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Hepatitis B susceptibility, infection and vaccine-induced immunity among health personnel in Sokoto, Nigeria: a cross-sectional serological study

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Abstract

Background

Health personnel in Nigeria have a high occupational risk of hepatitis B virus (HBV) infection, and vaccination status is usually established by self-report. The extent to which reported vaccination corresponds to serological protection has not been measured in northern Nigeria. We described HBV infection and immunity among health personnel, compared self-reported vaccination with serological markers and identified factors associated with vaccine-induced immunity, natural immunity and current infection.

Methods

We conducted an analytical cross-sectional serological study of 473 health personnel selected by multistage sampling from primary, secondary and tertiary facilities in Sokoto State between January and March 2023. An interviewer-administered semi-structured questionnaire was completed, and serum was tested for HBsAg, anti-HBs, anti-HBc, HBeAg and anti-HBe with a five-panel rapid test. Firth penalised logistic regression was used for each outcome.

Results

Current infection (HBsAg positive) was found in 7.8% (n = 37; 95% CI: 5.7–10.6) and evidence of any past or current infection in 17.1% (n = 81). Anti-HBs was detected in 16.5% (n = 78): 12.3% (n = 58) had vaccine-induced and 4.2% (n = 20) natural immunity, while 70.6% (n = 334) had no serological marker. Self-reported vaccination had a positive predictive value of 24.3% for vaccine-induced immunity (κ = 0.16). Among 96 participants who reported three or more doses, 69.8% (n = 67) had no detectable anti-HBs and six were HBsAg positive. Vaccine-induced immunity was associated with three or more reported doses (aOR 2.90; 95% CI: 1.37–6.22), positive attitude (aOR 1.98; 95% CI: 1.01–3.90), an employer request for vaccination status (aOR 2.05; 95% CI: 1.03–3.97) and insertion of tubes or catheters (aOR 2.75; 95% CI: 1.08–6.93). Natural immunity was more frequent in primary facilities (aOR 4.84; 95% CI: 1.56–15.30). Current infection was not associated with occupational exposures and was less frequent after more than 10 years of practice (aOR 0.23; 95% CI: 0.06–0.84).

Conclusions

Most health personnel in Sokoto had no serological protection against HBV, and self-reported vaccination overstated protection. Screening for HBsAg and anti-HBs at recruitment, documented vaccination with post-vaccination testing, and referral of infected staff for care should be part of routine occupational health services.

Background

Chronic hepatitis B virus (HBV) infection affected an estimated 254 million people worldwide in 2022 and is a major cause of cirrhosis and hepatocellular carcinoma; the WHO African Region accounts for most new

chronic infections [1]. In Nigeria, HBsAg prevalence was 12.2% in a 2016 national survey and 8.1% in the 2018 national indicator survey, which corresponds to an estimated 14 million people living with HBV [2–4].

Health personnel are exposed to blood and body fluids in the course of their work, and the risk of HBV transmission after a percutaneous injury is considerably higher than that of HIV or hepatitis C virus [5]. Sharps injuries account for about 37% of HBV infections in health personnel globally [6], and the pooled prevalence of HBV infection among health personnel in Africa is 6.8% [7]. A complete three-dose vaccine series produces protective anti-HBs concentrations (≥ 10 mIU/mL) in more than 90% of healthy adults, and vaccination of all health personnel at risk is recommended [8, 9]. Coverage in Africa remains low, with about one quarter of health personnel fully vaccinated, and recent Nigerian surveys show similar levels [10–12].

Vaccination status in these surveys is almost always self-reported. Vaccination cards are often unavailable, the number and timing of doses may be misremembered, and post-vaccination testing is uncommon, so reported vaccination may not reflect protection [9, 13]. Serological surveys of health personnel in Mozambique, Sierra Leone, Kenya, Uganda, Ethiopia and Ghana have shown large differences in the proportions who are susceptible, naturally immune or infected, and in the proportion of vaccinated staff with protective antibody [13–18]. Data of this kind are scarce for northern Nigeria, where HBV is highly endemic and most infections are acquired in early childhood [2, 4].

Self-reported vaccine uptake and its determinants among health personnel in Sokoto State have been reported elsewhere [19]. The present study used serological testing to examine whether reported vaccination corresponded to protection. The objectives were to describe the HBV infection and immunity profile of health personnel overall and by cadre, to compare self-reported vaccination with serological markers, and to identify factors associated with vaccine-induced immunity, natural immunity and current infection.

Methods

Design and setting

We carried out an analytical cross-sectional serological survey in Sokoto State, northwestern Nigeria, between 16 January and 14 March 2023. The state is divided into 23 Local Government Areas, has an estimated 6.6 million inhabitants and delivers care through primary health care centres, secondary (general) hospitals and tertiary hospitals [19]. When the survey took place, public facilities neither offered staff free or compulsory HBV vaccination nor tested new employees for HBV markers.

Participants and eligibility

Any doctor, dentist, nurse, midwife, laboratory worker, health officer or health assistant (including cleaners) whose work involved possible contact with blood or body fluids, and who was on duty in a selected public or private facility during fieldwork, was eligible. Staff with administrative duties only were excluded.

Sample size

To estimate the prevalence of HBV infection with an absolute precision of 2.5% at 95% confidence, we applied the Cochran formula [20] to an expected prevalence of 6.81%, the pooled figure for African health personnel [7]. After adding 10% for refusals and invalid results, at least 434 participants were required. Because the serological survey was nested within a larger study of health personnel in the same facilities [19], it was possible to enrol more than this minimum, which gave sufficient numbers for comparisons between cadres and for three multivariable models.

Sampling

A multistage design was used [19]. Facilities were first grouped by level of care and chosen at random within each level; staff were then drawn by balloting in proportion to the workforce of each facility. Valid results for all five markers were obtained for 473 people working in 15 facilities, and these form the analytical sample.

Questionnaire

Interviewers who had been trained for the study administered a semi-structured questionnaire whose development and pretesting are described elsewhere [19]. Questions dealt with personal and job characteristics, main clinical and support duties, HBV and other adult vaccines received, HBV and HIV tests in the past 12 months, knowledge of HBV, perceived risk, attitudes to HBV vaccination, workplace exposures and employer policies. Those who said they had been vaccinated against HBV were asked how many doses they had received and whether an antibody test had been done afterwards. Answers were entered directly into KoboCollect on tablets.

Blood collection and laboratory testing

Venous blood (5 mL) was drawn under aseptic conditions. Serum was examined for hepatitis B surface antigen (HBsAg), antibody to HBsAg (anti-HBs), hepatitis B e antigen (HBeAg), antibody to HBeAg (anti-HBe) and total antibody to hepatitis B core antigen (anti-HBc) with a five-panel lateral flow immunochromatographic cassette (ACON Laboratories), used as the manufacturer instructs; the stated sensitivity and specificity are 98% and 99%. Laboratory scientists trained in the procedure read each band as reactive or non-reactive. Every participant was told their result; those without markers were advised to seek vaccination, and HBsAg-positive individuals were referred for clinical review.

Serological classification

Marker combinations were classified using the algorithm published by the Advisory Committee on Immunization Practices of the Centers for Disease Control and Prevention and the current WHO guidelines [9, 21], the same approach taken in other surveys of African health personnel [13–15]. The categories were: susceptible (HBsAg, anti-HBc and anti-HBs all non-reactive); vaccine-induced immunity (anti-HBs alone reactive); natural immunity following resolved infection (anti-HBc and anti-HBs reactive, HBsAg non-reactive); current infection (HBsAg reactive, whatever the other markers); and isolated anti-HBc (anti-HBc alone reactive). A reactive HBsAg and/or anti-HBc result was taken as evidence of past or current infection. HBsAg reactivity

without anti-HBc was kept in the current infection group even though it can reflect very early acute infection or a false-positive reading [9]. Isolated anti-HBc can arise from resolved infection with waning anti-HBs, occult infection, resolving acute infection or a false-positive result [9, 22]. HBeAg and anti-HBe were described for HBsAg-positive participants only. Two people with a reactive HBeAg band and one with a reactive anti-HBe band, all non-reactive for HBsAg, anti-HBc and anti-HBs, were counted as susceptible, because e-antigen reactivity on its own cannot be interpreted.

Outcomes and explanatory variables

Each of three binary outcomes was analysed in its own denominator: vaccine-induced immunity among the 392 participants with neither HBsAg nor anti-HBc (Model A); natural immunity among the 436 HBsAg-negative participants (Model B); and current infection among all 473 participants (Model C). Reported HBV vaccination was coded as none, unsure, one or two doses, or three or more doses, with booster doses placed in the last group. Five cadre groups were formed: nurses/midwives; doctors/dentists; laboratory staff; health officers (community health officers, community health extension workers, environmental health officers and health information officers); and health assistants (health attendants, cleaners and other support staff). Scores for knowledge (14 items, rated good at 10 or above), risk perception (three items, positive at 11 or above out of 15) and attitude (seven items, three of them reverse-scored, positive at 28 or above out of 35) were dichotomised at the thresholds applied in the parent study [19].

Data analysis

All analyses were carried out in R version 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria). Counts with percentages summarise categorical variables, and medians with interquartile ranges summarise continuous ones. Confidence intervals (95% CI) for marker prevalence were obtained by the Wilson score method. Differences between serological groups or cadres were tested with the chi-squared test, replaced by a Monte Carlo Fisher exact test when any expected count was below five, and with the Kruskal–Wallis test for continuous measures. Positive and negative predictive values and Cohen's κ described how well reported vaccination agreed with vaccine-induced immunity, and the Cochran–Armitage test assessed trends across reported dose groups.

Candidate variables were screened one at a time against each outcome, and those with $p < 0.250$ went forward to the multivariable stage (Additional file 1: Table S2). Using purposeful selection [23], terms with $p \geq 0.100$ were then dropped in turn unless dropping them shifted the dose coefficients by more than 20%. Age group and sex were kept in every model, and reported doses, the main exposure, was kept in Model A. Education and cleaning duty were left out because they overlapped almost completely with cadre. Since events were few and some categories had no events, all models were fitted by Firth penalised likelihood logistic regression with the logistf package [24, 25]. Results are shown as adjusted odds ratios (aOR) with profile penalised likelihood 95% CIs and penalised likelihood ratio p-values, and $p < 0.050$ denoted statistical significance. As a sensitivity check, models containing every screened variable were also fitted (Additional file 1: Table S3). No variable used in the analysis had missing values; years of practice, absent for 109 participants in the serological file, was retrieved from their linked survey records. The completed STROBE checklist for cross-sectional studies [26] is supplied as Additional file 2. Generative AI tools (Claude, Anthropic; Posit Assistant in RStudio/Positron) were used to

help edit the language of the manuscript and to check the R code. The authors reviewed all suggested text and code and take full responsibility for the content.

Patient and public involvement

No patients or members of the public took part in setting the research question, designing the study, collecting or interpreting the data, or preparing this report. Each participant was given their own test result, and the main findings will be presented to the Sokoto State Ministry of Health and to the managers of the facilities that took part.

Results

Characteristics of participants

The 473 participants had a median age of 34.0 years (IQR: 27.0–42.0); 63.0% (n = 298) were female and 74.4% (n = 352) were Hausa (Table 1). Nurses and midwives formed the largest cadre (35.7%, n = 169), followed by health assistants (22.4%, n = 106), laboratory staff (22.0%, n = 104), health officers (10.8%, n = 51) and doctors/dentists (9.1%, n = 43), and 62.2% (n = 294) worked in tertiary facilities. In this sample, 37.8% (n = 179) reported at least one dose of HBV vaccine and 20.3% (n = 96) three or more doses; the determinants of uptake are reported elsewhere [19]. Age, education, chronic illness, reported doses, inpatient care, insertion of tubes or catheters, attitude, attending to patients with HBV and institutional HBV vaccination advocacy differed across serological groups (Tables 1 and 2).

Table 1
Sociodemographic characteristics and self-reported vaccination of health personnel by hepatitis B immunity and infection status

Variable	Overall n (%)	Susceptible n (%)	Immunity		Infection		*P*-Value
			Vaccine-induced Immunity n (%)	Natural Immunity n (%)	Current Infection n (%)	Isolated Anti-HBc n (%)	
Sociodemographic characteristics							
*Age (years)***	34.0 (27.0–42.0)	34.0 (27.0–42.8)	32.5 (27.0–40.0)	39.0 (35.0–45.0)	30.0 (25.0–39.0)	39.5 (33.8–47.2)	0.013[1]
Age group (years)							0.027[2]
18–26	107 (22.6%)	79 (23.7%)	13 (22.4%)	4 (20.0%)	11 (29.7%)	0 (0.0%)	
27–36	172 (36.4%)	123 (36.8%)	24 (41.4%)	3 (15.0%)	14 (37.8%)	8 (33.3%)	
37–46	107 (22.6%)	68 (20.4%)	14 (24.1%)	9 (45.0%)	7 (18.9%)	9 (37.5%)	
≥ 47	87 (18.4%)	64 (19.2%)	7 (12.1%)	4 (20.0%)	5 (13.5%)	7 (29.2%)	
Sex							0.580[3]
Female	298 (63.0%)	216 (64.7%)	37 (63.8%)	12 (60.0%)	19 (51.4%)	14 (58.3%)	
Male	175 (37.0%)	118 (35.3%)	21 (36.2%)	8 (40.0%)	18 (48.6%)	10 (41.7%)	
Marital status							0.172[2]
Married	312 (66.0%)	218 (65.3%)	39 (67.2%)	16 (80.0%)	20 (54.1%)	19 (79.2%)	
Single	130 (27.5%)	89 (26.6%)	18 (31.0%)	3 (15.0%)	16 (43.2%)	4 (16.7%)	
Widowed/Separated	31 (6.6%)	27 (8.1%)	1 (1.7%)	1 (5.0%)	1 (2.7%)	1 (4.2%)	
Ethnicity‡							0.448[2]
Hausa	352 (74.4%)	244 (73.1%)	43 (74.1%)	17 (85.0%)	31 (83.8%)	17 (70.8%)	
Yoruba	38 (8.0%)	29 (8.7%)	4 (6.9%)	0 (0.0%)	2 (5.4%)	3 (12.5%)	

Variable	Overall n (%)	Susceptible n (%)	Immunity		Infection		*P*-Value
			Vaccine-induced Immunity n (%)	Natural Immunity n (%)	Current Infection n (%)	Isolated Anti-HBc n (%)	
Sociodemographic characteristics							
Fulani	27 (5.7%)	22 (6.6%)	1 (1.7%)	1 (5.0%)	3 (8.1%)	0 (0.0%)	
Igbo	24 (5.1%)	19 (5.7%)	4 (6.9%)	1 (5.0%)	0 (0.0%)	0 (0.0%)	
Other tribes	32 (6.8%)	20 (6.0%)	6 (10.3%)	1 (5.0%)	1 (2.7%)	4 (16.7%)	
Religion							0.418[2]
Islam	409 (86.5%)	289 (86.5%)	46 (79.3%)	18 (90.0%)	35 (94.6%)	21 (87.5%)	
Christianity	62 (13.1%)	44 (13.2%)	11 (19.0%)	2 (10.0%)	2 (5.4%)	3 (12.5%)	
Other	2 (0.4%)	1 (0.3%)	1 (1.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Highest education†							0.028[2]
Secondary or below	105 (22.2%)	81 (24.3%)	6 (10.3%)	4 (20.0%)	10 (27.0%)	4 (16.7%)	
Tertiary (Diploma/HND)	256 (54.1%)	180 (53.9%)	34 (58.6%)	11 (55.0%)	23 (62.2%)	8 (33.3%)	
Bachelors	83 (17.5%)	57 (17.1%)	12 (20.7%)	4 (20.0%)	3 (8.1%)	7 (29.2%)	
Postgraduate	29 (6.1%)	16 (4.8%)	6 (10.3%)	1 (5.0%)	1 (2.7%)	5 (20.8%)	
Professional cadre							0.249[2]
Nurses/Midwives	169 (35.7%)	118 (35.3%)	23 (39.7%)	6 (30.0%)	14 (37.8%)	8 (33.3%)	
Health assistants	106 (22.4%)	81 (24.3%)	7 (12.1%)	4 (20.0%)	10 (27.0%)	4 (16.7%)	
Laboratory staff	104 (22.0%)	72 (21.6%)	14 (24.1%)	3 (15.0%)	10 (27.0%)	5 (20.8%)	
Health officers	51 (10.8%)	39 (11.7%)	5 (8.6%)	4 (20.0%)	1 (2.7%)	2 (8.3%)	
Doctors/Dentists	43 (9.1%)	24 (7.2%)	9 (15.5%)	3 (15.0%)	2 (5.4%)	5 (20.8%)	

Variable	Overall n (%)	Susceptible n (%)	Immunity		Infection		*P*-Value
			Vaccine-induced Immunity n (%)	Natural Immunity n (%)	Current Infection n (%)	Isolated Anti-HBc n (%)	
Sociodemographic characteristics							
Facility tier							0.147[2]
Tertiary	294 (62.2%)	207 (62.0%)	40 (69.0%)	7 (35.0%)	22 (59.5%)	18 (75.0%)	
Secondary	103 (21.8%)	72 (21.6%)	12 (20.7%)	6 (30.0%)	8 (21.6%)	5 (20.8%)	
Primary	76 (16.1%)	55 (16.5%)	6 (10.3%)	7 (35.0%)	7 (18.9%)	1 (4.2%)	
Years of practice							0.058[2]
< 1 year	76 (16.1%)	55 (16.5%)	9 (15.5%)	2 (10.0%)	9 (24.3%)	1 (4.2%)	
1–5 years	142 (30.0%)	99 (29.6%)	17 (29.3%)	5 (25.0%)	17 (45.9%)	4 (16.7%)	
6–10 years	91 (19.2%)	71 (21.3%)	8 (13.8%)	3 (15.0%)	4 (10.8%)	5 (20.8%)	
> 10 years	164 (34.7%)	109 (32.6%)	24 (41.4%)	10 (50.0%)	7 (18.9%)	14 (58.3%)	
Chronic illness							0.045[2]
No	416 (87.9%)	295 (88.3%)	51 (87.9%)	17 (85.0%)	36 (97.3%)	17 (70.8%)	
Yes	57 (12.1%)	39 (11.7%)	7 (12.1%)	3 (15.0%)	1 (2.7%)	7 (29.2%)	
Self-reported hepatitis B vaccination							
Number of HBV vaccine doses							< 0.001[2]
None	231 (48.8%)	169 (50.6%)	18 (31.0%)	5 (25.0%)	21 (56.8%)	18 (75.0%)	
Unsure	63 (13.3%)	50 (15.0%)	3 (5.2%)	5 (25.0%)	5 (13.5%)	0 (0.0%)	
1–2 doses	83 (17.5%)	58 (17.4%)	15 (25.9%)	3 (15.0%)	5 (13.5%)	2 (8.3%)	

Variable	Overall	Susceptible	Immunity		Infection		*P*-Value
	n (%)	n (%)	Vaccine-induced Immunity n (%)	Natural Immunity n (%)	Current Infection n (%)	Isolated Anti-HBc n (%)	
Sociodemographic characteristics							
≥ 3 doses	96 (20.3%)	57 (17.1%)	22 (37.9%)	7 (35.0%)	6 (16.2%)	4 (16.7%)	
Other vaccines received as an adult (self-reported)							
COVID-19 vaccine							0.129[3]
No	282 (59.6%)	198 (59.3%)	38 (65.5%)	7 (35.0%)	22 (59.5%)	17 (70.8%)	
Yes	191 (40.4%)	136 (40.7%)	20 (34.5%)	13 (65.0%)	15 (40.5%)	7 (29.2%)	
Tetanus vaccine							0.158[3]
No	282 (59.6%)	197 (59.0%)	37 (63.8%)	11 (55.0%)	27 (73.0%)	10 (41.7%)	
Yes	191 (40.4%)	137 (41.0%)	21 (36.2%)	9 (45.0%)	10 (27.0%)	14 (58.3%)	
Yellow fever vaccine							0.078[3]
No	336 (71.0%)	249 (74.6%)	35 (60.3%)	11 (55.0%)	24 (64.9%)	17 (70.8%)	
Yes	137 (29.0%)	85 (25.4%)	23 (39.7%)	9 (45.0%)	13 (35.1%)	7 (29.2%)	
Meningitis vaccine							0.894[3]
No	337 (71.2%)	235 (70.4%)	42 (72.4%)	14 (70.0%)	29 (78.4%)	17 (70.8%)	
Yes	136 (28.8%)	99 (29.6%)	16 (27.6%)	6 (30.0%)	8 (21.6%)	7 (29.2%)	
n	473	334	58	20	37	24	

Variable	Overall	Susceptible	Immunity		Infection		*P*-Value
	n (%)	n (%)	Vaccine-induced Immunity n (%)	Natural Immunity n (%)	Current Infection n (%)	Isolated Anti-HBc n (%)	
Sociodemographic characteristics							
Statistical tests: *[1] Kruskal–Wallis rank-sum test; [2] Fisher's exact test with Monte Carlo simulation; [3] Pearson's chi-squared test.*							
*** Median (IQR), where IQR is the 25th to 75th percentile.*							
Serological status (HBsAg/anti-HBc/anti-HBs): Susceptible −/−/−; Vaccine-induced immunity −/−/+; Natural immunity −/+/+; Current infection +/±/−; Isolated anti-HBc −/+/−. Column percentages; categories of nominal variables are listed in descending order of frequency.							
† Tertiary education corresponds to Diploma and Higher National Diploma (HND) qualifications; 'Secondary or below' includes no formal and primary education.							
‡ 'Other tribes' (n = 32): Zuru (9), Idoma (4), Tiv (3), Ebira (2), Edo (2), Igala (2), Kanuri (2) and eight groups with one participant each. Religion 'Other': Traditional (n = 2).							
Abbreviations: HBV, hepatitis B virus; HBsAg, hepatitis B surface antigen; anti-HBs, antibody to HBsAg; anti-HBc, antibody to hepatitis B core antigen; HND, Higher National Diploma; IQR, interquartile range.							

Table 2
Screening, duties, cognitive factors, exposure and policies by hepatitis B serological status

Variable	Overall n (%)	Susceptible n (%)	Immunity		Infection		*P*-Value
			Vaccine-induced Immunity n (%)	Natural Immunity n (%)	Current Infection n (%)	Isolated Anti-HBc n (%)	
Infectious disease screening (past year)							
Screened for hepatitis B							0.064[3]
No	291 (61.5%)	217 (65.0%)	26 (44.8%)	12 (60.0%)	21 (56.8%)	15 (62.5%)	
Yes	182 (38.5%)	117 (35.0%)	32 (55.2%)	8 (40.0%)	16 (43.2%)	9 (37.5%)	
Screened for HIV							0.992[3]
No	301 (63.6%)	211 (63.2%)	38 (65.5%)	13 (65.0%)	23 (62.2%)	16 (66.7%)	
Yes	172 (36.4%)	123 (36.8%)	20 (34.5%)	7 (35.0%)	14 (37.8%)	8 (33.3%)	
Professional duties (main)¶							
Inpatient care	176 (37.2%)	118 (35.3%)	30 (51.7%)	5 (25.0%)	11 (29.7%)	12 (50.0%)	0.048[3]
Outpatient care	171 (36.2%)	117 (35.0%)	24 (41.4%)	12 (60.0%)	11 (29.7%)	7 (29.2%)	0.138[3]
Blood sample collection	166 (35.1%)	114 (34.1%)	27 (46.6%)	5 (25.0%)	10 (27.0%)	10 (41.7%)	0.208[3]
Injection/cannulation	121 (25.6%)	81 (24.3%)	18 (31.0%)	6 (30.0%)	10 (27.0%)	6 (25.0%)	0.833[3]
Cleaning	109 (23.0%)	85 (25.4%)	8 (13.8%)	4 (20.0%)	9 (24.3%)	3 (12.5%)	0.251[2]
Child delivery	76 (16.1%)	55 (16.5%)	12 (20.7%)	1 (5.0%)	3 (8.1%)	5 (20.8%)	0.309[2]
Insertion of tubes/catheters	71 (15.0%)	47 (14.1%)	17 (29.3%)	1 (5.0%)	1 (2.7%)	5 (20.8%)	0.002[2]
Wound care	65 (13.7%)	46 (13.8%)	12 (20.7%)	1 (5.0%)	1 (2.7%)	5 (20.8%)	0.058[2]
Drainage of body fluids	53 (11.2%)	35 (10.5%)	9 (15.5%)	1 (5.0%)	3 (8.1%)	5 (20.8%)	0.350[2]

Variable	Overall	Susceptible	Immunity		Infection		*P*-Value
	n (%)	n (%)	Vaccine-induced Immunity n (%)	Natural Immunity n (%)	Current Infection n (%)	Isolated Anti-HBc n (%)	
Infectious disease screening (past year)							
Dispensing drugs	46 (9.7%)	34 (10.2%)	8 (13.8%)	0 (0.0%)	1 (2.7%)	3 (12.5%)	0.231[2]
Minor surgery	40 (8.5%)	28 (8.4%)	3 (5.2%)	1 (5.0%)	5 (13.5%)	3 (12.5%)	0.553[2]
Major surgery	27 (5.7%)	17 (5.1%)	4 (6.9%)	1 (5.0%)	3 (8.1%)	2 (8.3%)	0.720[2]
Cognitive factors							
*Knowledge score***	11.0 (9.0–13.0)	11.0 (8.0–13.0)	11.0 (9.2–13.0)	10.5 (9.0–12.0)	11.0 (8.0–12.0)	11.0 (8.8–13.2)	0.361[1]
HBV knowledge							0.892[3]
Good	323 (68.3%)	225 (67.4%)	43 (74.1%)	14 (70.0%)	25 (67.6%)	16 (66.7%)	
Poor	150 (31.7%)	109 (32.6%)	15 (25.9%)	6 (30.0%)	12 (32.4%)	8 (33.3%)	
*Risk perception score***	15.0 (12.0–15.0)	15.0 (12.0–15.0)	15.0 (12.2–15.0)	14.0 (12.0–15.0)	15.0 (12.0–15.0)	15.0 (13.0–15.0)	0.833[1]
Risk perception							0.226[2]
Positive	439 (92.8%)	305 (91.3%)	57 (98.3%)	19 (95.0%)	34 (91.9%)	24 (100.0%)	
Negative	34 (7.2%)	29 (8.7%)	1 (1.7%)	1 (5.0%)	3 (8.1%)	0 (0.0%)	
*Attitude score***	26.0 (23.0–29.0)	26.0 (23.0–28.0)	28.0 (24.0–31.0)	26.5 (25.0–29.0)	24.0 (21.0–28.0)	28.0 (23.0–30.0)	0.001[1]
Attitude to vaccination							0.002[3]
Negative	306 (64.7%)	230 (68.9%)	27 (46.6%)	14 (70.0%)	25 (67.6%)	10 (41.7%)	
Positive	167 (35.3%)	104 (31.1%)	31 (53.4%)	6 (30.0%)	12 (32.4%)	14 (58.3%)	

Variable	Overall	Susceptible	Immunity		Infection		*P*-Value
	n (%)	n (%)	Vaccine-induced Immunity n (%)	Natural Immunity n (%)	Current Infection n (%)	Isolated Anti-HBc n (%)	
Infectious disease screening (past year)							
Occupational exposure							
Attended to a patient with HBV							0.006[3]
Yes	266 (56.2%)	181 (54.2%)	43 (74.1%)	12 (60.0%)	14 (37.8%)	16 (66.7%)	
No	207 (43.8%)	153 (45.8%)	15 (25.9%)	8 (40.0%)	23 (62.2%)	8 (33.3%)	
Ever had needle-stick injury							0.068[3]
No	271 (57.3%)	196 (58.7%)	28 (48.3%)	10 (50.0%)	27 (73.0%)	10 (41.7%)	
Yes	202 (42.7%)	138 (41.3%)	30 (51.7%)	10 (50.0%)	10 (27.0%)	14 (58.3%)	
Institutional policy							
Employer requested HBV vaccination status							0.079[2]
No	388 (82.0%)	278 (83.2%)	40 (69.0%)	16 (80.0%)	32 (86.5%)	22 (91.7%)	
Yes	85 (18.0%)	56 (16.8%)	18 (31.0%)	4 (20.0%)	5 (13.5%)	2 (8.3%)	
Employer mentioned need for HBV vaccine							0.244[2]
No	356 (75.3%)	259 (77.5%)	38 (65.5%)	13 (65.0%)	27 (73.0%)	19 (79.2%)	
Yes	117 (24.7%)	75 (22.5%)	20 (34.5%)	7 (35.0%)	10 (27.0%)	5 (20.8%)	
Institutional HBV vaccination advocacy							0.002[2]
No	397 (83.9%)	285 (85.3%)	42 (72.4%)	20 (100.0%)	34 (91.9%)	16 (66.7%)	

Variable	Overall	Susceptible	Immunity		Infection		*P*-Value
	n (%)	n (%)	Vaccine-induced Immunity n (%)	Natural Immunity n (%)	Current Infection n (%)	Isolated Anti-HBc n (%)	
Infectious disease screening (past year)							
Yes	76 (16.1%)	49 (14.7%)	16 (27.6%)	0 (0.0%)	3 (8.1%)	8 (33.3%)	
Aware of NSI reporting protocol							0.387[3]
No	325 (68.7%)	232 (69.5%)	37 (63.8%)	11 (55.0%)	29 (78.4%)	16 (66.7%)	
Yes	148 (31.3%)	102 (30.5%)	21 (36.2%)	9 (45.0%)	8 (21.6%)	8 (33.3%)	
n	473	334	58	20	37	24	

Statistical tests: *[1] Kruskal–Wallis rank-sum test; [2] Fisher's exact test with Monte Carlo simulation; [3] Pearson's chi-squared test.*

*** Median (IQR). Knowledge score 0–14 (good ≥ 10); risk perception score 3–15 (positive ≥ 11); attitude score 7–35 (positive ≥ 28).*

Serological status (HBsAg/anti-HBc/anti-HBs): Susceptible −/−/−; Vaccine-induced immunity −/−/+; Natural immunity −/+/+; Current infection +/±/−; Isolated anti-HBc −/+/−. Column percentages; categories of nominal variables are listed in descending order of frequency.

¶ Duties are not mutually exclusive; each row shows participants who perform the duty, in descending order of frequency.

Abbreviations: HBV, hepatitis B virus; HIV, human immunodeficiency virus; NSI, needle stick injury; IQR, interquartile range.

Serological profile

Current HBV infection was detected in 7.8% (n = 37; 95% CI: 5.7–10.6) of participants and anti-HBc in 15.0% (n = 71; 95% CI: 12.1–18.5), giving a prevalence of past or current infection of 17.1% (n = 81; 95% CI: 14.0–20.8) (Fig. 1A; Additional file 1: Table S1). Of the 37 HBsAg-positive participants, 27 (73.0%) were anti-HBc positive, 26 (70.3%) anti-HBe positive and one (2.7%) HBeAg positive; 10 (27.0%) were anti-HBc negative. No participant was positive for both HBsAg and anti-HBs. Anti-HBs was detected in 16.5% (n = 78; 95% CI: 13.4–20.1), comprising vaccine-induced immunity in 12.3% (n = 58) and natural immunity in 4.2% (n = 20). Isolated anti-HBc was found in 5.1% (n = 24). Overall, 70.6% (n = 334; 95% CI: 66.4–74.5) had no serological marker, and 75.7% (n = 358) were HBsAg negative without detectable anti-HBs.

Serological profile by cadre

The prevalence of current infection ranged from 2.0% in health officers to 9.6% in laboratory staff (p = 0.428), and anti-HBc from 13.2% in health assistants to 23.3% in doctors/dentists (p = 0.585) (Additional file 1: Table S1; Fig. 1C). Among infection-naive participants, vaccine-induced immunity was 27.3% in doctors/dentists and 8.0% in health assistants (p = 0.087). More than three-quarters of health assistants (76.4%) and health officers (76.5%) had no serological marker. Only 2 of 106 health assistants (1.9%) reported three or more doses, compared with 18 of 43 doctors/dentists (41.9%) (Table 3).

Table 3
Self-reported hepatitis B vaccination compared with serological evidence of immunity and infection

Self-reported Vaccination	n	Immunity			Infection		Susceptible
		Anti-HBs+ n (%)	Vaccine-induced Immunity† n (%) [d]	Natural Immunity‡ n (%) [d]	HBsAg+ n (%)	Anti-HBc+ n (%)	n (%)
Self-reported number of doses							
None	231	23 (10.0%)	18 (9.6%) [187]	5 (2.4%) [210]	21 (9.1%)	39 (16.9%)	169 (73.2%)
Unsure	63	8 (12.7%)	3 (5.7%) [53]	5 (8.6%) [58]	5 (7.9%)	8 (12.7%)	50 (79.4%)
1–2 doses	83	18 (21.7%)	15 (20.5%) [73]	3 (3.8%) [78]	5 (6.0%)	9 (10.8%)	58 (69.9%)
≥ 3 doses	96	29 (30.2%)	22 (27.8%) [79]	7 (7.8%) [90]	6 (6.2%)	15 (15.6%)	57 (59.4%)
Exact doses among those reporting vaccination							
1 dose	38	6 (15.8%)	5 (14.7%) [34]	1 (2.9%) [35]	3 (7.9%)	3 (7.9%)	29 (76.3%)
2 doses	45	12 (26.7%)	10 (25.6%) [39]	2 (4.7%) [43]	2 (4.4%)	6 (13.3%)	29 (64.4%)
≥3 doses	96	29 (30.2%)	22 (27.8%) [79]	7 (7.8%) [90]	6 (6.2%)	15 (15.6%)	57 (59.4%)
Reporting ≥ 3 doses, by professional cadre							
Nurses/Midwives	39	9 (23.1%)	8 (23.5%) [34]	1 (2.8%) [36]	3 (7.7%)	4 (10.3%)	26 (66.7%)
Health assistants	2	0 (0.0%)	0 (0.0%) [2]	0 (0.0%) [2]	0 (0.0%)	0 (0.0%)	2 (100.0%)

Row percentages. Cochran–Armitage test for trend across none, 1–2 and ≥ 3 doses: anti-HBs p < 0.001; vaccine-induced immunity p < 0.001; natural immunity p = 0.032; HBsAg p = 0.322; anti-HBc p = 0.591.

† Among infection-naive participants (HBsAg − and anti-HBc−). ‡ Among HBsAg-negative participants. d, denominator, shown in brackets. '≥3 doses' includes participants who reported three doses (n = 88), more than three doses (n = 6) or a booster dose (n = 2).

Agreement between self-reported vaccination (yes vs no) and vaccine-induced immunity among infection-naive participants (n = 339): PPV 24.3%, NPV 90.4%, Cohen's κ = 0.16.

Abbreviations: anti-HBs, antibody to hepatitis B surface antigen; HBsAg, hepatitis B surface antigen; anti-HBc, antibody to hepatitis B core antigen; PPV, positive predictive value; NPV, negative predictive value.

Self-reported Vaccination	n	Immunity			Infection		Susceptible
		Anti-HBs+ n (%)	Vaccine-induced Immunity† n (%) [d]	Natural Immunity‡ n (%) [d]	HBsAg+ n (%)	Anti-HBc+ n (%)	n (%)
Self-reported number of doses							
Laboratory staff	24	7 (29.2%)	5 (26.3%) [19]	2 (9.1%) [22]	2 (8.3%)	4 (16.7%)	14 (58.3%)
Health officers	13	6 (46.2%)	4 (40.0%) [10]	2 (15.4%) [13]	0 (0.0%)	3 (23.1%)	6 (46.2%)
Doctors/Dentists	18	7 (38.9%)	5 (35.7%) [14]	2 (11.8%) [17]	1 (5.6%)	4 (22.2%)	9 (50.0%)
Post-vaccination immunity check (vaccinated only)							
Reported check: Yes	96	21 (21.9%)	13 (17.3%) [75]	8 (9.4%) [85]	11 (11.5%)	18 (18.8%)	62 (64.6%)
Reported check: No	83	26 (31.3%)	24 (31.2%) [77]	2 (2.4%) [83]	0 (0.0%)	6 (7.2%)	53 (63.9%)
All participants							
Total	473	78 (16.5%)	58 (14.8%) [392]	20 (4.6%) [436]	37 (7.8%)	71 (15.0%)	334 (70.6%)

Row percentages. Cochran–Armitage test for trend across none, 1–2 and ≥ 3 doses: anti-HBs p < 0.001; vaccine-induced immunity p < 0.001; natural immunity p = 0.032; HBsAg p = 0.322; anti-HBc p = 0.591.

† Among infection-naive participants (HBsAg − and anti-HBc−). ‡ Among HBsAg-negative participants. d, denominator, shown in brackets. '≥3 doses' includes participants who reported three doses (n = 88), more than three doses (n = 6) or a booster dose (n = 2).

Agreement between self-reported vaccination (yes vs no) and vaccine-induced immunity among infection-naive participants (n = 339): PPV 24.3%, NPV 90.4%, Cohen's κ = 0.16.

Abbreviations: anti-HBs, antibody to hepatitis B surface antigen; HBsAg, hepatitis B surface antigen; anti-HBc, antibody to hepatitis B core antigen; PPV, positive predictive value; NPV, negative predictive value.

Self-reported vaccination and serological status

The proportion with anti-HBs increased from 10.0% among participants who reported no dose to 21.7% among those who reported one or two doses and 30.2% among those who reported three or more doses (p for trend < 0.001) (Table 3; Fig. 1B). However, 67 of 96 participants (69.8%) who reported three or more doses had no detectable anti-HBs, including 57 of the 79 (72.2%) in this group who were infection-naive. In the same group, six (6.2%) were HBsAg positive and 15 (15.6%) were anti-HBc positive; neither marker declined with the number of doses reported (p for trend 0.322 and 0.591). Among infection-naive participants, self-reported vaccination had a PPV of 24.3% and an NPV of 90.4% for vaccine-induced immunity (κ = 0.16), and 18 of 187 (9.6%) who reported no vaccination had an anti-HBs-only profile.

Of the 179 participants who reported vaccination, 96 stated that their immunity had been tested after vaccination. Of these, 21 (21.9%) had detectable anti-HBs and 11 (11.5%) were HBsAg positive; all 11 vaccinated participants with current infection were in this group. Of the 37 participants with current infection, 21 (56.8%) had not been screened for HBV in the previous year.

Factors associated with immunity and infection

Bivariate estimates are given in Additional file 1: Table S2. In Model A, vaccine-induced immunity was associated with reporting three or more doses (aOR 2.90; 95% CI: 1.37–6.22), but not one or two doses (aOR 1.99; 95% CI: 0.88–4.43). Positive attitude towards vaccination (aOR 1.98; 95% CI: 1.01–3.90), an employer request for HBV vaccination status before employment (aOR 2.05; 95% CI: 1.03–3.97) and insertion of tubes or catheters (aOR 2.75; 95% CI: 1.08–6.93) were also associated with vaccine-induced immunity (Table 4; Additional file 1: Figure S1). Cadre was retained because it confounded the dose estimates, but no cadre differed significantly from nurses and midwives.

Table 4
Multivariable analysis of factors associated with vaccine-induced immunity, natural immunity and current hepatitis B infection

Variable	& Model A: Vaccine-induced Immunity (n = 392; events = 58)		§ Model B: Natural Immunity (n = 436; events = 20)		¶ Model C: Current Infection (n = 473; events = 37)	
	aOR (95% CI)	*P*-Value	aOR (95% CI)	*P*-Value	aOR (95% CI)	*P*-Value
Sociodemographic characteristics						
Age 27–36 years	0.72 (0.31–1.65)	0.428	0.57 (0.12–2.52)	0.454	1.04 (0.42–2.59)	0.936
Age 37–46 years	0.66 (0.27–1.64)	0.372	2.92 (0.91–10.75)	0.072	1.80 (0.54–5.63)	0.329
Age ≥ 47 years	0.60 (0.20–1.72)	0.349	1.93 (0.46–8.16)	0.360	1.78 (0.43–6.70)	0.414
Age 18–26 years (ref)	1		1		1	
Male	0.68 (0.33–1.39)	0.295	1.82 (0.67–4.83)	0.236	1.82 (0.87–3.80)	0.111
Female (ref)	1		1		1	
Professional factors						
Health assistants	1.58 (0.50–4.76)	0.426	—		—	
Laboratory staff	1.62 (0.68–3.86)	0.276	—		—	
Health officers	0.63 (0.19–1.74)	0.384	—		—	
Doctors/Dentists	1.77 (0.61–4.93)	0.284	—		—	
Nurses/Midwives (ref)	1		—		—	
Secondary facility	—		2.94 (0.91–9.42)	0.071	—	
Primary facility	—		**4.84 (1.56–15.30)****	**0.007**	—	
Tertiary facility (ref)	—		1		—	

Variable	& Model A: Vaccine-induced Immunity (n = 392; events = 58)		§ Model B: Natural Immunity (n = 436; events = 20)		¶ Model C: Current Infection (n = 473; events = 37)	
	aOR (95% CI)	*P*-Value	aOR (95% CI)	*P*-Value	aOR (95% CI)	*P*-Value
Sociodemographic characteristics						
1–5 years practice	—		—		1.01 (0.43–2.53)	0.976
6–10 years practice	—		—		0.32 (0.08–1.08)	0.066
>10 years practice	—		—		**0.23 (0.06–0.84)***	**0.026**
<1 year practice (ref)	—		—		1	
Insertion of tubes/catheters: Yes	**2.75 (1.08–6.93)***	**0.035**	—		—	
Insertion of tubes/catheters: No (ref)	1		—		—	
Drainage of body fluids: Yes	0.39 (0.12–1.16)	0.090	—		—	
Drainage of body fluids: No (ref)	1		—		—	
Vaccination and screening						
Unsure of doses	0.72 (0.18–2.25)	0.588	—		—	
1–2 doses	1.99 (0.88–4.43)	0.097	—		—	
≥3 doses	**2.90 (1.37–6.22)****	**0.005**	—		—	
No dose reported (ref)	1		—		—	
Yellow fever vaccine: Yes	1.50 (0.79–2.81)	0.208	—		—	
Yellow fever vaccine: No (ref)	1		—		—	
Cognitive factors						
Positive attitude	**1.98 (1.01–3.90)***	**0.048**	—		—	

Variable	& Model A: Vaccine-induced Immunity (n = 392; events = 58)		§ Model B: Natural Immunity (n = 436; events = 20)		¶ Model C: Current Infection (n = 473; events = 37)	
	aOR (95% CI)	*P*-Value	aOR (95% CI)	*P*-Value	aOR (95% CI)	*P*-Value
Sociodemographic characteristics						
Negative attitude (ref)	1		—		—	
Occupational exposure						
Attended to a patient with HBV: Yes	—		—		**0.42 (0.20–0.84)***	**0.014**
Attended to a patient with HBV: No (ref)	—		—		1	
Institutional policy						
Employer requested HBV vaccination status: Yes	**2.05 (1.03–3.97)***	**0.040**	—		—	
Employer requested HBV vaccination status: No (ref)	1		—		—	
Institutional HBV vaccination advocacy: Yes	—		**0.08 (< 0.01–0.65)***	**0.012**	—	
Institutional HBV vaccination advocacy: No (ref)	—		1		—	
Aware of NSI reporting protocol: Yes	—		2.60 (0.99–6.79)	0.053	—	
Aware of NSI reporting protocol: No (ref)	—		1		—	

Variable	& Model A: Vaccine-induced Immunity (n = 392; events = 58)		§ Model B: Natural Immunity (n = 436; events = 20)		¶ Model C: Current Infection (n = 473; events = 37)	
	aOR (95% CI)	*P*-Value	aOR (95% CI)	*P*-Value	aOR (95% CI)	*P*-Value
Sociodemographic characteristics						
& Model A: vaccine-induced immunity (anti-HBs+, HBsAg−, anti-HBc−) versus susceptible participants, among infection-naive participants.						
§ Model B: natural immunity (anti-HBc + and anti-HBs+) versus all other HBsAg-negative participants.						
¶ Model C: current infection (HBsAg+) versus HBsAg-negative participants.						
** p < 0.05, ** p < 0.01, *** p < 0.001; — variable not retained in, or not eligible for, the model.*						
Reference categories (shown as 1): age 18–26 years, female, married, Hausa, Islam, nurses/midwives, tertiary facility, < 1 year practice, no HBV vaccine dose, poor knowledge, negative risk perception, negative attitude, and 'No' for binary variables. Categories of nominal variables are listed in descending order of frequency.						
Variable selection: variables with bivariate p < 0.25 (Additional file 1: Table S2) were entered and removed one at a time if p ≥ 0.10, unless they were retained a priori (age group and sex in all models; self-reported doses in Model A) or their removal changed the dose coefficients by more than 20% (professional cadre and yellow fever vaccination in Model A). Cadre did not meet the screening threshold for Models B and C. Education and cleaning duty were not entered because they were collinear with cadre.						
Abbreviations: aOR, adjusted odds ratio; CI, confidence interval; HBV, hepatitis B virus; HBsAg, hepatitis B surface antigen; anti-HBs, antibody to HBsAg; anti-HBc, antibody to hepatitis B core antigen; NSI, needle stick injury.						
Statistical notes: Firth penalised likelihood logistic regression; 95% CIs are profile penalised likelihood intervals and p-values penalised likelihood ratio tests.						
Note on sparse data: in Model B, none of the 73 HBsAg-negative participants who reported institutional HBV vaccination advocacy had natural immunity (quasi-complete separation). The penalised estimate is finite but imprecise (aOR 0.08; 95% CI < 0.01–0.65).						

In Model B, natural immunity was more frequent in primary than in tertiary facilities (aOR 4.84; 95% CI: 1.56–15.30). No participant who reported institutional HBV vaccination advocacy had natural immunity (aOR 0.08; 95% CI: <0.01–0.65). In Model C, current infection was less frequent among participants with more than 10 years of practice (aOR 0.23; 95% CI: 0.06–0.84) and among those who had attended to a patient with HBV (aOR 0.42; 95% CI: 0.20–0.84). Needle stick injury and invasive duties were not associated with current infection, and cadre did not meet the screening threshold for Models B and C. The direction of these associations was unchanged in the sensitivity models (Additional file 1: Table S3).

Discussion

In this serological study of health personnel in Sokoto State, about one in thirteen had current HBV infection and one in six had evidence of past or current infection, whereas fewer than one in five had detectable anti-HBs

and seven in ten had no serological marker. Self-reported vaccination was a weak indicator of protection: most participants who reported a complete series had no detectable antibody, and some were already infected.

The prevalence of current infection (7.8%) was similar to the pooled estimate for African health personnel (6.8%) and to national estimates for the general population [3, 4, 7], and higher than the 2.3% reported among health personnel screened in Enugu [27]. Comparable studies found HBsAg in 10.0% of health personnel in Freetown, Sierra Leone, where 81.5% were susceptible [15], and chronic infection in 4% in Makueni, Kenya [16]. In Beira, Mozambique, by contrast, 60% had vaccine-induced immunity and 27.9% were susceptible [14]. In Cameroon, most hospital staff had serological evidence of past infection [28]. The large susceptible fraction in Sokoto is consistent with the low coverage reported among health personnel in Nigeria and across Africa [10–12].

Self-reported vaccination and protection

Only 30% of participants who reported a complete series had detectable anti-HBs. Studies that confirmed vaccination and measured antibody quantitatively found protective concentrations in 82% of fully vaccinated health personnel in Ethiopia and 83% in Uganda, 58% of vaccinated health personnel in Ghana and about 90% in Rwanda [13, 17, 18, 29]. Several factors may explain the lower figure in Sokoto. Recall of vaccination is imprecise, and the weak agreement between self-report and serology ($\kappa = 0.16$) is consistent with misclassification. Vaccine potency may have been reduced by cold-chain failures, and doses may have been given at incorrect intervals. Some participants may have been non-responders, a group that is more common among older adults, men and people with obesity [9, 29]. Anti-HBs also declines with time after vaccination, although immune memory persists and a booster dose produces a rapid anamnestic response in most people who have lost detectable antibody [30, 31]. Finally, a qualitative rapid test may not detect low antibody concentrations. The absence of vaccination dates and quantitative titres means that these explanations cannot be separated. For occupational health purposes, however, a worker without a documented complete series and a documented post-vaccination anti-HBs result cannot be assumed to be protected. Testing for anti-HBs one to two months after the last dose, with revaccination and repeat testing of those who do not respond, is recommended for health personnel [9]. In Ghana, keeping a vaccination record card and receiving a booster dose were associated with seroconversion [13], which supports the use of written records.

Eleven participants who reported vaccination had current infection, and all reported that their immunity had been tested after vaccination. The most likely explanation is that a pre-vaccination HBsAg screen was understood as an immunity test, or that vaccination was given without prior screening. These participants considered themselves protected, and more than half of all infected participants had not been screened in the previous year. Because vaccination offers no benefit to people who are already infected, occupational HBV programmes should include HBsAg screening before vaccination and referral for assessment and treatment [8, 21].

Factors associated with immunity and infection

Reporting three or more doses was associated with vaccine-induced immunity, and the gradient across dose groups indicates that self-report, although imprecise, carries some information. A positive attitude towards vaccination and an employer request for vaccination status were also associated with immunity. Both factors were linked to vaccine uptake in the parent survey [19], and the present results show that they are associated

with measurable protection. Participants who inserted tubes or catheters were more likely to be immune, which may reflect higher perceived risk or easier access to occupational health services in clinical units.

Natural immunity was more common in primary facilities. Staff of primary facilities are often recruited from nearby rural communities, where exposure to HBV in childhood is common [2, 4], and in Kenya complete vaccination was less common in primary facilities than in hospitals [16]. The inverse association with institutional advocacy is based on no events in the exposed group and should be regarded as exploratory. Current infection was not associated with needle stick injury or invasive duties and was less common among participants with longer service and among those who had cared for patients with HBV. Lower odds of current infection among older health personnel have also been reported in Sierra Leone [15]. In highly endemic settings, most chronic infections are acquired at birth or in early childhood [8], so many HBsAg-positive staff were probably infected before employment. The higher prevalence among recently employed staff suggests that HBV status is not assessed at recruitment. The inverse associations with length of service and patient contact may also reflect a healthy-worker effect, redeployment of staff known to be infected, or loss of HBsAg over time; a cross-sectional design cannot distinguish between these possibilities.

Differences between cadres

Infection markers did not differ significantly between cadres, but immunity did. Doctors and dentists had the highest prevalence of vaccine-induced immunity and of anti-HBc, whereas health assistants had the lowest immunity and almost none reported a complete series. Health assistants and cleaners handle waste, linen and sharps, often with limited training and limited access to staff clinics, and had the lowest vaccine uptake in the parent survey [19]. Occupational HBV programmes therefore need to include support staff as well as clinical cadres.

Among HBsAg-positive participants, HBeAg was rare (2.7%) and anti-HBe common, which suggests that most were in the HBeAg-negative phase of chronic infection; HBV DNA testing is required to assess infectivity and eligibility for treatment [21]. The 5.1% with isolated anti-HBc require HBV DNA testing to identify occult infection [22, 32].

Strengths and limitations

This study tested five HBV markers and linked the results to individual questionnaire data, which allowed self-reported vaccination to be compared directly with serological status. Participants were selected by probability sampling from all three tiers of care and from all cadres, including support staff, who are often omitted from serological surveys. Immunity and infection were analysed as separate outcomes with appropriate denominators, rather than as a single combined category, and Firth regression was used to obtain stable estimates for uncommon outcomes. Results were interpreted with a standard algorithm, and all participants received their results and appropriate advice or referral.

The study also has limitations. The rapid test was qualitative, so antibody concentrations could not be measured and the 10 mIU/mL threshold could not be applied; low concentrations may have been missed, which would overstate the proportion without protection. HBV DNA was not measured, so occult infection and infectivity could not be assessed. Vaccination history was self-reported without dates, which prevented assessment of time since vaccination. Participants who provided blood samples may differ from those who did

not; in the parent survey, tested participants were more often from primary facilities and were slightly younger, although reported vaccine uptake was similar. Model B was based on 20 events and its estimates are imprecise. The cross-sectional design does not allow the timing of infection relative to employment to be established.

Conclusions

About three in four health personnel in Sokoto had no serological protection against HBV, and one in thirteen had current infection. Self-reported vaccination overstated protection, as most of those who reported a complete series had no detectable anti-HBs and some were infected. Health facilities should screen all staff for HBsAg and anti-HBs at recruitment, provide free vaccination to those who are susceptible, record every dose, test for anti-HBs after the series and refer infected staff for care. Health assistants and other support staff should be included in these programmes.

Abbreviations

Anti-HBc
antibody to hepatitis B core antigen
Anti-HBe
antibody to hepatitis B e antigen
Anti-HBs
antibody to hepatitis B surface antigen
aOR
adjusted odds ratio
CI
confidence interval
DNA
deoxyribonucleic acid
HBeAg
hepatitis B e antigen
HBsAg
hepatitis B surface antigen
HBV
hepatitis B virus
HIV
human immunodeficiency virus
HND
Higher National Diploma
IQR
interquartile range
NPV
negative predictive value
NSI

needle stick injury
PPV
positive predictive value
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
WHO
World Health Organization

Declarations

Ethics approval and consent to participate:

The study protocol was reviewed and approved by the Health Research Ethics Committee of the Sokoto State Ministry of Health (reference SMH/1580/V.IV) and the Health Research and Ethics Committee of Usmanu Danfodiyo University Teaching Hospital, Sokoto (reference UDUTH/HREC/2022/1193/V2). The Hospital Services Management Board, the State Primary Health Care Agency and the head of each participating facility gave permission for the work to be carried out. Every participant gave written informed consent before the interview and the collection of blood. The study followed the principles of the Declaration of Helsinki, and records were stored without names or other personal identifiers.

Consent for publication:

Not applicable.

Competing interests:

None of the authors has a financial or non-financial interest to declare.

Clinical trial number

Not applicable.

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Authors' contributions:

SIA conceived and designed the study, obtained ethical approval, coordinated data and sample collection, analysed the data and wrote the first and final drafts. KLH, MSB and KS supervised the study and revised the manuscript. YM contributed to the methodology and investigation and revised the manuscript. LA, AO and AAA

contributed to the methodology and revised the manuscript. SS, AM, MUI, AOU and HA revised the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

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Availability of data and materials:

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request. Data are de-identified and are shared in line with the conditions of the ethics approvals. The R code used for the analysis is available from the same author.

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Figures

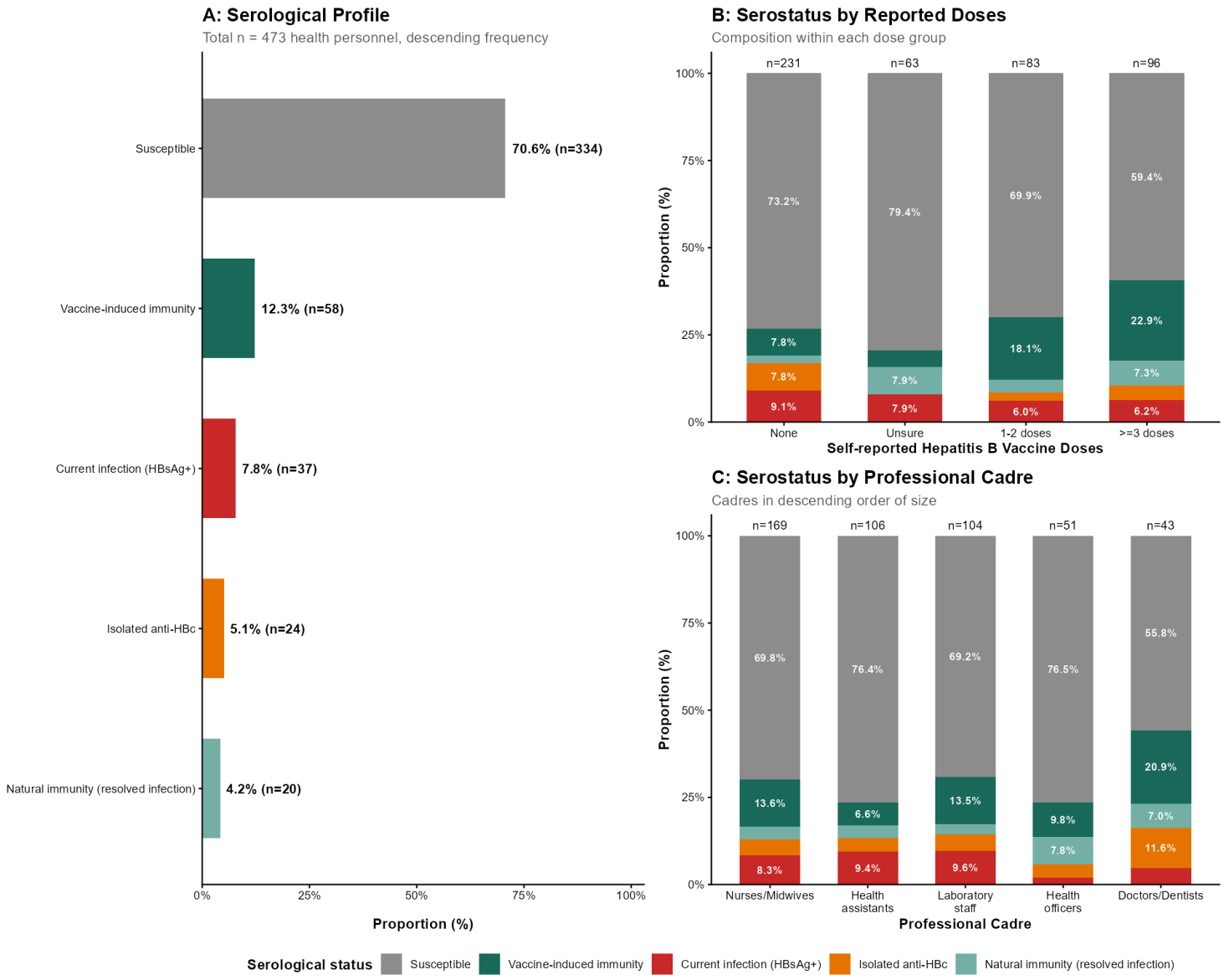


Figure 1

Hepatitis B serological profile of health personnel in Sokoto State, Nigeria

(A) Distribution of serological status in descending order of frequency (n = 473). (B) Serological status by self-reported number of hepatitis B vaccine doses. (C) Serological status by professional cadre, in descending order of cadre size. Susceptible: HBsAg, anti-HBc and anti-HBs negative; vaccine-induced immunity: anti-HBs positive only; natural immunity: anti-HBc and anti-HBs positive; isolated anti-HBc: anti-HBc positive only; current infection: HBsAg positive.

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