, proportion of the country's population living abroad as migrants, the proportion of working age population who were migrants, proportion of the working population working in the health care sector, and information on the number of doctors and nurses per 1000 people. A full list of the measures considered, and their sources, are given in Table B.9 below.

The models summarise the relationships between the various measures and the three outcome variables. This relationship is then used to predict the outcome for countries where the information about foreign-born health workers is missing. Whilst the primary aim of this analysis was to fill in information that was missing for the four selected countries, all 194 countries in the NHWA data were included in the modelling in order to build the best models and get the best understanding of the relationships between the different country measures and the outcome variables. The result is a dataset containing, for all countries, the reported proportions of foreign-born doctors, nurses and midwives, plus imputed values from the model.

In order to incorporate as much information as possible, more than one model was used to predict the proportion of foreign-born doctors and foreign-born nurses. The proportion of foreign-born doctors was estimated using two models. A model was run on those countries where there was information on foreign-trained doctors, since this measure was strongly predictive of the proportion of foreign-born doctors but was also missing for many countries. Hence where this information was available it was included in the model. A second model was run that excluded this measure, drawing on wider but less predictive information to estimate the proportion of foreign-born doctors. This

approach meant the fullest, most predictive information was used where available. A similar approach was taken for nurses, resulting in two models for the estimate of the proportion of foreign-born nurses. The high proportion of missing data for midwives meant a single model was used here: there was no benefit to running additional models. The estimated and actual figures were checked using the root mean square error (RMSE) to ensure predicted values were within an acceptable range. The RMSE checks the difference between the predicted value of the model and the actual value for countries where that figure is available. The closer the RMSE is to zero, the closer the model's predicted values are to the real figures of countries where that data is available. Given the large number of entry variables, the model outputs were checked for issues with co-linearity and inflated covariates.

Table B.1 Output from modelling the proportion of foreign-born doctors

	Model 1				Model 2			
	Coef.	Std Err.	Z-value	P-value	Coef.	Std Err.	Z-value	P-value
Proportion of migrant workers in overall workforce (ILO)	-3.71	0.46	-8.16	0.00	3.50	1.24	2.83	0.01
Proportion of Nurses+Docs+MW Foreign Trained	5.42	0.53	10.16	0.00				
Proportion of men aged 25-54 in the population who are migrants	0.11	0.01	8.98	0.00	0.08	0.02	4.50	0.00
Proportion of the population aged less than 15 years old	3.35	1.71	1.97	0.05				
Proportion of human health and social work sector employees who are female	2.57	0.58	4.40	0.00	-1.95	1.18	-1.65	0.10
Number of doctors per 1000 population	-0.09	0.06	-1.55	0.12				
GNI per capita Atlas method (current US$) 2019	0.00	0.00	-1.89	0.06				
Population growth (annual %) 2019					-0.45	0.22	-2.04	0.04
Population size (log)					0.35	0.15	2.25	0.02

	Model 1				Model 2			
	Coef.	Std Err.	Z-value	P-value	Coef.	Std Err.	Z-value	P-value
Urban population as a proportion of the total population 2020					-0.03	0.01	-2.17	0.03
High Income Country					5.44	1.73	3.15	0.00
Upper Middle Income Country					4.13	1.39	2.97	0.00
Lower Middle Income Country					1.48	0.87	1.71	0.09
Country density of forest (log)					-0.38	0.11	-3.52	0.00
Immunization measles (% of children ages 12-23 months) 2019					0.04	0.02	1.86	0.06
Ratio of nationals living abroad to number of foreign migrants in this couuntry					0.22	0.04	4.99	0.00
Female migrants as a % of migrant stock aged 25-54 years					-0.04	0.03	-1.32	0.19
Region: Europe+North America					-2.65	0.67	-3.98	0.00
Region: Latin America+Carib+Oceania					-0.36	0.45	-0.81	0.42
Region: Sub-Saharan Africa					3.94	0.87	4.53	0.00
Region: North Africa+Middle East					-1.79	0.51	-3.53	0.00
Region: Asia (baseline)					(baseline)			
Missing ILO information on foreign born workers					0.57	0.38	1.48	0.14
Current Health Expenditure (CHE) as % Gross Domestic Product (GDP) 2019					0.21	0.04	4.96	0.00

	Model 1				Model 2			
	Coef.	Std Err.	Z-value	P-value	Coef.	Std Err.	Z-value	P-value
Agriculture forestry and fishing value added (% of GDP) 2019					0.13	0.06	2.35	0.02
HDI 2019					7.08	3.61	1.96	0.05
Labor force female (% of total labor force) 2020					0.09	0.04	2.32	0.02
UN Proportions of in-migrants from the same sub-region					1.77	0.66	2.70	0.01
Constant	-5.53	0.80	-6.90	0.00	-19.20	5.25	-3.66	0.00
AIC	34.6				77.9			
BIC	46.6				125.6			
P-value overall	0				0			
Number of cases	33				54			

Table B.2 Output from modelling the proportion of foreign-born nurses

	Model 1				Model 2			
	Coef.	Std Err.	Z-value	P-value	Coef.	Std Err.	Z-value	P-value
Proportion of migrant workers in overall workforce (ILO)	-7.09	0.61	-11.68	0.00				
Proportion of Nurses+Docs+MW Foreign Trained	3.05	0.45	6.81	0.00				
Proportion of men aged 25-54 in the population who are migrants	0.13	0.01	10.77	0.00				

	Model 1				Model 2			
	Coef.	Std Err.	Z-value	P-value	Coef.	Std Err.	Z-value	P-value
Proportion of the population aged less than 15 years old	-4.88	2.37	-2.06	0.04				
Proportion of human health and social work sector employees who are female	5.50	0.59	9.26	0.00				
Number of doctors per 1000 population	0.15	0.04	3.42	0.00				
Population growth (annual %) 2019	0.07	0.08	0.90	0.37	-1.22	0.35	-3.46	0.00
Population size (log)	0.44	0.03	13.18	0.00	0.41	0.15	2.70	0.01
Urban population as a proportion of the total population 2020	-0.07	0.01	-14.50	0.00	-0.03	0.01	-2.88	0.00
High Income Country	1.77	0.95	1.85	0.06	4.18	1.68	2.49	0.01
Upper Middle Income Country	0.00	0.67	0.00	1.00	4.01	1.51	2.65	0.01
Lower Middle Income Country	-1.19	0.45	-2.67	0.01	0.75	1.10	0.69	0.49
Low Income Country (baseline)	(baseline)				(baseline)			
Country density of forest (log)	-0.43	0.02	-20.75	0.00	-0.20	0.10	-1.99	0.05
Life expectancy at birth (in years) 2019	-0.27	0.03	-8.68	0.00				
GNI per capita PPP (current international $) 2019	0.00	0.00	-2.98	0.00	0.00	0.00	-2.10	0.04
Proportion of employees working in human health and social work sector (ILO)	19.38	1.94	9.98	0.00	26.72	9.72	2.75	0.01
Immunization measles (% of children ages 12-23 months) 2019	-0.02	0.01	-4.18	0.00				

	Model 1				Model 2			
	Coef.	Std Err.	Z-value	P-value	Coef.	Std Err.	Z-value	P-value
Ratio of nationals living abroad to number of foreign migrants in this couuntry	-0.11	0.01	-8.22	0.00				
Female migrants as a % of migrant stock aged 25-54 years	0.06	0.01	5.55	0.00	-0.06	0.02	-2.57	0.01
Unemployment total (% of total labor force) 2021	0.12	0.01	8.91	0.00	-0.13	0.05	-2.68	0.01
Region: Europe+North America	-1.49	0.38	-3.91	0.00	-3.53	0.95	-3.72	0.00
Region: Latin America+Carib+ Oceania	-0.26	0.38	-0.70	0.49	-1.69	0.65	-2.59	0.01
Region: Sub-Saharan Africa	-4.58	0.55	-8.32	0.00	2.63	1.47	1.79	0.07
Region: North Africa+Middle East	0.87	0.48	1.83	0.07	-0.74	0.63	-1.18	0.24
Region: Asia (baseline)	(baseline)				(baseline)			
Agriculture forestry and fishing value added (% of GDP) 2019					0.13	0.02	7.89	0.00
HDI2019					14.02	5.24	2.68	0.01
Labor force female (% of total labor force) 2020					0.08	0.03	2.38	0.02
Proportion of migrants in population (%) Female_2554					0.12	0.02	5.35	0.00
Proportion of the population aged over 65 years old					-11.58	6.59	-1.76	0.08
ExpImp2010to2019					0.02	0.01	2.65	0.01
Number of nurses per 1000 population					-0.17	0.10	-1.70	0.09

	Model 1				Model 2			
	Coef.	Std Err.	Z-value	P-value	Coef.	Std Err.	Z-value	P-value
Constant	13.47	2.21	6.10	0.00	-17.86	3.28	-5.44	0.00
AIC	63.27				70.56			
BIC	104.21				119.11			
P-value overall	0				0			
Number of cases	38				61			

Table B.3 Output from modelling the proportion of foreign-born midwives

	Coef.	Std Err.	Z-value	P-value
Proportion of men aged 25-54 in the population who are migrants	-0.06	0.03	-2.03	0.04
Proportion of human health and social work sector employees who are female	-8.55	2.12	-4.04	0.00
Population size (log)	0.19	0.07	2.74	0.01
High Income Country	-5.23	1.71	-3.06	0.00
Upper Middle Income Country	-7.61	2.02	-3.77	0.00
Lower Middle Income Country	-9.96	2.63	-3.78	0.00
Life expectancy at birth (in years) 2019	0.23	0.08	3.08	0.00
GNI per capita PPP (current international $) 2019	0.00	0.00	4.84	0.00

	Coef.	Std Err.	Z-value	P-value
Female migrants as a % of migrant stock aged 25-54 years	-0.12	0.03	-3.79	0.00
Unemployment total (% of total labor force) 2021	0.09	0.04	2.01	0.04
Constant	-9.57	4.11	-2.33	0.02
AIC	33.404			
BIC	48.058			
P-value overall	0			
Number of cases	28			

Notes: The coefficient (coef.) summarises the relationship between the proportion of foreign-born health workers in a country and the country characteristics. It shows the expected increase or decrease in the proportion of that country's foreign-born health workers associated with a unit change in the characteristic. The value of this coefficient is tested in the model using a z-test. The resulting p-value indicates whether the characteristic is significantly related to changes in the proportion of foreign-born health workers. The difference is deemed to be significant at the 95% level if the p-value is smaller than 0.05. P-values are probabilities, a small p-value indicates that there is a very small probability that the differences we are testing occurred purely by chance.

The modelled estimates were used for doctors, nurses and midwives in India, for nurses in Mexico, and for midwives in Nigeria. They are shown in Table B.4 below.

Table B.4 The proportion of foreign-born health workers in the four trial countries

	Medical doctors	Nursing professionals	Midwives	Human Health and Social Work Sector
India[1]	0.3%	0.8%	0.02%	0.5%
Mexico[2]	1.1%	1.9%	0.3%	1.5%
Nigeria[3]	4.8%	0.6%	0.004%	1.2%
UK[4]	29.0%	17.5%	7.5%	22.3%

1. All figures for India are based on modelled estimates
2. Proportion of foreign-born doctors from NHWA (2015), proportion of foreign-born midwives from NHWA (2010). Proportion of foreign-born nurses based on modelled estmates.
3. Proportion of foreign-born doctors and nurses from NHWA (2016). Proportion of foreign-born midwives on NHWA is zero (negligible, rounded to zero (2016)). The modelled proportion (0.0044%) has been used in the estimates.
4. All UK estimates are from the Office for National Statistics – Annual Population Survey 3-year pooled dataset 2016-18.

Tables B.5-B.8 show the estimated numbers of foreign-born health workers, overall and by age and sex. These figures were calculated by applying the proportion of foreign-born health workers from Table B.4 to the total number of health workers from Tables A.1-A.4. An assumption is made that the age and sex distribution of foreign-born health workers matches that of all health workers. Whilst this is unlikely to be true (there is some evidence from the UK that foreign-born health workers have a different age profile, although differences between foreign-born and native health workers are likely to vary by country) there is no robust, global, data source that allows this to be checked.

Table B.5 Estimated foreign-born health workers in India based on data from the NHWA and ILO

	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Total	3,044	19,301	168	30,995
Female, less than 25 years	0.5%	12.0%	1.9%	7.1%
Female, 25-44 years	8.5%	57.7%	43.1%	32.0%
Female, 45-54 years	3.2%	14.8%	24.6%	10.4%
Female, 55-64 years	1.4%	2.6%	3.5%	2.7%
Female, 65 years or more	0.6%	1.0%	0.8%	0.3%
Male, less than 25 years	2.9%	1.6%	0.7%	4.8%
Male, 25-44 years	51.6%	7.8%	15.2%	25.8%
Male, 45-54 years	19.2%	2.0%	8.7%	9.7%
Male, 55-64 years	8.7%	0.4%	1.2%	5.3%
Male, 65 years or more	3.4%	0.1%	0.3%	1.9%

	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Female, less than 25 years	15	2,315	3	2,186
Female, 25-44 years	260	11,132	72	9,925
Female, 45-54 years	97	2,860	41	3,218
Female, 55-64 years	44	511	6	841
Female, 65 years or more	17	187	1	82
Male, less than 25 years	89	313	1	1,487
Male, 25-44 years	1,569	1,504	26	8,002
Male, 45-54 years	585	386	15	3,017
Male, 55-64 years	264	69	2	1,638
Male, 65 years or more	104	25	0	599

Table B.6 Estimated foreign-born health workers in Mexico based on data from the NHWA and ILO

	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Total	3,404	6,772	0	24,400
Female, less than 25 years	0.0%	1.6%	0.0%	6.3%
Female, 25-44 years	22.6%	47.5%	97.0%	34.4%
Female, 45-54 years	9.9%	22.5%	0.0%	15.9%
Female, 55-64 years	10.0%	10.8%	3.0%	7.1%
Female, 65 years or more	1.5%	2.5%	0.0%	1.3%
Male, less than 25 years	0.0%	0.3%	0.0%	3.0%
Male, 25-44 years	28.9%	8.4%	0.0%	17.0%
Male, 45-54 years	12.6%	4.0%	0.0%	7.6%
Male, 55-64 years	12.7%	1.9%	0.0%	5.2%
Male, 65 years or more	1.9%	0.5%	0.0%	2.0%
Female, less than 25 years	0	109	0	1,532
Female, 25-44 years	769	3,214	0	8,400
Female, 45-54 years	336	1,524	0	3,891
Female, 55-64 years	339	730	0	1,738
Female, 65 years or more	51	172	0	326
Male, less than 25 years	0	19	0	742
Male, 25-44 years	982	572	0	4,155

	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Male, 45-54 years	429	271	0	1,854
Male, 55-64 years	433	130	0	1,279
Male, 65 years or more	65	31	0	483

Table B.7 Estimated foreign-born health workers in Nigeria based on data from the NHWA and ILO

	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Total	3,578	1,084	5	14,717
Female, less than 25 years	0.5%	1.6%	1.8%	6.4%
Female, 25-44 years	43.1%	52.6%	60.4%	33.0%
Female, 45-54 years	16.0%	15.7%	18.0%	10.4%
Female, 55-64 years	3.9%	15.4%	17.6%	4.0%
Female, 65 years or more	2.0%	1.9%	2.2%	0.4%
Male, less than 25 years	0.2%	0.2%	0.0%	2.2%
Male, 25-44 years	22.8%	7.7%	0.0%	25.8%
Male, 45-54 years	8.4%	2.3%	0.0%	8.7%
Male, 55-64 years	2.1%	2.3%	0.0%	4.2%
Male, 65 years or more	1.0%	0.3%	0.0%	4.9%
Female, less than 25 years	16	17	0	939
Female, 25-44 years	1,542	571	3	4,856
Female, 45-54 years	571	170	1	1,537

	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Female, 55-64 years	140	167	1	592
Female, 65 years or more	70	21	0	54
Male, less than 25 years	9	3	0	327
Male, 25-44 years	816	84	0	3,796
Male, 45-54 years	302	25	0	1,283
Male, 55-64 years	74	24	0	617
Male, 65 years or more	37	3	0	717

Table B.8 Estimated foreign-born health workers in the UK based on data from the NHWA and ILO

	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Total	59,133	99,428	2,473	1,017,993
Female, less than 25 years	0.0%	2.8%	5.9%	5.3%
Female, 25-44 years	30.8%	39.6%	51.9%	34.7%
Female, 45-54 years	11.2%	25.4%	23.7%	19.3%
Female, 55-64 years	6.0%	18.4%	16.8%	15.3%
Female, 65 years or more	1.0%	2.3%	1.3%	2.2%
Male, less than 25 years	0.0%	0.4%	0.0%	1.2%
Male, 25-44 years	32.0%	5.1%	0.2%	11.6%
Male, 45-54 years	11.7%	3.3%	0.1%	5.4%
Male, 55-64 years	6.2%	2.4%	0.1%	4.2%
Male, 65 years or more	1.1%	0.3%	0.0%	0.9%

	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Female, less than 25 years	0	2,822	145	53,531
Female, 25-44 years	18,196	39,417	1,284	353,147
Female, 45-54 years	6,635	25,220	587	196,510
Female, 55-64 years	3,535	18,342	417	155,623
Female, 65 years or more	608	2,293	32	21,984
Male, less than 25 years	0	363	0	11,959
Male, 25-44 years	18,939	5,072	4	117,599
Male, 45-54 years	6,906	3,245	2	55,178
Male, 55-64 years	3,679	2,360	1	43,043
Male, 65 years or more	633	295	0	9,419

Validating the estimates using external data

In the UK, figures on the proportion of foreign-born health workers are available from the ONS[21] that were sufficiently robust to use in place of the modelled estimates. These figures suggest 29.0% of doctors, 17.5% nurses, and 7.5% of midwives are foreign-born. This compares well with the model estimates of 26.5% for doctors. The estimates for nurses (20.5%) and midwives (4.5%) are less accurate, but still acceptable. The ONS figures were used in the estimation instead of the modelled estimates in the absence of reported figures from the NHWA.

It was not possible to find external figures with which to validate the remaining estimates. The modelled proportion of foreign-born health workers in India was low. Whilst this was expected (India is known to be a major source country of international health care workers) there were no figures available that could be used to validate the estimated proportion. There were also no figures available that could be used to validate the estimates of nurses in Mexico or midwives in Nigeria. Again, these modelled proportions were low.

21 Office for National Statistics – Annual Population Survey 3-year pooled dataset 2016-18.

Table B.9 A list of information used to model the proportion of foreign-born health workers, and their sources

Measure	Source
Proportion of Nurses+Docs+MW Foreign Trained	NHWA
Proportion of foreign-born workers in the overall workforce (ILO)	ILO
Proportion of men aged 25-54 in the population who are migrants	ILO
Proportion of women aged 25-54 in the population who are migrants	ILO
Female migrants as a % of migrant stock aged 25-54 years	UN
Female migrants as a % of migrant stock aged 55-64 years	UN
Ratio of nationals living abroad to the total number of foreign migrants in this country	UN
Proportion of in-migrants from the same sub-region	UN
Proportion of employees working in human health and social work sector (ILO)	ILO
Proportion of human health and social work sector employees who are female	ILO
Number of doctors per 1000 population	NHWA
Number of nurses per 1000 population	NHWA
Labor force female (% of total labor force) 2020	ILO
Unemployment total (% of total labor force) 2021	ILO
Population size (log)	WB
Population growth (annual %) 2019	WB
Urban population as a proportion of the total population 2020	WB
Proportion of the population aged less than 15 years old	WB
Proportion of the population aged over 65 years old	WB
Life expectancy at birth (in years) 2019	WB
WB - change in life exp - 2019/1999	WB
WB - change in life exp - 2019/2009	WB
Human Development Index	UNDP
Domestic Health Expenditure (DOM) as % of Current Health Expenditure (CHE) 2019	WB
Current Health Expenditure (CHE) as % Gross Domestic Product (GDP) 2019	WB

Country Income (HIC/UMIC/LMIC/LIC)	ILO
GNI per capita Atlas method (current US$) 2019	WB
GNI per capita PPP (current international $) 2019	WB
Births attended by skilled health staff (% of total) 2019	WB
Immunization measles (% of children ages 12-23 months) 2019	WB
Primary completion rate total (% of relevant age group) 2019	WB
Agriculture forestry and fishing value added (% of GDP) 2019	WB
Foreign direct investment net (BoP current US$) 2019	WB
Export of goods and services (% of GDP)	WB
High technology exports (as % of manufactured exports)	WB
Foreign direct investment net inflows (BoP current US$) 2019	WB
Forest area (sq KM) (log)	WB
Region: Europe+North America	WB
Region: Latin America+Carib+Oceania	WB
Region: Sub-Saharan Africa	WB
Region: North Africa+Middle East	WB
Region: Asia (baseline)	WB
Ratio of exports to imports	WB
ILO – Employment to pop ratio - females 25 plus	ILO
ILO - Gender wage pay gap (overall)	ILO
ILO - Trade union density rate (%)	ILO
SDG indicator 5.5.2 - proportion of women managers	ILO
SDG indicator 8.8.2 - Level of national compliance with labour rights	ILO
ILO - Female share of low pay earners (%)	ILO
ILO - Share of temporary female employees (%)	ILO

APPENDIX C POPULATION ESTIMATES FOR THE FOUR TRIAL COUNTRIES

Table C.1 2020 population estimates for the four trial countries by age and sex (distribution and count)

	India	Mexico	Nigeria	UK
Total	1,380,004,385	128,932,753	206,139,587	67,081,000
Distribution				
Female, 0-14 years	12.4%	12.6%	21.3%	8.6%
Female, 15- 25 years	8.5%	8.5%	9.5%	5.6%
Female, 25-44 years	14.6%	15.3%	11.7%	13.3%
Female, 45-54 years	5.2%	6.1%	3.3%	6.7%
Female, 55-64 years	3.9%	4.3%	2.1%	6.3%
Female, 65-69 years	1.4%	1.5%	0.7%	2.6%
Female, 70 years or more	2.0%	2.7%	0.8%	7.5%
Male, 0-14 years	13.7%	13.2%	22.2%	9.0%
Male, 15-25 years	9.5%	8.7%	9.9%	5.8%
Male, 25-44 years	16.1%	14.4%	12.0%	13.4%
Male, 45-54 years	5.5%	5.4%	3.3%	6.5%
Male, 55-64 years	4.0%	3.8%	2.0%	6.1%
Male, 65-69 years	1.4%	1.3%	0.6%	2.4%
Male, 70 years or more	1.8%	2.1%	0.7%	6.2%

	India	Mexico	Nigeria	UK
Female, 0-14 years	171,609,375	16,280,814	43,820,702	5,790,623
Female, 15- 25 years	117,013,704	10,949,238	19,657,257	3,762,338
Female, 25-44 years	201,714,051	19,701,699	24,129,837	8,915,944
Female, 45-54 years	72,356,974	7,921,898	6,766,970	4,467,287
Female, 55-64 years	53,301,852	5,590,746	4,318,421	4,240,822
Female, 65-69 years	19,092,154	1,938,297	1,369,452	1,713,804
Female, 70 years or more	27,815,305	3,478,575	1,607,311	5,045,518
Male, 0-14 years	189,408,211	17,029,309	45,824,482	6,067,470
Male, 15-25 years	131,536,666	11,200,174	20,321,764	3,906,406
Male, 25-44 years	221,539,388	18,506,069	24,805,701	8,956,795
Male, 45-54 years	75,959,268	7,018,813	6,755,317	4,357,472
Male, 55-64 years	54,844,944	4,911,762	4,094,904	4,102,989
Male, 65-69 years	19,168,129	1,657,202	1,232,451	1,627,856
Male, 70 years or more	24,644,364	2,748,157	1,435,018	4,125,674

Source: World Bank

APPENDIX D WORKED EXAMPLE OF THE BASIC ESTIMATE FOR MEXICO

The first step was to estimate a crude Covid-19 death rate for the overall population of Mexico. This was based on the total number of Covid-19 deaths reported to the WHO up to 31 December 2021 divided by the total country population:

128932753 / 303408 = 0.235%

The second step was to estimate the number of foreign-born doctors in Mexico. The NHWA contains estimates of the number of doctors in Mexico (309,414, most recent figures from 2019) and the estimated proportion that are foreign-born (1.1%, most recent figures from 2015). The estimated number of migrant doctors in Mexico is therefore 3,403 (309,414 × 1.1%).

The final step for the basic estimate was to apply the crude mortality rate to the estimated number of foreign-born doctors: 0.235% of 3,403 is 8. This gave the estimated number of reported deaths for foreign-born doctors in Mexico.

The steps above can be repeated using the estimated excess deaths due to Covid-19 to estimate an alternative crude death rate. This gives a basic estimate of the number of excess deaths due to Covid-19 among foreign-born health workers. For Mexico the total number of excess deaths in the period up to 31 December 2021 was 626,219, giving a crude excess death rate of 0.49%. The estimated number of excess deaths due to Covid-19 among foreign-born doctors is therefore 17.

The process can be repeated for nurses, midwives, health professionals and associate professionals, and workers in the health sector by substituting the relevant figures in steps 2 and 3 of the calculation.

APPENDIX E FURTHER INFORMATION ON THE AGE-SEX STANDARDISED

had asked that Estimate be added after Standardised.

The estimate requires, for each country, a set of population estimates and reported Covid-19 deaths by age and sex. This information is used to calculate a set of crude mortality rates. The calculation excludes the population (and associated Covid-19 deaths) for people outside the working-age population, specifically aged 0-14 years and 70 years and over. The crude mortality rates by age and sex for all four trial countries are shown in Table E.1. The same crude mortality rate is applied to each health group. Whilst is it not likely that each occupation will have the same Covid-19 risk for each age and sex group, it is not possible to adjust the mortality rates per occupation group as the required data are not available.

Table E.1 Crude Mortality Rates based on reported Covid-19 deaths by age and sex

	India	Mexico	Nigeria	UK
Female, 0-14 years	0.00%	0.00%	0.00%	0.00%
Female, 15- 25 years	0.00%	0.01%	0.00%	0.00%
Female, 25-44 years	0.01%	0.06%	0.00%	0.01%
Female, 45-54 years	0.03%	0.21%	0.00%	0.05%
Female, 55-64 years	0.07%	0.49%	0.00%	0.10%
Female, 65-69 years	0.13%	0.86%	0.02%	0.21%
Female, 70 years or more	0.32%	1.23%	0.01%	1.12%
Male, 0-14 years	0.00%	0.00%	0.00%	0.00%
Male, 15-25 years	0.00%	0.01%	0.00%	0.00%
Male, 25-44 years	0.01%	0.12%	0.00%	0.02%
Male, 45-54 years	0.05%	0.44%	0.01%	0.08%
Male, 55-64 years	0.12%	0.89%	0.02%	0.18%
Male, 65-69 years	0.22%	1.51%	0.01%	0.38%
Male, 70 years or more	0.48%	2.32%	0.04%	1.54%

An upper threshold of 70 years was chosen. Whilst some doctors and other health workers will continue working beyond this age, the numbers are likely to be small, meaning the impact of excluding older health workers on the estimates should be small despite the higher mortality rate among this group. Similarly, the lower threshold of 15 years is based on there being a small number of workers in the 15-24-year age band, particularly for professions with a shorter training period and for workers in the wider health care sector that may not require university or medical training, such as porters, receptionists and cleaners. The low mortality rate among this group means, in real terms, any changes to the lower age threshold should have only a minor impact on the estimated total number of Covid-19 deaths among foreign-born health workers.

The data requirement is the number of foreign-born doctors by age and sex. It is assumed that the age and sex distribution of foreign-born health workers is the same as that for all health workers. This assumption has been made in the absence of fuller cross-country data on the age and sex distribution of foreign-born health workers. There is some evidence to suggest the age distribution of foreign-born doctors is not the same as that of all doctors. Figures from the UK show that UK-born health workers are more likely to be at both the younger and older ends of the age distribution, with a third of foreign-born health workers aged 35-44 years, compared to 23% of UK-born health workers.[22] However, data are not available for many other countries. This means it is not possible to make an adjustment for different age profiles by country and the two age profiles are assumed to be the same. The number of foreign-born health workers by age and sex for all four trial countries is shown in Tables B.5-B.8 in Appendix B.

The crude mortality rates are applied to the estimated number of foreign-born doctors within each age and sex sub-group. This gives the estimated number of reported deaths for foreign-born health workers by age and sex, shown below. These are then summed to get the total number. The estimated numbers of reported Covid-19 deaths by age and sex for all health groups and all four trial countries are given in Tables E.2-E.5.

Table E.2 Estimated reported Covid-19 deaths for foreign-born health workers by age and sex in India

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Total Covid-19 deaths	1	3	0	8	375	334	184	1,532
Male	1	1	0	6	342	63	70	1,093
Female	0	2	0	2	33	271	114	438

22 Source: Office for National Statistics – Annual Population Survey 3-year pooled dataset 2016-18

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
15-25 years	0	0	0	0	0	4	0	8
25-44 years	0	1	0	1	60	104	35	273
45-54 years	0	1	0	3	113	132	100	485
55-64 years	0	0	0	3	119	58	34	499
65-69 years	0	0	0	1	83	37	14	267
Female, 15-25 years	0	0	0	0	0	3	0	4
Female, 25-44 years	0	1	0	1	5	85	22	115
Female, 45-54 years	0	1	0	1	10	106	61	181
Female, 55-64 years	0	0	0	1	11	47	22	118
Female, 65-69 years	0	0	0	0	7	30	9	20
Male, 15-25 years	0	0	0	0	0	0	0	3
Male, 25-44 years	0	0	0	1	55	20	13	159
Male, 45-54 years	0	0	0	2	103	26	39	303

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Male, 55-64 years	0	0	0	2	108	11	13	381
Male, 65-69 years	0	0	0	1	76	7	5	247

Table E.3 Estimated reported Covid-19 deaths for foreign-born health workers by age and sex in Mexico

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Total Covid-19 deaths	11	14	0	56	1,012	725	0	3,711
Male	8	3	0	32	717	186	0	2,097
Female	3	10	0	25	295	539	0	1,614
15-25 years	0	0	0	0	0	1	0	17
25-44 years	2	3	0	10	147	133	0	642
45-54 years	3	4	0	16	236	237	0	1,083
55-64 years	6	5	0	20	500	251	0	1,306
65-69 years	1	2	0	10	128	103	0	663

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Female, 15-25 years	0	0	0	0	0	1	0	10
Female, 25-44 years	0	2	0	5	40	97	0	313
Female, 45-54 years	1	3	0	8	65	174	0	549
Female, 55-64 years	2	4	0	8	150	189	0	557
Female, 65-69 years	0	1	0	3	40	79	0	184
Male, 15-25 years	0	0	0	0	0	0	0	7
Male, 25-44 years	1	1	0	5	107	36	0	328
Male, 45-54 years	2	1	0	8	171	63	0	534
Male, 55-64 years	4	1	0	11	350	61	0	749
Male, 65-69 years	1	0	0	7	89	25	0	479

Table E.4 Estimated reported Covid-19 deaths for foreign-born health workers by age and sex in Nigeria

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Total Covid-19 deaths	0	0	0	0	2	4	2	34
Male	0	0	0	0	1	1	0	29
Female	0	0	0	0	1	2	2	6
15-25 years	0	0	0	0	0	0	0	0
25-44 years	0	0	0	0	0	1	1	5
45-54 years	0	0	0	0	1	1	0	12
55-64 years	0	0	0	0	0	1	1	9
65-69 years	0	0	0	0	0	1	0	9
Female, 15-25 years	0	0	0	0	0	0	0	0
Female, 25-44 years	0	0	0	0	0	1	1	3
Female, 45-54 years	0	0	0	0	0	0	0	1
Female, 55-64 years	0	0	0	0	0	1	1	1

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Female, 65-69 years	0	0	0	0	0	1	0	1
Male, 15-25 years	0	0	0	0	0	0	0	0
Male, 25-44 years	0	0	0	0	0	0	0	3
Male, 45-54 years	0	0	0	0	1	0	0	11
Male, 55-64 years	0	0	0	0	0	1	0	8
Male, 65-69 years	0	0	0	0	0	0	0	8

Table E.5 Estimated reported Covid-19 deaths for foreign-born health workers by age and sex in the UK

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Total Covid-19 deaths	28	48	1	511	95	276	12	2,293
Male	18	9	0	176	61	50	0	790
Female	10	39	1	335	35	226	12	1,503

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
15-25 years	0	0	0	2	0	0	0	8
25-44 years	6	6	0	63	19	32	2	283
45-54 years	9	14	0	135	29	82	4	605
55-64 years	10	22	0	230	35	127	5	1,030
65-69 years	4	6	0	82	13	34	1	367
Female, 15-25 years	0	0	0	1	0	0	0	6
Female, 25-44 years	2	5	0	43	8	27	2	191
Female, 45-54 years	3	12	0	91	11	67	4	410
Female, 55-64 years	3	18	0	153	12	103	5	687
Female, 65-69 years	1	5	0	47	4	28	1	209
Male, 15-25 years	0	0	0	0	0	0	0	2
Male, 25-44 years	3	1	0	21	11	5	0	92
Male, 45-54 years	5	3	0	43	19	15	0	194

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Male, 55-64 years	7	4	0	76	22	24	0	342
Male, 65-69 years	2	1	0	35	8	6	0	159

The same figures are replicated using excess deaths. These figures are shown in the tables below. Table E.6 contains crude mortality rates based on estimated excess Covid-19 deaths by age and sex for all four trial countries. Tables E.7-E.10 contain the estimated number of excess Covid-19 deaths by age and sex for all health groups and all four trial countries.

Table E.6 Crude Mortality Rates based on estimated excess Covid-19 deaths by age and sex

	India	Mexico	Nigeria	UK
Female, 0-14 years	0.00%	0.00%	0.00%	0.00%
Female, 15- 25 years	0.00%	0.00%	0.00%	0.00%
Female, 25-44 years	0.04%	0.10%	0.01%	0.02%
Female, 45-54 years	0.26%	0.37%	0.15%	0.07%
Female, 55-64 years	0.77%	0.88%	0.50%	0.15%
Female, 65-69 years	1.43%	1.53%	1.02%	0.25%
Female, 70 years or more	3.85%	2.90%	2.07%	0.86%
Male, 0-14 years	0.00%	0.00%	0.00%	0.01%
Male, 15-25 years	0.00%	0.00%	0.00%	0.01%
Male, 25-44 years	0.05%	0.21%	0.00%	0.04%

	India	Mexico	Nigeria	UK
Male, 45-54 years	0.39%	0.85%	0.21%	0.16%
Male, 55-64 years	1.08%	1.85%	0.70%	0.34%
Male, 65-69 years	1.98%	3.14%	1.45%	0.53%
Male, 70 years or more	5.37%	5.70%	3.20%	1.35%

Table E.7 Estimated excess Covid-19 deaths for foreign-born health workers by age and sex in India

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Total Covid-19 deaths	9	22	0	66	3002	2784	1524	12494
Male	8	4	0	46	2688	447	514	8672
Female	1	19	0	20	315	2338	1010	3822
15-25 years	0	0	0	0	0	0	0	0
25-44 years	1	6	0	9	323	693	224	1629
45-54 years	3	9	0	20	841	1108	817	3794
55-64 years	3	5	0	24	1066	586	338	4600
65-69 years	2	3	0	13	772	398	146	2471

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Female, 15-25 years	0	0	0	0	0	0	0	0
Female, 25-44 years	0	5	0	4	37	590	154	797
Female, 45-54 years	0	7	0	8	83	920	533	1570
Female, 55-64 years	0	4	0	6	112	493	226	1231
Female, 65-69 years	0	3	0	1	82	335	98	223
Male, 15-25 years	0	0	0	0	0	0	0	0
Male, 25-44 years	1	1	0	4	287	103	70	832
Male, 45-54 years	2	2	0	12	758	188	284	2223
Male, 55-64 years	3	1	0	18	954	94	112	3369
Male, 65-69 years	2	1	0	12	689	63	48	2249

Table E.8 Estimated excess Covid-19 deaths for foreign-born health workers by age and sex in Mexico

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Total Covid-19 deaths	22	25	0	106	1957	1310	0	6984
Male	16	7	0	64	1437	367	0	4179
Female	6	18	0	43	520	943	0	2804
15-25 years	0	0	0	0	0	0	0	0
25-44 years	3	4	0	17	255	227	0	1103
45-54 years	5	8	0	30	446	422	0	1987
55-64 years	11	9	0	39	1001	469	0	2567
65-69 years	3	4	0	20	256	191	0	1327
Female, 15-25 years	0	0	0	0	0	0	0	0
Female, 25-44 years	1	3	0	8	67	163	0	528
Female, 45-54 years	1	6	0	14	113	299	0	944

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Female, 55-64 years	3	6	0	15	271	341	0	1005
Female, 65-69 years	1	3	0	5	70	140	0	328
Male, 15-25 years	0	0	0	0	0	0	0	0
Male, 25-44 years	2	1	0	9	188	64	0	576
Male, 45-54 years	4	2	0	16	334	123	0	1043
Male, 55-64 years	8	2	0	24	730	128	0	1561
Male, 65-69 years	2	1	0	15	185	51	0	999

Table E.9 Estimated excess Covid-19 deaths for foreign-born health workers by age and sex in Nigeria

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Total Covid-19 deaths	4	2	0	24	85	268	172	1903

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Male	2	0	0	17	35	45	0	1404
Female	2	1	0	6	50	224	172	499
15-25 years	0	0	0	0	0	0	0	0
25-44 years	0	0	0	0	2	7	5	27
45-54 years	2	0	0	5	31	52	33	406
55-64 years	1	1	0	7	25	167	106	585
65-69 years	1	0	0	11	26	43	27	885
Female, 15-25 years	0	0	0	0	0	0	0	0
Female, 25-44 years	0	0	0	0	2	7	5	27
Female, 45-54 years	1	0	0	2	18	43	33	189
Female, 55-64 years	1	1	0	3	15	138	106	238
Female, 65-69 years	1	0	0	1	15	36	27	45
Male, 15-25 years	0	0	0	0	0	0	0	0

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Male, 25-44 years	0	0	0	0	0	0	0	0
Male, 45-54 years	1	0	0	3	13	9	0	217
Male, 55-64 years	1	0	0	4	11	28	0	347
Male, 65-69 years	1	0	0	10	11	7	0	840

Table E.10 Estimated excess Covid-19 deaths for foreign-born health workers by age and sex in the UK

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
Total Covid-19 deaths	51	78	1	849	174	445	19	3809
Male	35	17	0	333	120	96	0	1495
Female	16	61	1	516	54	349	19	2314
15-25 years	0	0	0	1	0	0	0	5
25-44 years	12	10	0	124	41	60	4	558

	Covid-19 deaths for foreign-born workers per health occupation				Total Covid-19 deaths per health occupation			
	Doctors	Nurses	Midwives	Human Health and Social Work Sector	Doctors	Nurses	Midwives	Human Health and Social Work Sector
45-54 years	16	24	0	233	55	136	6	1044
55-64 years	18	36	1	385	61	207	9	1726
65-69 years	5	7	0	106	17	42	1	477
Female, 15-25 years	0	0	0	0	0	0	0	2
Female, 25-44 years	4	8	0	75	13	48	4	335
Female, 45-54 years	5	19	0	145	17	106	6	648
Female, 55-64 years	5	28	1	240	19	162	9	1078
Female, 65-69 years	2	6	0	56	5	33	1	251
Male, 15-25 years	0	0	0	1	0	0	0	3
Male, 25-44 years	8	2	0	50	28	12	0	223
Male, 45-54 years	11	5	0	88	38	30	0	396
Male, 55-64 years	12	8	0	145	43	45	0	648
Male, 65-69 years	3	2	0	50	12	9	0	226

APPENDIX F WORKED EXAMPLE OF AGE-SEX STANDARDISED ESTIMATE FOR MEXICO

By way of demonstration, the calculation for the age-sex standardised estimates is reproduced for doctors using data from Mexico.

The first step is to use population estimates and reported Covid-19 deaths by age and sex to calculate a set of crude mortality rates. This is shown in Table F.1 below. The calculation excludes the population (and associated Covid-19 deaths) for people outside the working age population, specifically aged 0-14 years and 70 years and over.

Table F.1 Population estimates, reported Covid-19 deaths and Crude Mortality Rates for doctors in Mexico by age and sex for the period up to 31 December 2021

had asked that this table number and titled be put in bold, like all the other such titles.

	Population	Reported deaths	Crude Mortality Rate
Female, 0-14 years	16,280,814	239	0.00%
Female, 15- 25 years	10,949,238	1,084	0.01%
Female, 25-44 years	19,701,699	11,172	0.06%
Female, 45-54 years	7,921,898	16,988	0.21%
Female, 55-64 years	5,590,746	27,250	0.49%
Female, 65-69 years	1,938,297	16,609	0.86%
Female, 70 years or more	3,478,575	42,916	1.23%
Male, 0-14 years	17,029,309	264	0.00%
Male, 15-25 years	11,200,174	1,534	0.01%
Male, 25-44 years	18,506,069	22,215	0.12%
Male, 45-54 years	7,018,813	30,714	0.44%
Male, 55-64 years	4,911,762	43,705	0.89%
Male, 65-69 years	1,657,202	24,974	1.51%
Male, 70 years or more	2,748,157	63,744	2.32%
Total	128,932,753	303,408	

The second step is to estimate the number of foreign-born doctors by age and sex. For Mexico these figures were taken from the NHWA and are shown in Table F.2 below.

Table F.2 Number of foreign-born doctors, Crude Mortality Rates and estimated deaths for doctors in Mexico by age and sex for the period up to 31 December 2021

	Estimated number of foreign born doctors	Crude Mortality Rate for this age-sex group	Estimated number of deaths
Total	3,404		11
Female, less than 25 years	0	0.01%	0
Female, 25-44 years	769	0.06%	0
Female, 45-54 years	336	0.21%	1
Female, 55-64 years	339	0.49%	2
Female, 65 years or more	51	0.86%	0
Male, less than 25 years	0	0.01%	0
Male, 25-44 years	982	0.12%	1
Male, 45-54 years	429	0.44%	2
Male, 55-64 years	433	0.89%	4
Male, 65 years or more	65	1.51%	1

The final step is to apply the crude mortality rate to the estimated number of foreign-born doctors within each age and sex sub-group. The number of foreign-born health workers by age and sex for Mexico is shown in Table B.6 in Appendix B.

This calculation gives the estimated number of reported deaths for foreign-born doctors in Mexico by age and sex (given in Table E.3), which are then summed to get the total number. The age-sex standardised estimate of the total number of Covid-19 deaths for foreign-born doctors in Mexico is 11.

for those highlighted above, 65 years or more should be corrected to 65-69 years

APPENDIX G CREDIBILITY INTERVALS

Each estimate has an accompanying set of credibility intervals (CIs). These intervals perform the same function as confidence intervals and demonstrate that there is a degree of uncertainty around the precision of each estimate. Each estimate has a lower and upper bound indicating a range of values in which the true estimate is expected to lie.

The credibility intervals are not confidence intervals in the traditional sense, since the estimates are not based on sampling or modelling. The intervals are also unequal – the distance between the estimate and the lower bound is not equal to the distance between the estimate and the upper bound. This is because the intervals incorporate uncertainty from two different stages in the estimation procedure: uncertainty around the estimated crude mortality rate, and uncertainty around the estimate of the proportion of foreign-born health workers. An interval was generated around each of these two sources of uncertainty:

- Intervals around the crude mortality rate based on reported deaths were based on the monthly variance in reported figures in the period up to 31 December 2021 and using 95% confidence. For the estimated excess deaths, the reported credibility intervals, produced by WHO as part of their estimation process, were used.
- Intervals around the estimated proportion of foreign-born health workers taken from the NHWA were generated directly from the estimated proportions. A standard approach was taken here as the source of the information available on the NHWA was not always clear; some countries would have taken these figures from administrative data and others from survey data. However, confidence intervals were not reported. For the imputed estimates of foreign-born workers the intervals were generated using model outputs. Again, a 95% confidence level was used.

The lower bound of the credibility interval for foreign-born Covid-19 deaths was then generated using the lower bound of the crude mortality rate and an estimate of foreign-born health workers based on the lower bound of the proportion of foreign-born workers, whilst the higher bound of the credibility interval is based on the higher bound of both estimates.

The credibility intervals for overall health workers were based on uncertainty around the crude mortality rate only. As a result these tend to be narrower and are equally spaced around the estimate.

Table G.1 Covid-19 deaths based on reported deaths with 95% credibility intervals

	Estimated Covid-19 Deaths (Lower bound, Upper bound)			
	Basic		Age-sex	
	Foreign born workers	All health workers	Foreign born workers	All health workers
India				
Doctors	1 (0, 3)	354 (335, 372)	1 (0, 3)	375 (355, 395)
Nurses	7 (3, 11)	841 (797, 885)	3 (1, 4)	334 (317, 352)
Midwives	0 (0, 0)	293 (278, 309)	0 (0, 0)	184 (175, 194)
Sector	11 (4, 18)	2049 (1941, 2156)	8 (3, 13)	1532 (1451, 1612)

	Estimated Covid-19 Deaths (Lower bound, Upper bound)			
	Basic		Age-sex	
	Foreign born workers	All health workers	Foreign born workers	All health workers
Mexico				
Doctors	8 (2, 15)	728 (707, 749)	11 (2, 20)	1012 (982, 1041)
Nurses	16 (7, 26)	848 (823, 872)	14 (6, 22)	725 (704, 746)
Midwives	0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0)
Sector	57 (31, 85)	3779 (3670, 3888)	56 (30, 84)	3711 (3604, 3819)
Nigeria				
Doctors	0 (0, 0)	1 (1, 1)	0 (0, 0)	2 (1, 2)
Nurses	0 (0, 0)	3 (2, 3)	0 (0, 0)	4 (3, 4)
Midwives	0 (0, 0)	2 (1, 2)	0 (0, 0)	2 (1, 2)
Sector	0 (0, 0)	17 (14, 21)	0 (0, 1)	34 (27, 41)
UK				
Doctors	132 (107, 159)	455 (432, 479)	28 (22, 33)	95 (91, 100)
Nurses	222 (178, 270)	1269 (1204, 1334)	48 (39, 59)	276 (261, 290)
Midwives	6 (3, 9)	73 (70, 77)	1 (0, 1)	12 (12, 13)
Sector	2273 (1986, 2579)	10193 (9670, 10717)	511 (447, 580)	2293 (2175, 2411)

Table G.2 Covid-19 deaths based on estimated excess deaths with 95% credibility intervals

	Estimated Covid-19 Deaths (Lower bound, Upper bound)			
	Basic		Age-sex	
	Foreign born workers	All health workers	Foreign born workers	All health workers
India				
Doctors	10 (0, 30)	3485 (2415, 4748)	9 (0, 26)	3002 (2080, 4090)
Nurses	66 (20, 140)	8288 (5742, 11291)	22 (7, 47)	2784 (1929, 3793)
Midwives	1 (0, 4)	2890 (2002, 3937)	0 (0, 2)	1524 (1056, 2076)
Sector	106 (33, 224)	20189 (13987, 27503)	66 (21, 139)	12494 (8656, 17021)

	Estimated Covid-19 Deaths (Lower bound, Upper bound)			
	Basic		Age-sex	
	Foreign born workers	All health workers	Foreign born workers	All health workers
Mexico				
Doctors	17 (3, 30)	1503 (1460, 1529)	22 (4, 39)	1957 (1902, 1991)
Nurses	33 (13, 53)	1750 (1700, 1779)	25 (10, 40)	1310 (1273, 1332)
Midwives	0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0)
Sector	119 (64, 174)	7799 (7579, 7932)	106 (57, 156)	6984 (6787, 7103)
Nigeria				
Doctors	3 (0, 10)	67 (1, 140)	4 (0, 13)	85 (0, 177)
Nurses	1 (0, 5)	163 (2, 340)	2 (0, 7)	268 (0, 558)
Midwives	0 (0, 0)	109 (1, 227)	0 (0, 0)	172 (0, 357)
Sector	13 (0, 42)	1073 (12, 2230)	24 (0, 75)	1903 (0, 3956)
UK				
Doctors	131 (99, 164)	453 (400, 493)	51 (38, 63)	174 (154, 190)
Nurses	221 (165, 278)	1261 (1114, 1375)	78 (58, 98)	445 (393, 486)
Midwives	5 (2, 9)	73 (64, 79)	1 (1, 2)	19 (17, 21)
Sector	2260 (1837, 2659)	10133 (8947, 11047)	849 (691, 999)	3809 (3364, 4153)

APPENDIX H DATA CLEANING

Data cleaning and calculations were carried out using a combination of Stata and R.

Officially-reported deaths

Minimal data cleaning was required to obtain a single figure of deaths for each country. As mentioned above, the WHO COVID-19 Dashboard was used to obtain data on officially reported deaths. In the dataset obtained from the dashboard, cumulative deaths were reported for each country at regular intervals between 3 January 2020 and 14 March 2022. As the cut-off period for the project was 31 December 2021, the last reported cumulative death count for each country in 2021 was taken as the number of officially-reported deaths.

Proportion of deaths by sex and age for all countries globally

The proportion of deaths by sex and age was initially calculated for most countries globally using data from the WHO COVID-19 Detailed Surveillance Data dashboard. The data was downloaded as six files, which were combined into a single dataset using R. Further manipulation was carried out in Stata to provide estimates of age within sex.

In line with the cut-off date of 31 December 2021, the data was filtered for entries from 2020 or 2021. In the dataset two figures were reported for deaths by both sex and age: reported daily cases and detailed daily cases. The detailed daily cases figure included additional data sources, such as case notes, compared to the daily cases. However, as there was no consistent relationship between the two figures (such as detailed daily cases being larger than daily cases), the two figures were summed for each country and then used to obtain a count for each sex of deaths per country. For most countries, the sum of male deaths and female deaths did not equal the sum of all deaths, so the proportion of deaths was calculated using the following formulae:

$$Proportion_{male} = Count_{male} / (Count_{male} + Count_{female})$$
$$Proportion_{female} = 1 - Proportion_{male}$$

A similar process was used to calculate the proportion of deaths per age bracket and per age bracket within sex. As stated above, age brackets were forced to align with those used by the NHWA. Where deaths were reported over a different range, a uniform distribution across the age bracket was assumed. For example, if deaths were reported for the 30 – 39 age bracket, it was assumed that half these deaths occurred between 30-34, contributing the 25-34 age bracket, and half occurred between 35 and 39, contributing to the 35-44 year age bracket. Data cleaning also involved checking that the 'AGEGROUP' column actually contained an age range rather than a date. For example, the 'AGEGROUP' entry was occasionally '5 September'. This likely occurred as the data had been passed between programmes and the age bracket 5-9 had been interpreted as a date by one of them. This incorrect interpretation was then passed on to the WHO's database. As this project only dealt with those of a working age, it is unlikely that these data issues affected our results. Nevertheless, this is an issue that other research teams should be mindful of.

Further data cleaning was required after the sex and age proportion of deaths was calculated for each country as the WHO COVID-19 dashboard and the WHO COVID-19 Detailed Surveillance Data dashboard used different codes for countries (two letter codes and three letter codes respectively). R was therefore used to identify countries whose full designation differed between the datasets and ensure conformity. For example, the country name "Kosovo[1]" in the COVID-19 Detailed Surveillance

Data dataset was updated to “Kosovo”. Once country names were uniform across the two datasets, they could be combined into a single dataset using R, eliminating manual errors.

Proportion of deaths by sex and age for India

After inspection of the dataset with both official counts of Covid-19 deaths and proportion of deaths by sex and age, it was noted that data was missing related to the sex and age of deaths in India and the sex of deaths in Nigeria. In Nigeria an open access dataset associated with an academic article was used to obtain figures for the age within sex. The dataset listed the age and sex of each person who had passed away in the case-study, and data cleaning merely involved summing the numbers within each age-sex group.

For India, data was downloaded from Covid19india.org. The dataset contained around one million rows of data split across 35 files on patients who had suffered from Covid-19, including those who had recovered and those who had passed away. Stata was used to combine the files and filter the data set so that only data on deceased patients was included in the analysis. Combination of these files required some data cleaning, as the columns contained in each file differed. All files contained the necessary columns to calculate sex and age proportions, so after opening a file in Stata, unnecessary columns were discarded to make combination into a single dataset simple.

Data cleaning was then required to calculate the sex of patients, as the notation used to record the sex of a patient was inconsistent. For example, a male patient could be recorded as ‘Male’ or ‘M’. The data also included entries for three non-binary individuals. As other datasets were based on sex rather than gender, and three was not a large enough number to calculate a standalone proportion for ‘non-binary’, these individuals were excluded from the analysis.

In the Covid19india.org dataset, as each row represented an individual, age data was reported as a single precise age. This allowed easy calculation of how many individuals in the dataset were present for each age bracket for each sex. Proportions of deaths per age bracket by sex were subsequently calculated as above.