PLOS ONE

RESEARCH ARTICLE

Cost-effectiveness and return on investment of protecting health workers in low- and middle-income countries during the COVID-19 pandemic

Nicholas Risko[1]*, Kalin Werner[2], O. Agatha Offorjebe[3], Andres I. Vecino-Ortiz[4], Lee A. Wallis[2], Junaid Razzak[1]

1 Johns Hopkins University School of Medicine, Baltimore, MD, United States of America, **2** University of Cape Town, Cape Town, South Africa, **3** University of Southern California Keck School of Medicine, Los Angeles, CA, United States of America, **4** Johns Hopkins University Bloomberg School of Public Health, Baltimore, MD, United States of America

* nrisko1@jhmi.edu

OPEN ACCESS

Citation: Risko N, Werner K, Offorjebe OA, Vecino-Ortiz AI, Wallis LA, Razzak J (2020) Cost-effectiveness and return on investment of protecting health workers in low- and middle-income countries during the COVID-19 pandemic. PLoS ONE 15(10): e0240503. https://doi.org/10.1371/journal.pone.0240503

Editor: Francesco Di Gennaro, National Institute for Infectious Diseases Lazzaro Spallanzani-IRCCS, ITALY

Received: June 23, 2020

Accepted: September 28, 2020

Published: October 9, 2020

Data Availability Statement: All relevant data are available at https://figshare.com/projects/Cost_effectiveness_of_PPE/83378

Funding: The authors received no specific funding for this work.

Competing interests: The authors have declared that no competing interests exist. All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no

Abstract

Background

In this paper, we predict the health and economic consequences of immediate investment in personal protective equipment (PPE) for health care workers (HCWs) in low- and middle-income countries (LMICs).

Methods

To account for health consequences, we estimated mortality for HCWs and present a cost-effectiveness and return on investment (ROI) analysis using a decision-analytic model with Bayesian multivariate sensitivity analysis and Monte Carlo simulation. Data sources included inputs from the World Health Organization Essential Supplies Forecasting Tool and the Imperial College of London epidemiologic model.

Results

An investment of $9.6 billion USD would adequately protect HCWs in all LMICs. This intervention would save 2,299,543 lives across LMICs, costing $59 USD per HCW case averted and $4,309 USD per HCW life saved. The societal ROI would be $755.3 billion USD, the equivalent of a 7,932% return. Regional and national estimates are also presented.

Discussion

In scenarios where PPE remains scarce, 70–100% of HCWs will get infected, irrespective of nationwide social distancing policies. Maintaining HCW infection rates below 10% and mortality below 1% requires inclusion of a PPE scale-up strategy as part of the pandemic response. In conclusion, wide-scale procurement and distribution of PPE for LMICs is an

support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work. This does not alter our adherence to PLOS ONE policies on sharing data and materials.

essential strategy to prevent widespread HCW morbidity and mortality. It is cost-effective and yields a large downstream return on investment.

Background

On March 3, 2020, eight days before the World Health Organization (WHO) declared coronavirus 2019 (COVID-19) a global pandemic, there was already concern about depleted global stock of personal protective equipment (PPE). At that time, the WHO estimated a need to increase worldwide production by 40% to provide monthly requirements of 80 million masks, 76 million gloves, 30 million gowns, and 1.59 million goggles [1]. As COVID-19 swept parts of East Asia, Europe and the United States (US), it became evident that even in resource-rich health systems there was inadequate supply of PPE to protect frontline health care workers (HCWs) [2]. A survey conducted by the US Association for Professionals in Infection Control and Prevention in late March found that 48% of healthcare facilities were out or nearly out of N-95 respirators and only 32% reported having sufficient gowns [3]. The supply shortages have led to PPE rationing and reuse of equipment beyond manufacturer recommendations [4]. The US Centers for Disease Control and Prevention (US CDC) and the WHO have released recommendations for optimizing PPE supply [5, 6] and the US Food and Drug Administration has taken the unprecedented step of issuing emergency approval for sterilization techniques to allow reuse of previously disposable PPE [7]. The resulting global bidding war, exportation restrictions and supply chain disruptions have hit low- and middle-income countries the hardest [8, 9].

Over 80% of the world's population lives in LMICs where fragile health systems with few resources make HCWs vulnerable to COVID-19 [10, 11]. Given the pre-existing shortage of HCWs [12], even minimal workforce depletion due to illness, death or absenteeism could threaten the stability of LMIC health systems. The COVID-19 pandemic has yet to reach its peak in many of these countries, however they are already bracing for the potential of a long and devastating disaster. This paper presents the findings of a cost-effectiveness and a return on investment analysis to determine the health and economic impact of immediate scale-up in the production and distribution of PPE for 139 LMICs. The aim is to inform active global, regional and national discussions on policy, strategy and financing to protect HCWs and the integrity of health systems in LMICs.

Methods

We developed a decision-analytic model to compare the costs and effects of two PPE use scenarios at the global and regional levels for all LMICs, following standard guidelines for cost-effectiveness analyses [13, 14]. A base case where full PPE supply maintains a low rate of HCW infection was compared to a scenario where inadequate PPE leads to higher rates of HCW infection. Our main outcomes were: 1) cost per HCW death averted and 2) cost per HCW case averted. Results are presented as an incremental cost-effectiveness ratio (ICER), a ratio of cost per each unit of effect. A Return on Investment (ROI) analysis was also performed by comparing the societal economic gains from having HCWs fully protected against exposure with the current investment required to afford the PPE. Finally, we assessed the impact of the projected HCW infections and deaths on the estimated worker pool in each region.

To estimate PPE resource use and costs we utilized the WHO COVID-19 Essential Supplies Forecasting Tool (ESFT) [15]. The ESFT is designed to help governments and other stakeholders estimate essential supply requirements to respond to the COVID-19 pandemic. We ran projections for each LMIC for a 30-week period starting in August of 2020 and incorporated costs related to the "hygiene" and "PPE" outputs into our decision analytic model. PPE requirements are based on WHO best practice guidelines [6]. This implies gloves, gown, face shield and masks for all encounters involving a suspected case and enhanced precautions for aerosol generating procedures. Supply availability that allows full adherence to these guidelines was considered "adequate", whereas our "inadequate" scenario implies absence of one or more of the PPE elements. PPE costs in EFST are intended to directly inform procurement and reflect competitive market prices in the global market. The EFST does not provide confidence intervals for their costing data, so we created sampling bounds of plus and minus 15% for our sensitivity analysis informed by variations in market prices for bulk order PPE.

The costs of labor and healthcare utilization were taken from the WHO Choosing Interventions that are Cost-Effective (WHO-CHOICE) project [16]. Costs were tabulated in 2020 US dollars (USD) from the societal perspective. Consistent with this, lost future productivity due to early mortality was included in assessment of the economic impact. Training costs, whether viewed as a lost investment in HCWs that have died or as a replacement cost to replenish the work pool, were not included due to the difficulty of estimating this for each setting globally. Their absence has likely led us to underestimate the economic benefit of averted mortality. Our tool and the EFST align with standard international definitions for who constitutes a HCW [12, 15]. In general, HCWs are professional providers of health care, such as: doctors, nurses, technicians/medics, and ancillary staff.

The ESFT utilizes a basic Susceptible-Infectious-Removed (SIR) model that is described in the tool [15], which is a standard approach to calculating epidemic projections. The tool was run on default settings of a medium clinical attack rate of 20%, a targeted testing strategy for all severe/critical patients, and 10% of mild/moderate cases being tested. These settings were thought to best approximate the average global scenario. We incorporated incidence data for each country and utilized the projected PPE costs as inputs into our model. In addition, we incorporated estimates of national mortality and hospitalizations from published projections calculated by the WHO Collaborating Center for Infectious Disease Modeling at the Imperial College of London (ICL) [17]. The three scenarios presented in the ICL model, including unmitigated pandemic spread, suppression with intensive social distancing after reaching a trigger of 1.6 deaths per 100,000 population per week, and suppression after reaching 0.2 deaths per 100,000 population per week were analyzed for their varying impact on case and mortality counts. This informed the ranges for Bayesian sensitivity analysis and our exploration of policy impact on workforce depletion.

PPE use decreases transmission of aerosolized respiratory viruses and PPE shortages will be associated with elevated HCW infection rates, however uncertainty remains around the exact level of impact [18, 19]. Due to the inherent difficulty of directly measuring the real-world efficacy of PPE, we used the variation in the proportion of HCW infections to total infections, as a proxy indicator for the quality of protection in the workplace. Available figures demonstrate a range from nearly 0% to over 20% [20–30]. Given this high level of uncertainty, for the comparator case with low-PPE availability we designed the model to randomly sample from a wide range of infection rates (4.5–25%) during the 10,000 run Monte Carlo simulation. The "adequate PPE" scenario conservatively assumes equal vulnerability of HCWs to infection as the general public, through community spread. **Table 1** presents key parameter values, their ranges of uncertainty, their distribution for Bayesian analysis and their sources.

Sensitivity analysis

We performed a Bayesian multivariate sensitivity analysis to consider the uncertainty surrounding all key parameters. A 10,000 run Monte Carlo simulation randomly re-sampled

Table 1. Key model parameters.

Parameter	Value	Distribution	Source
Epidemiologic Variables			
LMIC deaths (millions)	15.82 (13.45–18.19)	lognormal	15,17
LMIC cases (millions)	1,146 (974.3–1,318)	lognormal	15,17
HCW infections as % of total infections (*full PPE case*)	0.42 (0.36–0.49)	lognormal	20–28
HCW infections as % of total infection (*limited PPE case*)	14.5 (4.0–25.0)	lognormal	20–28
Case acuity mix % (*mild/moderate/critical*)	80.0/13.8/6.20	beta	17
Case fatality (%)	1.38 (1.23–1.53)	lognormal	17
Utilization Inputs	**Value (range for sensitivity analysis)**		
Mean hospital days for severe infection	11 (6–21)	lognormal	Estimate
Days of work missed for infection (*mild/moderate/severe*)	13/28/40	lognormal	Estimate
Cost Inputs (2020 USD)			
Nitrile gloves (per pair)	0.06 (0.01–2.63)	gamma	15
Polypropylene contact gown	0.80 (0.69–4.40)	gamma	15
Plastic face shield	0.60 (0.50–3.28)	gamma	15
N-95 Mask	0.70 (0.58–0.92)	gamma	15
Liquid soap (per liter)	0.90 (0.85–1.15)	gamma	15
Hospital bed per day	Varies by country	gamma	23
GDP per capita	Varies by country	gamma	20
Number of HCW per country	Varies by country	lognormal	22

* Assumes HCW are at same risk as rest of population.

**2019 US bulk purchase price at the facility level.

https://doi.org/10.1371/journal.pone.0240503.t001

across the input distributions for each model parameter for each regional projection. Beta distributions were used for sampling within the 95% confidence interval of probability variables, gamma distributions for cost variables and lognormal distribution for the remaining parameters. The design of the sensitivity analysis, including simulation runs and the distributions selected, were based on international standards for cost-effectiveness analysis [13, 14].

Results

The model predicts that across all LMICs there will be 166,689,862 HCW cases and 2,299,543 deaths if PPE supply remains constrained. Purchasing and distribution of PPE to allow for adequate protection of all HCWs requires an investment of $9.6 billion USD. This would result in a reduction to 4,863,299 HCW cases and 67,283 HCW deaths, saving roughly 2,232,260 lives with a mean incremental cost-effectiveness ratio of $59 USD per HCW case averted and $4,309 USD per HCW life saved.

Figs 1 and 2 contain cost-effectiveness plane scatter plots for both the number of cases averted, averted mortality for all LMICs, along with breakdown by World Bank Region for 139 LMICs in East Asia and Pacific (EAP), Europe and Central Asia (ECA), Latin America and Caribbean (LAC), Middle East and North Africa (MENA), South Asia (SA) and sub-Saharan Africa (SSA). Fig 3 presents the ROI curves for each region generated by the Monte Carlo simulation.

The societal ROI from productivity gains is estimated to be $755.3 billion USD, yielding the equivalent of a 7,932% ROI. Breakdown by World Bank Region can be found in **Table 2.**

Fig 4 illustrates the estimated percentage of the HCW pool infected under various scenarios. Fig 5 examines mortality as a percentage of the HCW pool. The unmitigated, mitigated

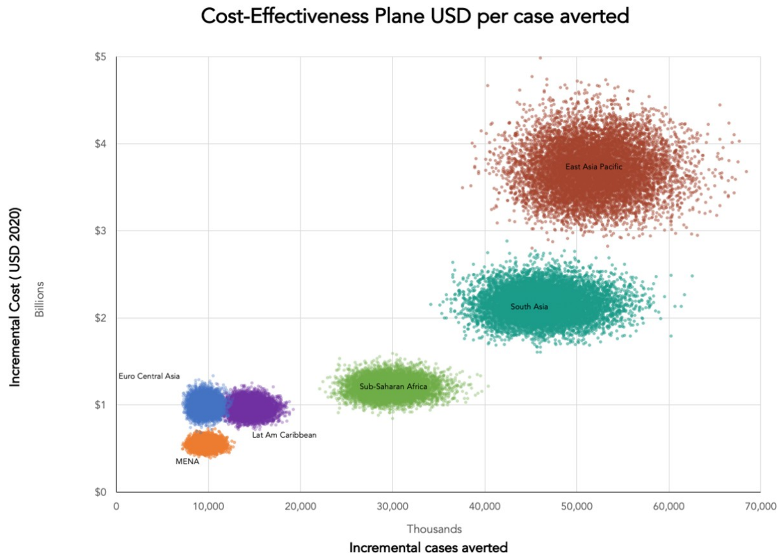

Fig 1. Cost-effectiveness planes for cases averted.

https://doi.org/10.1371/journal.pone.0240503.g001

(1.6 deaths/100,000 population/week trigger) and suppressed (0.2 deaths/100,000 population/week trigger) labels correspond to the three levels of social distancing in the ICL model. In scenarios where PPE remains scarce and there is less than full suppression, 100% of HCWs are projected to get infected. Keeping the proportion infected under 70% requires incorporation of PPE scale-up into overall public health strategy. Likewise, the inclusion of a PPE strategy significantly reduces mortality.

Discussion

The global shortage of PPE has become a critical issue given the high risk of COVID-19 transmission to HCWs during care encounters. Scarcity is highest in LMICs, where projections

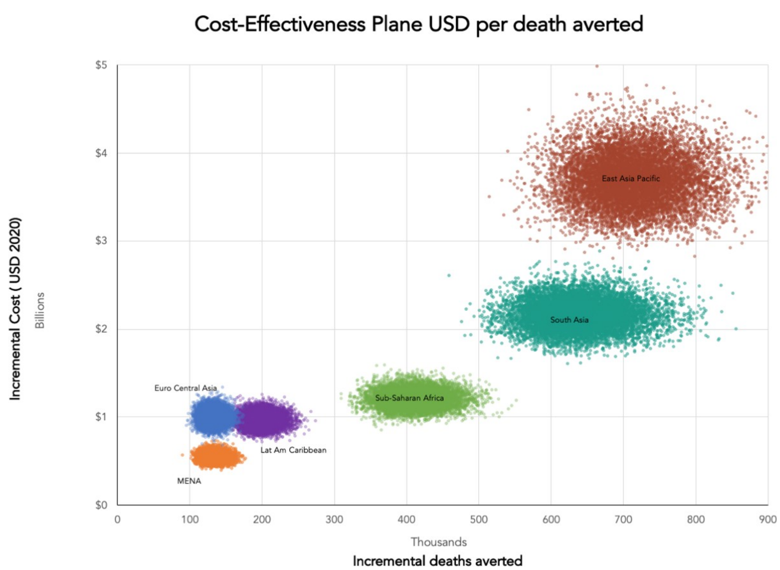

Fig 2. Cost-effectiveness planes for deaths averted.

https://doi.org/10.1371/journal.pone.0240503.g002

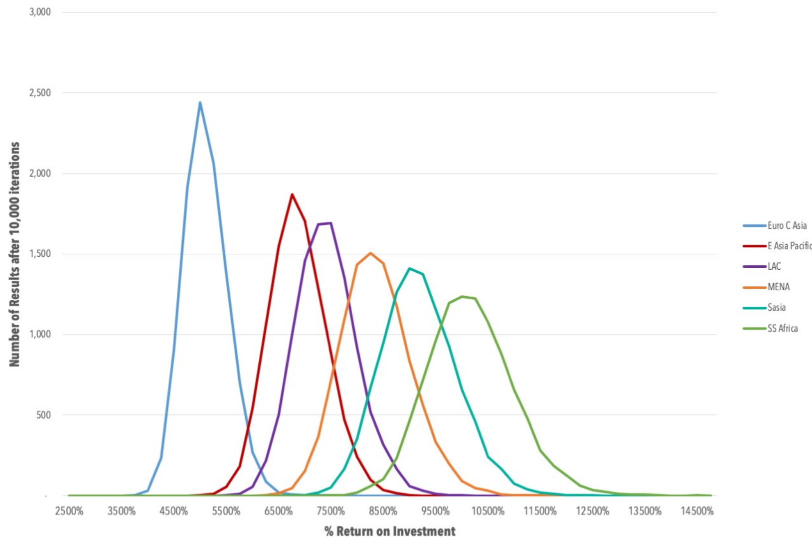

Fig 3. Return on investment curves by region.

https://doi.org/10.1371/journal.pone.0240503.g003

estimate the pandemic's impact will be the heaviest. Utilizing data regarding variations in HCW infection rates across PPE availability scenarios alongside the WHO ESFT, we projected the cost-effectiveness and ROI of PPE scale-up.

Our PPE demand forecasts, costs, infection and mortality estimates are driven by projections from ICL and the EFST, whose methods and limitations have been previously described [15, 17]. While imperfect, they provide the best available projections for disease spread and resource use. Given the speed of this pandemic, further limitations exist in the availability of data examining the precise effect of PPE on HCW infection rates. To inform our model we relied on a collection of sources that include rigorous scientific studies, data published by

Table 2. Results of cost-effectiveness analysis by region*.

	Incremental Change			Cost-effectiveness Ratios		
Region	HCW Cases Averted (in millions)	HCW Deaths Averted	Investment (in millions)	Cost per Case Averted	Cost Per Death Averted	Economic Gains (in millions)
East Asia & Pacific	51.9 (49.3 to 54.5)	713,277 (677,963 to 748,590)	$3,711 (3,526 to 3,895)	$72 (67 to 78)	$5,237 (4,862 to 5,611)	$257,421 (247,433 to 267,407)
Europe & Central Asia	9.61 (9.11 to 10.1)	132,632 (125,831 to 139,433)	$993.4 (946.2 to 1,040)	$104 (97 to 111)	$7,541 (7,014 to 8,069)	$51,769 (49,839 to 53,698)
Latin America & Caribbean	14.5 (13.7 to 15.2)	200,069 (189,920 to 210,219)	$959.9 (914.6 to 1,005)	$67 (62 to 71)	$4,830 (4,496 to 5,164)	$72,125 (69,623 to74,986)
Middle East & North Africa	9.72 (9.25 to 10.2)	133,895 (127,364 to 140,427)	$544.7 (518.7 to 570.6)	$56 (53 to 60)	$4,094 (3,811 to 4,376)	$46,024 (44,187 to 47,865)
South Asia	46.4 (44.1 to 48.7)	640,080 (608,652 to 671,507)	$2,158 (2,056 to 2,260)	$47 (44 to 50)	$3,393 (3,163 to 3,623)	$200,343 (191,551 to 209,135)
Sub-Saharan Africa	29.8 (28.4 to 31.3)	412,148 (392,387 to 431,909)	$1,202 (1,144 to 1,259)	$41 (38 to 43)	$2,934 (2,735 to 3,132)	$123,442 (117,922 to 128,961)
LMIC aggregated	161.8 (153.9 to 169.8)	2,232,260 (2,122,083 to 2,342,436)	$9,557 (9,100 to 10,014)	$59 (55 to 63)	$4,309 (4,010 to 4,608)	$755,314 (724,335 to 786,293)

95% confidence intervals are derived using the standard error of the simulation results.

*All monetary values are in 2020 US dollars, rounded to nearest dollar.

https://doi.org/10.1371/journal.pone.0240503.t002

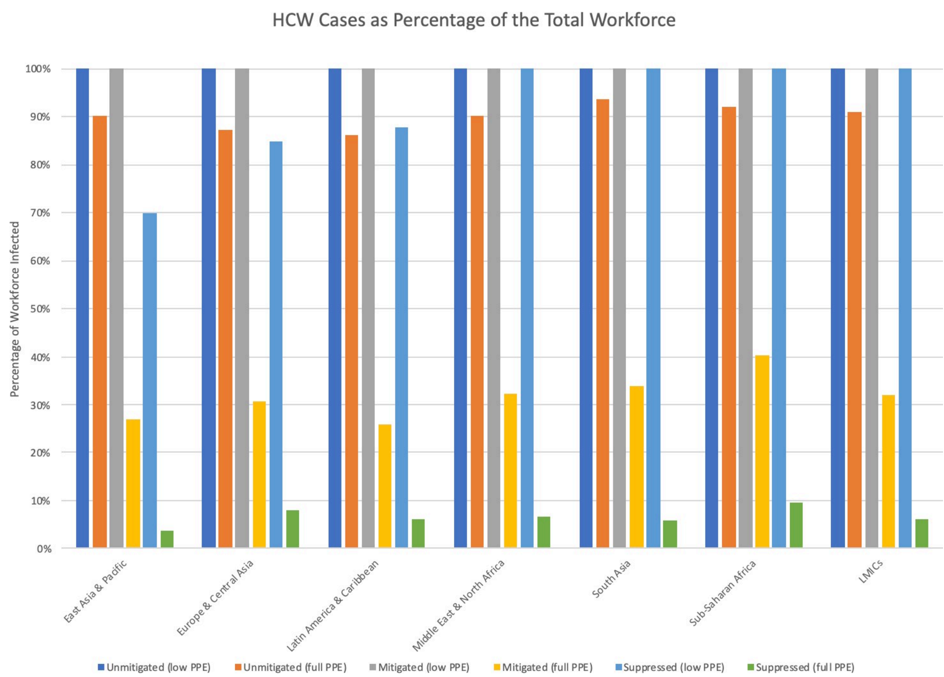

Fig 4. Cumulative HCW cases as a percentage of total workforce, by strategy.

https://doi.org/10.1371/journal.pone.0240503.g004

government entities, and media reports that cite government sources. Overall, data are consistent in showing low to zero HCW infection rates in highly controlled settings with strict PPE compliance. On the other hand, public health figures that incorporate a range of healthcare settings with varied PPE compliance demonstrate rates up to, or above 20%. Examples of the percentage of cases that are HCWs from a variety of settings include: 0–1% in high PPE

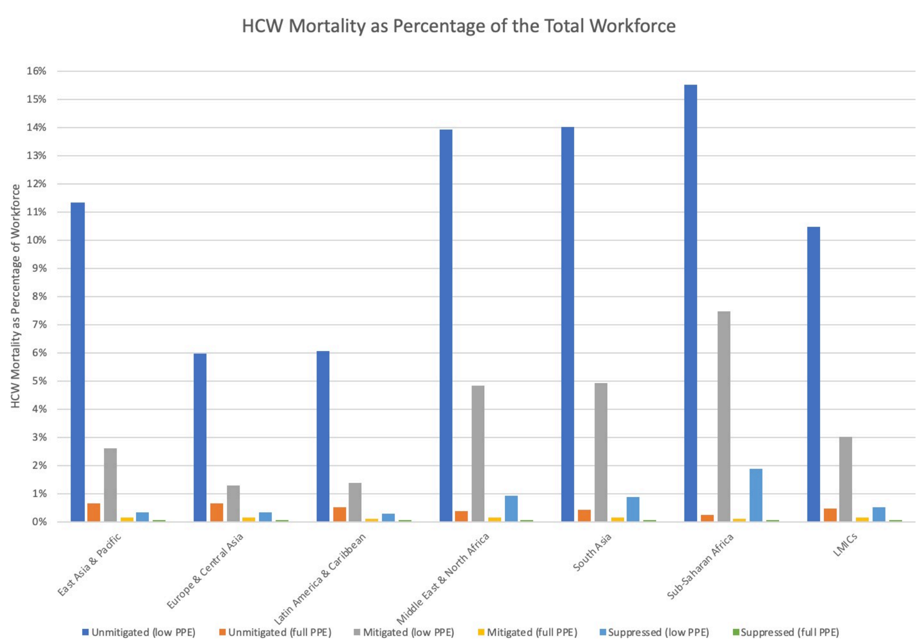

Fig 5. Cumulative HCW mortality as a percentage of total workforce, by strategy.

https://doi.org/10.1371/journal.pone.0240503.g005

compliance scenarios in Hong Kong, China and the Netherlands [20–22]; 19.9% in the United States [23]; 12.2% in Italy [24]; 3% in South Africa [25]; 7.5% in Nigeria [26]; 13% in Egypt [27]; and 18% in the Philippines [28]. In another Chinese example, initial studies estimated that up to 41% of total cases were acquired in the healthcare setting; however, later reports after enforcement of stringent PPE guidelines show HCW infections comprised 3.8% of the total cases [29]. One organization estimates that globally HCWs make up 7% of all cases [30].

The absence of data on the comparative risk of poor PPE to HCWs in LMICs is was a major limitation. However, in the absence of perfect data, we have endeavored to make all assumptions as conservative as possible and to rigorously explore them in our sensitivity analysis. Whenever possible, our approach was to allow this real-world uncertainty to exist in the model. For example, our comparator case uses a wide range of HCW infection rates (from 4.5–25%), from which the model samples during the Monte Carlo simulation. Our costing assumption are also conservative as we have not integrated the downstream impact on future patients of keeping HCWs safe and healthy. In locations where workforce depletion could affect the quality of healthcare service, there is likely to be a substantial positive benefit to keeping HCWs safe and working.

Unfortunately, fierce competition in the global PPE market has led wealthy countries to outbid poorer ones and, in some cases, activate legislation preventing exportation of domestically produced PPE [31]. Global financing mechanisms have been developed to provide COVID-19 relief to LMICs; however, it remains unclear if funding will be earmarked for PPE and if resources will be adequate to protect HCWs [32]. It is likely that national governments will need to take proactive measures towards procuring and producing PPE. In a time of global economic recession, it appears this is an investment that can yield significant returns.

There are strong reasons for societies to protect their HCWs. Our analysis addresses only one of these reasons: immediate investment in the wide-scale production and distribution of PPE for LMICs yields a significant benefit in lives saved and ROI. Our findings also suggest it is a required component of public health strategy in order to prevent massive depletion of the health care workforce.

Author Contributions

Conceptualization: Nicholas Risko, Kalin Werner, O. Agatha Offorjebe, Andres I. Vecino-Ortiz, Lee A. Wallis, Junaid Razzak.

Data curation: Nicholas Risko, Kalin Werner, Andres I. Vecino-Ortiz.

Formal analysis: Nicholas Risko, Kalin Werner, O. Agatha Offorjebe, Andres I. Vecino-Ortiz, Lee A. Wallis.

Investigation: Nicholas Risko, Kalin Werner, Andres I. Vecino-Ortiz, Junaid Razzak.

Methodology: Nicholas Risko, Kalin Werner, Andres I. Vecino-Ortiz, Lee A. Wallis, Junaid Razzak.

Project administration: Nicholas Risko, Kalin Werner.

Resources: Nicholas Risko.

Software: Nicholas Risko, Andres I. Vecino-Ortiz.

Supervision: Nicholas Risko, Lee A. Wallis.

Validation: Nicholas Risko, Andres I. Vecino-Ortiz.

Visualization: Nicholas Risko, Kalin Werner, Andres I. Vecino-Ortiz.

Writing – original draft: Nicholas Risko, Kalin Werner, O. Agatha Offorjebe, Andres I. Vecino-Ortiz, Lee A. Wallis, Junaid Razzak.

Writing – review & editing: Nicholas Risko, Kalin Werner, O. Agatha Offorjebe, Andres I. Vecino-Ortiz, Lee A. Wallis, Junaid Razzak.

References

1. World Health Organization. Rolling updates on coronavirus disease (COVID-19). [Cited 19 June 2020]. Available from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen
2. Ranney ML, Griffeth V, Jha AK. Critical Supply Shortages—The Need for Ventilators and Personal Protective Equipment during the Covid-19 Pandemic. New England Journal of Medicine. 2020 Mar 25.
3. Association for Professionals in Infection Control and Prevention. Protecting Healthcare Workers During the COVID-19 Pandemic. 2020 March 27. [Cited 19 June 2020]. Available from: https://apic.org/wp-content/uploads/2020/03/Protecting-Healthcare-Workers-Survey_Report_3_26_20_Final.pdf
4. Degesys NF, Wang RC, Kwan E, Fahimi J, Noble JA, Raven MC. Correlation Between N95 Extended Use and Reuse and Fit Failure in an Emergency Department. JAMA. 2020 Jun 4.
5. United States Centers for Disease Control and Prevention (US CDC). Use of Personal Protective Equipment When Caring for Patients with Confirmed or Suspected COVID-19. [Cited 19 June 2020]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/hcp/ppe-strategy/index.html
6. World Health Organization. Rational use of personal protective equipment (PPE) for coronavirus disease (COVID-19). 2020 March 19. [Cited 19 June 2020]. Available from: https://apps.who.int/iris/bitstream/handle/10665/331498/WHO-2019-nCoV-IPCPPE_use-2020.2-eng.pdf
7. United States Food and Drug Administration. Investigating decontamination and resuse of respirators in public health emergencies. [Cited 19 June 2020]. Available from: https://www.fda.gov/emergency-preparedness-and-response/mcm-regulatory-science/investigating-decontamination-and-reuse-respirators-public-health-emergencies
8. Keller JM, Silverman R, Yadav P, Estes J, Landers C. How can DFI's contribute to the COVID-19 response? Center for Global Development. 2020 April 23. [Cited 19 June 2020]. Available from: https://www.google.com/url?q=https://www.cgdev.org/blog/how-can-dfis-contribute-covid-19-response&sa=D&ust=1592256109108000&usg=AFQjCNG3-mxkvEmy6x4FeJr7cHOwRcQ9YQ
9. European Commission. Export Requirements for Certain Personal Protective Equipment. 2020 April 29. [Cited 19 June 2020]. Available from: https://www.google.com/url?q=https://trade.ec.europa.eu/doclib/docs/2020/april/tradoc_158693.pdf&sa=D&ust=1592256109107000&usg=AFQjCNEkQ9QcfCv7SgOEjiCiitvdCuWHtw
10. The World Bank. World Bank Country and Lending Groups. [Cited 19 June 2020]. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups
11. Hopman J, Allegranzi B, Mehtar S. Managing COVID-19 in low-and middle-income countries. Jama. 2020 Apr 28; 323(16):1549–50. https://doi.org/10.1001/jama.2020.4169 PMID: 32176764
12. World Health Organization. Global strategy on human resources for health: Workforce 2030. [Cited 19 June 2020]. Available from: https://apps.who.int/iris/bitstream/handle/10665/250368/9789241511131-eng.pdf?sequence=1
13. Husereau D, Drummond M, Petrou S, Carswell C, Moher D, Greenberg D, et al. Consolidated health economic evaluation reporting standards (CHEERS)—explanation and elaboration: a report of the ISPOR health economic evaluation publication guidelines good reporting practices task force. Value in Health. 2013 Mar 1; 16(2):231–50. https://doi.org/10.1016/j.jval.2013.02.002 PMID: 23538175
14. Sanders GD, Neumann PJ, Basu A, Ganiats T, De Vos MA, Bos AP, et al. Recommendations for conduct, methodological practices, and reporting of cost-effectiveness analyses: Second Panel on Cost-Effectiveness in Health and Medicine. JAMA.
15. World Health Organization. FAQ: COVID-19 Essential Supplies Forecasting Tool. 24 April 2020. [Cited 19 June 2020]. Available from: https://www.who.int/publications/m/item/faq-covid-19-essential-supplies-forecasting-tool
16. World Health Organization. Cost-effectiveness and strategic Planning (WHO-CHOICE). [Cited 19 June 2020]. Available from: https://www.who.int/choice/en
17. Walker PG, Whittaker C, Watson O, Baguelin M, Ainslie KE, Bhatia S, et al. The global impact of covid-19 and strategies for mitigation and suppression. WHO Collaborating Centre for Infectious Disease

Modelling, MRC Centre for Global Infectious Disease Analysis, Abdul Latif Jameel Institute for Disease and Emergency Analytics, Imperial College London. 2020 Mar 26.

18. Chu DK, Akl EA, Duda S, Solo K, Yaacoub S, Schünemann HJ, et al. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. The Lancet. 2020 Jun 1.
19. World Health Organization. Coronavirus Disease 2019 (COVID-19) Situation Report 82. 11 April 2020. [Cited 19 June 2020]. Available from: https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200411-sitrep-82-covid-19.pdf
20. Cheng VC, Wong SC, Chen JH, Yip CC, Chuang VW, Tsang OT, et al. Escalating infection control response to the rapidly evolving epidemiology of the Coronavirus disease 2019 (COVID-19) due to SARS-CoV-2 in Hong Kong. Infection Control & Hospital Epidemiology. 2020 May; 41(5):493–8.
21. Kluytmans-van den Bergh MF, Buiting AG, Pas SD, Bentvelsen RG, van den Bijllaardt W, van Oudheusden AJ, et al. Prevalence and clinical presentation of health care workers with symptoms of coronavirus disease 2019 in 2 Dutch hospitals during an early phase of the pandemic. JAMA network open. 2020 May 1; 3(5):e209673-. https://doi.org/10.1001/jamanetworkopen.2020.9673 PMID: 32437576
22. Lai J, Ma S, Wang Y, Cai Z, Hu J, Wei N, et al. Factors associated with mental health outcomes among health care workers exposed to coronavirus disease 2019. JAMA network open. 2020 Mar 2; 3(3): e203976-. https://doi.org/10.1001/jamanetworkopen.2020.3976 PMID: 32202646
23. Centers for Disease Control and Prevention. Cases and Deaths Among Healthcare Personnel. 19 June 2020. [Cited 19 June 2020]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/cases-in-us.html
24. Istituto Superiore di Sanità. Integrated surveillance of COVID-19 in Italy. Rome: Istituto Superiore di Sanità;2020. [Accessed 19 June 2020]. Available from: https://www.epicentro.iss.it/coronavirus/bollettino/Infografica_19giugno%20ITA.pdf
25. Republic of South Africa Department of Health. NICD COVID-19 Surveillance in Selected Hospitals. 13 June 2020. [Cited 19 June 2020]. Available from: https://www.google.com/url?q=https://www.nicd.ac.za/wp-content/uploads/2020/06/NICD-COVID-19-Daily-Sentinel-Hospital-Surveillance-report-National-20200613.pdf&sa=D&ust=1592235014421000&usg=AFQjCNHeDaslN1B85CnEGWGnJVCwu4i0eA
26. Tih F. Nigeria: 800 Health workers infected with COVID. Anadolu Agency. 3 June 2020. [Cited 19 June 2020]. Available from: https://www.google.com/url?q=https://www.aa.com.tr/en/africa/nigeria-800-health-workers-infected-with-covid-19/1863747&sa=D&ust=1592398692928000&usg=AFQjCNHa4lAum8EutZqeQCU-KDQpKuI_qw
27. Daily News Egypt. 13% of Egypt's Coronavirus Infections Amongst Healthcare Workers. 13 April 2020. [Cited 19 June 2020]. Available from: https://www.google.com/url?q=https://wwww.dailynewssegypt.com/2020/04/13/13-of-egypts-coronavirus-infections-amongst-healthcare-workers-who/&sa=D&ust=1592398692880000&usg=AFQjCNGv0zi_XQlWPDfWqufLS1I6_4TqRw
28. Rey A. DOH says 1,886 health workers infected with coronavirus. Rappler News. 07 May 2020. [Cited 19 June 2020]. Available from: https://www.rappler.com/nation/260236-health-workers-coronavirus-cases-philippines-may-7-2020
29. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus–infected pneumonia in Wuhan, China. Jama. 2020 Mar 17; 323(11):1061–9. https://doi.org/10.1001/jama.2020.1585 PMID: 32031570
30. International Council of Nurses. More than 600 nurses die from COVID-19 worldwide. 3 June 2020. [Cited 19 June 2020]. Available from: https://www.icn.ch/news/more-600-nurses-die-covid-19-worldwide
31. Congressional Research Services (CRS). The Defense Production Act (DPA) and COVID-19: Key Authorities and Policy Considerations. Washington, DC. 18 Mar. 2020. [Cited 19 June 2020]. Available at: https://fas.org/sgp/crs/natsec/IN11231.pdf.
32. Kentikelenis A, Gabor D, Ortiz I, Stubbs T, McKee M, Stuckler D. Softening the blow of the pandemic: will the International Monetary Fund and World Bank make things worse? The Lancet Global Health. 2020 Jun 1; 8(6):e758–9. https://doi.org/10.1016/S2214-109X(20)30135-2 PMID: 32278363