Examining the Cost-effectiveness of Personal Protective Equipment for Formal Healthcare Workers in Kenya during the COVID-19 Pandemic

Jacob Kazungu (kjacob@kemri-wellcome.org)  
KEMRI | Wellcome Trust Research Programme

Kenneth Munge  
World Bank, Kenya Country Office

Kalin Werner  
The University of Cape Town

Nicholas Risko  
Johns Hopkins University School of Medicine

Andres Vecino Ortiz  
Johns Hopkins University School of Medicine

Vincent Were  
KEMRI | Wellcome Trust Research Programme

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Abstract

Background: Healthcare workers are at a higher risk of COVID-19 infection during care encounters compared to the general population. Personal Protective Equipment (PPE) have been shown to protect COVID-19 among healthcare workers, however, Kenya has faced PPE shortages that can adequately protect all healthcare workers. We, therefore, examined the health and economic consequences of investing in PPE for healthcare workers in Kenya.

Methods: We conducted a cost-effectiveness and return on investment (ROI) analysis using a decision-analytic model following the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) guidelines. We examined two outcomes: 1) the cost per healthcare worker death averted, and 2) the cost per healthcare worker COVID-19 case averted. We performed a multivariate sensitivity analysis using 10,000 Monte Carlo simulations.

Results: Kenya would need to invest $3.12 million to adequately protect healthcare workers against COVID-19. This investment would avert 416 and 30,041 healthcare worker deaths and COVID-19 cases respectively. Additionally, such an investment would result in a societal ROI of $170.64 million – equivalent to an 11.04 times return.

Conclusion: Despite other nationwide COVID-19 prevention measures such as social distancing, over 70% of healthcare workers will still be infected if the availability of PPE remains scarce. As part of the COVID-19 response strategy, the government should consider adequate investment in PPE for all healthcare workers in the country as it provides a large return on investment and it is value for money.

Introduction

On March 11, 2020, the World Health Organization (WHO) declared coronavirus 2019 (COVID-19) a global pandemic. The WHO estimates that 10% of the global COVID-19 clinically diagnosed cases are among health workers with over 10,000 of the infected health workers coming from 40 African countries (1). Health care workers have been reported to have 11.7 times the risk of testing positive for COVID-19 compared to the general community (2). This increased risk of infection has been primarily attributed to a lack of adequate personal protective equipment (PPE) (3, 4).

Although existing evidence indicates that the type of PPE may determine the level of protection against COVID-19 infection among healthcare workers (5), there is a consensus for the consistent use of PPEs (a surgical mask, gloves, eye protection and a gown) when providing care for COVID-19 patients (2, 6). Providing PPE to healthcare workers is, therefore, a critical component of the response to the COVID-19 pandemic (7, 8).

Countries are experiencing PPE shortages for frontline health care workers. PPE availability is affected by increased demand, global supply chain disruptions resulting from interventions to control the pandemic (9), challenges with ensuring rational use, ensuring supplies are preserved for areas with the greatest
need, and lack of accountability in delivering PPE supplies to the frontline. This is despite the growth in local manufacturing of PPE in many countries and gradual improvements in international supply chains (10).

Ensuring healthcare workers are protected from COVID-19 infection is paramount especially in those countries with low healthcare worker numbers in absolute and relative terms (11). These same countries will experience greater strain on their ability to manage cases of COVID-19.

Kenya is a lower-middle-income country with 13.8 health care workers per 10,000 population in 2016. There is a steady pipeline of human resources for health development mainly from non-university tertiary level institutions (12, 13). The workers are employed in both public and private sectors with dual practice common (14). Public sector employment is mainly through county governments who are the main providers of public health services (15). Private sector employment is through not-for-profit and for-profit organizations and sole proprietorships (16). Healthcare workers are inequitably distributed with urban areas attracting and retaining more. There are challenges with the effective management of public sector workers contributing to repeated episodes of industrial action in recent years (17).

Kenya reported 3,068 infections and 32 mortalities among healthcare workers as of 11th January 2021 (18). This represents 3.1% of total infections as of this date. Anecdotal evidence identifies the availability of PPE as a key contributor to these infections. Concerns about the availability of PPE in Kenya have led to industrial unrest among healthcare workers (19). The impacts of continued infection of healthcare workers are likely to be severe but are yet unknown. This paper seeks to quantify the costs and cost-effectiveness of availing adequate PPE to healthcare workers in Kenya and the resulting return on investment at a societal level.

Methods

For this analysis, we adopted an approach described elsewhere (20) to generate country-specific estimates. In summary, we developed a decision-analytic model to compare the costs and consequences of two PPE use scenarios in Kenya following the Consolidated health economic evaluation reporting standards (CHEERS) guidelines (21). We compared a scenario where adequate/full PPE utilisation reduces healthcare worker infection and mortality to a scenario where healthcare workers had an inadequate supply of PPE thus higher rates of infection and mortality. PPE was considered adequate if healthcare workers had access to gloves, gown, surgical masks, and face shields, otherwise, a lack of either of these was considered as inadequate supply of PPE. Two outcomes were examined: 1) the cost per healthcare worker death averted and 2) the cost per healthcare worker case averted. We then performed a Return on Investment (ROI) analysis that compared the societal economic benefits from having all healthcare workers against COVID-19 infection to the investment required to afford the PPE. Several data sources and approaches were adopted for this analysis. Our definition of healthcare workers includes those recorded as nurses, clinical officers, doctor and lab technologists in the Statistical Abstract (13).
First, we utilised the WHO COVID-19 Essential Supplies Forecasting Tool (ESFT) to estimate the costs and required resources (22). The projections represent a 30-week period starting March 2021 following the WHO guideline on PPE requirements (23).

Second, healthcare worker labour costs were abstracted from a salary survey in four counties in Kenya (data not yet published) whereas costs for utilization of COVID-19 services were adopted from a study in Kenya (24). Costs are presented in 2020 US dollars from a societal perspective. These costs also included the healthcare worker lost productivity resulting from early death and training costs were included (unlike in the global study – Risko et al., (20)). Healthcare worker premature death was estimated to result in the loss of 16 years of working life (calculated as the difference between retirement age – 60 years – and the average age of a healthcare worker – 44 years (25). In Kenya, healthcare workers are comprised of doctors, nurses, clinical officers, technicians and ancillary staff. Table 1 summarises the main parameter values, their ranges, distribution and sources.
Table 1
Main model parameters

| Parameter | Value | Distribution | Source |
|-----------|-------|--------------|--------|
| **Epidemiologic Variables** | | | |
| Kenyan deaths due to COVID19 | 8,914 (101-36,864) | lognormal | (26) |
| Kenyan COVID19 cases (thousands) | 645.97 (7.35-2671.33) | lognormal | (26) |
| HCW infections as % of total infections | 0.034 (0.029-0.039) | beta | Estimate, (12) |
| (full PPE case) | | | |
| HCW infections as % of total infection | 0.05 (0.04-0.06) | beta | (27) |
| (limited PPE case) | | | |
| Case acuity mix % | 80.0/13.8/6.20 | beta | (28) |
| (mild/moderate/critical) | | | |
| Case fatality (%) | 1.38 (1.23 – 1.53) | beta | (29) |
| **Utilization Inputs** | | | |
| Mean hospital days for severe infection | 11 (6-21) | lognormal | (30) |
| Days of work missed for infection | 13/28/40 | lognormal | (30) |
| (mild/moderate/severe) | | | |
| **Cost Inputs (2020 USD)** | | | |
| Cost of supplies (millions) | 3.12 (2.65 -3.59) | gamma | (31) |
| Hospital bed per day | 30.26 (8.17-52.35) | gamma | (24, 31) |
| GDP per capita | 1,817 (1,544-2,088) | gamma | |
| Number of HCW | 161,160 | lognormal | (12) |

**Sensitivity Analysis**

Third, we performed probabilistic sensitivity (PSA) analyses to examine how a simultaneous change in all random parameters affected the ICER using 10,000 simulations (32). 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. We present these simulation results as cost-effectiveness planes and cost-effectiveness acceptability curves.

**Results**

At baseline, the model predicts that across Kenya there will be 32,299 healthcare worker cases and 446 deaths if PPE supply is limited. However, with adequate PPE, only 2,189 healthcare worker cases and 30 deaths would be recorded. An extra investment of USD 1.56 million will be required to achieve the reduced number of healthcare worker cases and deaths under the adequate PPE scenario. With this investment, an average of 30,041 healthcare worker cases and 416 healthcare worker deaths will be averted. Overall, a societal ROI from productivity gains is estimated to be USD 170.64 million, translating into a 11.04 times ROI. Table 2 summarizes the findings from this analysis.

| Incremental Change | Cost-effectiveness Ratios |
|--------------------|--------------------------|
| HCW Cases Averted  | HCW Deaths Averted       | Investment (in millions) | Cost per case Averted | Cost per death Averted | Economic Gains (in millions) |
| 30,041             | 416                      | $1.55                    | $51                   | $3,716                 | $170.64                      |
| (28,638 – 31,265)  | (412–418)                | ($1.54 - $1.55)          | ($49 - $54)           | ($3,682 - $3,748)      | ($169.34 - $172.09)          |

95% confidence intervals are derived using estimation of percentiles through a binomial distribution method

HCW – Healthcare worker

*All monetary values are in 2020 US dollars

Figure 1 shows the cost-effectiveness plane scatter plot for the number of healthcare worker deaths averted in Kenya. All simulated observations indicate that a higher number of healthcare worker deaths are averted when healthcare workers are provided with adequate PPE compared to when the availability of PPE for healthcare workers is limited. However, this would require an additional investment. Figure 2 shows the cost-effectiveness acceptability curve indicating the probability that the scenario with adequate PPE would be cost-effective at averting a healthcare worker death compared to the current scenario where healthcare workers have inadequate PPE over a range of investment values (willingness to pay thresholds). There is a 50%, and 75% chance that relative to providing inadequate PPE, investing in adequate PPE would be value for money (cost-effective) if the government or donor would be willing to invest USD 3,700, and USD 4,800 per averted COVID-19 HCW death.

Figure 3 shows the cost-effectiveness plane scatter plot for the number of healthcare worker COVID-19 cases averted in Kenya whereas Fig. 4 shows the cost-effectiveness acceptability curve indicating the
probability that the scenario with adequate PPE would be cost-effective at averting a healthcare worker COVID-19 case relative to when healthcare workers have inadequate PPE. Relative to inadequate PPE for healthcare workers, investing in adequate PPE would be 25%, 50%, and 75% cost-effective if the government or donor is willing to pay USD 210, USD 417 and USD 517 per healthcare worker COVID-19 case averted.

Discussion

This study examined the cost-effectiveness and return on investment (ROI) of protecting healthcare workers in Kenya with personal protective equipment (PPE) during the COVID-19 pandemic using data from Kenya models alongside the WHO ESFT estimates. We found that providing adequate PPE results in 30,041 cases and 416 deaths averted, however, an investment of USD 1.55 million would be required. Such an investment results in a societal gain of USD 170.64 million, equivalent to an 11.04 times ROI.

The higher number of healthcare worker cases and deaths averted is consistent with evidence suggesting that adequate PPE confer some protection against COVID-19 among healthcare workers (2, 5, 33, 34). Additionally, our findings are similar to those reported by Risko et al (20).

With the increasing number of COVID-19 cases and healthcare workers contributing over 7% of all cases, there is a need for further investment into PPE. However, this investment should be tied to the enforcement of strict PPE guidelines in the country. Evidence from studies in China showed a decline in the number of cases acquired in the healthcare setting from 41–3.8% after enforcing compliance to PPE use (35, 36).

Findings from this study should be interpreted with consideration to the following limitations. First, we omitted several cadres of healthcare workers from the analysis, including community health workers (CHW). Protecting CHW is critical to supporting home-based isolation and care, and other aspects of the pandemic response (37). Including CHW could have resulted in an even better ROI. Second, not all healthcare workers utilize all PPE daily and our findings may overestimate the investment required to adequately protect all healthcare workers. However, we considered this overestimate as the use of all PPE would reduce the risk of infection among healthcare workers during care encounters. Furthermore, existing evidence supports a zero to low healthcare worker infection rates in countries with stringent PPE compliance (38). Third, there is a chance that the COVID-19 related mortality in Kenya may be higher than predicted in the model we used as a result of a likely underreporting of COVID-19 deaths in Kenya. If indeed the mortality rate is higher than predicted, then more healthcare worker deaths could be averted for the same investment.

Conclusion
This analysis provides evidence to inform policy in Kenya and other LMIC of the value of investing in PPE for healthcare workers. Specifically, investing in adequate PPE for protecting all healthcare workers in Kenya has over ten-fold return and would prevent over 70% infection among HCW. We recommend urgent investment into PPEs for health workers but also adherence to the appropriate use of the PPEs.

**Abbreviations**

CHEERS Consolidated Health Economic Evaluation Reporting Standards

CHW Community Health Worker

ESFT Essential Supplies Forecasting Tool

GDP Gross Domestic Product

HCW Health Care Workers

ICER Incremental Cost Effectiveness Ratio

LMICs Low- and Middle-Income Countries

PPE Personal Protective Equipment

PSA Probabilistic Sensitivity Analysis

ROI Return on Investment

USD United States Dollars

WHO World Health Organization

**Declarations**

**Ethics approval and Consent to participate**

The study involved a secondary analysis of publicly available data – Table 1 – (12, 22, 24, 26, 28-30) hence ethics approval was not required.

**Consent for publication**

Not applicable

**Availability of Data and Materials**
The data obtained and analysed in this current study is publicly available (12, 22, 24, 26, 28-30). The model developed for this analysis can be obtained shared upon request to the authors (kjacob@kemri-wellcome.org).

**Competing interests**

The authors declare no competing interests.

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**Authors’ contributions**

JK, KM, KW and NR conceptualised the study. All authors contributed to the development of the model. JK drafted the first manuscript. All authors read and approved the final manuscript.

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**References**

1. WHO. Over 10 000 health workers in Africa infected with COVID-19 2020 [Available from: https://www.afro.who.int/news/over-10-000-health-workers-africa-infected-covid-19.

2. Nguyen LH, Drew DA, Graham MS, Joshi AD, Guo C-G, Ma W, et al. Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. The Lancet Public Health. 2020;5(9):e475-e83.

3. Mhango M, Dzobo M, Chitungo I, Dzinamarira T. COVID-19 risk factors among health workers: A rapid review. Safety and Health at Work. 2020.

4. Organization WH. Risk assessment and management of exposure of health care workers in the context of COVID-19: interim guidance, 19 March 2020. World Health Organization; 2020.
5. Verbeek JH, Rajamaki B, Ijaz S, Sauni R, Toomey E, Blackwood B, et al. Personal protective equipment for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare staff. Cochrane Database of Systematic Reviews. 2020(4).

6. Organization WH. Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected. March 13, 2020. 2020.

7. Africa CDC. COVID-19 Guidance on Use of Personal Protective Equipment for Different Clinical Settings and Activities. 2020.

8. World Health Organization. Rational use of personal protective equipment for coronavirus disease (COVID-19) and considerations during severe shortages: interim guidance, 6 April 2020. World Health Organization; 2020.

9. Burki T. Global shortage of personal protective equipment. The Lancet Infectious Diseases. 2020;20(7):785-6.

10. MAMO LT. Insights From Africa’s Covid-19 Response: Repurposing Manufacturing. 2020.

11. Mills A. Health care systems in low-and middle-income countries. New England Journal of Medicine. 2014;370(6):552-7.

12. KNBS. Economic Survey 2020. 2020.

13. KNBS. Statistical Abstract 2020 2020.

14. Ministry of Health. Kenya Health Workforce Report: The Status of Healthcare Professionals in Kenya, 2015. 2015.

15. Kimathi L. Challenges of the devolved health sector in Kenya: teething problems or systemic contradictions? Africa Development. 2017;42(1):55-77.

16. KENYA MASTER HEALTH FACILITY LIST [Internet]. 2021 [cited 20/02/2021]. Available from: http://kmhfl.health.go.ke/#/facility_filter/results.

17. Waithaka D, Kagwanja N, Nzinga J, Tsofa B, Leli H, Mataza C, et al. Prolonged health worker strikes in Kenya-perspectives and experiences of frontline health managers and local communities in Kilifi County. International journal for equity in health. 2020;19(1):23.

18. Mbewa DO. More than 3,000 healthcare workers in Kenya test positive for COVID-19. CGTN. 2021.

19. Shilitsa J, Mbenywe M, Kajilwa G. Crisis deepens as doctors join striking medics. Standard. 2020.

20. Risko N, Werner K, Offorjebe A, Vecino-Ortiz A, Wallis L, Razzak J. Cost-Effectiveness and Return on Investment of Protecting Health Workers in Low-and Middle-Income Countries during the COVID-19 Pandemic. Available at SSRN 3581455. 2020.

21. Husereau D, Drummond M, Petrou S, Carswell C, Moher D, Greenberg D, et al. Consolidated health economic evaluation reporting standards (CHEERS) statement. Cost Effectiveness and Resource Allocation. 2013;11(1):6.

22. Organization WH. COVID-19 essential supplies forecasting tool: frequently asked questions (FAQ), 25 August 2020. World Health Organization; 2020.
23. Organization WH. Rational use of personal protective equipment (PPE) for coronavirus disease (COVID-19): interim guidance, 19 March 2020. World Health Organization; 2020.
24. Barasa E, Kairu A, Nganga W, Maritim M, Were V, Akech S, et al. Examining Unit Costs for COVID-19 Case Management in Kenya. medRxiv. 2020.
25. Wakaba M, Mbindyo P, Ochieng J, Kirinya R, Todd J, Waudo A, et al. The public sector nursing workforce in Kenya: a county-level analysis. Human resources for health. 2014;12(1):1-16.
26. COVID-19 estimate downloads [Internet]. 2021.
27. Shange N. Coronavirus infection rate among health workers in SA is 5% — below global average. Times. 2020.
28. Walker P, Whittaker C, Watson O, Baguelin M, Ainslie K, Bhatia S, et al. Report 12: The global impact of COVID-19 and strategies for mitigation and suppression. 2020.
29. Verity R, Okell LC, Dorigatti I, Winskill P, Whittaker C, Imai N, et al. Estimates of the severity of coronavirus disease 2019: a model-based analysis. The Lancet infectious diseases. 2020.
30. Guan W-j, Ni Z-y, Hu Y, Liang W-h, Ou C-q, He J-x, et al. Clinical characteristics of coronavirus disease 2019 in China. New England journal of medicine. 2020;382(18):1708-20.
31. COVID W. essential supplies forecasting tool. 2020.
32. Briggs A, Sculpher M, Claxton K. Decision modelling for health economic evaluation: Oup Oxford; 2006.
33. Liu M, Cheng S-Z, Xu K-W, Yang Y, Zhu Q-T, Zhang H, et al. Use of personal protective equipment against coronavirus disease 2019 by healthcare professionals in Wuhan, China: cross sectional study. bmj. 2020;369.
34. Zhao Y, Liang W, Luo Y, Chen Y, Liang P, Zhong R, et al. Personal protective equipment protecting healthcare workers in the Chinese epicentre of COVID-19. Clinical Microbiology and Infection. 2020.
35. 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;323(11):1061-9.
36. Zhu S, Zong Z. Why did so few healthcare workers in China get COVID-19 infection. QJM: An International Journal of Medicine. 2020.
37. Ballard M, Bancroft E, Nesbit J, Johnson A, Holeman I, Foth J, et al. Prioritising the role of community health workers in the COVID-19 response. BMJ Global Health. 2020;5(6):e002550.
38. Neuwirth MM, Mattner F, Otchwemah R. Adherence to personal protective equipment use among healthcare workers caring for confirmed COVID-19 and alleged non-COVID-19 patients. Antimicrobial Resistance & Infection Control. 2020;9(1):1-5.

**Figures**
Figure 1

Cost-effectiveness plane for incremental cost per healthcare worker death averted
Figure 2

Cost-effectiveness acceptability curve showing the probability that providing adequate PPE is cost-effective in averting a healthcare worker death compared to when healthcare workers are provided with inadequate PPE.
Figure 3

Cost-effectiveness plane for incremental cost per healthcare worker COVID-19 case averted
Figure 4

Cost-effectiveness acceptability curve showing the probability that providing adequate PPE is cost-effective in averting a healthcare worker COVID-19 case compared to when healthcare workers are provided with inadequate PPE.