Projected health-care resource needs for an effective response to COVID-19 in 73 low-income and middle-income countries: a modelling study

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Summary

Background Since WHO declared the COVID-19 pandemic a Public Health Emergency of International Concern, more than 20 million cases have been reported, as of Aug 24, 2020. This study aimed to identify what the additional health-care costs of a strategic preparedness and response plan (SPRP) would be if current transmission levels are maintained in a status quo scenario, or under scenarios where transmission is increased or decreased by 50%.

Methods The number of COVID-19 cases was projected for 73 low-income and middle-income countries for each of the three scenarios for both 4-week and 12-week timeframes, starting from June 26, 2020. An input-based approach was used to estimate the additional health-care costs associated with human resources, commodities, and capital inputs that would be accrued in implementing the SPRP.

Findings The total cost estimate for the COVID-19 response in the status quo scenario was US$52·45 billion over 4 weeks, at $8·60 per capita. For the decreased or increased transmission scenarios, the totals were $33·08 billion and $61·92 billion, respectively. Costs would triple under the status quo and increased transmission scenarios at 12 weeks. The costs of the decreased transmission scenario over 12 weeks was equivalent to the cost of the status quo scenario at 4 weeks. By percentage of the overall cost, case management (54%), maintaining essential services (21%), rapid response and case investigation (14%), and infection prevention and control (9%) were the main cost drivers.

Interpretation The sizeable costs of a COVID-19 response in the health sector will escalate, particularly if transmission increases. Instituting early and comprehensive measures to limit the further spread of the virus will conserve resources and sustain the response.

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Introduction

On Jan 30, 2020, WHO declared SARS-CoV-2 a Public Health Emergency of International Importance, later formally identified as COVID-19.[1] The declaration advised the member states to prepare for containment and prevention of onward spread of the virus. After a week, 24 363 cases were reported, 99% of which were in China and the rest in 24 other countries. In response, WHO appealed for US$675 million to support member states over a 3-month period, as they began implementing priority public health measures.[2] The priority public health measures were outlined in the eight pillars of the strategic preparedness and response plan (SPRP), and ranged from country coordination to clinical case management.[3]

As of July 1, 2020, more than 10 million cases of COVID-19, including more than 500 000 deaths, had been reported globally.[4] WHO explicitly expanded the scope of the SPRP to include a ninth pillar on the maintenance of essential health services in acknowledgment that the pandemic was already straining the health system.[5] WHO also released guidance on public health and social measures (PHSM) to slow down the transmission of the virus.[6] Countries closed offices, schools, restaurants, places of worship, and banned large gatherings to restrict movement and to avoid further straining of the health system.[7] Epidemiological models have predicted that many more deaths and infections would have occurred if these measures were not implemented.[8] However, the social and economic repercussions of the PHSM are also beginning to emerge. The World Bank has forecast global GDP will contract by 5·2% in 2020, on the assumption that measures will start to be lifted in the second half of the year. If the COVID-19 pandemic persists, and movement restrictions are maintained or intensified, greater losses are predicted.[9] This study aims to project the future costs of the strategic response and preparedness actions in the health sector to counter the COVID-19 outbreak. Given the

Research in context

Evidence before this study

Since Jan 30, 2020, when WHO labelled the COVID-19 pandemic a Public Health Emergency of International Concern, countries have tried to limit its spread, instituting measures on physical distancing and restrictions on movement. With more than 10 million cases reported, the World Bank and other major financing institutions have projected an overall contraction of 5·2% of global gross domestic product due to COVID-19 in 2020, with persisting effects in the years to come. This projection was made on the assumption that the restrictions will be lifted in the second half of 2020; however, the costs of the actions needed to respond to the pandemic, which could enable the lifting of these restrictions, have not been estimated for low-income and middle-income countries. From a different perspective, some costing work has been done on preparedness. In 2016, after the Ebola outbreak, The National Academy of Medicine launched the Commission on a Global Health Risk Framework for the Future. The Commission estimated US$4·5 billion a year globally for pandemic preparedness versus an annualised expected loss from potential pandemics of more than $60 billion. In December 2017, the International Working Group on Financing Preparedness issued a report on investing in health security. Based on a few country studies costing the multisectoral national action plans for health security, they estimated a cost of $0·5–1 per person per year on preparedness.

Added value of this study

To our knowledge, this is the first study costing a strategic response to COVID-19, a Public Health Emergency of International Concern. Considering the baseline preparedness of low-income and middle-income countries, and the limited resilience of their health systems, major investment will be needed to counter the virus. The result of the status quo scenario, a health-care cost total of US$52·45 billion or $8·60 per capita after 4 weeks for 73 low-income and middle-income countries, is not an insignificant cost, but reflects the constrained capacity in the countries facing a virus that has spread and established itself. Some hope is offered by the scenario in which the public health and social measures are intensified, resulting in a decrease in transmission by 50%. However, the costs, when the restrictions are relaxed and transmission increases by 50%, escalated at 4 weeks and further escalated at 12 weeks. The results show which pillars of the strategic preparedness and response drive the costs. This study should inform governments, as they consider relaxing restrictions to jumpstart their economies.

Implications of all the available evidence

The arguments for investing in preparedness are strong, juxtaposed against the price tag for the response versus COVID-19, and coupled with the expected shock on the global economy. Future work at the country level is needed to strategically identify the gaps in both preparedness and response against not only COVID-19, but also for other potential future pandemics.

uncertainty in the future course of the disease, estimates are provided in the short term, and separate scenarios are modelled where current measures to restrict movement are maintained, relaxed, or intensified.

Methods

Scope

This study estimates the costs of implementing the nine pillars of the SPRP in 73 low-income and middle-income countries (appendix p 20), accounting for 93·4% of the total population in that group of countries. The nine pillars of the SPRP and the key cost items in each pillar are presented in table 1.

See Online for appendix

The study includes low-income countries, and the most populous lower-middle-income and upper-middle-income countries, and it excludes countries for which no GDP or epidemiological data were available.

The costs were additional to what is currently known to exist, or to have been spent by the countries at the start of the analysis (June 26, 2020), and were estimated in the 4-week and 12-week periods after this date (ie, until July 24 and Sept 18, 2020). The costing was therefore synchronised chronologically to show the same time period in countries at different stages of the epidemic. All of the one-time and recurrent inputs that were expected to occur within these two time periods to prevent new cases, and to treat prevalent and incident cases, were costed. During this time, the course of the pandemic might change, depending on decisions taken by national leaders on either relaxing or intensifying PHSM. In an attempt to capture this potential uncertainty, for each time period, three scenarios were analysed with the current measures to restrict movement, and facilitate physical and social distancing, being either maintained, relaxed, or intensified.

Only costs expected to be borne by the health sector were included, and costs related to any social mitigation interventions, such as cash or in-kind transfers, were excluded. An inputs-based approach was taken, where quantities of items related to each activity were multiplied by the unit price for each item. The interim guidance documents issued by WHO and consultations with experts from relevant technical programmes were the sources of the types and quantities for key items.

Modelling of the number of new cases and deaths from COVID-19

The estimated number of cases of COVID-19 were secondary data taken from the epidemiological model from Imperial College (London, UK).[10] This model was used because it provides publicly available estimates for a

	Key cost items
(1) Country-level coordination, planning, and monitoring	Coordination teams and communications equipment
(2) Risk communication and community engagement	Risk communications teams, mass media campaigns, and materials
(3) Surveillance, rapid-response teams, and case investigation	Rapid response, surveillance, and contact-tracing teams, including additional human resources for contact tracing
(4) Points of entry, and international travel and transport	Points of entry teams, training, personal protective equipment, and test kits
(5) National laboratories	Diagnostic machines and laboratory consumables
(6) Infection prevention and control	Personal protective equipment, cloth masks, hygiene commodities (soap and hand sanitisers), and hand-washing stations
(7) Case management	Human resources for health (incentives and hazard pay), field hospitals, biomedical equipment, drugs and consumables, and safe burial teams
(8) Operational support and logistics	Logistics teams, warehouses
(9) Maintaining essential health services and systems	Coordination teams, salaries of new hires, facility repurposing, outreach teams, and rented ambulances

Table 1: **Pillars of strategic preparedness and response plan and associated key cost items**

large number of low-income and middle-income countries. This susceptible, exposed, infected, and recovered or removed (SEIR) model was calibrated on confirmed deaths from the start of the COVID-19 outbreak up to June 26, 2020. Imperial College runs the model regularly for all countries, except those where low levels of reported COVID-19 deaths does not permit accurate modelling. For this costing exercise, countries without projected COVID-19 epidemiology from the model were China, Iran, Tanzania, Uganda, and Zimbabwe. For these countries, a separate SEIR model, provided by Imperial College as a script in the R programming language, was run by our research team using effective reproduction (*Rt*) values taken from the Centre for Mathematical Modelling and Infectious Diseases Repository associated with the London School of Hygiene & Tropical Medicine (London, UK).[11] *Rt* values are commonly described as the number of contacts that a case infects. The model projected cases for the 4 weeks and 12 weeks following June 26, 2020, under three scenarios: status quo (maintain current transmission), an increase in transmission by 50%, and a decrease in transmission by 50%. The increased and decreased transmission scenarios work through changes in the *Rt* and the level of mobility in the epidemiological model. As the projections are made based on the current state of the pandemic in each country, the results reflect a wide range of response strategies. We also report outputs of the epidemiology modelling at the start and the end of the period according to the Oxford Stringency Index, which measures the level of COVID-19 mitigation measures implemented at the country level.[7]

Calculating capital and one-time costs

Capital costs included within the resource needs for COVID-19 response are intended for upgrading laboratories for diagnostic testing (pillar 5), buying field hospitals to expand capacity for treating COVID-19 patients (pillar 7), and repurposing health facilities to enable them to cope with non-COVID-19 patients who would otherwise have been treated in hospitals providing care to COVID-19 patients (pillar 9) to lift the supply side constraint of hospital and intensive care unit beds, procuring communications equipment (pillar 1), and providing motorcycles for contact-tracing teams (pillar 3; table 1). Another capital cost would be the provision of handwashing stations for hygiene (pillar 6). In addition to capital costs, a series of one-time costs are included, such as the hiring of consultants to develop or adapt guidance documents, prepare online training courses, document plans, design communications materials, and other related duties. All these components would be scaled depending on the level of the epidemic and according to appropriate administrative scalars (eg, by the number of subnational administrative units or number of health facilities per country).

Calculating costs of commodities

The essential supplies forecasting tool version 2 (ESFT2)[12] was used to estimate the costs of key commodities and supplies as part of the COVID-19 response. These commodities and supplies included personal protective equipment, single-use masks, diagnostic tests, supportive drugs (including dexamethasone), disposable supplies, and oxygen for hospitalised patients. To estimate the quantities of commodities needed for a country's COVID-19 response, the ESFT2 combined the assumptions on the number of items related to each case with the number of cases, split by severity. Only 20% of cases (15% severe and 5% critical) were assumed to need hospitalisation.[13] The prices of each item, although found in the ESFT2, were updated using international market prices.[14]

For diagnostics and testing, the ESFT2 assumed that all hospitalised COVID-19 patients were tested, and that there was a targeted testing strategy, where 10% of all suspected cases were also tested. Testing was constrained by a country's diagnostic capacity, as determined by the available diagnostic instruments and the number of laboratory technicians available to focus on COVID-19 diagnostics and do the PCR-based tests. These supply-side constraints were lifted partly by the purchase of automated extraction platforms, expanding the working week for laboratories from 5 days to 6 days, and adding another 8 h shift to laboratory operations.

	Number of countries			Population* (millions)	Oxford Stringency Index* (median)	Number of daily contacts* (average)	Percentage infected	Percentage infected at 4 weeks†			Percentage infected at 12 weeks‡		
	Low Income	Lower-middle income	Upper-middle income					Status quo	Decrease transmission 50%	Increase transmission 50%	Status quo	Decrease transmission 50%	Increase transmission 50%
Rt category													
<1	6	1	0	178	74·07	3·47	0·40%	0·50%	0·44%	0·62%	0·74%	0·45%	3·68%
1 to <1·5	11	10	9	3223	67·56	6·16	1·26%	2·87%	1·82%	3·70%	10·71%	1·92%	24·31%
1·5 to <2	10	13	11	2690	69·19	8·23	0·93%	7·51%	2·38%	10·70%	54·93%	3·59%	69·24%
≥2	0	2	0	8	78·94	8·85	0·82%	12·74%	3·21%	15·77%	66·50%	7·13%	72·28%

Data are n, unless stated otherwise. *At June 26, 2020. †At July 24, 2020. ‡At Sept 18, 2020.

Table 2: **Epidemiological profile and projections for the 4-week and 12-week (after June 26, 2020) timeframes**

Calculating human resource costs

To calculate health worker costs, the Health Workforce Estimator tool (HWE)[15] was used instead of ESFT, because it went into greater detail in identifying the time requirements of more cadres of workers needed in treating people with COVID-19. As a result, the costing included cadres ranging from doctors to cleaners and other patient support personnel. Baseline numbers of health workers were drawn from the Global Health Observatory.[16] An assumption was made that a supply side constraint existed, and only a maximum of 60% of the existing health workers could be prioritised for the COVID-19 response. They continued to receive their salaries, and these are not included in the costing. Incentives, both financial and non-financial (eg, paid sick leave including time spent in quarantine; occupational risk insurance or life insurance; ensuring treatment for illness; provision of child or elder care support; or accommodation near the health facility, transport, or relocation allowance, or all three), estimated at 50% of the average monthly salary, were paid to all those working directly in the COVID-19 response in health facilities. Hazard pay at 25% of salary was paid to all those at increased risk, defined as those having close contact with a COVID-19-positive patient. To maintain essential health services, salaries were paid to new hires to replace half of the number of existing health workers prioritised for COVID-19 response, on the assumption that 100% replacement was not needed because non-urgent consultations and elective admissions are being postponed. The new hires were expected to come from the private sector, or from retirees or soon-to-be graduates. Salaries were obtained from the WHO-CHOICE salary database[17] and were updated to 2020 US$.

Sensitivity analysis

To capture the main uncertainty in the cost of the pandemic response that arises from the course of the pandemic itself and the policy responses of the governments, both increase and decrease in transmission of 50% were modelled. In addition, because providing incentives is a policy response that governments might choose to exercise, the costs are presented with (base case) and without the incentives. More details are available in the full technical documentation (appendix pp 11–12).

Role of the funding source

Resources from WHO (funding for consultants and salaries of staff) were used to produce the estimates in this paper. The authors (all from WHO except OW, who is funded by the UK Foreign Commonwealth and Development Office) were solely responsible for the design, conduct, analysis, and writing up of the study. The corresponding author had full access to the data and took the decision to submit for publication.

Results

At the start of the analysis on June 26, 2020, seven countries had an *Rt* of less than 1, two countries had an *Rt* of 2 or more, but most countries had an *Rt* of 1–2 (table 2). Across the *Rt* categories, the median Oxford Stringency Index, ranged from 67·56 to 78·94 (with 100 representing the most stringent measures); the mean number of daily contacts, which is the number of personal interactions, ranged from 3·47 to 8·85; and the percentage of the population infected, which is an estimate of cumulative infections, ranged from 0·40% to 1·26%. At the end of 4 weeks, the percentage infected was projected to increase in the status quo, particularly in those with an *Rt* of 1·5 or greater, and much larger burdens were projected for the 50% increase in transmission scenario. Under the 50% decrease in transmission scenario, only a slight increase in the percentage infected was projected. During the 12-week timeframe, a similar pattern emerged, and many more cases were projected in the status quo and 50% increased transmission scenarios, whereas in the 50% decreased transmission scenario, the case burden remained relatively stable, except in countries where the *Rt* was 2 or greater.

	Low income (population 685 066 000)		Lower-middle income (population 2 920 000 000)		Upper-middle income (population 2 493 375 000)		Total (population 6 098 441 000)	
	Total cost (billions)	Cost per capita	Total cost (billions)	Cost per capita	Total cost (billions)	Cost per capita	Total cost (billions)	Cost per capita
Total cost (4 weeks)								
Status quo	2·25	3·28	24·74	8·48	25·46	10·21	52·45	8·60
Decrease transmission 50%	1·65	2·41	14·18	4·86	17·24	6·92	33·08	5·42
Increase transmission 50%	3·30	4·82	30·08	10·30	28·54	11·45	61·92	10·15
Total cost (12 weeks)								
Status quo	6·20	9·06	80·97	27·73	66·69	26·75	153·86	25·23
Decrease transmission 50%	2·30	3·36	23·28	7·97	26·53	10·64	52·11	8·54
Increase transmission 50%	10·99	16·04	104·88	35·92	80·98	32·48	196·85	32·28

Costs are in 2020 US$.

Table 3: **4-week and 12-week (after June 26, 2020) cost of COVID-19 response by country income group**

The costs of the COVID-19 response in low-income, lower-middle-income, and upper-middle-income countries after 4 weeks and 12 weeks under the different scenarios are shown in table 3. The total cost at this stage of the epidemic, if the status quo is maintained over 4 weeks, is $52·45 billion with a per-capita cost of $8·60. If more measures to facilitate physical and social distancing, and to restrict movement were applied, and countries' transmission was reduced by 50%, the 4-week resource requirements would be reduced to $33·08 billion ($5·42 per capita). With 50% increased transmission, under a scenario of relaxed restrictions, costs of $61·92 billion ($10·15 per capita) over the same 4-week period would be generated. In the 12-week projection, costs would more than tripled under the status quo and 50% increased transmission scenarios. The costs of the 50% decreased transmission scenario over 12 weeks is equivalent to the cost of the status quo scenario at 4 weeks. Most of the costs would be accrued in the middle-income countries. The top ten countries (appendix p 21) would account for 74% of the costs in the 1-month status quo scenario, and this pattern is stable across the different timeframes and scenarios. The dominance by a handful of countries is due to a combination of factors: larger populations, higher prices, and a more widespread epidemic.

The distribution of the costs over the nine pillars are shown at 4 weeks in table 4 (data for 12 weeks are provided in the technical documentation; appendix p 24). Under the status quo scenario, case management would account for around 54% of the costs, 21% would go to maintaining essential health services, and around 14% to investigation, surveillance, and rapid response. The building of handwashing stations, and procurement of personal protective equipment and cloth masks within pillar 6 accounts for about 9% of the cost. These pillars would be the major cost drivers of implementing an effective COVID-19 response. The pattern of the distribution of the costs is generally maintained under the 50% increased and decreased transmission scenarios, except for a decrease in the proportion of costs in investigation in the 50% decreased transmission scenario and an increase in the same costs under the 50% increased transmission scenario, compared with the status quo scenario.

	Status quo scenario		Decrease transmission 50%		Increase transmission 50%	
	Cost (billions)	Total (%)	Cost (billions)	Total (%)	Cost (billions)	Total (%)
Pillar of the response						
(1) Country-level coordination	0·05	0·1	0·05	0·1	0·05	0·1
(2) Risk communications and community engagement	0·59	1·1	0·59	1·8	0·59	1·0
(3) Investigation, surveillance, and rapid response	7·07	13·5	2·23	6·7	11·32	18·3
(4) Points of entry	0·04	0·1	0·04	0·1	0·04	0·1
(5) National laboratory system	0·54	1·0	0·43	1·3	0·56	0·9
(6) Infection prevention and control	4·48	8·5	3·57	10·8	5·05	8·2
(7) Case management	28·40	54·1	18·59	56·2	31·47	50·8
(8) Logistics and supply management	0·18	0·3	0·18	0·6	0·18	0·3
(9) Maintaining essential services	11·09	21·2	7·39	22·4	12·65	20·4

Table 4: **4-week (after June 26, 2020) status quo cost of COVID-19 response for 73 countries by pillar of response (2020 US$)**

The costs by category for human resources, commodities, capital, and other costs at 4 weeks and 12 weeks for the status quo scenario are shown in table 5. At 4 weeks, capital costs are nearly equivalent to human resources costs; however, at 12 weeks, the costs of human resources becomes higher than all other categories, at 63% of the total cost. Recurrent costs are primarily for human resources, and secondarily for commodities. Costs for human resources are high, at $21·83 billion at 4 weeks, and they are driven by salaries for newly hired staff and incentives. The cost of the status quo scenario would decrease to $45 billion and $132 billion at 4 weeks and 12 weeks, respectively, if incentives are not included.

	4-week status quo	12-week status quo
Cost category*		
HR	42%	63%
Commodities	13%	17%
Capital	41%	16%
Other	4%	4%
HR costs (billions 2020 US$)		
Low income	0·27	2·02
Lower-middle income	10·29	51·58
Upper-middle income	11·27	43·23
Total	21·83	96·84
HR cost components†		
Salaries	51%	68%
Hazard pay	15%	9%
Incentives	34%	23%

HR=human resources. *Percentage of total. †Percentage of total HR.

Table 5: **Composition of costs for the COVID-19 response for 4 weeks and 12 weeks (after June 26, 2020)**

Discussion

As of June 26, 2020, the costs of the full, nine-pillar response to COVID-19 in 73 low-income and middle-income countries after 4 weeks, on July 24, 2020, were projected to be approximately $52 billion, assuming that the *Rt* was unchanged and the status quo continued. Costs are estimated to be more than three times that amount after 12 weeks on Sept 18, 2020, under a status quo scenario. The costs were projected to be greater at 4 weeks and 12 weeks if transmission values increased by 50%. This analysis shows that the cost of responding to a pandemic with 50% decreased transmission at 12 weeks is coincidentally equivalent to the cost at 4 weeks under the status quo scenario.

The per-capita cost of the response under the status quo scenario for 4 weeks is $3·28 for low-income countries and $8·48 to $10·21 in lower-middle-income and upper-middle-income countries. For 12 weeks, the costs per capita are $9·06 for low-income countries and about $27 for middle-income countries. To put this in context, the health expenditure per capita in 2017, for a whole year, in low-income countries was $41, and from $130 to $371 in lower-middle-income and upper-middle-income countries.[18] The potentially huge opportunity costs within the health sector in not responding rapidly are clearly evident. The benefits of acting early and comprehensively, like in Vietnam,[19] are a clear lesson that can be drawn from this costing exercise.

An early and rapid response will not only mitigate future COVID-19 costs, but more importantly, it will be able to mitigate future COVID-19 costs because of a lower number of COVID-19 infections, and a corresponding lower number of deaths and long-term consequences among survivors. A strong pillar 9 response on maintaining essential health services can also potentially decrease the number of deaths[20] indirectly caused by COVID-19. Social and economic[21] disruptions can also be shortened.

This analysis also shows the interconnectedness of the nine pillars of the COVID-19 response. As the number of cases increases, the share of costs found in case management (in pillar seven) and in maintaining essential health services (in pillar nine) both increase. Increases in the number of cases will also generate increased demand for personal protective equipment, hospitalisation and attendant costs, and contact tracing. However, it is important to note that, for preparedness, all countries must invest in more handwashing stations, and better risk communication and community engagement, even with low numbers of cases.

The predicted resource needs for a full response for 12 weeks continue to be onerous burdens for countries with a high expected number of cases. However, some of the resource requirements can be decreased by examining where efficiencies or cost savings can be made. The analysis described in this Article has used international market prices that are readily obtainable for many commodities. However, some items can be locally produced, such as personal protective equipment (including gloves and cloth masks),[22] some medicines, and single-use supplies. Testing kits might be able to be produced at a lower price in countries with local manufacturing capacity, and good quality assurance and regulatory capacity.

For human resources needed to respond to COVID-19 and maintain essential health services, perhaps the current workforce is capable of providing enough surge capacity, and together with approaches such as telemedicine, task shifting, and quick upskilling through intensive training and supervision, there will be no need to replace the health workers directly engaged in the COVID-19 response, and the large resource requirement this implies. However, the assumption of spare capacity within the health workforce in low-income and middle-income countries should be questioned. The health system response to COVID-19 has been shown to have a negative impact on the delivery of other services, from immunisation[23] to non-communicable diseases,[24] with decreased coverage rates, substantiating the need to at least partially replace health workers prioritised to the COVID-19 response. Aside from hiring new health workers and paying salaries, hazard pay and incentives should be provided to workers in direct contact with patients diagnosed with COVID-19. Countries might choose whether they will provide incentives, but hazard pay for arduous conditions is consistent with legally binding conventions of the International Labor Office.[25]

A more effective approach to reduce the costs will be to decrease the transmission of the virus and have fewer cases to respond to, from the implementation of interventions such as contact tracing and subsequent effective quarantine or isolation,[26] use of cloth masks[27] by the general population, and increased availability of hand washing stations. All these individual-level measures have been fully costed within this exercise, but their slowing of the transmission of the virus has not been taken into account, as each country's *Rt* is fixed at the start for the period of analysis. As such, the true costs for countries would probably be lower than those estimated per scenario. This difference highlights the need for more dynamic[28] and more frequent modelling and costing to get a more accurate estimate.

The precision of the modelling used and the scope of the study have some limits. The first is that the costing is primarily driven by the epidemiological model used. Running an epidemiological model and making projections for many countries is fraught with uncertainty, especially given the assumption that the *Rt* remains fixed over the 4-week and 12-week timeframes. In this exercise, to cope with this uncertainty, scenarios with different transmission levels were projected to provide higher and lower bounds to the base case estimate.

In terms of scope, this costing exercise did not include the isolation or quarantine costs of people with mild to moderate COVID-19, and their contacts who are unable to successfully isolate or quarantine themselves in their own homes, and where mass quarantine shelters or facilities would need to be set up. This could potentially be a large cost, but it is usually borne by local governments or ministries of social welfare. The use of international market prices, without freight, insurance, and import tariffs also underestimates the costs. However, countries have been known to allow time-bound, tariff-free entry for supplies and medicines for COVID-19.[29] In addition, countries would have to bear costs of waste management of the COVID-19 response, primarily for non-durable personal protective equipment, which are not included in our estimates, but could require significant amounts of resources. Finally, these costs would change significantly once directly acting medicines or vaccines proven to be effective against COVID-19 are produced and added to standard treatment or prevention protocols.[30]

In summary, the results of this study show the need to account for health systems in the context of health security. Preparedness for health emergencies and disasters has been highlighted as a key component of the Common Goods for Health that require explicit public investment to overcome market failures. These results emphasise that critical components of health systems essential to the surge capacity, which can deliver an effective response (eg, human resources and laboratories), need to be in place, and mechanisms for mobilisation need to exist for when an outbreak occurs.[31]

This study also shows that, when faced with a decision to adjust PHSM, epidemiological modelling and costing of different scenarios based on different *Rt* values, often reflecting various policy options, updated frequently and using good local data, can be informative. Whatever the estimated costs of the response, it might be the case that this amount is not fully within the financial capacity of low-income and some middle-income countries. This gap in the resources can be partly filled by development partners and the private sector. To facilitate modelling, costing, and priority setting, WHO will be releasing a country level costing tool based on this exercise. It will be made available through the COVID-19 Partners Platform,[32] where countries and partners can interact in real time to prepare for and respond to the COVID-19 pandemic. Finally, this study highlights that while fully implementing a COVID-19 response will entail significant resource needs, the impact of such an early and comprehensive response in limiting the spread of the virus will markedly reduce the resources needed to respond to a more widespread pandemic just a few weeks later.

Contributors

TT-TE, OH, AM, GL, LLB, and AS conceptualised the Article. TT-TE, OH, AM, GL, and OJW reviewed articles, contacted experts, and collected data. TT-TE, OH, AM, PV, and OJW ran the analysis. TT-TE, OH, and AM wrote the first draft of the Article and revised it based on feedback from co-authors. All authors reviewed and approved the Article.

Declaration of interests

We declare no competing interests.

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