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# Hepatitis B virus vaccination post serological testing and antibody levels of vaccinated health care workers in Accra, Ghana

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ABSTRACT

*Introduction:* Hepatitis B Virus (HBV) infection is an important occupational hazard to Health Care Workers (HCWs) all over the world. International health organizations have strongly recommended the use of the HBV vaccine, especially among individuals at risk of HBV infection. A laboratory test aimed at measuring Anti-HBs concentration (titer) 1–2 months following a 3-dose vaccination schedule is the most reliable approach for diagnosing seroprotection against HBV. This study sought to assess post-vaccination serological testing, seroprotection against HBV, and associated factors among vaccinated HCWs in Ghana.

*Methods:* A hospital-based analytical cross-sectional study involving 207 HCWs. Pretested questionnaires were used to collect data. 5mls of venous blood were collected from consenting HCWs under strict aseptic conditions and quantitatively analyzed for Anti-HBs using ELISA procedures. SPSS Version 23 was used to analyze data with the level of significance set at 0.05.

*Results:* Median age; 33, IQR of 29–39. The post-vaccination serological testing rate was 21.3 %. HCWs with high-risk perception and working at the regional hospital had lower odds of adherence to post-vaccination serological testing (aOR = 0.2; 95 % CI = 0.1–0.7) and (aOR = 0.1; 95 % CI = 0.1–0.6) $p < 0.05$. The seroprotection rate was 91.3 % (95 % CI = 87 %-95 %). Minority, 18 (8.7 %) of the 207 vaccinated HCWs had antibody titers below 10mIU/mL and were not seroprotected against HBV. Geometric Mean Titers (GMTs) were higher in those who received three doses, took a booster, and were less than 25 kg/m$^2$.

*Conclusion:* The post-vaccination serological testing practice was sub-optimal. The seroprotection rate was higher with higher GMTs in those who adhered to the 3-dose vaccination regimen, took a booster dose, and had BMI < 25 kg/m$^2$. It may be inferred that those with Anti-HBs below 10 IU/ml had their antibodies diminishing or waning off with time or they are true vaccine non-responders. This observation calls for strict adherence to post-vaccination serological testing, especially for HCWs who are at high risk of percutaneous and mucocutaneous exposures that could result in HBV infection.



## Introduction

Hepatitis B Virus (HBV) infection is a global public health concern resulting in close to 820 000 deaths in the year 2019 alone. In that same year, the World Health Organization (WHO) estimated that 296 million people were living with chronic hepatitis B infection, with 1.5 million new infections occurring across the world each year [1] There is significant heterogeneity in the burden of HBV infection with infection rates being disproportionately high in the WHO Western Pacific and WHO African Regions, where 116 million and 81 million people, respectively, are chronically infected [1] Apart from vertical transmission which is the predominant mode of spread in highly endemic countries, HBV is also spread by needlestick injury, injury from contaminated sharp objects, and exposure to infected blood and body fluids. This is the basis for recognizing HBV as a huge and important occupational hazard for Health Care Workers (HCWs) all over the world especially those in highly endemic zones [2] where the disease prevalence is ≥ 8 %–20 % [3,4,5] In such highly endemic settings, HCWs are considered to have a 2–4 times higher risk of infection with HBV compared to the general population [6].

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In recognition of the high occupational risk of HBV to HCWs, the WHO in its global health sector strategy for viral hepatitis emphasized the protection of HCWs as one of its priorities for eliminating the virus by 2030 [7] The United States Centers for Disease Control and Prevention and other international health organizations have all called for the protection of this high-risk population [8,9,10] These organizations and many more have strongly recommended the use of a very effective hepatitis B vaccine since its invention in the early 1980 s. The widely recommended series of three intramuscular injections are known to induce long-lasting immunity. Evidence across multiple studies shows that following the standard 3-dose schedule of HBV vaccination in immunocompetent populations, close to 90–95 % of vaccinees who are < 40 years at the time of vaccination develop neutralizing antibodies against HBV to the levels of $\geq$ 10mIU/mL. This means that close to 5–10 % of immunocompetent vaccinees fail to respond to the primary HBV vaccine series by failing to elicit detectable specific antibodies and therefore remain susceptible to HBV [10,11]. Therefore, HBV vaccine non-responders are considered as people who fail to develop protective antibodies (>10mIU/mL) despite a primary course of hepatitis B vaccination. Anti-HBs levels above 10mIU/mL are indicative of adequate protection against HBV infection [12] A laboratory test aimed at measuring antibody concentration (titer) 1–2 months following the successful completion of a 3-dose vaccination schedule is the most reliable procedure for diagnosing clinical protection against HBV [13] hence post-vaccination antibody testing against HBV is strongly recommended for HCWs and all individuals who are at high risk of HBV infection [13,14] This current study was implemented to assess the level of adherence to the post-vaccination serological testing recommendations as well as assess the antibody levels against HBV infection among vaccinated HCWs in Accra, Ghana.

*Country context and research problem*

Ghana is endemic for HBV infection with an estimated national prevalence of 12.3 % [15] Among HCWs, prevalence rates of 1 %–5.9 % have been reported [16,17] HBV vaccination coverage has also been estimated to be 53.4 % [18] among HCWs. There is the widespread absence of post-vaccination serological testing and most importantly, seroprevalence surveys for HCWs who belong to the occupational category with the highest risk of HBV infection are not available. This makes it very difficult to identify HCWs who are non-responders to the HBV vaccine. In this light, this study was undertaken to assess the factors associated with post-vaccination serological testing for hepatitis B and determine seroprotection rates among vaccinated HCWs.

## Materials and methods

*Study design and setting*

The researchers employed a cross-sectional hospital-based analytical study and recruited 207 healthcare workers belonging to six different cadres or professional categories from five selected hospitals in the capital city of Ghana, Accra between January to June 2019. Accra is known to be the second most populous region in the country with the smallest land area with the highest distribution of all categories of HCWs as well as health facilities [19].

*Study population and eligibility*

The population of this study comprised of HCW groups or professionals including Doctors, Nurses, Laboratory staff, Anesthetists, Physician Assistants, and Orderlies (Sanitation workers) who were working within the five selected health facilities in the Greater Accra Region of Ghana.

This study was restricted to HCWs who were 18 years and above and were permanent workers with an employment history of over a year. These individuals confirmed the receipt of the primary Hepatitis B vaccine in the past six months per vaccination records and had non-reactive or negative hepatitis B surface antigen (HBsAg) status based on HBsAg screening results from a related study[16].

*Sample size estimation*

The formula for estimating proportions in cross-sectional studies proposed by Cochrane[20] was used to compute the sample size, with a 95 % confidence interval and margin of error of 5 %. A 10 % post-vaccination serological testing rate was anticipated using results from a pilot study. Other statistical assumptions such as population correction factor, design effect, and allocation for non-response were duly considered and a total minimum sample of 200 healthcare workers was deemed adequate to identify any difference between vaccine responders and non-responders as well as those who performed post-vaccination serological testing and their non-adhering counterparts.

*Sampling procedure*

The Healthcare facilities in the Greater Accra Region were stratified into five levels of care (Regional Hospitals, District Hospitals, Polyclinics, Health centers, and CHPs Compounds). One facility was randomly selected from each stratum. A proportional allocation to size procedure was used to allocate HCWs to the five study facilities. Thereafter, in each selected facility, HCWs were again stratified into six cadres of staff (Doctors, Nurses/Midwives, Laboratory Staff, Physician Assistants, Anesthetists, and orderlies). The cadre-specific staff list for each selected facility served as a sampling frame for the random selection of HCWs. The study estimated a minimum sample of 200 participants, however, 207 eligible HCWs participated in the study.

*Data collection instrument*

A structured questionnaire that was validated (through evaluation by experts and pretesting) was used to collect data from all consenting HCWs. The questions ranged from (a) sociodemographics (age, sex, duration of employment, etc.), (b) occupational characteristics (Cadre, duration of employment, unit, or department of work), and (c) HBV vaccination history (number of doses, age at vaccination, post-vaccination serological testing, receipt of booster doses, etc.).

*Sample collection and laboratory procedure*

All eligible participants gave informed consent to partake in the study after the nature and purpose, procedures, risks and benefits, and other components of research ethics were thoroughly explained to them. Following the successful completion of the questionnaire session, and for each consenting HCW, 5 ml of venous blood was aseptically collected under a strict aseptic phlebotomy procedure using 5mls sterile syringes into an Ethylene Diamine Tetra-acetic Acid (EDTA) tube and centrifuged at 2200–2500 RPM for 15 min to separate the serum. The serum samples were then transported at 2–4 °C under cold chain conditions to the Immunology laboratory of the Noguchi Memorial Institute of Medical Research where an ELISA procedure was performed to quantitatively estimate Anti-HBs concentrations using Antisurase B-96II TMB Catalog number 4SBE3 manufactured by General Biologicals.

The tests were performed in duplicates with strict adherence to the manufacturer's instructions.

*Statistical analysis*

Data entry and analysis were done using Statistical Package for Social Scientists (SPSS) version 21 software. Descriptive analysis was performed for background characteristics and data was summarized using frequencies, proportions, means, standard deviations, medians, and interquartile ranges. Multivariable logistic regression analysis was performed to identify factors associated with post-vaccination serological testing and seroprotection against HBV.

Proportions of vaccinated HCWs with neutralizing antibodies above 10mlU/mL were calculated and reported as seroprotection rates. The Anti-HBs concentrations of participating HCWs were classified into three groups using the WHO and National Center for Immunization Research (NCIR) antibody titer reference range for Anti-HBs. The raw antibody concentrations were transformed into Geometric Mean Titers (GMTs) and subsequently compared between groups.

## Results

*Baseline characteristics of study participants*

Data for 207 vaccinated HCWs were evaluated in the study. Most of the participants 152/207 (73.4 %) were females, mainly nurses/midwives 95/207, (46.0 %), and aged 22 to 58 years (median: 33 years; IQR: 29–39). A high proportion of the participants (74.4 %) have tertiary/post-tertiary level education and ever participated in at least one training workshop on the prevention of blood-borne infections (84.1 %). A majority (75.4 %) of the participants have less than 10 years of working experience. In all, 51.7 % of them work as care providers in critical units and departments known for having a high risk of exposure to blood and body fluids. The majority (51.2 %) of the participants were recruited from the regional hospital. Also, 156 (77 %) and 129 (62.3 %) adhered to the recommended 3 doses and 0, 1, 6 vaccination schedules respectively (Table 1).

**Table 1**
Sociodemographic and Occupational characteristics of Respondents (N = 207).

| Variables | N | Percent (%) |
|---|---|---|
| **Age** | | |
| 21–30 | 76 | 36.7 |
| 31–40 | 95 | 45.9 |
| 41–50 | 27 | 13.1 |
| 51–60 | 9 | 4.3 |
| **Sex** | | |
| Female | 152 | 73.4 |
| Male | 55 | 26.6 |
| **Cadre of staff** | | |
| Doctor | 44 | 21.3 |
| Nurse/Midwife | 95 | 46.0 |
| Anesthetist | 11 | 5.2 |
| laboratory | 31 | 15.0 |
| Orderly | 13 | 6.3 |
| Physician Assistants | 13 | 6.2 |
| **Risk Perception** | | |
| Low | 23 | 11.0 |
| High | 184 | 89.0 |
| **Duration of employment** | | |
| <10 years | 156 | 75.4 |
| ≥10 years | 51 | 24.6 |
| **Training** | | |
| No training in IPC * | 33 | 15.9 |
| Received Training in IPC | 174 | 84.1 |
| **Facility Type** | | |
| CHPs** | 10 | 4.8 |
| Health center | 11 | 5.4 |
| Polyclinic | 35 | 16.9 |
| District | 45 | 21.7 |
| Regional | 106 | 51.2 |
| **Work Unit** | | |
| Non-critical (minimum to moderate exposure) | 100 | 48.3 |
| Critical (High exposure) | 107 | 51.7 |
| **Vaccination completion status** | | |
| Complete Vaccination (3doses or more) | 159 | 77 |
| Partial Vaccination (<3 doses) | 48 | 23 |
| **Adherence to 0, 1.6 vaccination schedule** | | |
| Adhered | 129 | 62.3 |
| Did not adhere | 78 | 37.7 |

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*Testing for Anti-HBs after vaccination (post-vaccination serological testing)*

This study determined the proportion of HCWs who tested for Anti-HBs. Out of the 207 vaccinated HCWs, 21.3 % (44/207) adhered to the post-vaccination serological testing recommendation to confirm the development of Anti-HBs. The 21.3 % represents an overall low level of adherence among the HCWs. More of the female HCWs undertook the test 82 % (36/44) compared to the males 18 % (8/44). Orderlies were the category that adhered more to the recommendation with 30.8 % (4/13) of them taking the post-vaccination test.

The results presented in Table 2 showed that HCWs with high-risk perception and those working at the regional hospital level both had lower odds of undertaking post-vaccination serological testing (aOR = 0.2; 95 % CI = 0.1–0.7) and (aOR = 0.1; 95 % CI = 0.1–0.6) respectively.

*Determining Anti-HBs levels (seroprotection) among 207 vaccinated HCWs*

This study equally determined the Anti-HBs levels of the 207 vaccinated HCWs. The antibody concentrations of participating HCWs were classified into three groups using the WHO and NCIR antibody titer reference range. The results illustrated in Table 3 showed that a total of 18 (8.7 %) out of 207 vaccinated HCWs had antibody titers below 10mIU/mL and hence referred to as non-seroprotected after having received at least one dose of HBV vaccination. Ninety-three 93 (44.9 %) were adequately protected with antibody levels between 10 and 100mIU/mL. The majority of the vaccinated HCWs 96 (46.4 %) had antibody levels above 100mIU/mL indicating a high level of seroprotection against HBV. In all, 189 HCWs demonstrated anti-HBs levels above 10mIU/mL giving an overall seroprotection prevalence of 91.3 % (95 % CI = 87 %-95 %) among the vaccinated HCWs. Fig. 1.

*Comparison of GMT and factors associated with seroprotection*

The GMTs of Anti-HBs were higher in HCWs with less than 5 years of vaccination history. The GMT was also found to be higher for those who strictly adhered to 3-dose vaccination schedules, took booster doses, and had a BMI of less than 25 kg/m$^2$. A logistic regression analysis did not reveal any statistically significant association between seroprotection and vaccination indicators or variables as well as sociodemographic variables that are known to affect Anti-HBs development. Table 4.

**Table 2**
Factors associated with post vaccination serological testing.

| Variables | N | n | Unadjusted Estimates | | Adjusted Estimates | |
|---|---|---|---|---|---|---|
| | | | UOR (95 % CI) | P-value | AOR (95 % CI) | P-value |
| **Age** | | | | | | |
| 21–30 | 76 | 16 | 1.00 | | 1.00 | |
| 31–40 | 95 | 19 | 0.9(0.4–2) | 0.865 | 0.9(0.4–2.1) | 0.822 |
| 41–50 | 27 | 6 | 1.1(0.4–3.1) | 0.899 | 1.2(0.3–4.7) | 0.839 |
| 51–60 | 9 | 3 | 1.9(0.4–8.3) | 0.409 | 2.2(0.3–14.3) | 0.422 |
| **Sex** | | | | | | |
| Female | 152 | 36 | 1.00 | | 1.00 | |
| Male | 55 | 8 | 0.5(0.2–1.3) | 0.160 | 0.7(0.3–1.8) | 0.449 |
| **Cadre of staff** | | | | | | |
| Doctor | 44 | 10 | 1.00 | | 1.00 | |
| Nurse/Midwife | 95 | 20 | 0.9(0.4–2.1) | 0.823 | 0.8(0.3–2.3) | 0.727 |
| Anesthetist | 11 | 2 | 0.8(0.1–4.1) | 0.745 | 1.9(0.3–14.1) | 0.532 |
| Laboratory | 31 | 5 | 0.7(0.2–2.1) | 0.484 | 0.8(0.2–3.8) | 0.82 |
| Orderly | 13 | 4 | 1.5(0.4–6) | 0.556 | 1.7(0.3–9.1) | 0.514 |
| Physician Assistant | 13 | 3 | 1(0.2–4.4) | 0.979 | 0.7(0.1–4.4) | 0.734 |
| **Risk Perception** | | | | | | |
| Low | 23 | 8 | 1.00 | | 1.00 | |
| High | 184 | 36 | 0.5(0.2–1.2) | 0.099 | 0.2(0.1–0.7) | 0.014 |
| **Duration of employment** | | | | | | |
| <10 years | 156 | 33 | 1.00 | | 1.00 | |
| ≥10 years | 51 | 11 | 1.0(0.5–2.2) | 0.950 | 0.6(0.2–1.9) | 0.418 |
| **Training** | | | | | | |
| No Training in IPC* | 33 | 9 | | | | |
| Training in IPC | 174 | 35 | 0.7(0.3–1.6) | 0.359 | 0.8(0.3–2.1) | 0.609 |
| **Facility Type** | | | | | | |
| CHPs**** | 10 | 5 | 1.00 | | 1.00 | |
| Health center | 11 | 1 | 0.1(0.1–1.1) | 0.06 | 0.1(0–1.2) | 0.064 |
| Polyclinic | 35 | 13 | 0.6(0.1–2.4) | 0.467 | 0.8(0.2–4.2) | 0.828 |
| District | 45 | 12 | 0.4(0.1–1.5) | 0.158 | 0.5(0.1–2.3) | 0.343 |
| Regional | 106 | 13 | 0.1(0.1–0.5) | 0.005 | 0.1(0.1–0.6) | 0.008 |
| **Work unit** | | | | | | |
| Non-critical | 100 | 25 | 1.00 | | 1.00 | |
| Critical | 107 | 19 | 0.6(0.3–1.3) | 0.205 | 1.2(0.5–2.9) | 0.747 |

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**Table 3**
Anti-HBs levels and Seroprotection following HBV vaccination.

| Antibody Level | Category | Frequency N = (207) | Percent (%) |
|---|---|---|---|
| <10mIU/mL | No Protection | 18 | 8.7 |
| 10-100mIU/mL | Adequate seroprotection | 93 | 44.9 |
| >100mIU/mL | High level of seroprotection | 96 | 46.4 |
| **Total** | | **207** | **100.00** |

## Discussion

### *Adherence to post-vaccination serological testing*

The present study that sought to assess post-vaccination serological testing among vaccinated HCWs found only 21.3 % of vaccinated HCWs undertook post-vaccination serological testing. This finding agrees with observations made by a previous study that suggested that uptake of vaccination among 'at-risk' groups may be high but the assessment of seroprotection status may be suboptimal in the face of increasing risk of HBV acquisition [21] Similarly, in Africa, two studies from Nigeria and Tanzania found only 29 % and 33.6 % of vaccinated HCWs undertaking post-vaccination serological testing [22,23].

Assessment and documentation of immune status among HCWs are important as this could influence subsequent post-exposure management in cases of accidental exposure to contaminated blood and body fluids [24] When the response to the vaccine is unknown, the management of the HCW who is exposed to HBV is more complex. However, in most settings in developing and poor countries, testing services and for, that matter, Anti-HBs results may not be readily available to inform a timely decision to use Post Exposure Prophylaxis (PEP). This means that PEP use in such individuals may be delayed or completely compromised. Secondly, Hepatitis B Virus Immunoglobulin (HBIG) is not readily available for HCWs in resource-poor health settings. The HBIG is expensive, and unaffordable to most people including HCWs [25] Therefore, people who are exposed yet are seroprotected may end up receiving Hepatitis B Immunoglobulin (HBIG) unnecessarily if their Anti-HBs status is unknown. This may result in the mismanagement of scarce resources and may lead to financial hardship to the HCW or the facility depending on who is bearing the cost of the HBIG [25].

Given that, HCWs from the higher-level facility in this present study had better facility-level systems, structures, and programs in place that promote HCW adherence to HBV vaccination protocol, this study surprisingly found that working in a regional hospital was associated with lower odds of post-vaccination serological testing. This observation is contrary to reports from Poland where higher odds of post-vaccination serological testing were reported among Polish HCWs working at a higher-level facility [26] The plausible reason perhaps for this observation in this study could be a lack of awareness regarding the importance of post-vaccination serological testing among the respondents. HCW who failed to undertake the post-vaccination serological test could be one of the 5–10 % immunocompetent individuals (vaccinees) (as indicated by immunogenic studies) who may have failed to respond to the vaccine and therefore will remain unprotected and susceptible to HBV without even knowing. Additionally, Ghana as a developing country has gaps in country-level HBV control implementation strategies. This has translated to inadequate

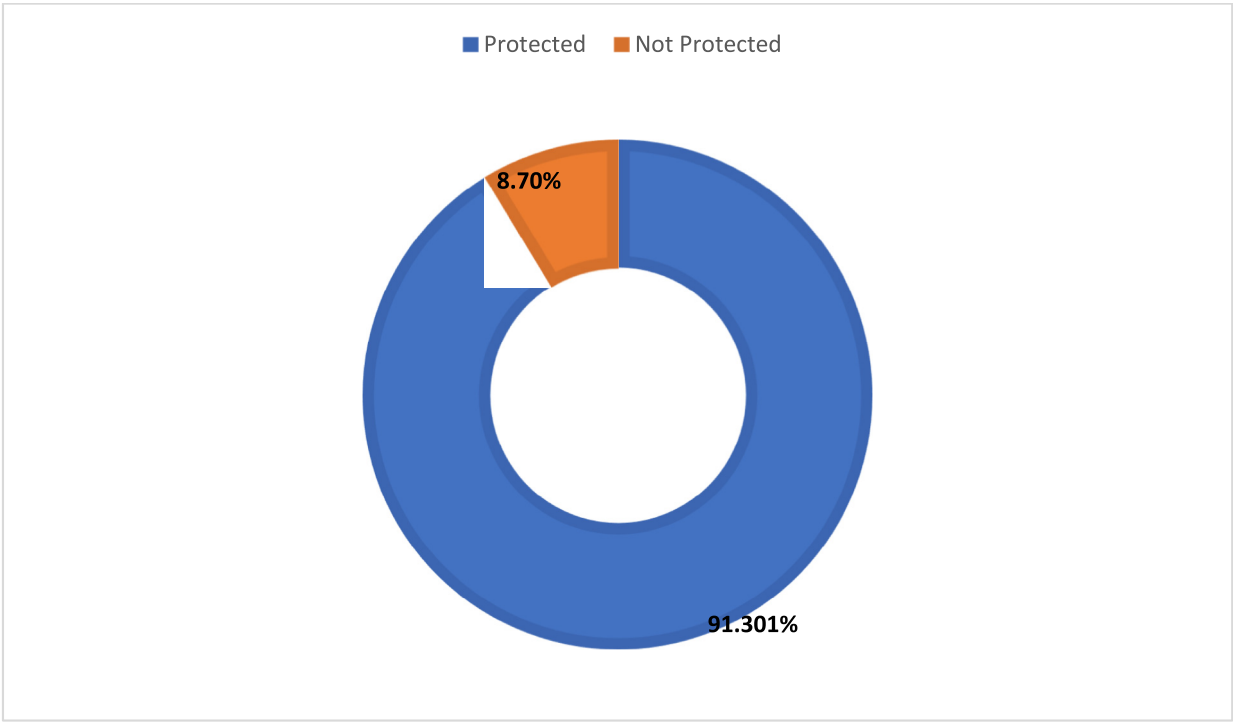


**Fig. 1.** Seroprotection rate among vaccinated HCWs.

**Table 4**
Distribution of Geometric Mean Titres (GMTs) of HCWs.

| Variables | GMT | 95 % CI |
|---|---|---|
| **Duration of Vaccination** | | |
| <5 years | 91.37 | 69.27–123.39 |
| ≥5years | 79.19 | 57.85–101.64 |
| **Age at vaccination** | | |
| <40 years | 81.69 | 65.53–102.32 |
| ≥40 years | 91.71 | 55.51–154.89 |
| **Vaccination Status** | | |
| Complete vaccination (3 doses) | 91.26 | 72.39–117.43 |
| Partial Vaccination (<3 doses) | 61.73 | 39.55–96.86 |
| **Sex** | | |
| Male | 73.84 | 48.81–110.47 |
| Female | 87.08 | 68.54–110.70 |
| **Smoking Status** | | |
| Smoker | 37.23 | 12.74–108.00 |
| Non-Smoker | 84.00 | 67.40–103.62 |
| **Booster** | | |
| Taken Booster | 134.21 | 81.01–221.21 |
| Not Taken Booster | 78.30 | 62.30–96.37 |
| **Chronic Condition*** | | |
| Condition present | 108.00 | 32.57–250.62 |
| Condition Absent | 81.55 | 66.18–100.59 |
| **BMI(Kg/m$^2$)** | | |
| <25 | 87.94 | 66.37–114.28 |
| ≥25 | 77.29 | 54.93–118.86 |

***History of any chronic disease such as hypertension, Diabetes etc that can influence Anti-HBs levels.

support for HCWs in terms of the prevention of occupational acquisition of HBV. For example, health facilities championed HBV screening and vaccination programs are not pursued vigorously. HBV vaccines and testing services are not available in the immediate environment of HCWs. HCWs have to bear the cost of these services in most cases. These system barriers could have contributed largely to the low post-vaccination testing rate being reported in this study [27].

*Anti-HBs levels, seroprotection against HBV, and associated factors*

Anti-HBs is the serological marker denoting immunity to HBV therefore its presence in global obligatory levels of > 10mIU/mL is an indication of seroprotection against HBV [10]. The overall frequency of seroprotection among the vaccinated HCWs was 91.3 % regardless of the time between vaccination and data collection for this study. This observation is comparable to what is known about the immunogenicity of the HBV vaccine that 90–95 % of immunocompetent individuals would develop Anti-HBs following primary HBV vaccination [10,11,28].

The high level of seroprotection reported in this current study, notwithstanding was accompanied by 8.7 % of vaccinated HCWs not possessing serological evidence of immunity against HBV per WHO and NCIR classification of antibody titer although there was evidence that they had received at least one dose of HBV vaccination.

This current study could have declared these individuals 18 (8.7 %) as true non-responders to the vaccine if there was clear evidence that they undertook post-vaccination serological testing 1–2 months post-vaccination. Since Anti-HBs testing performed years after vaccination is not adequate for evaluating the response to the vaccine because anti-HBs concentrations decline over time [29,30] Therefore, it is unclear from this study whether these individuals are true non-responders or the immunity waned off with time. This finding reemphasizes the need for HCWs to undertake post-vaccination serological testing to know their seroprotection status following the primary series of HBV vaccination.

Even though studies have reported that the absence of seroprotection in vaccinated individuals is associated with vaccination at age > 40 years [31], this study did not identify any association between age at vaccination and seroprotection against HBV. This is consistent with findings from a Sri Lankan study which also found no association between age at vaccination and seroprotection [30] It is worth noting that the average age of participants in

this present study was 34.55 years which is below the age of 40 years.

It is not surprising that this present study found no statistically significant difference between HCWs who were vaccinated < 5 years and > 5 years in terms of seroprotection against HBV. Among HCWs elsewhere, two studies were done in Sri Lanka and Italy reported no significant association between seroprotection and duration of vaccination and therefore concluded that the use of routine booster doses of HBV vaccine did not seem necessary to maintain long-term protection in immunocompetent individuals including HCWs [32,33]. The basis for their argument was that they found no indication that the duration of vaccination influenced the maintenance of seroprotection. The observation from our study favours the hypothesis that booster doses are not necessary for HCWs who were vaccinated as adults and have seroconverted following primary HBV vaccination. Contrary to the findings of this study, a study involving Ghanaian children under five years observed that duration of vaccination could influence seroprotection against HBV, and hence recommended the use of booster doses among Ghanaian children 5 years after receipt of childhood immunizations against HBV [34].

Clinical trials conducted in healthy adults suggest that seroprotection and for that matter, anti-HBs levels > 10mIU/mL could be influenced by dosage and schedule of HBV vaccination [35], and that, seroprotection increases progressively from 35 % with the first dose to 90 % following the receipt of the third dose [10], hence the basis for the 0, 1, 6 schedule that has been widely approved [36,37] Our study showed that not all the study participants adhered to the recommended 3 doses and 0, 1, 6 schedule of vaccine administration. This could have contributed to the absence of seroprotection observed in the 8.7 % of the participants. Nevertheless, this study recognized the fact that 93 % of HCWs who had adequate Anti-HBs levels (seroprotected) suffer continuous exposure to HBV in the workplace, and for that matter, the high Anti-HBs levels are a result of a natural response to the continuous exposure to HBV and not necessarily having followed the recommended 3 doses and 0, 1, 6 HBV vaccination schedule.

In Ghana, no official institution regulates HCWs' vaccination programs. HBV vaccines are largely supplied by private individuals who also procure the vaccines from varied international vaccine producers. The HBV vaccine supply chain is not regulated compared to vaccines for childhood immunizations which are strictly regulated under the Expanded Program of Immunization (EPI) program. All these system factors could affect the immunogenicity of HBV vaccines.

## Conclusions

The post-vaccination serological testing practice was suboptimal among the HCWs. Working in a regional hospital and having a high-risk perception of HBV were negatively associated with post-vaccination serological testing. Nevertheless, the seroprotection rate was high in the population with higher GMT recorded in those who adhered to the 3-dose vaccination regimen, took a booster dose, and had a BMI of less than 25 kg/m$^2$. The evidence available in this present study could not tell whether there was an absence of seroconversions following the primary vaccination series or whether the antibody levels waned with time in the 8.7 % vaccinated HCWs with Anti-HBs below 10mlU/mL. This indicates that post-serological vaccination testing 1–2 months after receipt of the HBV vaccine in adults who are at risk of HBV infection is an important strategy in identifying true non-responders to the HBV vaccine.

## Data availability

Data will be made available on request.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Ethics statement

Ethical approval for the conduct of this study was obtained from the Institutional Review Board of the Noguchi Memorial Institute for Medical Research, University of Ghana (Study number: 005/17-18). Permission was also obtained from all the facility heads. Written informed consent was obtained from each study participant after the nature, purpose, and procedures of the study were thoroughly explained to them. This study did not receive funding from any institution or organization.

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