BMJ Open

Estimating the health workforce requirements and costing to reach 70% COVID-19 vaccination coverage by mid-2022: a modelling study and global estimates

Mathieu Boniol ,[1] Amani Siyam,[1] Shalini Desai ,[2] Santosh Gurung,[2] Andrew Mirelman,[3] Tapas Sadasivan Nair,[1] Khassoum Diallo,[1] James Campbell[1]

To cite: Boniol M, Siyam A, Desai S, *et al*. Estimating the health workforce requirements and costing to reach 70% COVID-19 vaccination coverage by mid-2022: a modelling study and global estimates. *BMJ Open* 2022;**12**:e063059. doi:10.1136/bmjopen-2022-063059

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2022-063059).

Received 21 March 2022
Accepted 07 July 2022

[1]Health Workforce Department, World Health Organization, Geneva, Switzerland
[2]Immunization, Vaccines & Biologicals Department, World Health Organization, Geneva, Switzerland
[3]Health System Governance and Financing Department, World Health Organization, Geneva, Switzerland

Correspondence to
Dr Mathieu Boniol;
boniolm@who.int

ABSTRACT

Objectives The implementation of COVID-19 vaccination globally poses unprecedented stress to health systems particularly for countries with persisting health workforce shortages prior the pandemic. The present paper estimates the workforce requirement to reach 70% COVID-19 vaccination coverage in all countries by mid-2022 using service target–based estimation.

Methods Health workforce data from National Health Workforce Accounts and vaccination coverage reported to WHO as of January 2022 were used. Workload parameters were used to estimate the number of health workers needed with a service target–based approach, the gap and the scale-up required partially accounting for countries' challenges, as well as the associated costs in human resources.

Results As of 1 January 2022, only 34 countries achieved 70% COVID-19 vaccination coverage and 61 countries covered less than a quarter of their population. This analysis showed that 1 831 000 health workers working full time would be needed to reach a global coverage of 70% COVID-19 vaccination by mid-2022. To avoid severe disruptions to health system, 744 000 additional health workers should be added to domestic resources mostly (77%) in low-income countries. In a sensitivity analysis, allowing for vaccination over 12 months instead of 6 months would decrease the scale-up to 476 000 health workers. The costing for the employment of these 744 000 additional health workers is estimated to be US$2.5 billion. In addition to such a massive scale-up, it is estimated that 29 countries would have needed to redeploy more than 20% of their domestic workforce, placing them at serious risk of not achieving the mid-year target.

Conclusion Reaching 70% global coverage with COVID-19 vaccination by mid-2022 requires extraordinary efforts not before witnessed in the history of immunisation programmes. COVID-19 vaccination programmes should receive rapid and sustainable investment in health workforce.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study provides a global assessment of the health workforce with the same method of estimation applied throughout, therefore enabling the identification of groups of countries lagging behind in terms of human resources capacity.
⇒ The modelling approach of this study enabled the inclusion of country-specific data such as vaccination coverage, size of health workforce and number of health worker graduates as a proxy to absorption capacity.
⇒ This assessment does not replace a country contextualisation in which additional resources could be identified or mobilised, and for which the vaccination settings could differ significantly from this global perspective.
⇒ Another limitation is the use of health workforce statistics mostly prior to COVID-19 pandemic. It is reasonable to consider, although not quantifiable, that the workforce available for vaccination could have decreased because of various impacts COVID-19 could have had to health and care workers.

INTRODUCTION

The COVID-19 pandemic is having an unrelenting impact on the health and well-being of the world's population. This is threatening, directly and indirectly, to reverse decades of progress in health systems strengthening and improving health outcomes. WHO reports that the routine provision of essential health services has been disrupted in more than 90% of countries,[1] with 'insufficient staff availability' emerging as the most common cause of disruption in 66% of countries.[2] Following major reorganisation of services, health workers remain at the forefront of COVID-19 response, with significant exposure to SARS-CoV-2 virus. Incidence rates of COVID-19 infection among health and care workers were especially high in the first 6 months of the pandemic, several times more than the general population.[3] While the incidence

rate reduced over time, WHO estimates that the probable number of deaths among health and care workers, up to May 2021, ranges between 80 000 and 180 000 globally with a central population-based estimate of 115 500.[4] In addition, the impact of COVID-19 on health and care workers goes beyond infections and deaths[5] with negative effects on their mental health (stress, burnout, depression), working conditions and well-being.[5] In appreciation and gratitude for their unwavering dedication in the fight against the COVID-19 pandemic, 2021 was designated the International Year of Health and Care Workers by WHO's World Health Assembly.[6] They continue to be among the critical staff necessary to deliver the biggest vaccination programme in the history of public health.

The production of effective COVID-19 vaccines is critical for mitigating the effects of the pandemic. Joint global actions are actively taking place with the Access to COVID-19 Tools Accelerator (ACT-A) Vaccines Pillar (COVAX) that aims to guarantee fair and equitable access of COVID-19 vaccines to all countries. In recognition of the key role that health workers play in caring for those who are ill and in delivery of vaccinations, health workers are among the groups that are prioritised for vaccines during times of limited supply.[7] One deterministic input for an effective COVID-19 vaccines roll-out is the health workforce requirements for an unprecedented scale of vaccinations, covering almost the entire global population, over several months or years to come. Effective COVID-19 vaccines roll-out will be hampered by a global shortage of health workers. Well before the pandemic, the Global Strategy for Human Resources for Health: Workforce 2030[8] estimated a shortage of 17.4 million health workers in 2013, predominantly in low-income countries. Low-income countries are also struggling to provide basic and essential health services as measured by the universal health coverage (UHC) service coverage index (SCI).[9] The data from the National Health Workforce Accounts[10] show that low-income countries only have access to 17% of the world's health workforce population (measured by the registration of medical doctors, nursing and midwifery personnel, and pharmacists) when their population size is 41% of the world's population. They have an average UHC SCI of 49%, which can be roughly interpreted as an inability to provide half of their population, mostly the rural and vulnerable communities, with access to essential health services. Conversely, high-income countries have access to 38% of the global health workforce who cater to only 14% of the world population. It is no surprise that their average UHC SCI is far higher at 81%.

Health workforce will be a critical constraint to the surge needed for the COVID-19 response and is a major component of COVID-19 vaccines delivery. In the context of the Global COVID-19 vaccination strategy[11] with an objective of 70% global coverage, it is therefore critical to assess whether low-income and lower-middle income countries have the capacity to redeploy health workers to national COVID-19 vaccination programmes without further aggravating the disruption of other essential health services. Several health workforce–related questions need addressing. If the existing capacity to manage routine health services and the COVID-19 response continue to be insufficient, then what is the estimated number of additional health workers and support personnel required to staff the vaccination teams? From this analysis, what is the estimated total cost of labour for the vaccination teams, what share can be covered from domestic resources, and what share will require international financial assistance and solidarity if it is true that 'we are all in this together'?[12]

Therefore, the main objectives of this paper are 1) to estimate the health workforce and support staff requirements for COVID-19 vaccination implementation to cover 70% of the global population by mid-2022, and 2) to estimate the cost associated with recruiting and employing the additional health workforce needed to fill the gap.

METHODS

Overarching approach

The estimation of the health workforce requirements was based on the service target–based approach described by Dreesch *et al*.[13] The workload components were based on the principles of the Workload Indicators of Staffing Needs (WISN)[14] methodology adapted to the COVID-19 team-based vaccination context.

Table 1 summarises the series of key steps, adapted from,[13] for the estimation.

First, the service needs are the number of vaccine doses to deliver. In this paper, it is done by estimating the doses, based on a two-dose regimen, to reach 70% of coverage by mid-2022 accounting for the vaccination status of each country as of 1 January 2022. The doses were computed using the total population size from the United Nation's World Population Prospects.[15] No attempt was made to adjust for age structure of each population as the global targets are for 70% coverage of each population irrespective of the size of population of children for which vaccination might be seen as optional.

Second, the overall workload was estimated with a series of working components: number of minutes per dose administered, number of working hours, days per weeks and resting time. The workload includes all necessary activities beyond the immunisation of patients such as registration, screening, answering questions related to vaccine and providing follow-up appointment. The workload is multiplied by the number of doses to derive the number of full time equivalent (FTE) individuals needed to conduct the vaccination implementation. This will be referred to as the workforce *Need* going forward.

Third, because not all countries have the same capacity to redeploy enough health workforce to cover the *Need*, a *Gap* in health workforce was estimated. The maximum redeployment capacity was estimated by multiplying the size of the health and care workforce of each country from the International Labour Organization[16] to a variable redeployment factor ranging from 0% to 5%. For

Table 1 Overview of steps and key inputs to estimate the health workforce requirements for COVID-19 vaccination implementation

Steps	Input	Type	Output
STEP 1. Doses	Population size (UN World Population Prospects), no of doses per vaccine regimen	Population based	No of doses required per country
STEP 2. Workload—total labour requirements	Workload key elements (no of working days per week, no of working hours per day, no of leave days…), time needed to administer vaccination, no of support staff and supervisors per vaccinator	Workforce and vaccination based	Need=no of health workers needed in FTE to deliver COVID-19 vaccination programme
STEP 3. Health workforce gap	Health workforce density, UHC service coverage index	Workforce based	No of health workers deployable from domestic resources, Gap in health workers to cover the Need
STEP 4. Country absorption capacity	No of health worker graduates	Workforce based	Scale-up: no of health workers needed adjusted for the absorption capacity
STEP 5. Costing	Average wages and salaries for each type of staff involved in vaccination	Workforce based	Cost of the workforce for vaccination implementation from domestic resources, scale-up

FTE, full time equivalent; UHC, universal health coverage.

countries where the redeployment capacity was lower than the *Need*, the *Gap* in health workers was computed.

Fourth, for countries with a *Gap* identified, additional health workers, the *Scale-up*, would need to be newly employed. In an ideal unrestricted situation, the *Scale-up* would be equal to the *Gap*. However, the absorption capacity of countries might be limited, and to avoid estimating an unrealistic additional health workforce to employ beyond their production, the absorption capacity of each countries was factored in. A fixed percentage of 70% of the number of newly graduating health workers in a year was used as a proxy of the capacity of each country to mobilise other resources which could include health worker retirees, workers in other sectors or those involved in the army medical services.

Fifth, the FTE of health workforce *Need*, *Gap* and *Scale-up* required can be costed by multiplying these estimates to the relevant monthly wages and salaries.[17] These costs include salaries and social packages but exclude incentives and specific training requirements which were costed separately.

Estimating labour requirements

The total time needed to deliver all doses depended on the average time to administer a vaccine, which includes more than the simple injection time with all the preparatory work, safe disposal activities and documentation. In this analysis, knowledge was gained from multiple sources, including experience from other vaccination campaigns.[18] A main scenario of 10 min average time needed per patient to deliver a vaccine was retained and compared with two alternative scenarios of 5 min and 15 min, respectively. This average time would also allow for some peaks and falls in the vaccination workload. Some examples of vaccination time results are shown in online supplemental appendix 1 (table A1).

The vaccination setting and team composition can vary from place to place and are deterministic factors of productivity. In the present analysis, we considered a middle ground between fixed site settings (with many support staff per vaccinator) and mobile units (with limited support staff but requires factoring in travel time). The 'team composition' does not necessarily require an actual team to be setup however reflects the ratios of support staff and supervision required in addition to vaccinators. Using similar sources and experience from other vaccination campaigns, for 10 vaccinators, we considered the additional staff as one supervisor, 10 support staff and five community mobilisers (it is frequently observed that each vaccinator requires one community mobiliser working part time). While negligible in terms of workload, the importance of infection prevention and control (IPC) measures in vaccination settings is underpinned by the addition of one IPC trainer per 30 vaccinators for 1 day of training.

The average working time (AWT) of a health worker was defined using 7 working hours per day, 4.5 working days per week to account for annual leave, and 4.34 weeks worked per month. We also included an efficiency factor of 85% to account for unforeseeable constraints, such as sick leave and difficulty to recruit among other factors.

These workload elements facilitated the following calculation:

Number of vaccinators needed = (number of doses to be administered × 10 min) / available working time (AWT) per vaccinator during a given period

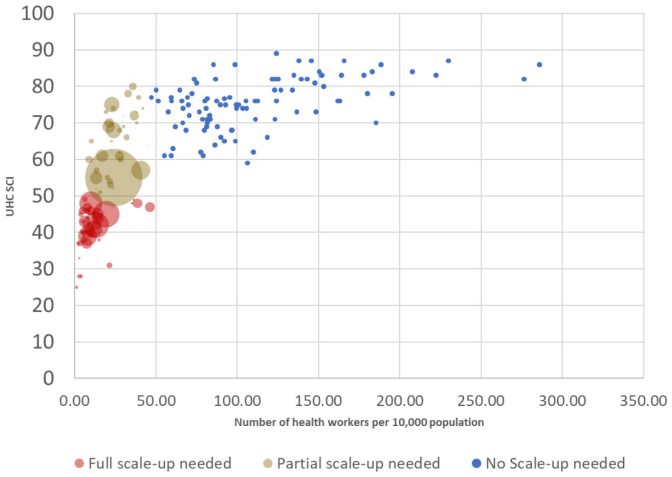

Figure 1 Computation of redeployment percentages relative to the health workforce density (medical doctors, nurses and midwives) per 10 000 population and universal health coverage service coverage index (UHC SCI). Full scale-up needed: countries with a UHC SCI value less than 50 and the number of health workers (doctors, nurses and midwives) less than 48.5 per 10 000 population. Partial scale-up needed: countries with a UHC SCI value less than 80 and the number of health workers (doctors, nurses and midwives) less than 48.5 per 10 000 population. No scale-up needed: countries with a UHC SCI greater than 80 and the number of health workers (doctors, nurses and midwives) greater than 48.5 per 10 000 population. Bubble size proportional to the scale-up required and set to a simple dot for countries with no scale-up needed.

where the AWT=12-month period × 4.34 weeks × 4.5 days × 7 hours × 0.85 efficiency.

Then the number of supervisors, support staff and community mobilisers was calculated based on the 'team composition', and thus the overall number of health workers needed 'the *Need*' was the tally of the number of vaccinators, supervisors, support staff and community mobilisers.

Redeployment factor to estimate domestic redeployment and the remaining gap in the number of health workers needed

The total labour requirement *Need* was compared with the count of health workforce personnel in the country. In this context, the health workforce stock considers the latest counts of medical doctors, nursing personnel, midwifery personnel and pharmacists as collated in the National Health Workforce Accounts.[10]

An initial maximum redeployment proportion (factor) of 5% was used since only a proportion of health workers, which includes workers already involved in immunisation activities, can be redeployed for COVID-19 vaccination. For countries with existing health workforce shortages and low capacity to provide essential health services, redeploying health workers can be challenging. The redeployment proportion of 5% was further adjusted relative to the current health workforce density and the UHC SCI (figure 1), with a value of 5% for countries with UHC SCI above 80 and health workers density above 48.5 per 10 000 population, a value of 0% for countries with a UHC SCI below 50 and a density below 48.5 per 10 000, and an intermediate value ranging from 0% to 5% for countries between these two groups proportionally to the health workforce density and UHC SCI. It was applied to the health workforce stock to estimate the maximum stock of health workers available for vaccination implementation from the domestic labour market (as collated in the National Health Workforce Accounts). Examples of the use of other redeployment percentages are shown in online supplemental appendix 2 (figure A1). As a sensitivity analysis, a minimum redeployment of 0.4%, corresponding to the average redeployment share from high-income countries, was applied to all countries, as well as a minimum of 2% redeployment.

The difference between the *Need* and the maximum redeployment from the domestic market provided the *Gap* in the number of health workers needed for vaccines deployment. Consequently, the estimated *Gap* corresponds to the surge in recruitment of additional health workers (*Scale-up*) that would be needed to deploy COVID-19 vaccines without further compromising essential health service provisions in the country.

Production and absorption capacities

The graduation capacity of each country was used as a proxy of the country's capacity to absorb new health workers in the service delivery system. A percentage of 70% of annual graduates of medical doctors, nursing personnel, midwifery personnel and pharmacists was used to represent the proportion of new graduates potentially entering the health labour market on annual basis. This percentage was deduced from OECD Stat data[19] by activity level from the latest available year, which shows an average ratio between 'practising' and 'licensed to practice' of around 70% for each occupation such as physicians (74%), nurses (70%), dentists (70%) and pharmacists (66%), respectively. It must be noted that this absorption capacity might not cover all needs in all countries. As a consequence, after inclusion of the potential health worker graduates as scale-up, a higher redeployment factor than 5% of domestic staff might be needed to reach 70% coverage for countries with low health workforce and low absorption capacity.

Costing

The costing was estimated considering both the number to be domestically redeployed and those to be recruited in the *Scale-up* required. It was estimated using country-specific average gross salaries from the WHO-CHOICE country-specific estimated health worker wages.[17] The monthly wages were determined by type of health workers as follows: nursing personnel's average salaries were used in the case of supervisors and vaccinators; clerks' average salaries in the case of support staff; as no standard exists for community mobilisers which have usually the lowest salaries or informal employment, we used the lowest wage available, that is, of cleaners in the health and care sector.

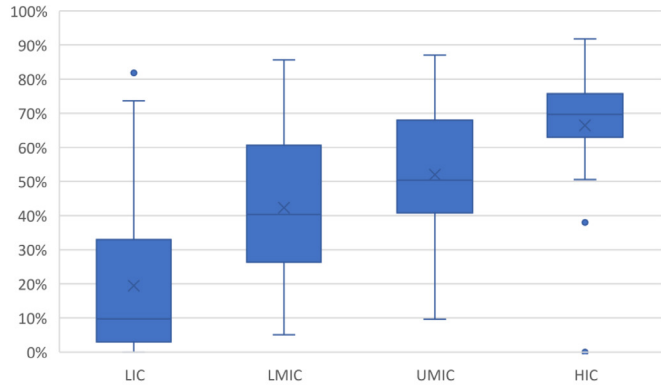

Figure 2 Global COVID-19 vaccination coverage of the general population as of 1 January 2022 by income groups. HIC, high-income countries; LIC, low-income countries; LMIC, lower-middle-income countries; UMIC, upper-middle-income countries.

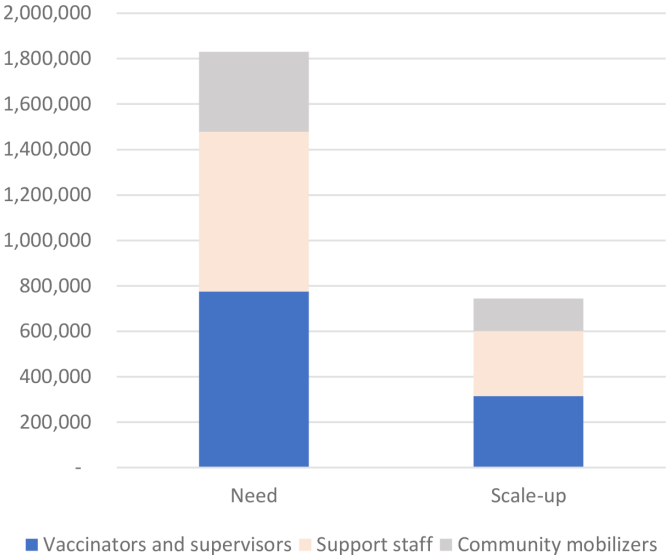

Figure 3 Number of health workers Need and Scale-up required by occupational groups to reach 70% COVID-19 vaccination coverage* by mid-2022. *Reaching 70% coverage from 1 January 2022 to 31 May 2022 based on countries' vaccination status as of 1 January 2022.

Patient and public involvement

No patients involved.

RESULTS

As of 1 January 2022, only 34 countries (17.5%) out of the 194 WHO Member States reached 70% coverage of their population by COVID-19 vaccination. A total of 47 countries did not yet reach the targeted coverage but vaccinated more than 50% of their population. Among the remaining 113 countries which did not reach 50% vaccination coverage, about half (61 countries) did not yet vaccinate a quarter of their population (as of 1 January 2022). Importantly, the vaccination coverage was highly unequal by income group (figure 2).

Going forward, to reach a 70% coverage of the world population, a total of 2.9 billion doses will need to be administered, 76% of these in low-income countries (table 2). There is a large imbalance in population size, health workforce available and doses to deliver by income group with low-income and lower-middle-income group countries representing 78% of the global population and only half of the global stock of medical doctors, nurses, midwives and pharmacists.

Applying the methods and assumptions described in previous sections, the *Need* of health workforce globally would be 1 831 000 health workers, distributed as 775 000 vaccinators and supervisors, 704 000 support staff and 352 000 community mobilisers working full time during a 6-month period from 1 January until the end of June 2022.

Compared with the health workforce stock in countries, the additional health workers to employ, that is, the *Scale-up*, would be 744 000 health workers: 315 000 vaccinators and supervisors, 286 000 support staff and 143 000 community mobilisers (figure 3). The majority of the *Scale-up* is in low-income countries (figure 4) where service disruptions have been evident throughout the pandemic.

Because of the capping of the scale-up with an absorption capacity of 70%, a total of 49 countries would need to redeploy more than 5% of their existing workforce and 29 above 20% of their existing workforce, respectively.

Table 2 Distribution of population, health workers (medical doctors, nurses, midwives and pharmacists) and number of COVID-19 doses to deliver to reach 70% coverage, by income group

	Population (million) (%)		Number of medical doctors, nurses, midwives, pharmacists (thousands) (%)		Number of doses to deliver to reach 70% coverage (million) (%)	
Low-income countries	3184	(41)	7886	(17)	2252	(76)
Lower-middle-income countries	2833	(37)	16 530	(35)	506	(17)
Upper-middle-income countries	659	(9)	5226	(11)	186	(6)
High-income countries	1074	(14)	18 019	(38)	1	(0)
Total	7750	(100)	47 660	(100)	2945	(100)

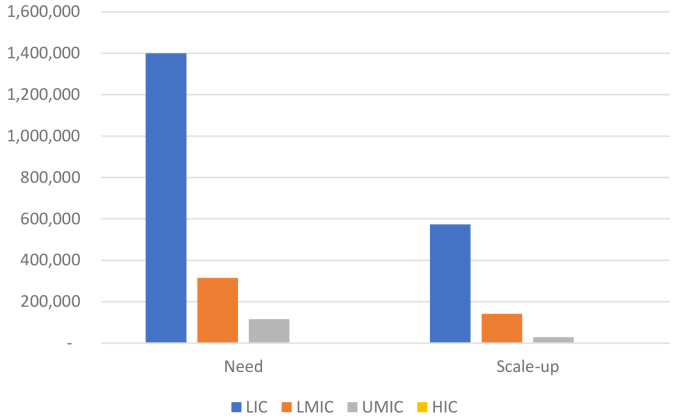

Figure 4 Number of health workers Need and Scale-up required by income groups to reach 70% COVID-19 vaccination coverage* by mid-2022. *Reaching 70% coverage from 1 January 2022 to 31 May 2022 based on countries' vaccination status as of 1 January 2022. HIC, high-income countries; LIC, low-income countries; LMIC, lower-middle-income countries; UMIC, upper-middle-income countries.

These countries are mostly low-income countries. A total of 12 countries have been identified as having to redeploy above 50% of their existing workforce because of its insufficient size and insufficient absorption capacity; therefore these countries are unlikely to achieve the 70% target by mid-2022.

In a sensitivity analysis, allowing a minimum of 0.4% redeployment of domestic health workforce as the average redeployment estimated for high-income countries, the *Scale-up* remained high with 742 000 health workers: 314 000 vaccinators and supervisors, 285 000 support staff and 142 000 community mobilisers. Even allowing a minimum of 2% redeployment for all countries would require a sizeable Scale-up of 506 000 health workers.

This analysis was also replicated under two alternative scenarios with a low average time per vaccination of 5 min per vaccination and a high average time of 15 min per vaccination (table 3) showing the important effect of the duration of vaccination administration. Similarly, the duration of the vaccination period had an important impact as increasing the vaccination of 70% of the global population over 12 months instead of 6 months. It would reduce the *Scale-up* required to 476 000 health workers (compared with 744 000).

Under assumption of a 10 min requirement for vaccine administration, a total of US$6.5 billion would be required to cover the overall health workforce need, mostly for vaccinators (table 4). Out of this overall cost, about US$2.5 billion would need to be allocated to recruit additional health workers.

Several countries are unlikely to reach the 70% coverage by mid-2022 given the high redeployment of domestic resources required. It is probable that new targets will be considered for achieving vaccination coverage by the end of 2022. With such an extended deadline, the health

Table 3 Health workforce requirements to reach 70% COVID-19 vaccination coverage* by mid-2022 with three scenarios depending on average time required per vaccination

Income groups (number of countries)	Health workforce requirements, low timing scenario (5 min per vaccination or 84 vaccinations per day per vaccinator)		Health workforce requirements, central scenario (10 min per vaccination or 42 vaccinations per day per vaccinator)		Health workforce requirements, high timing scenario (15 min per vaccination or 21 vaccinations per day per vaccinator)	
	Need	Scale-up	Need	Scale-up	Need	Scale-up
Low-income countries (n=62)	699 900	388 900	1 399 600	573 900	2 099 400	740 500
Lower-middle-income countries (n=54)	157 400	70 100	314 700	141 300	472 000	210 900
Upper-middle-income countries (n=39)	57 900	17 400	115 800	28 700	173 700	34 300
High-income countries (n=39)	300	–	600	–	900	100
Global (n=194)	915 500	476 300	1 830 800	744 000	2 746 000	985 800

Values were rounded to the closest hundred.
*Vaccination required to reach 70% from 1 January 2022 to 31 May 2022 based on countries' vaccination status as of 1 January 2022.

Table 4 Estimation of the costs associated with overall health workers Needs and Scale-up required to reach 70% COVID-19 vaccination coverage* by mid-2022

	Vaccinators and supervisors	Support staff	Community mobilisers
Income groups	Costs in million US$	Costs in million US$	Costs in million US$
Overall health workers' needs			
Low-income countries	2420	1312	392
Lower-middle-income countries	868	471	141
Upper-middle-income countries	525	285	85
High-income countries	9	5	1
Global	3823	2072	619
Scale-up in health workers			
Low-income countries	1007	546	163
Lower-middle-income countries	324	176	53
Upper-middle-income countries	130	70	21
High-income countries	–	–	–
Global	1462	792	237

*Vaccination required to reach 70% from 1 January 2022 to 31 May 2022 based on countries' vaccination status as of 1 January 2022.

workforce requirements would be less than 1 million, with a scale-up of less than half a million health workers (table 5).

Such an extended target would also decrease the pressure on countries struggling to redeploy health workers. In a scenario with 6 months to vaccinate, 29 countries required to redeploy more than 20% of their staff, if the timeline was extended to the end of 2022, it would mean that only 14 countries would be in such a situation. It can also be estimated that if the vaccination period extends to the end of 2022, an estimate of the costs for scale-up will be around US$3.2 billion.

An alternative estimation can be made to estimate the time required to reach 70% coverage under the constraint of a maximum of 5% redeployment of existing staff. For the 49 countries for which our estimation showed that more than 5% of health workers would need to be redeployed, the average total duration required would be 3 years and 9 months (ranging from 6 months in Gabon to 15 years in Somalia). Also, 22 countries would need more than 3 years to reach 70% COVID-19 vaccination coverage while limiting the redeployment of their existing staff to 5%.

DISCUSSION

The present analysis shows that to reach 70% COVID-19 vaccination coverage by mid-2022, and based on countries' vaccination status as of 1 January 2022, 1 831 000 health workers working full time will be needed out of which 744 000 are extra health and care workers added to domestic resources mostly in low-income countries.

This estimation is based on a standard and country-applied[20] health workforce requirement approach[13] applying workload components, and an adaptation allowing the estimation of a scale-up required based on the most recent health workforce density and UHC SCI. Several parameters play an important role, and the average time required per vaccine administration is one important parameter. While an average 10 min was used, it is plausible that in large vaccination centres an average duration of vaccination can be decreased down to 5 min

Table 5 Health workforce requirements to reach 70% COVID-19 vaccination coverage* by end of 2022

	Health workforce requirements, central scenario (10 min per vaccination or 42 vaccinations per day per vaccinator)	
Income groups (number of countries)	Need	Scale-up
Low-income countries (n=62)	699 900	388 900
Lower-middle-income countries (n=54)	157 400	70 100
Upper-middle-income countries (n=39)	57 900	17 400
High-income countries (n=39)	300	—
Global (n=194)	915 500	476 300

Values were rounded to the closest hundred.
*Vaccination required to reach 70% from 1 January 2022 to 31 December 2022 based on countries' vaccination status as of 1 January 2022.

which would accelerate vaccination and optimise recruitment of health workers. However, in such case, many more support workers, and further staffing involved in entry, exit management and security would be needed. While this model could be used in an urban setting, remote areas and areas with limited access to the population to be vaccinated will need a different strategy. On the other hand, using mobile clinics would reduce the team composition to a vaccinator, a support staff and a community mobiliser working part time, but extra time per vaccination would be required.

In the present analysis, the redeployment factor was defined by the size of health workforce in each country and the UHC SCI. This proved to be practical in differentiating countries that would require some support from those who are better resourced with higher health workforce density and achieving high essential services coverage. It could be argued that all countries would be able to redeploy at least a minimum number of health workers instead of 0% applied in the main analysis. However, the sensitivity analysis using a minimum redeployment for all countries showed that the *Scale-up* required was not decreased by substantial amount. In addition, because the scale-up requirements was based on the absorption capacity of each country, it was noted that several countries would still likely not be able to reach 70% coverage because of too few health workers and a low absorption capacity, and that attaining such target could take more than 3 years with existing staff.

Our study has a number of limitations which are associated with the parameters used and applied to all countries. This assessment would therefore not replace a country contextualisation in which additional resources could be identified or mobilised, and for which the vaccination settings could differ significantly. Another limitation is the use of health workforce statistics mostly prior to COVID-19 pandemic. As a consequence, it is possible, although not quantifiable, that the workforce available for vaccination could have decreased because of various impacts COVID-19 could have had to health and care workers, including illness, burnout and deaths.[5 21]

The additional recruitments and associated costs are a must, not an option in the short term to close the *Gap* with the necessary *Scale-up*. In doing so, systems solutions could be introduced such as hiring unemployed health workers as well as anticipating employment of medical and nursing students. More importantly, these short-term solutions can be perceived as long-term investments for four main reasons. First, the pre-COVID-19 world saw a situation of major health workforce shortages in many low-income countries. The World Health Assembly called for transformative actions on multiple occasions[22 23] to accelerate investments in the health workforce. The pandemic continues to demonstrate the importance of greater investment in preparedness which also translates into expanded staffing needs. Second, while vaccine deployment against COVID-19 showed unequal progress, the need for booster doses will further impact the total health workforce needed after 70% coverage is achieved. Third, health workforce investments entail several economic returns that in most cases surmount the initial cost.[24] In global terms, investing in the health workforce is a short-term response to the pandemic with economic returns. Fourth, according to current recommendations, COVID-19 vaccination is almost a universal population coverage of all ages. Vaccination is fundamentally a primary healthcare (PHC) activity. Investing in skilled health workers to expand PHC capacity would also result in strengthened health systems and improved population health outcomes. Specifically, as we think about the almost 8% of children (19.7 million) globally who are unvaccinated or undervaccinated for routine immunisations, the scaled up workforce which primarily target low-income countries could potentially assist in reaching these 'Zero dose' children.[25] It can be anticipated that, because of fiscal space constraints in several countries, the investment will initially be from short-term assistance from external funding. However, this vision of long-term strengthening on PHC should be incorporated by investigating means of converting the surge into permanent positions in the longer term.

This COVID-19 vaccination roll-out occurs in pre-existing situation with various political instability and health hazards such as conflict, environmental hazards and floods. These situations could create a barrier to implementing immunisation against COVID-19. Also, although not costed in our assessment, these contextual situations of specific risks might require additional investment to ensure safety and decent working condition of health workers. In addition, the present study presents only the health workforce perspective for the COVID-19 vaccine deployment, but other elements are also important such as supply of vaccine and materials, all possibly creating additional bottleneck to the COVID-19 vaccination programme. From Pulse surveys conducted to assess continuity of essential health services during COVID-19 pandemic, malfunctions and failures of various component health systems often occur simultaneously.[2] This means that countries identified with low health workforce in the present study would also likely face other critical failures within their health system which should also be addressed. In addition to health system components, vaccine hesitancy would also affect the roll-out of vaccination. A review of studies on COVID-19 vaccine acceptance showed that populations of low-income and middle-income countries could have a higher willingness to take a COVID-19 vaccine.[26] In addition. this study also highlighted the specific role of health and care workers as trusted sources of information, in line with our approach which included a role for community mobilisers.

CONCLUSION

Having the right number and right health workforce is a fundamental component of a COVID-19 vaccination delivery plan in any country regardless of economic

status. Countries are facing the biggest vaccination programme in the history of public health that is rolling out in the fastest timeframe possible. While the costs associated with the deployment of health workers are high with US$6.5 billion to reach 70% vaccination coverage, these are negligible as compared with the economic costs of the pandemic.[27] A global shortage of health workers prevailed pre-COVID-19 coupled with chronic health labour market imbalances (in subnational distribution, market share (public/private/formal/informal), and in terms of mobility between countries and sectors). Sizing the health workforce requirements for vaccination implementation is essential to avert the risks of diverting health workers from essential services and further aggravating the impact of the pandemic.

Acknowledgements The authors would like to acknowledge Ulla Griffith (UNICEF), Alex de Jonquieres (GAVI), Ann Lindstrand and Kate O'Brien (WHO IVB), Gilles Guillot (WHO HWF) and staff from the IVB department of WHO for helpful discussion when preparing this method paper.

Contributors MB, KD and JC conceptualised the study. MB, AS, SD and AM conducted data management and statistical analysis. MB, AS, SD, SG, AM, TSN, KD and JC assessed and interpreted the results. MB drafted the first manuscript. All authors contributed to editing the manuscript. All authors read and approved the final manuscript. MB acts as guarantor.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request to hrhstatistics@who.int and raw statistics on health workforce on the NHWA online platform (http://apps.who.int/nhwaportal/).

ORCID iDs
Mathieu Boniol http://orcid.org/0000-0003-1052-5604
Shalini Desai http://orcid.org/0000-0003-3913-2505

REFERENCES

1 WHO. Pulse survey on continuity of essential health services during the COVID-19 pandemic: interim report. Geneva World Health organization; 2020 [Accessed 27 Aug 2020].
2 WHO. *Second round of the national pulse survey on continuity of essential health services during the COVID-19 pandemic*. Geneva: World Health Organization, 2021.
3 WHO. Weekly epidemiological update. Geneva World Health Organization; 2021 [Accessed 2 Feb 2021].
4 World Health Organization. The impact of COVID-19 on health and care workers: a closer look at deaths, 2021. Available: https://apps.who.int/iris/handle/10665/345300
5 WHO. Weekly epidemiological update on COVID-19. Geneva World Health Organization; 2021 [Accessed 30 Mar 2021].
6 Seventy-third world health assembly - Resolutions and decisions, 2020
7 WHO. WHO SAGE roadmap for prioritizing uses of COVID-19 vaccines in the context of limited supply. Geneva World Health Organization; 2021. https://www.who.int/publications/i/item/who-sage-roadmap-for-prioritizing-uses-of-covid-19-vaccines-in-the-context-of-limited-supply [Accessed 16 Jul 2021].
8 WHO. *Global strategy on human resources for health: workforce 2030*. Geneva: World Health Organization, 2016. http://apps.who.int/iris/bitstream/10665/250368/1/9789241511131-eng.pdf
9 Hogan DR, Stevens GA, Hosseinpoor AR, *et al*. Monitoring universal health coverage within the sustainable development goals: development and baseline data for an index of essential health services. *Lancet Glob Health* 2018;6:e152–68.
10 World Health Organization. National health workforce accounts data portal, 2021. Available: https://apps.who.int/nhwaportal/
11 World Health Organization. *Strategy to achieve global Covid-19 vaccination by mid-2022*. Geneva: World Health Organization, 2021.
12 Guterres A, Nations U, eds. *United Nations*, 2021. https://www.un.org/en/un-coronavirus-communications-team/we-are-all-together-human-rights-and-covid-19-response-and
13 Dreesch N, Dolea C, Dal Poz MR, *et al*. An approach to estimating human resource requirements to achieve the millennium development goals. *Health Policy Plan* 2005;20:267–76.
14 WHO. *Workload indicators on staffing needs (WISN). User's manual*. Geneva: World Health Organization, 2010. https://apps.who.int/iris/handle/10665/44414
15 United Nations - Department of Economic and Social Affairs - Population Division. World population prospects 2019; 2019. https://population.un.org/wpp/
16 Employment by sex and age — ILO modelled estimates, 2021. Available: https://ilostat.ilo.org/data [Accessed 1 Sep 2021].
17 Stenberg K, Lauer JA, Gkountouras G, *et al*. Econometric estimation of WHO-CHOICE country-specific costs for inpatient and outpatient health service delivery. *Cost Eff Resour Alloc* 2018;16:1–15.
18 WHO. Planning and Implementing High-Quality Supplementary Immunization Activities for Injectable Vaccines. Geneva World Health Organization; 2016.
19 OECD. OECD.Stat Paris: OECD, 2021. Available: https://stats.oecd.org/
20 Kunjumen T, Okech M, Diallo K, *et al*. Global experiences in health workforce policy, planning and management using the Workload Indicators of Staffing Need (WISN) method, and way forward. *Hum Resour Health* 2022;19:1–4.
21 WHO. The impact of COVID-19 on health and care workers: a closer look at deaths – Working Paper 1 Health Workforce Department; 2021. https://apps.who.int/iris/handle/10665/345300
22 World Health Assembly. Human resources for health and implementation of the outcomes of the United Nations' High-Level Commission on Health Employment and Economic Growth. Geneva World Health Organization; 2017.
23 World Health Assembly. Global strategy on human resources for health: workforce 2030. Geneva World Health Organization; 2016.
24 High-Level Commission on Health Employment and Economic.. *Working for health and growth: investing in the health workforce*. World Health Organization, 2016. http://apps.who.int/iris/bitstream/10665/250047/1/9789241511308-eng.pdf?ua=1
25 Cata-Preta BO, Santos TM, Mengistu T, *et al*. Zero-dose children and the immunisation cascade: understanding immunisation pathways in low and middle-income countries. *Vaccine* 2021;39:4564–70.
26 Solís Arce JS, Warren SS, Meriggi NF, *et al*. COVID-19 vaccine acceptance and hesitancy in low- and middle-income countries. *Nat Med* 2021;27:1385–94.
27 United Nations Department of Economic and Social Affairs. World Economic Situation and Prospects (WESP) mid-2020 report 2020, 2020. Available: https://www.un.org/development/desa/publications/world-economic-situation-and-prospects-wesp-mid-2020-report.html