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Hepatitis B vaccination coverage among health-care workers in Africa: a systematic review and meta-analysis

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Abstract

Objective: To estimate full hepatitis B vaccination coverage (uptake of ≥3 doses of vaccine) among health-care workers (HCWs) in Africa.

Methods: We systematically searched the PubMed®, Embase®, CINAHL and Psych-Info databases for studies published from January 2010 to October 2017 that reported full hepatitis B vaccination coverage among HCWs in Africa. A random effects meta-analysis was conducted to determine pooled estimates of full vaccination coverage.

Results: Of the 331 articles identified, 35 studies from 15 African countries met the inclusion criteria and were included in the review. The estimated full hepatitis B vaccination coverage was 24.7% (95% CI: 17.3 – 32.0). Regional coverage was highest in northern Africa (62.1%, 95% CI: 42.5 – 81.7) and lowest in central Africa (13.4%, 95% CI: 4.5 – 22.3). Doctors were more likely (OR: 2.6, 95% CI: 1.8 – 3.7) to be fully vaccinated than Nurses with estimated pooled estimates of 52.4% (95% CI: 31.1 – 73.8) and 26.3% (95% CI: 9.7 – 42.9), respectively. Also, HCWs with 10 or more years of experience were more likely to be vaccinated than those with less than 10 years of experience (OR: 2.2, 95% CI: 1.5 – 3.3). The common reasons identified for non-vaccination of HCWs were unavailability of vaccine 50.5% (95% CI: 26.5 – 74.4), busy work schedule 37.5% (95% CI: 12.6 – 62.4) and cost of vaccination 18.4% (95% CI: 7.1 – 29.7).

Conclusion: The evidence available suggests that many HCWs in Africa are at risk of Hepatitis B infection as only a quarter of them were fully vaccinated against Hepatitis B virus. This study highlights the need for all African governments to establish and implement hepatitis B vaccination policies for HCWs.

Keywords: Hepatitis B; vaccination; occupational exposure; healthcare workers; Africa

Introduction

Hepatitis B is a communicable disease caused by the hepatitis B virus (HBV) and transmitted through contact with blood or other body fluids of an infected person.[1, 2] The disease has become a 'major public health challenge' ranking as one of the leading global causes of mortality.[2] An estimated two billion people around the world are infected with HBV, and of these, approximately 257 million people suffer from chronic hepatitis B infection.[2] The liver is primarily affected in HBV infection resulting in acute or chronic infection. Acute infection may result in a spectrum from asymptomatic to acute liver disease.[3, 4] About 5 -10% of adults with acute HBV infection progress to the chronic state.[3] Chronic infection can result in cirrhosis of the liver, liver cancer and liver failure. In 2015, hepatitis B resulted in about 887 000 deaths, mostly associated with liver cirrhosis and liver cancer.[2]

The African continent has one of the highest burden of Hepatitis B with 6.1% of the adult population living with the infection.[2] However, significant variation exist in HBV infection across African countries. Hepatitis B is hyper-endemic (> 8% of the general population are hepatitis B surface antigen chronic carriers) in some sub-Saharan African countries including Nigeria, Namibia, Gabon, Cameroon and Burkina Faso while other countries such as Kenya, Zambia, Sierra Leone and Senegal are of intermediate endemicity (2%-8%).[5] On the other hand, countries in Northern Africa including Egypt, Tunisia, Algeria and Morocco had low endemicity levels (< 2%).[5]

Hepatitis B virus is highly contagious. Individuals with chronic infection are usually the main reservoir for continued HBV transmission.[1] Health-care workers (HCWs) particularly have greater chances of hepatitis B infection due to the risk of occupational contact with blood and other body fluids of infected individuals.[6] This may occur following percutaneous injury (when a needle or other sharp object penetrates the skin), blood and body fluids coming in contact with the mucous membrane (eyes, nose and mouth) or non-intact skin exposure to blood and other body fluids. [7] Percutaneous injuries carry the greatest risk of HCW HBV infection and account for about 66,000 HBV infections annually.[8] Every year, about a third of HCWs working in Africa are occupationally exposed to body fluids through percutaneous injuries,[7] which in the context of high prevalence of Hepatitis B in Africa puts HCWs at a high risk of HBV infection.

Vaccination against HBV remains the most important strategy in the prevention and elimination of the infection.[2, 9] A safe and effective vaccine has been available since 1982.[2] The World Health Organisation (WHO) and the Centre for Disease Control Advisory Committee on Immunization Practices recommend hepatitis B vaccination for HCWs who are at risk of occupational exposure to blood and other body fluids.[1, 2] Primary vaccination in

immunocompetent adults consists of a 3-dose series of Hepatitis B vaccine which when completed confers a protective antibody response in more than 90% of healthy recipients aged ≤ 40 years. [1] The proportion of adults with protective antibody response decreases below 90% in healthy adults over 40 years of age. From the age of 60 years, neutralising antibody protection reduces to 75% in vaccine recipients.[1]

Given the consequences of HBV infection among HCWs and the potential for viral transmission to vulnerable patients (immuno-compromised or unimmunized), many developed countries have established policies and strategies to prevent the infection among their HCWs. In many countries across Europe, vaccination against Hepatitis B is a requirement for employment of HCWs at risk of occupational exposure to blood and other body fluids.[10] Hepatitis B vaccination strategies for infants and children have to a large extent been implemented with considerable success in many countries of Africa. However, policies regarding adult vaccination including those involving HCWs are yet to be implemented in many African countries.[11, 12]

Several studies have investigated the level of hepatitis B vaccination coverage among HCWs in Africa and have reported full coverage as low as in 0.8% in Rwanda [13] and as high as 72.0% in Libya [14]. However, no study to date has pooled the available data on the current hepatitis B vaccination coverage among HCWs in the continent. Therefore, we performed a systematic review of observational studies to estimate the level of hepatitis B vaccination coverage among HCWs in Africa and describe the regional variation. Findings may inform policies for improved hepatitis B vaccination coverage among HCWs in the continent thereby contributing towards achieving the 2030 agenda for the elimination of the infection.[15]

Methods

Protocol registration and search strategy

The research protocol was registered in the PROSPERO international prospective register of systematic reviews (CRD42017077808). We searched four databases (PubMed®, Embase®, CINAHL and PsychInfo) to identify studies reporting hepatitis B vaccination coverage among HCWs in Africa. These databases were searched for original research articles published from January 2010 to October 2017. The following search terms were combined using Boolean operators, hepatitis B, hepatitis B virus, vaccination, immunisation, health care workers, health workers, health personnel and Africa (Table 1). Additional articles including grey literature were identified through checking of the reference lists, Google and Google Scholar search. No language restrictions were applied to all the searches conducted.

Eligibility criteria

Studies were included if they reported full hepatitis B vaccination coverage among HCWs in Africa. In this review, we considered HCWs to encompass all paid and unpaid individuals working in healthcare settings who have the potential for exposure to infectious materials including blood and body fluids. Therefore, we included studies that enrolled a variety of participants including doctors, nurses, laboratory technicians, auxiliary health care workers and students undertaking clinical training or experience in healthcare settings.

Other inclusion and exclusion criteria relate to the design of the study. Studies were included if they were either of cohort or cross-sectional designs. Case reports, case series, case-control studies and qualitative studies were excluded. Conference articles and studies that contained fewer than 100 participants were similarly excluded.[7, 16]

Two reviewers independently screened studies against the inclusion and exclusion criteria and any discrepancy was resolved by consensus.

Quality assessment of included studies

All included studies were assessed for quality on ten (10) criteria developed based on existing quality appraisal frameworks.[17, 18] These ten criteria assessed the internal and external validity of each included study with each criterion equally weighted (see Table 2). On the basis of the assessment, each article received a quality grade of low, moderate or high if they meet 1-4, 5-7 and 8-10 criteria, respectively.

Data extraction

Two reviewers extracted data and any discrepancy was resolved by consensus. The following data were extracted from each included article and entered into a piloted form designed in Microsoft Excel (version 2016): author, year of publication, country where the study was conducted, sample size, response rate and hepatitis B vaccination coverage based on percentage of HCWs fully-vaccinated (completed three or more doses of hepatitis B vaccine) or partially-vaccinated (received 1 or 2 doses of hepatitis B vaccine). Other data extracted were vaccination status by sex, years of working experience and profession. The reasons for non-vaccination were also extracted.

Data analysis

Statistical analyses were carried out using Stata version 14.2 (StataCorp. LP, College Station, United States of America). A random effects meta-analysis based on the DerSimonian and Laird approach,[19] was conducted to determine pooled estimates (with 95% confidence intervals) of hepatitis B vaccination coverage among HCWs. Sensitivity analyses were carried

out by excluding low-quality studies and the impact of excluding them was evaluated on the summary results. This was done to test the robustness of our findings.

Inter study heterogeneity was assessed with Cochran's Q (reported with a χ^2-value and p-value) and Higgin's I-squared (I^2) statistic was employed to measure the percentage of total variation across studies that is due to heterogeneity.[20] Sub-group and meta-regression analyses were conducted to explore the causes of heterogeneity. The covariates considered included geographical region, type of health facility, sampling procedure (random vs convenience sampling), sample size, proportion of doctors, proportion of nurses and study quality. Covariates were first tested individually and only those identified to be significant ($p < 0.10$) were included in the multivariable model.

Stratified analyses were conducted to determine the pooled prevalence of hepatitis B vaccination among doctors and nurses. In addition, Individual data for odd ratio were pooled together using a random effects model to present the odds of vaccination between groups.

Results

Study selection

The literature search identified 331 articles but only 35 were eligible for inclusion (Figure 1).

Study characteristics

Thirty-five (35) cross-sectional studies comprising 14802 HCWs from 15 African countries were included in the meta-analysis. West and East African countries contributed the largest numbers of studies evaluated, accounting for twelve studies (n=12) each (Table 3). The majority of the studies (n=25) were conducted solely among hospital staff. Following the methodological quality assessment, 5 (14.3%) studies were of high quality, 27 (77.1%) studies were of moderate quality and the remaining 3 (8.6%) were of low quality. None of the assessed studies was deemed representative of their national HCWs' population.

Full Hepatitis B vaccination coverage among HCWs

The proportion of HCWs fully-vaccinated (received 3 or more doses of vaccines) against Hepatitis B varied widely with some studies reporting as low as 0.8% in Rwanda and as high as 72.0% in Libya (Figure 2). Consequently, national estimate was highest in Libya with a pooled vaccination coverage of 62.1% (see Table 4). The overall pooled full hepatitis B vaccination coverage among HCWs in Africa was 24.7% (95% CI: 17.3 – 32.0). The pooled full vaccination coverage following sensitivity analysis (exclusion of low-quality studies) was 23.7% (95% CI: 16.1 – 31.3). This figure was comparable to the overall pooled estimate.

Subgroup analyses revealed a marked variation in regional vaccination coverage among HCWs in Africa (Table 5). The North African region had the highest regional coverage of fully vaccinated HCWs (62.1%, 95% CI: 42.5 – 81.7). Regional coverage was lower in Central (13.4%, 95% CI: 4.5 – 22.3) and East Africa (15.1%, 95% CI: 9.4 – 20.8). The estimated full hepatitis B vaccination coverage among medical doctors and nurses were 52. 4% (95% CI: 31.1 – 73.8) and 26.3% (95% CI: 9.7 – 42.9), respectively. Our analysis shows that medical doctors were more likely to be vaccinated than nurses with a pooled odds ratio (OR) of 2.6 (95% CI: 1.8 – 3.7). The estimated full vaccination coverage among male and female HCWs were 24.2% (95% CI: 9.8 – 38.6) and 23.35% (95% CI: 10.4 – 36.2), respectively. There was no significant difference in the odds of vaccination between male and female HCWs (OR: 0.9, 95%CI: 0.6 – 1.2). A statistically significant difference was demonstrated in the odds of vaccination in HCWs with 10 or more years of work experience versus those with less than 10 years (OR: 2.2, 95% CI: 1.5 – 3.3). Three studies, Abdela et al.[21] (conducted in Ethiopia), Noubiap et al.[22] (conducted in Cameroon) and Atiba et al.[23] (conducted in Nigeria) reported full vaccination coverage among clinical students, the figures were 2.0% , 18.0% and 39.2% , respectively.

Overall, substantial heterogeneities were observed among the studies for the estimated full vaccination coverage among HCWs ($\mathcal{X}^2$ = 9310.0, p < 0.000, I^2= 99.6%). The sources of the variation were investigated using meta-regression, two covariates had p values below 0.10 in the bivariate analyses: geographical region (p = 0.0085) and type of health-care facility (p=0.0770). These covariates explained 30.6% of the between-study variation in the estimated full vaccination coverage of HCWs in Africa.

Partial hepatitis B vaccination

Thirty studies reported disaggregated data on the proportion of HCWs with partial vaccination (1 or 2 doses of vaccines) against Hepatitis B. The partial vaccination coverage ranged from 2.4% in Sudan [24] to 48.0% in South Africa [25]. The pooled estimate for partial vaccination coverage in Africa was 17.8% (95% CI: 13.7 – 21.8) (Figure 3). The regional coverage of partial vaccination does not mimic the pattern for full vaccination coverage. Partial vaccination coverage was highest in Southern Africa (34.0%, 95% CI: 21.1 – 46.9) and lowest in East Africa (7.6%, 95% CI: 4.7 – 10.5). The estimates for West, Central and North Africa were 26.9% (95% CI: 21.4 – 32.5), 17.8% (95% CI: 9.9 – 25.8) and 17.6% (95% CI: 10.6 – 24.7), respectively. We found a large proportion of partially vaccinated doctors and nurses in studies conducted in Nigeria 42.6% [26] and Burkina Faso 38.2%, respectively [27].

Reasons for non-vaccination

Ten studies explored reasons for non-vaccination among HCWs who were not vaccinated. The most commonly reported reasons from these studies were: unavailability of vaccine 50.5% (95% CI: 26.5 – 74.4), busy work schedule 37.5% (95% CI: 12.6 – 62.4) and cost of vaccination 18.4% (95% CI: 7.1 – 29.7) (Figure 4). Other reasons cited included Hepatitis B vaccination was not considered necessary/important 6.4% (95% CI: 1.7 – 11.0) and vaccine safety concerns 2.2% (95% CI: 1.0 – 3.5).

Discussion

This study presents a continent-wide estimate of hepatitis B vaccination coverage among HCWs in Africa. The results indicate that many HCWs in Africa are at risk of Hepatitis B infection as only a quarter are estimated to be fully vaccinated against the disease. Our estimate of full hepatitis B vaccination coverage (24.7%) among HCWs in Africa was not far from the 2003 WHO estimate of 18.0%.[8] This indicates little progress over a decade to increase hepatitis B vaccination coverage in Africa. The high prevalence of HBV infection across the continent and limited HBV vaccination coverage demonstrated in our study indicates a major shortfall in the drive to eliminate HBV infection.

We found marked variation in the level of hepatitis B vaccination coverage across regions and countries of Africa, with lower vaccination coverage in Sub-Saharan African countries where there is intermediate to high hepatitis B endemicity. The reason for this variation is not entirely clear but it could be a reflection of national or local policies and strategies regarding hepatitis B vaccination of HCWs. For instance, in Libya where the vaccination coverage was highest, a free hepatitis B vaccination programme has been implemented in all the sites in which the studies were conducted.[14, 28] This free availability of vaccines could be responsible for the high coverage seen in Libya. In addition, the economic and political situations across African countries may explain the variation in vaccination coverage since these factors have been reported to impact on vaccine availability.[29] African countries with better economies such as Libya, Botswana and Nigeria had higher full vaccination coverage than those with worse economies such as Uganda, Rwanda and Democratic Republic of the Congo. Some studies conducted in certain hyper-endemic countries including Niger and Cameroon found that more than 90% of the surveyed HCWs have been exposed to HBV and have acquired natural immunity.[30, 31] This reason may account for the low vaccination coverage in these hyper-endemic countries.

Overall, about 18% of HCWs in Africa had partial vaccination. These HCWs may be in the process of achieving full vaccination. Partial vaccination coverage was more common in Southern and Western African countries. This may represent a renewed effort to scale-up

vaccination given the high endemicity of blood-borne infections in these regions, and the concerns about health workers' protection following the significant loss of HCWs to occupationally acquired infections including tuberculosis and Ebola virus in the last decade.[32, 33] On the other hand, partial vaccination may reflect difficulties with access to Hepatitis B vaccine or a lack of understanding that a full course provides longer lasting protection. These areas can be targeted by national governments when prioritizing strategies to increase vaccination coverage among HCWs in Africa.

This review found that medical doctors were more likely to be vaccinated than nurses (OR: 2.6, 95% CI: 1.8 – 3.7). Many studies conducted in Africa have attributed greater knowledge of HBV infection to doctors in comparison to other professional groups. [34, 35] The high vaccination coverage seen among doctors in our review possibly reflects their greater awareness on the risk of Hepatitis B infection and the importance of its prevention. We also found that HCWs with 10 or more years of employment were more likely to be vaccinated when compared to those with less than 10 years of practice (OR: 2.2, 95% CI: 1.5 – 3.3). This is unsurprising given that HCWs with longer duration of employment have probably experienced more frequent incidents of occupational exposure to blood and other body fluids in their career. This increase in the number of incidents of occupational exposure to blood and other body fluids is likely to have facilitated actions toward the prevention of blood-borne infections including vaccination against HBV. Furthermore, it is likely that HCWs with a few years of employment have less appreciation of the occupational risk of Hepatitis B infection or might not have had the opportunity for vaccination earlier in their career because of the irregularity in the availability of vaccines in many African healthcare settings.

Given that a safe and effective vaccine against hepatitis B virus exists, we strongly recommend a mandatory HCW vaccination policy for Africa tied to employment requirements. In France, hepatitis B vaccination is mandatory for students going into clinical training.[36] This practice has helped to increase vaccination coverage among clinical students in France. [36] Targeting matriculating students entering into health-care professional training programmes or professional certification in Africa could increase vaccination coverage among future health-care professionals and help in protecting them during clinical training and their future medical careers.

Several reasons for non-vaccination of HCWs including unavailability of vaccines and cost of vaccination were identified in this review. Many African countries have successfully implemented universal hepatitis B vaccination programmes for new-born babies improving vaccination coverage among infants.[12] HCW vaccination programs could be delivered alongside infant programs or modelled after them. Limited availability of vaccines which is the

major constraint to uptake will require active government financial investment for procurement, storage and distribution of vaccines to frontline HCWs. Countries that have significant challenges in rolling out full Hepatitis B immunization coverage for HCWs may depend on technical support and resources from organizations such as the World Health Organisation, GAVI and other international health organizations.

Universal vaccination of HCWs (without prior testing) may only be a cost-effective strategy in countries with low or intermediate endemicity and not hyper-endemic countries such as Cameroon and Niger where a large proportion of HCWs have already been exposed to HBV and have acquired natural immunity. While natural immunity is conferred in a large number of HCWs in hyper-endemic countries, progressive disease can occur. Therefore, the priority in these countries should be the screening of HCWs for hepatitis B surface antigen and hepatitis B core antibody.[11] Such screening would help identify HCWs requiring vaccination and those with chronic infection who may benefit from antiviral treatment.

This study is not without limitations. First, the reviewed studies were based on self-reported data which may be prone to recall and social desirability biases. Second, our review included single or limited reports from some countries and many of the included reports were regional studies which were not nationally representative of the countries in which they were conducted. This lack of national representativeness could potentially impact on the generalisability of our findings. Third, our findings are likely to be under-estimates of hepatitis B vaccination coverage given that many papers lacking disaggregated data on full and partial vaccination coverage were excluded. Although partial vaccination is not encouraged, many immunocompetent adults can be protected with two doses of hepatitis B vaccine.[1] Finally, direct comparisons of our findings with other world regions with similar HBV infection burden such as the Western Pacific Region, is not possible given the absence of regional-wide systematic reviews and meta-analysis in this area.

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Conflicts of interests

The authors declare that they have no conflicts of interests.

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Tables and figures

Table 1: Search strategy

#	Searches
1	(Hepatitis B or HBV or Hep B or Hepatitis B Virus or Hepatitis B Antigen or Hepatitis B Antibodies or Anti-HBsAg or viral hepatitis or hepatitis).af.
2	(Vaccine* or immunisation or vaccinat* or immuni* or Viral Hepatitis Vaccines or Viral Hepatitis **Vaccines** or Hepatitis B Vaccines or Immunotherapy).af
3	(Health care worker* or Nurse* or Midwive* or Physician* or Surgeon* or Doctor* or Health personnel or Health worker* or Dentist* or Health staff or Medical personnel or Health personnel or Health officer*).af.
4	(Africa or Nigeria or Senegal or Morocco or South Africa or Ethiopia or Kenya or Mauritius or Mauritania or Tanzania or Congo or Algeria or Tunisia or Libya or Ghana or Madagascar or Gabon or Cameroon or Mali or Zimbabwe or Sudan or Uganda or Somalia or Namibia or Angola or Mozambique or Rwanda or Eritrea or Burkina Faso or Gambia or Zambia or Botswana or Guinea or Djibouti or Niger or Malawi or Egypt or Togo or Liberia or Benin or Sierra Leone or Swaziland or Côte d'Ivoire or Chad or Central African Republic or Seychelles or Sao Tome and Principe or Cape Verde or Comoros or Burundi or Lesotho).af.
5	1 and 2 and 3 and 4
6	limit 5 to yr="2010 -Current"

Table 2: Criteria used for the methodological quality assessment

Criteria used for the methodological quality assessment
Internal validity
Description of methods
1. Are important population characteristics specified?
2. Is the study period specified?
3. Is there a clear definition of hepatitis B vaccination status?
4. Is the method of data collection properly described?
Measurement instrument
5. Is the measurement instrument validated?
Reported prevalence
6. Were prevalence data reported for those with partial and complete vaccination?
7. Were prevalence data reported by demographic category?
External validity
8. Is the response rate >70%, or is the information on non-responders sufficient to make inference on the representativeness of the study population?
9. Is the included population representative of the target/subnational population?
10. Is the included population representative of the national population?

All points were equally weighted

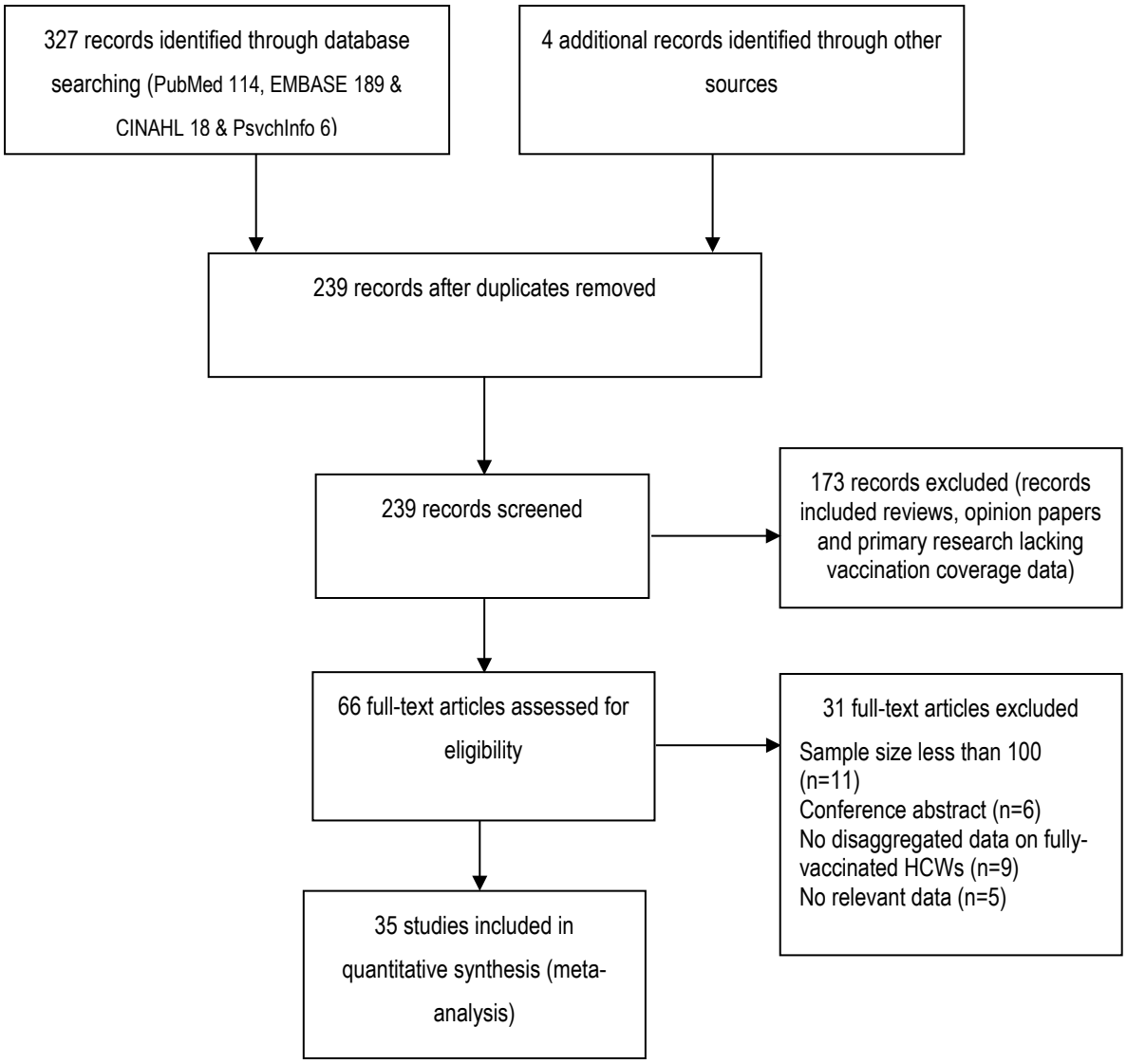

Figure 1: Flow diagram of article selection process

Table 3: Characteristics of included studies

Study authors	Study year	Study participants and setting[a]	% of HCWs with full vaccination	% Full vaccination coverage by demographic category	Quality grading
Abdela et al.[21]	2016	246 clinical students of the College of Medicine and Health Sciences, University of Gondar, Northwest Ethiopia	2.0	ND	Moderate
Abebaw et al.[37]	2017	410 HCWs in health facilities across Shashemene Zonal Town, Oromia Region, Ethiopia	12.9	Nurse: 15.3, Male: 8.5, Female: 15.9	High
Abeje and Azage [38]	2015	374 HCWs in health facilities across Bahir Dar city administration. Bahir Dar town	5.4	ND	Moderate
Abiola et al.[26]	2016	134 HCWs including doctors and nurses in a hospital in Lagos State, Nigeria	48.5	Doctors: 40.4, Nurses: 52.9, Male: 45.9, Female: 49.5	High
Adekanle et al.[35]	2015	382 HCWs including doctors, nurses and laboratory technologists in Obafemi Awolowo University Teaching Hospitals, Ile-Ife, Nigeria	65	Doctors: 85.0, Nurses: 52	Moderate
Alese et al.[39]	2016	187 HCWs including doctors, nurses, health attendants and porters in Ekiti State University Teaching Hospital, Ado- Ekiti.	16	ND	Low
Amira and Awobusuyi [40]	2014	102 HCWs including doctors, nurses, dialysis technicians and auxiliary health staff in four (two government and two private) dialysis units in Lagos, Nigeria.	32.4	ND	Moderate
Amsalu et al.[41]	2016	152 medical waste handlers in three government hospitals, southern Ethiopia	4.6	ND	Moderate
Atiba et al.[23]	2014	594 clinical students of Obafemi Awolowo University	39.2	ND	Moderate
Ayalew and Horsa [42]	2017	286 HCWs including doctors and nurses in Gondar University Hospital, Gondar, Ethiopia.	28.7	ND	High
Burnett et al.[25]	2011	723 HCWs including nursing students from three colleges in Gauteng, doctors and nurses working in private and public hospitals/clinics in Tshwane Metro and Ekurhuleni Metro of Gauteng.	19.9	ND	Moderate
Elzouki et al.[28]	2014	601 HCWs including doctors, nurses, lab technicians, nurse-aids and cleaners in five main hospitals in eastern Libya.	52	ND	Moderate

Kassa et al.[43]	2016	1624 HCWs including doctors, nurses and laboratory technicians in 3 public hospitals in Botswana: a referral hospital and 2 district hospitals.	47	ND	Moderate
Kateera et al.[13]	2015	378 doctors, nurses and laboratory and support staff in the University Teaching Hospital of Butare, Huye District, Southern Province, Rwanda	0.8	ND	Moderate
Kesieme et al.[44]	2011	228 operating room personnel in four university teaching hospitals in Nigeria	26.8	ND	Moderate
Machiya et al.[45]	2015	200 HCWs including doctors, nurses and laboratory staff in Princess Marina Hospital	31.0		Moderate
Mueller et al.[46]	2015	598 HCWs including doctors, nurses, lab staff and cleaners in Bugando Medical Centre in Mwanza, Tanzania	48.8	ND	Moderate
Noubiap et al.[22]	2013	111 clinical medical students of the Faculty of Medicine and Biomedical Sciences of the University of Yaoundé	18	ND	Moderate
Noah et al.[47]	2013	282 HCWs including doctors and nurses of Yaoundé Central Hospital	4.6	ND	Moderate
Nouetchognou et al.[48]	2016	150 HCWs including doctors, nurses, nursing assistants and laboratory technicians in Yaoundé University Teaching Hospital	36.7	ND	Moderate
Ogoina et al.[49]	2014	290 HCWs including doctors, nurses and laboratory staff in two tertiary hospitals in North-central and South-south Nigeria	36.2	ND	Moderate
Okwara et al.[50]	2012	169 HCWs including doctors, nurses, lab staff and cleaners in a tertiary hospital	29.8	ND	Low
Olatosi and Anaegbu[51]	2016	274 HCWs including doctors, nurses, anaesthetic technicians and porters in five hospitals in Lagos, Nigeria	58	Doctors: 69.8, Nurses: 26.4	Low
Quedraogo et al.[27]	2013	452 HCWs including doctors, nurses, nursing assistants and laboratory technicians in two health districts of Burkina Faso.	10.9	Doctors: 30.0, Nurses: 11.8, Male: 9.8, Female: 12.0	Moderate
Pellissier et al.[30]	2012	207 HCWs including medical, nurses, paramedical, cleaning and administrative staff in Niamey's National Hospital, Niger.	7.2	ND	Moderate
Phillips et al.[52]	2012	473 HCWs including doctors, nurses, mid-wives, lab technicians in five Zambian health facilities	8	ND	Moderate
Shindano et al.[34]	2017	217 HCWs including doctors and nurses in Bukavu, an eastern town of the Democratic Republic of Congo	0.9	ND	Moderate

Tatsilong et al.[53]	2016	100 HCWs in one health centers in Mvog-Ada Health Area	9	ND	Moderate
Ziglam et al.[14]	2013	2705 HCWs including doctors, nurses and other paramedical staff in a university hospital in Tripoli	72	ND	Moderate
Ziraba et al.[54]	2010	370 HCWs including doctors, nurses, lab technicians in a tertiary hospital, Mulago, Uganda.	2.2	ND	High
Zoungrana et al.[55]	2014	275 student nurses and midwives working in the medical ward of the Bobo-Dioulasso teaching hospital, Burkina Faso.	11	ND	Moderate
Mbaisi et al.[56]	2013	305 HCWs including doctors, clinical officers, nurses, laboratory personnel, mortuary attendants, housekeeping staff and clinical students in Rift valley provincial general hospital, Kenya.	42	ND	Moderate
Elduma and Saeed[24]	2011	245 HCWs including doctors, dentists, nurses, laboratory and support staff in 3 teaching hospitals in Khartoum	4.5	Doctors: 30.5, Nurses: 1.4, Male: 5.2, Female: 4.2	Moderate
Bett[57]	2014	384 HCWs including doctors, nurses, lab technicians in hospitals in Nairobi, Rift Valley and Western provinces	32	ND	High
Akalu et al.[58]	2016	313 HCWs including doctors and nurses in St Paul Hospital Millennium Medical College, Addis Ababa	1.6	ND	Moderate

[a]All studies were of cross-sectional design.

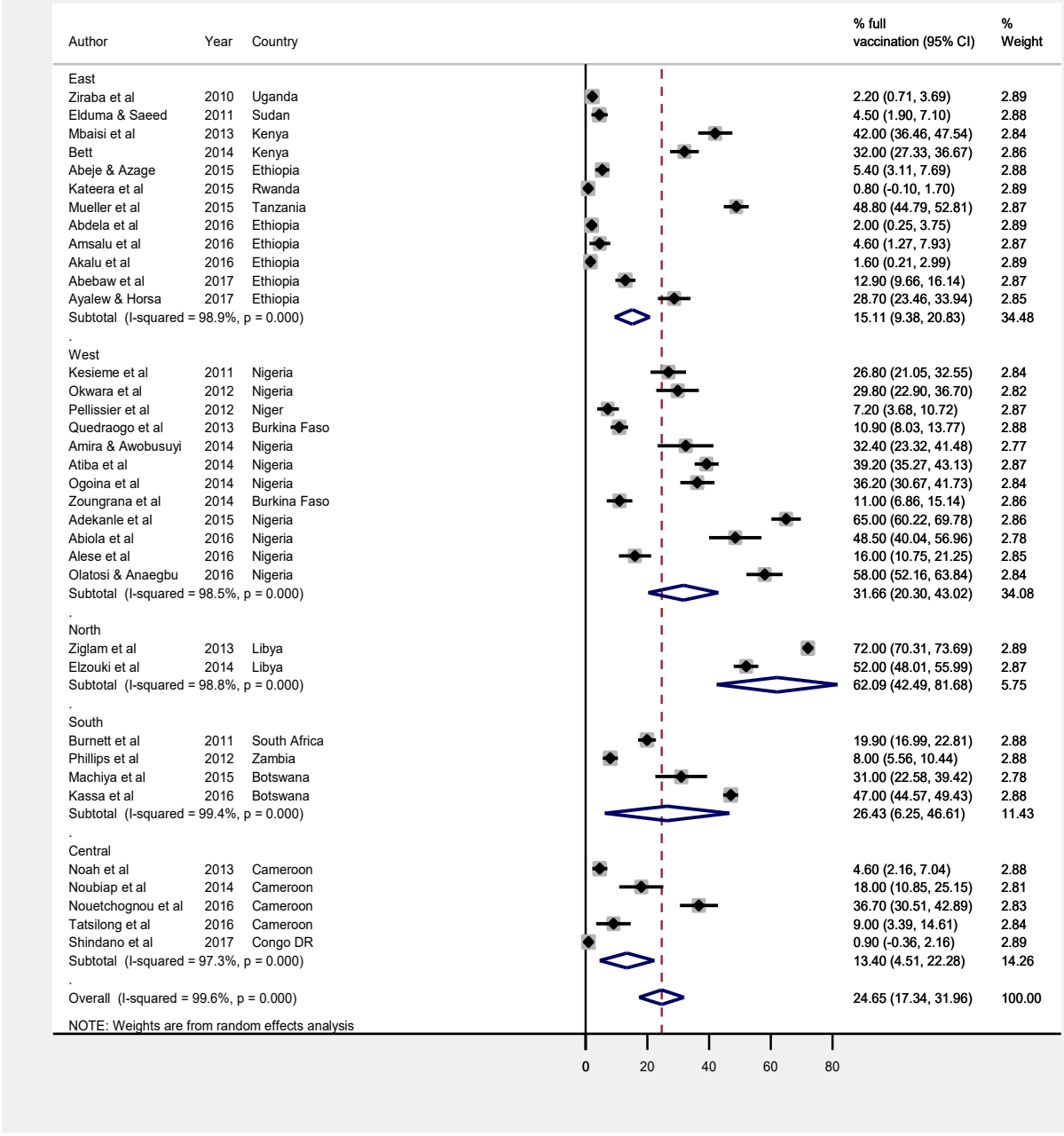

Figure 2: Meta-analysis for full vaccination coverage among HCWs in Africa

Table 4. Country estimates of full vaccination coverage among health-care workers

Country	No. of studies	Fully-vaccinated HCWs (%)
Botswana	2	39.5
Burkina Faso	2	10.9
Cameroon	4	16.9
Congo DR	1	0.9
Ethiopia	6	8.7
Kenya	2	36.9
Libya	2	62.1
Niger	1	7.2
Nigeria	9	39.1
Rwanda	1	0.8
South Africa	1	19.9
Sudan	1	4.5
Tanzania	1	48.8
Uganda	1	2.2
Zambia	1	8.0

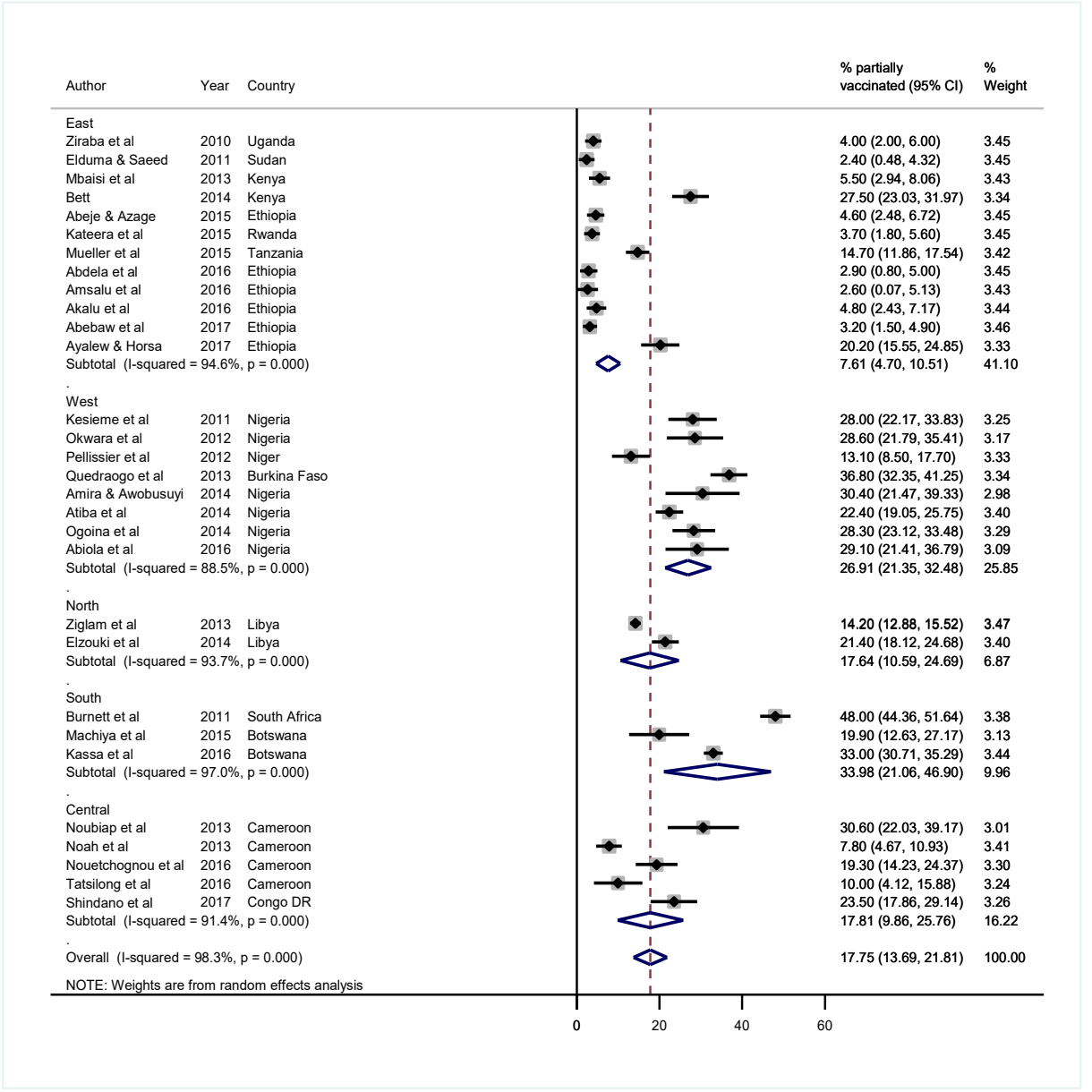

Figure 3: Meta-analysis for partial vaccination coverage among HCWs in Africa

Table 5. Subgroup meta-analysis, full vaccination coverage among health-care workers in Africa

Subgroup	Fully-vaccinated HCWs	No. studies included	Study heterogeneity
	% (95% CI)		I^2 (*P*-value)
African region			
West	31.7 (20.3 – 43.0)	12	98.5% (< 0.001)
Central	13.4 (4.51 – 22.3)	5	97.3% (< 0.001)
East	15.1 (9.4 – 20.8)	12	98.9% (< 0.001)
South	26.4 (6.3 – 46.6)	4	99.4% (< 0.001)
North	62.1 (42.5 – 81.7)	2	98.8% (< 0.001)
Job category			
Doctors	52. 4 (31.1 – 73.8)	5	93.9% (< 0.001)
Nurses	26.3 (9.7 – 42.9)	6	98.6% (< 0.001)
Sex			
Male	24.2 (9.8 – 38.6)	5	81.7% (< 0.001)
Female	23.35 (10.4 – 36.2)	5	98.6% (< 0.001)
Type of health-care facility			
Hospital	29.5 (19.2 – 39.9)	25	99.7% (< 0.001)
Mixed[a]	9.6 (3.9 – 15.3)	6	97.3% (< 0.001)
Study quality			
High	24.5 (10.1 – 39.0)	5	98.7% (< 0.001)
Moderate	23.6 (14.8 – 32.3)	27	99.7% (< 0.001)
Low	34.6 (8.9 – 60.2)	3	98.2% (< 0.001)
Overall	24.7 (17.3 – 32.0)	35	99.6% (< 0.001)

[a] Both hospitals and primary care facilities.

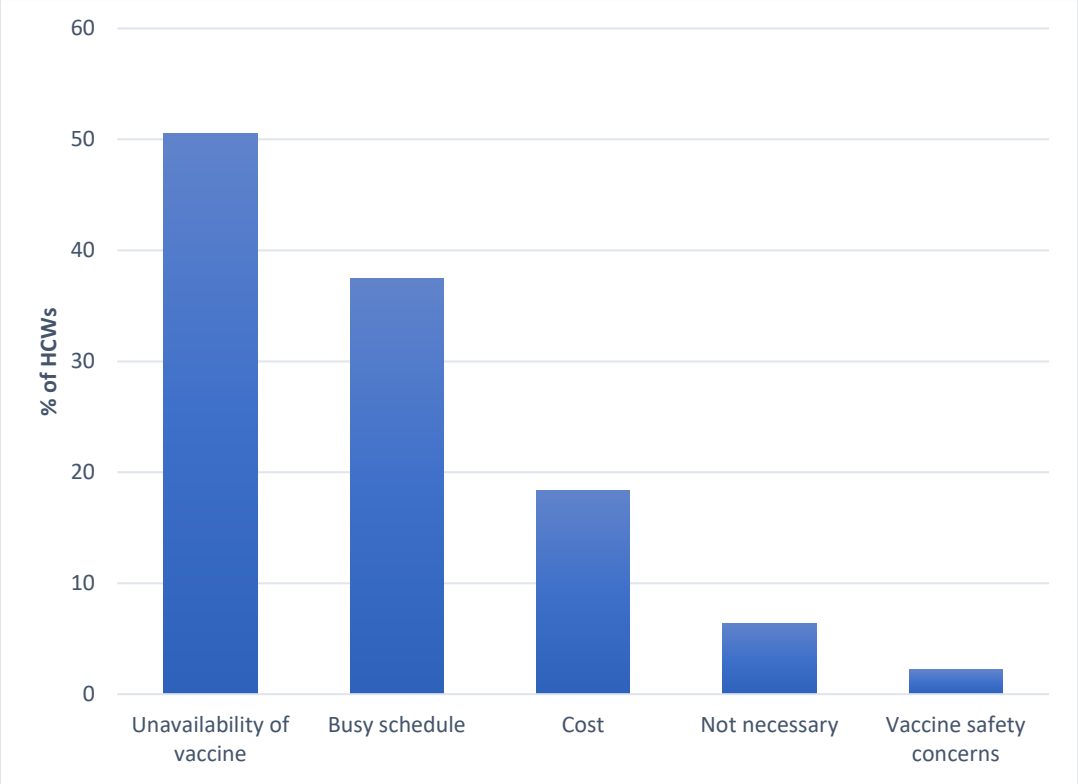

Figure 4: Common reasons for non-vaccination given by health-care workers