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Incidence of dynamic seroconversion in subjects received the first dose of the SARS-COV-2 vaccine (AstraZeneca, Moderna and Pfizer) in Kinshasa, Democratic Republic of Congo: *prospective cohort study*

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Abstract

Background Mass vaccination efforts worldwide have reduced the incidence of COVID-19, but despite this reduction, seroconversion studies in sub-Saharan Africa are limited. The aim of this study is to assess the incidence of seroconversion in subjects who received the first dose of SARS-COV-2 vaccine (AstraZeneca, Moderna and Pfizer) in Kinshasa.

Methods This was a prospective study recruiting 918 subjects vaccinated at the Cliniques Universitaires de Kinshasa between 19 April and 14 August 2021. Sociodemographic, haematological, biochemical and serological data were collected. Cox proportional hazards were used to identify predictors of seroconversion with a threshold of $p < 0.05$.

Results Of the 918 vaccinated individuals, 69.3% were men with a mean age of 47.4 ± 16.0 years. The incidence of seroconversion at last follow-up was 3.00 per 100 P-D. Patients receiving Pfizer (aRR: 3.19; 95% CI: 2.62–3.88) and Modern (aRR: 1.91; 95% CI: 1.60–2.29) vaccines, men (aRR: 2.03; 95% CI: 1.89–3.20), those with comorbidities (aRR: 2.38; 95% CI: 1.89–3.21); subjects with normal creatinine (aRR: 2.08; 95% CI: 1.88–3.32) and normal ALT (aRR: 3.04; 95% CI: 1.89–4.22) were the factors independently predicting seroconversion.

Conclusion The vaccines used had conferred significant immunity on subjects upon receipt of the first dose. This immunity appears to be greater when using the mRNA vaccine than when using the inactivated vaccine.

Keywords Seroconversion, IgG, COVID-19 vaccine, Democratic Republic of Congo

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Introduction

Coronavirus 2019 (COVID-19) has posed an unprecedented challenge to public health worldwide. As of December 31, 2023, more than 773 million cases of COVID-19 have been reported to the World Health Organization (WHO), with more than 7 million deaths due to COVID-19 [1–3].

To halt the spread of SARS-CoV-2, global mass vaccination efforts have been launched, with 13.6 billion doses of vaccine administered by December 31, 2023, saving tens of millions of lives worldwide and dramatically altering the course of the pandemic [4, 5]. Controlled clinical trials and real-life clinical studies have provided clear evidence of the efficacy of COVID-19 vaccines [6]. In clinical trials, the BNT162b2 mRNA vaccine developed by Pfizer/BioNTech showed 95.0% efficacy (95% CI: 90.3–97.6%) in preventing symptomatic COVID-19 with onset seven days or more after the second dose [7, 8]. Moderna's mRNA-127 vaccine was 94.1% (95% CI: 89.3–96.8%) effective in preventing symptomatic infection with onset at least 14 days after the second dose [9]. When the prevalence of COVID-19 increased, only about 50% of the population was fully vaccinated, with an even smaller fraction fully vaccinated worldwide [10]. In addition, there have been reports of reduced vaccine efficacy against emerging variants and local increases in COVID-19 cases despite mass vaccination, raising questions about the potential and necessity of booster doses [11]. Vaccination rates in the Democratic Republic of Congo (DRC) are low compared with expectations, due to the reluctance of a large proportion of the population to take the vaccine [12]. During vaccination three vaccines were increasingly used (AstraZeneca, Moderna and Pfizer) to protect all social strata against the severe form of SARS-COV-2. These vaccines have been shown to be more effective in seroconversion after administration of doses according to the literature [6–8], but in the DRC, studies showing this efficacy are so far rare. The aim of this study is to assess the incidence of seroconversion in subjects who received the first dose of SARS-COV-2 vaccine (AstraZeneca, Moderna and Pfizer) in Kinshasa.

Methods

Study design

This was a prospective cohort conducted at the Cliniques Universitaires de Kinshasa during the period from April 19 to August 14, 2021. This cohort consisted of three arms (A, B and C) to evaluate the serological, biochemical and hematological parameters in pre-dose 1 and 2 of AstraZeneca, Moderna and Pfizer vaccines. Sampling was exhaustive and of convenience. Sample size was 500 participants per arm.

Enrolment was based on written informed consent, with freedom to withdraw without coercion. Inclusion criteria were: no symptoms suggestive of COVID-19, residence in Kinshasa and age 18 or over, having received a dose of one of the selected vaccines. Criteria for non-inclusion included IgG-positive subjects prior to vaccine administration, and patients with COVID-19 hospitalized in COVID-19 treatment centers. A total of 1,500 subjects were randomized according to the 3 vaccines used in the vaccination.

Hematological, serological and biochemical data collection and analysis

Data were collected using a form prepared by our research group. The parameters of interest were selected and collected by means of questioning for sex, age and profession; and by haematological, serological and biochemical analysis in the laboratory of the University Clinics of Kinshasa.

Assessment of anti-COVID-19 immunoglobulin G (IgG) and anti-COVID-19 immunoglobulin M titres

Collection of 2 blood samples in tubes of approx. 5. 0 ml each, one with Vacu Lab K3EDTA anticoagulant (purple cap) (Belliver Industrial Estate Belliver Way Roborough, Plymouth, PL6 7BP, UK) for haematological analysis in the hours following collection, the other dry without anticoagulant (red cap) for subsequent serological and biochemical analyses prior to administration of the first dose (Pre-dose 1) and repeat the same operation on day 28 prior to administration of the 2nd dose for the 2 RNA vaccines and on day 56 prior to administration of the 2nd dose (Pre-dose 2) for AstraZeneca.

Blood samples collected at the vaccination site were transported to the analysis laboratory in a suitable cooler, then stored at −20°C or −80°C. As soon as the blood was introduced into the Vacu Lab K3EDTA tube (Belliver Industrial Estate Belliver Way Roborough, Plymouth, PL6 7BP, UK), the tube was held vertically and then gently inverted 8–10 times to allow mixing with the anticoagulant, a sine qua non for hematological analysis. The blood collected in the dry tube was centrifuged at 3,000 rpm for 5 min to obtain serum. This serum was aliquoted and stored at −20°C or −80°C at the Laboratoire Central of des University Clinics of Kinshasa until the day of analysis. Blood samples collected at both times were processed within 24 h of collection for haematological analysis, and later for serological-biochemical analysis at the Laboratoire of de the Department of Clinical Biology at University Clinics of Kinshasa.

IgG levels were assessed by high-throughput multiplex quantitative suspension technology against a panel of SARS-CoV-2 antigens: the full-length spike protein (S)

and receptor-binding domain (RBD) produced at IDIBAP (both fused with C-terminal 6xHis and StrepTag purification sequences and purified from the supernatant of lentivirally translated CHO-S cells grown in a fed-batch system) [13]. Serology, biochemistry and haematology were performed on Mindray CL1200i and Automate d'hématologie BC5150, respectively.

Vaccination data

In this study, the vaccines used were Pfizer BioNTech-Pfizer, AstraZeneca (ChAdOx1 nCoV-19, Oxford-AstraZeneca) and Moderna (ARNm-1273, Moderna, Cambridge, USA). These vaccines were offered on a voluntary basis to all individuals. We used vaccination records to identify the number of doses, date of administration and trade names of the vaccines for each study participant. We defined participants as partially vaccinated when they had received one dose out of two scheduled in the vaccination schedule.

Operational definitions

Seroconversion was defined as a change from negative IgG serological status to positive serological status after administration of [14] vaccine doses. A positive serological state is defined as any individual with an IgG level ≥ 10.0 Cut off index (COI) [15]. The abnormal creatinine level was defined in the subject having a serum creatinine level greater than 1.47 mg/dL.

Statistical analysis

Data were compiled in an Excel 2010 (Microsoft 365) database designed for COVID-19 vaccination surveillance at Cliniques Universitaires de Kinshasa. The results were presented as means (± standard deviation), medians (IQR) and proportions (%) according to the cases. Paired t-tests (Wilcoxon test) were performed to compare IgG in pre-dose 1 and 2. One-way ANOVA t-test supplemented by Bonforoni post hoc test, Kruskall Wallis H and Pearson Chi-square or Fischer exact test were performed, respectively, to compare means, medians and proportions in the two groups. Probabilities of seroconversion were described using Kaplan–Meier curves, and comparisons of these groups were made using the Log-rank test. The Cox regression test was used to identify factors associated with seroconversion, and the Adjusted Relative Risk (aRR) and their 95% confidence intervals (CI: 95%) were calculated to estimate the beneficial effect of the vaccine in the population. The threshold for statistical significance was set at $p < 0.05$. Statistics were performed using IBM SPSS (SPSS Inc., 233 South Wacker Drive, 11th Floor, Chicago, IL 60606–6412) for Windows version 24.

Ethical considerations

The research protocol had obtained the favorable opinion of the Ethics Committee of the School of Public Health of the University of Kinshasa at No. ESP / CE / 078 / 2023. The data was collected and analyzed anonymously with rigor respecting the standards of confidentiality to be used only for the drafting of the work. The study was carried out in accordance with the Declaration of Helsinki (see supplementary data).

Results

A total of 1,500 subjects were randomized into 3 arms. arm A received AstraZeneca vaccine ($n = 500$ subjects), arm B received Moderna vaccine ($n = 500$) and arm C received Pfizer vaccine ($n = 500$). According to the study inclusion criteria, each subject had to have a negative IgG level, and any individual with a positive IgG level was excluded from the study. A total of 582 subjects were excluded after initial screening (Fig. 1).

The mean age of the study population was 47.4 ± 16.0 years with a significantly higher mean age in subjects who received the AstraZeneca vaccine ($p < 0.001$). Males predominated in the vaccinated sample (69.3%, sex ratio of 2 M/1F), 26.1% had comorbidity, the difference in sex distribution and comorbidity according to the vaccine was not the same ($p < 0.05$). The mean and median values of creatinine, urea, ALT, AST, T bil, Hb and Hct were significantly different compared to the 3 vaccines ($p < 0.05$) (Table 1).

In predose 1, all hematological and biochemical parameters had abnormal values in excess of 10%, with the exception of creatinine and basophil, where only 3.2% and 1.7% of the population respectively had abnormal values (Table 2).

Evolution of IgG in the study population

The median of IgG had significantly increased after administration of the first dose of the vaccine ($p < 0.001$). This increase was greater in subjects who had received the Moderna and Pfizer vaccines (Fig. 2).

The observed increase in IgG tended to be significantly greater in subjects who received Moderna and Pfizer ($p < 0.001$). In addition, the other parameters analyzed (age, sex, occupation and comorbidity) did not show statistically significant differences ($p > 0.05$) (Table 3).

Seroconversion

Seroconversion rate

During follow-up, 889 of 918 subjects (96.8) had increased IgG within normal limits. All patients who received Pfizer had dynamic seroconversion compared

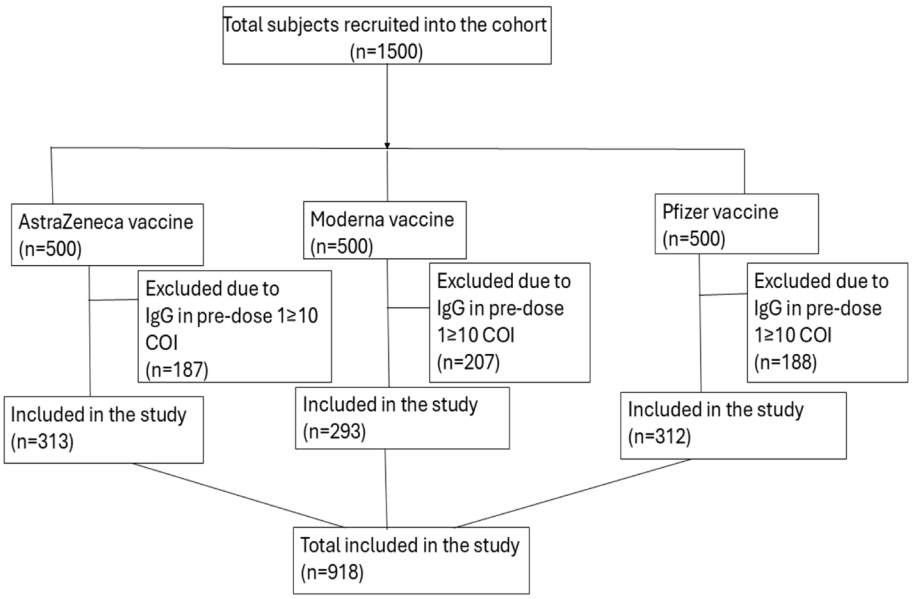

Fig. 1 Study flow-chart showing the recruitment subject into the cohort. COI: Cut off index, IgG: immunoglobulin G. Arm A: subjects who received AstraZeneca vaccine, Arm B: Subjects who received Moderna vaccine and Arm C: Subjects who received Pfizer vaccine

to 95.2% in those who received AstraZeneca and Moderna, respectively (Fig. 3).

This table indicates that seroconversion was significantly higher in men ($p=0.004$) and in subjects with comorbidity ($p=0.005$). It was also observed that the median values of urea ($p=0.009$) and total bilirubin ($p<0.001$) were significantly higher in subjects with seroconversion (Table 4).

Overall seroconversion

The median duration between the first vaccine and the tenth vaccine (follow-up time) was 30.0 (IQR: 29.2–30.8) days with the extremes varying between 25 and 59 days. The incidence of seroconversion was 0.427 per 100 P-D at day 25, 0.824 per 100 P-D at day 30, 1.168 per 100 P-D at day 35, 1.452 per 100 P-D at day 40, 1.714 per 100 P-D at day 45, 1.937 per 100 P-D at day 50 and 3.00 per 100 P-D at day 59 of follow-up, respectively (Fig. 4).

This Kaplan–Meier curve estimates for dynamic seroconversion incidence in subjects vaccinated with the 3 vaccines note that the probability of seroconversion was significantly higher in subjects who received Pfizer compared to those who received Moderna and AstraZeneca (Logrank, $p<0.001$) (Fig. 5).

Predictive factors of seroconversion in pre-dose 2 in the cohort

The general characteristics of the subjects were comparable with each other on the incidence of seroconversion, with the exception of the incidence of the Pfizer vaccine which was significantly higher than that of Moderna and AstraZeneca; the incidence of men which was significantly higher than that of women; the incidence of subjects with comorbidity was also higher compared to those without comorbidities; Subjects with a normal creatinine level; normal ALT level, normal total bilirubin level; normal Hb level and normal monocyte level had a higher incidence of seroconversion compared to those with pathological levels ($p<0.05$).

After multivariate adjustment for these variables, patients who received Pfizer (aRR: 3.19 95% CI: 2.62–3.88) and Moderna (aRR: 1.91 95% CI: 1.60–2.29) vaccines; male subjects (aRR: 2.03 95% CI: 1.89–3.20); those with comorbidity (aRR: 2.38 95% CI: 1.89–3.21); subjects with normal creatinine (aRR: 2.08 95% CI: 1.88–3.32) and normal ALT (aRR: 3.04 95% CI: 1.89–4.22) were the factors independently predicting seroconversion in the study population (Table 5).

Discussion

This study assessed the incidence of dynamic seroconversion and the factors predictive of this incidence in subjects who received the first dose of SARS-COV-2 vaccine (AstraZeneca, Moderna and Pfizer) in Kinshasa. We know that the aim of any vaccine is to train the immune system to recognize a pathogen, without actually confronting the organism with the real pathogen. In this way, infection can be prevented, or at the very least, symptoms can be considerably reduced, avoiding severe forms of the disease. In this study,

Table 1 General characteristics of the study population

Variable	Overall (*n* = 918)	AstraZeneca (*n* = 313)	Moderna (*n* = 293)	Pfizer (*n* = 312)	*p*
Age	47.4 ± 16.0	51.4 ± 15.5	45.5 ± 15.4	45.5 ± 16.1	**< 0.001**
18–39 years	338(36.8)	80(25.6)	123(42.0)	135(43.3)	
40–59 years	329(35.8)	116(37.1)	105(35.8)	108(34.6)	
≥ 60 years	251(27.3)	117(37.4)	65(22.2)	69(22.1)	
Sex					**0.001**
Male	636(69.3)	240(76.7)	185(63.1)	211(67.6)	
Female	282(30.7)	73(23.3)	108(36.9)	101(32.4)	
Occupation					0.690
Healthcare	261(28.4)	93(29.7)	78(26.6)	90(28.8)	
Non-healthcare	657(71.6)	220(70.3)	215(73.4)	222(71.2)	
Comorbidity	240(26.1)	123(39.3)	59(20.1)	58(18.6)	**< 0.001**
Creatinine (mg/dl)	0.94(0.90–1.00)	1.04(0.94–1.20)	0.90(0.86–0.98)	0.91(0.82–1.03)	**0.001**
Urea (mg/dl)	24.2(23.5–24.7)	22.9(22.1–23.7)	22.5(21.1–23.4)	26.8(26.0–27.4)	**< 0.001**
ALT (UI/L)	19.9(18.8–20.8)	16.1(14.9–17.2)	18.5(17.8–19.6)	29.7(27.1–32.5)	**< 0.001**
AST (UI/L)	28.2(27.1–29.4)	24.1(23.0–25.9)	26.0(24.9–27.0)	32.4(31.8–34.8)	**< 0.001**
ALP (UI/L)	57.4(55.4–58.9)	57.3(53.8–59.2)	57.1(53.3–59.6)	58.4(55.4–61.9)	0.111
T BILIRUBIN (mmol/L)	1.7(1.3–3.9)	0.7(0.7–0.9)	0.8(0.7–1.0)	12.7(12.2–13.5)	**< 0.001**
RBCC (Cell/mm^3)	4.69(4.63–4.75)	4.58(4.49–4.67)	4.82(4.75–4.92)	4.69(4.61–4.78)	0.410
Hemoglobin (g/L)	11.4(13.4–13.6)	13.1(12.9–13.4)	13.7(13.6–14.0)	13.6(13.4–13.9)	**0.038**
Hematocrit (%)	41.7 ± 9.4	40.2 ± 6.8	43.1 ± 14.0	41.8 ± 5.3	**0.001**
Plateletcount (Cell/mm^3)	220.8 ± 75.4	223.8 ± 80.3	218.4 ± 66.4	219.9 ± 78.3	0.658
WBC (Cell/mm^3)	5.70(5.58–5.57)	5.72(5.50–5.94)	5.73(5.46–6.06)	5.68(5.56–5.87)	0.214
Neutrophils (Cell/mm^3)	2.49(2.41–2.55)	2.54(2.41–2.63)	2.53(2.34–2.73)	2.42(2.33–2.51)	0.722
Lymphocytes (Cell/mm^3)	2.37(2.30–2.45)	2.39(2.30–2.50)	2.32(2.26–2.46)	2.38(2.27–2.48)	0.549
Monocytes (Cell/mm^3)	0.43(0.42–0.45)	0.42(0.39–0.44)	0.43(0.41–0.45)	0.46(0.43–0.48)	0.582
Eosinophils (Cell/mm^3)	0.20(0.18–0.21)	0.18(0.16–0.22)	0.19(0.15–0.20)	0.22(0.20–0.24)	0.235
Basophils (Cell/mm^3)	0.01(0.01–0.02)	0.01(0.01–0.02)	0.01(0.01–0.02)	0.01(0.01–0.02)	0.280

subjects with a negative IgG level prior to receiving a dose of one of three vaccines (AstraZeneca, Moderna and Pfizer) were included and summoned on day 30 or 59 to receive the second dose. The median time elapsed between the first and second dose was 30.0 (IQR:29.2–30.8) days. The IgG level collected post-dose 1 was compared with the level collected pre-dose 1. The evolution of this level was used to estimate the seroconversion rate.

After data analysis, the results on the incidence of seroconversion showed that in subjects having received doses of these three vaccines, the overall incidence of seroconversion was 3.00 per 100 P-D. Thus, IgG levels rose significantly between two doses, demonstrating the impact of vaccination and the acquisition of defenses against SARS-COV-2 in the population.

The chances of protection against SARS-CoV-2 infection after primary vaccination were higher when the subject received the Pfizer and Moderna vaccines compared with the AstraZeneca vaccine. However, irrespective of the vaccine used, the probability of protection persisted from day 25 to day 59 of follow-up without dropping.

These results are in line with those reported in the ZOE COVID study which showed that mRNA vaccines (Pfizer and Moderna) offered better efficacy than Oxford-AstraZaneca's COVID-19 vaccine in the UK population [16].

Consistent with this finding, previous studies around the world have reported that IgG levels increase 2–6 weeks after vaccination with Pfizer and AstraZeneca vaccines, and levels begin to decline as early as 3–24 weeks [17–19]. Numerous studies have shown that peak antibody responses elicited by mRNA vaccines decline rapidly within 6–8 months of vaccination [15–17]. However, there are also reports of longer durability (> 6 months) of SARS-CoV-2-specific IgG antibodies in subjects after vaccination with [20, 21] mRNA vaccines. In a multi-country longitudinal cohort study of around 13,000 US adults receiving mRNA vaccines, IgG persisted for up to around 9 months, with only 2.4% of the

Table 2 Description of hematological and biochemical characteristics of the pre-dose 1 study population

Variable	*n*	Normal *n* (%)	Abnormal *n* (%)
Creatinine (mg/dl)	918	889 (96.8)	26 (3.2)
Urea (mg/dl)	918	821 (89.4)	97 (10.6)
ALT (UI/L)	918	773 (84.2)	145 (15.5)
AST (UI/L)	918	762 (83.0)	156 (17.0)
ALP (UI/L)	918	786 (85.6)	132 (14.4)
T BILIRUBIN (mmol/L)	918	572 (62.3)	346 (37.7)
RBCC (Cell/mm^3)	918	739 (80.5)	179 (19.5)
Hemoglobin (g/L)	918	578 (63.0)	340 (37.0)
Hematocrit (%)	918	658 (71.7)	260 (28.3)
Plateletcount (Cell/mm^3)	918	793 (86.4)	125 (13.6)
WBC (Cell/mm^3)	918	809 (88.1)	109 (11.9)
Neutrophils (Cell/mm^3)	918	754 (82.1)	164 (17.9)
Lymphocytes (Cell/mm^3)	918	810 (88.2)	108 (11.8)
Monocytes (Cell/mm^3)	918	692 (75.4)	226 (24.6)
Eosinophils (Cell/mm^3)	918	670 (73.0)	248 (27.0)
Basophils (Cell/mm^3)	918	902 (98.3)	16 (1.7)

study population showing seroreversion [22]. Compared with the low conversion rate of AstraZeneca's vaccine; studies around the world have shown that inactivated whole-virus vaccines produce a lower initial antibody response than mRNA vaccines [23, 24]. Another reason could explain this low incidence of seroconversion of AstraZeneca vaccine is the high age of the population that received this vaccine, in general, the elderly, especially those over 65, often have a diminished immune response due to immunosenescence, the presence of several comorbidities [22].

The Cox model in multivariate analysis with the time-dependent variable allowed us to take into account the variables significantly associated with the incidence of seroconversion in univariate analysis. After adjustment, patients who had received Pfizer (aRR: 3.19; 95%CI: 2.62–3.88) and moderna (aRR: 1.91; 95%CI: 1.60–2.29) vaccines; male subjects (aRR: 2.03; 95%CI: 1.89–3.20); those with a comorbidity (aRR: 2.38; 95%CI: 1.89–3.21); subjects with normal creatinine (aRR: 2.08; 95%CI: 1.88–3.32) and normal ALT (aRR: 3.04; I95%CI: 1.89–4.22) emerged as predictive factors for seroconversion after the first dose of SARS-COV-2 vaccine.

The Pfizer and Moderna vaccines differ from the AstraZeneca vaccine in their ability to induce seroconversion in that the Pfizer and Moderna vaccines are based on the messenger RNA technique, whereas the AstraZeneca vaccine is based on a non-replicating viral vector. And the two techniques differ in the way the decoy is created. Where the AstraZeneca vaccine introduces an altered version of the infectious agent, the Pfizer and Moderna vaccines consist of having the human body directly produce a fragment of the pathogenic agent, thus developing immunity faster than that induced by AstraZeneca [25–28]. Men were twice more likely to seroconvert than women. This seroconversion is higher in men than in women, because physiologically, men and women have a hormonal difference that can influence their immune system. Our study is contradictory to several studies in the literature that report higher seroconversion in women than in men [29, 30]. The difference between these studies could be due to the nature of the study carried out, our study being carried out only in non-sick people could make a difference, behaviors and hormonal variation between the population included in this study are not

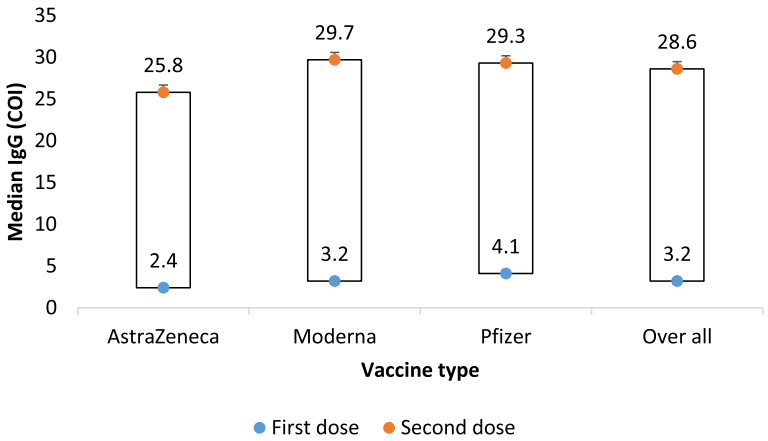

Fig. 2 Evolution of IgG in the study population and according to the vaccine used

Table 3 Evolution of IgG in the predefined subgroups during follow-up

Subgroup	*Pre-dose 1*	*Pre-dose 2*	*Δ* (95%CI)	*p*
Vaccine				
AstraZeneca	2.40(1.90–2.80)	25.80(23.90–27.90)	22.40(21.30–24.39)	**< 0.001**
Moderna	3.20(2.70–3.80)	29.70(27.50–31.50)	26.60(24.53–27.60)	
Pfizer	4.10(3.65–4.80)	29.30(27.90–31.20)	25.70(23.85–27.00)	
Age				
18–39 years	3.15(2.60–3.75)	28.45(26.70–29.70)	24.50(22.30–26.40)	0.901
40–59 years	3.05(2.38–3.60)	29.10(26.70–30.63)	25.10(23.15–26.60)	
≥ 60 years	3.60(2.85–3.60)	28.40(25.58–29.80)	24.70(22.10–26.30)	
Sex				
Male	3.20(2.80–3.60)	28.50(27.25–29.60)	24.73(23.3–25.98)	0.543
Female	3.20(2.40–3.75)	28.88(26.65–29.90)	24.80(21.85–26.25)	
Occupation				
Pro-health	3.10(2.50–3.75)	27.95(25.75–30.10)	22.85(21.40–25.30)	0.453
Non-pro-health	3.20(2.80–3.70)	28.80(27.30–29.60)	25.20(23.90–26.40)	
Comorbidity				
Yes	3.25(2.80–3.77)	28.33(23.90–29.65)	24.75(23.30–26.10)	0.599
No	3.15(2.70–3.65)	28.90(27.3–29.75)	24.55(21.81–27.20)	

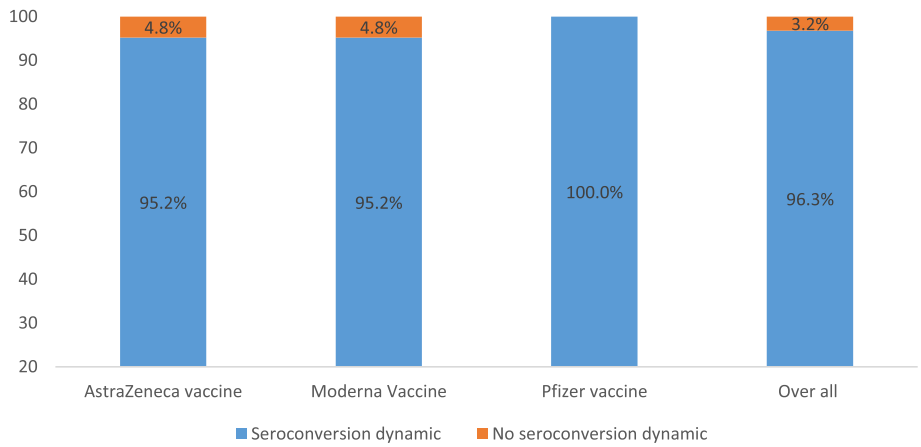

Fig. 3 Seroconversion rates by vaccine received

comparable with those of the population of other studies. The mechanism by which men develop more seroconversion than women is not clearly elucidated, but there are hypotheses and theories that point to processes occurring within the immune and endocrine systems. In addition, men have higher levels of cytokines, which are proteins displayed as part of the body's innate immune response [31, 32]. It also emerges in this study that subjects with comorbidity were more efficient at developing seroconversion than those without comorbidity. Studies from around the world show that adaptive immunity is strongly activated in people with comorbidity; however, the T-cell and antibody response may differ, which could explain the low frequency of seroconversion over time observed in people without comorbidity [33, 34]. With regard to creatinine and normal ALT as predictors of seroconversion, the literature shows that in cases of renal or hepatic insufficiency, there is a reduction in cytokines and T lymphocytes, resulting in low efficacy in seroconversion [35].

The limitations of this study are related to the fact of not including hospitalized patients to compare the response of healthy subjects to sick ones. Another limitation of this study is the difference in follow-up times for the different vaccines, which could lead to a potential bias in the seroconversion of different individuals.

Table 4 Sociodemographic characteristics by seroconversion

Variable	No seroconversion	Seroconversion	*p*
Age	45.2 ± 16.5%	47.4 ± 15.9	0.590
18–39 years	13(44.8)	325(36.6)	
40–59 years	8(27.6)	321(36.1)	
≥ 60 years	8(27.6)	243(27.3)	
Sex			**0.004**
Male	16(55.2)	620(69.7)	
Female	13(44.8)	269(30.3)	
Occupation			0.446
Healthcare	9(31.0)	252(28.3)	
Non-healthcare	20(69.0)	637(71.7)	
Comorbidity			**0.005**
No	25(86.2)	653(73.5)	
Yes	4(13.8)	236(26.5)	
Creatinine (mg/dl)	0.90(0.80–1.58)	0.94(0.90–1.00)	0.598
Urea (mg/dl)	21.8(18.2–23.0)	24.3(23.8–24.9)	**0.009**
ALT	16.4(14.9–20.5)	19.9(18.9–21.2)	0.208
AST	24.3(19.0–27.4)	28.6(27.3–29.7)	0.250
ALP	57.4(49.9–62.0)	57.5(55.4–58.9)	0.457
T BILIRUBIN	0.6(0.4–0.7)	1.9(1.4–5.5)	**< 0.001**
RBCC	4.48(4.3–4.79)	4.7(4.63–4.74)	0.788
Hemoglobin	13.2(12.6–13.8)	13.5(13.4–13.7)	0.500
Hematocrit	40.6 ± 4.7	41.7 ± 9.6	0.511
Platelet	224.7 ± 57.3	220.6 ± 75.9	0.776
WBC	6.15(5.41–7.00)	5.69(5.57–5.84)	0.691
Neutrophils	2.93(2.39–3.39)	2.48(2.40–2.54)	0.708
Lymphocytes	2.34(2.02–2.93)	2.37(2.30–2.45)	0.685
Monocytes	0.44(0.38–0.63)	0.43(0.42–0.45)	0.618
Eosinophils	0.21(0.11–0.37)	0.20(0.18–0.21)	0.356

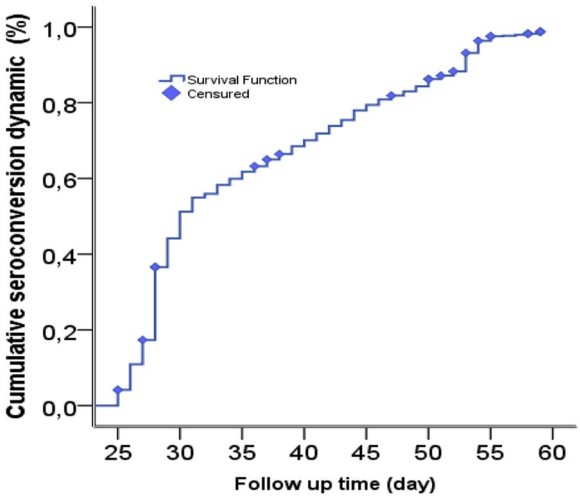

Fig. 4 Cumulative incidence of seroconversion in the study population

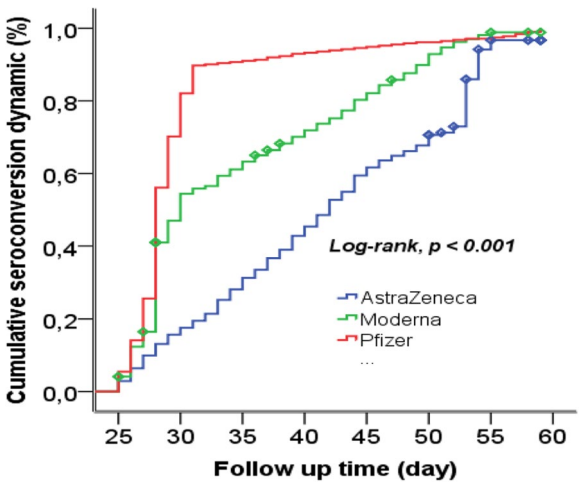

Fig. 5 Cumulative incidence of seroconversion according to the vaccine received

Table 5 Predictive factors for seroconversion at pre-dose 2 in the follow-up cohort

Variable				Bivariate analysis	Multivariate analysis	
	N	Duration	Seroconversion /100 P-D (95%CI)	RR (95%CI)	aRRa (95%CI)	*p*
Overall	918	32528	3.0(1.4–4.6)	-	-	-
Vaccine type						
AstraZeneca	313	13090	7.3(3.1–11.5)	1		
Moderna	293	10070	9.5(4.5–14.4)	1.87(1.58–2.21)	1.91(1.60–2.29)	**< 0.001**
Pfizer	312	9368	10.7(5.6–15.8)	3.07(2.59–3.63)	3.19(2.62–3.88)	**< 0.001**
Age						
18–39 years	338	11633	8.3(4.0–12.6)	1		
40–59 years	329	11739	8.3(3.9–12.7)	1.07(0.91–1.27)	-	-
≥ 60 years	251	9156	10.6(5.0–16.2)	1.15(0.97–1.36)	-	-
Sex						
Female	636	22844	4.3(2.0–6.6)	1	1	
Male	282	9684	9.9(4.8–15.0)	2.12(1.73–3.29)	2.03(1.89–3.20)	**0.043**
Occupation						
Non pro-health	657	23517	4.1(1.9–6.3)	1		
Pro-health	261	9011	10.7(5.1–16.3)	1.10(0.95–1.27)	-	-
Comorbidity						
No	678	23639	4.1(2.0–6.2)	1	1	
Yes	240	8889	11.1(5.2–17.0)	2.59(1.91–3.35)	2.38(1.89–3.21)	**0.033**
Creatinine						
Abnormal	779	27707	3.5(1.7–5.3)	1	1	
Normal	139	4821	19.4(9.1–29.7)	2.04(1.87–3.26)	2.08(1.88–3.32)	**0.038**
ALT						
Abnormal	145	4756	3.5(0.7–7.7)	1	1	
Normal	773	27772	20.9(16.4–25.4)	3.37(2.14–4.64)	3.04(1.89–4.22)	**< 0.001**
Bil T						
Abnormal	572	21014	4.5(2.1–6.9)	1	1	
Normal	346	11514	8.6(4.3–12.9)	2.68(1.94–3.57)	1.49(0.87–2.27)	0.622
Hb						
Abnormal	340	12396	4.8(1.5–8.1)	1	1	
Normal	578	20132	7.9(4.7–11.1)	1.51(1.16–1.99)	1.02(0.88–1.17)	0.829
Monocyte						
Abnormal	226	8084	4.0(0.3–7.7)	1	1	
Normal	692	24444	11.8(8.2–15.4)	1.92(1.73–2.79)	1.03(0.84–1.24)	0.689

Conclusions

This prospective cohort study compared seroconversion induced by AstraZeneca, Moderna, and Pfizer COVID-19 vaccines. The study found that the incidence of seroconversion was higher in participants vaccinated with Pfizer and Moderna compared to AstraZeneca. In addition to age, sex, and comorbidities, normal creatinine and ALT levels emerged as predictors of seroconversion. These findings emphasize the importance of tailoring vaccination campaigns to available vaccines, population characteristics, and health conditions to maximize vaccine effectiveness.

Abbreviations

COVID-19	Coronavirus disease 2019
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
DRC	Democratic Republic of Congo
IQR	Interquartile range
RR	Relative risk
aRR	Adjusted relative risk
95% CI	95% Confidence interval
ALT	Alanine aminotransferase
AST	Aspartate aminotransferase
Hb	Haemoglobin
Hct	Haematocrit
ALP	Alkaline phosphatase
RBCC	Red blood cell
WBC	White blood cell
COI	Cut off index

Supplementary Information

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Additional file 1. Data collection sheet

Additional file 2. Informed consent of participants

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Authors' contributions
EKM and ANN conceptualized the research topic, BMS, JMM, JRRM, MZN, BIB, MML and JMNK drafted the protocol with input from EKM and ANN for the methods, prepared the submission for institutional review board approval, supervised the data collection and drafted the manuscript. ANN provided guidance for the statistical analysis. GK, HNS, BLM, GLM, BB, JCK, DKM, EMM, DSM, MNN GNI, FTN, CNL and SMA provided content oversight for the manuscript. All authors read and approved the final manuscript.

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Data availability
The datasets during the current study are available from the corresponding author upon reasonable request on nkodilaaliocha@gmail.com.

Declarations

Ethics approval and consent to participate
Written informed consent was obtained from all the participants and/or their legally acceptable representatives. Non-literate participants were accompanied by a literate peer of their choice. Participants under 18 years of age were accompanied by their parent or guardian. Their informed assents and consent from parent or guardian were requested and signed before the enrolment to the study. Participants had the right to provide consent or not and to withdraw from the study at any time during the interview, without having to provide a reason. The risks incurred by the participants in this study were supposed to be minimal, given that the vaccines used had already undergone clinical trials and been approved by scientists.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Changing epidemiology of COVID-19 : potential future impact on vaccines andvaccination strategies. Expert Rev Vaccines 2024;23(1):510-522. https://doi.org/10.1080/14760584.
2. Watson OJ, Barnsley G, Toor J, et al. Global impact of the first year ofCOVID-19 vaccination : a mathematical modelling study. Lancet Infect-Dis. 2022;22(9):1293–302.
3. Yau K, Chan CT, Kento TA, Yidi J, Atiquzzaman M, Mullin SI, et al. Différences d'immunogénicité des vaccins anti SRAS-CoV-2 mRNA-1273 (Moderna) et BNT162b2 (Pfizer-BioNTech) chez les patients dialysés. CMAJ. 2022;28(194):E297-305. https://doi.org/10.1503/cmaj.211881-f.
4. Puranik A, Lenehan PJ, Silvert E, et al. Comparison of two highly effective mRNA vaccines for COVID-19 during periods of Alpha and Delta variant prevalence. medRxiv 2021. https://doi.org/10.1101/2021.08.06.21261707.
5. Ritchie H, Ortiz-Ospina E, Beltekian D, et al. Coronavirus Pandemic (COVID-19). Our World in Data. Published online March 5, 2020. https://ourworldindata.org/coronavirus. Accessed 12 Sep 2024.
6. Pawlowski C, Lenehan P, Puranik A, Agarwal V, Venkatakrishnan AJ, Niesen MJM, et al. FDA-authorized mRNA COVID-19 vaccines are effective per real-world evidence synthesized across a multi-state health system. Med. 2021;2(8):979-992.e8. https://doi.org/10.1016/j.medj.2021.06.007.
7. Thomas SJ, Perez JL, Lockhart SP, Hariharan S, Kitchin N, Bailey R, et al. Efficacy and safety of the BNT162b2 mRNA COVID-19 vaccine in participants with a history of cancer: subgroup analysis of a global phase 3 randomized clinical trial. Vaccine. 2022;40(10):1483–92.
8. Sadoff J, Le Gars M, Shukarev G, Heerwegh D, Truyers C, de Groot AM, et al. Interim results of a phase 1–2a trial of Ad26.COV2.S Covid-19 vaccine. N Engl J Med. 2021;384(19):1824–35.
9. Baden LR, El Sahly HM, Essink B, Kotloff K, Frey S, Novak R, et al. Efficacy and Safety of the mRNA-1273 SARS-CoV-2 Vaccine. N Engl J Med. 2021;384(5):403–16. https://doi.org/10.1056/NEJMoa2035389.
10. COVID-19 Cumulative Infection Collaborators. Estimating global, regional, and national daily and cumulative infections with SARS-CoV-2 through Nov 14,. a statistical analysis. Lancet. 2021;2022(399):2351–80.
11. Monin-Aldama L, Laing AG, Muñoz-Ruiz M, McKenzie DR, del Molino del Barrio I, Alaguthurai T, et al. Interim results of the safety and immune-efficacy of 1 versus 2 doses of COVID-19 vaccine BNT162b2 for cancer patients in the context of the UK vaccine priority guidelines. Oncology. 2021. Disponible sur : http://medrxiv.org/lookup/doi/10.1101/2021.03.17.21253131.
12. Barrall AL, Hoff NA, Nkamba DM, Musene K, Ida N, Anna Bratcher A, et al. Hesitancy to receive the novel coronavirus vaccine and potential influences on vaccination among a cohort of healthcare workers in the Democratic Republic of the Congo. Vaccine. 2022;40(34):4998–5009.
13. Ortega N, Ribes M, Vidal M, Rubio R, Aguilar R, Williams S, et al. Seven-month kinetics of SARS-CoV-2 antibodies and role of pre-existing antibodies to human coronaviruses. Nat Commun. 2021;12:4740.
14. Nash D, Srivastava A, Shen Y, Penrose K, Kulkarni SG, Zimba R et al. Seroincidence of SARS-CoV-2 infection prior to and during the rollout of vaccines in a community-based prospective cohort of U.S. adults. Sci Rep. 2024;14:644. https://doi.org/10.1038/s41598-023-51029-9.
15. Yoon SW, Widyasari K, Jang J, Lee S, Kang T, Kim S. Kinetics of adaptive immune responses after administering mRNA-Based COVID-19 vaccination in individuals with and without prior SARS-CoV-2 infections. BMC Infect Dis. 2023;23:732. https://doi.org/10.1186/s12879-023-08728-5.

16. Ryan FJ, Norton TS, McCafferty C, Blake SJ, Stevens NE, James J. A systems immunology study comparing innate and adaptive immune responses in adults to COVID-19 mRNA and adenovirus vectored vaccines. Cell Rep Med. 2023;4(3):100971. https://doi.org/10.1016/j.xcrm.2023.100971.
17. Addo IY, Dadzie FA, Okeke SR, Boadi C, Boadu EF. Duration of immunity following full vaccination against SARSCoV-2: a systematic review. Arch Public Health 2022;80:200. https://doi.org/10.1186/s13690-022-00935-x.
18. Dadras O, SeyedAlinaghi S, Karimi A, Shojaei A, Amiri A, Mahdiabadi S. COVID-19 vaccines' protection over time and the need for booster doses; a systematic review. Arch Acad Emergency Med. 2022;10(1):e53. https://doi.org/10.22037/aaem.v10i1.1582.
19. Shrotri M, Navaratnam A, Nguyen V, Byrne T, Geismar C, Fragaszy E et al. Spike-antibody waning after second dose of BNT162b2 or ChAdOx1. Lancet. 2021;398:385–387. https://doi.org/10.1016/S0140-6736(21)01642-1.
20. Choi JH, Kim YR, Heo ST, Oh H, Kim M, Lee HR et al. Healthcare workers in south korea maintain a SARS-CoV-2 antibody response 6 months after receiving a second dose of the BNT162b2 mRNA vaccine. Front Immunol. 2022;13:827306. https://doi.org/10.3389/fimmu.2022.827306.
21. Hosseinian S, Powers K, Vasudev M, Palma AM, Rafael de Assis, Jain A et al. Persistence of SARS-CoV-2 antibodies in vaccinated health care workers analyzed by coronavirus antigen microarray. Front Immunol. 2022;13:817345. https://doi.org/10.3389/fimmu.2022.817345.
22. Berry AA, Tjaden AH, Renteria J, Klabanoff DF, Hinkelman AN, Gibbs AM. Persistence of antibody responses to COVID-19 vaccines among participants in the COVID-19 community research partnership. Vaccine X. 2023;15:100371. https://doi.org/10.1016/j.jvacx.
23. Chen Y, Yin S, Tong X, Tao Y, Ni J, Pan J et al. Dynamic SARS-CoV-2-specific B-cell and T-cell responses following immunization with an inactivated COVID-19 vaccine. Clin Microbiol Infect. 2022;28:410–418. https://doi.org/10.1016/j.cmi.2021.10.006.
24. Kwok SL, Cheng SM, Leung JN, Leung K, Lee CK, Peiris JSM et al. Waning antibody levels after COVID-19 vaccination with mRNA Comirnaty and inactivated CoronaVac vaccines in blood donors, Hong Kong, April 2020 to October 2021. Euro Surveill. 2022;27(2):2101197. https://doi.org/10.2807/1560-7917.ES.2022.27.2.2101197.
25. Dobano C, Jimenez A, Rubio R, Alonso S, Ramirez-Morros A, Vidal M, et al. Spike-based COVID-19 immunization increases antibodies to nucleocapsid antigen. Transl Res. 2022;240:26–32.
26. Munro APS, Janani L, Cornelius V, Aley PK, Babbage G, Baxter D, et al. Safety and immunogenicity of seven COVID-19 vaccines as a third dose (booster) following two doses of ChAdOx1 nCov-19 or BNT162b2 in the UK (COV-BOOST): a blinded, multicentre, randomised, controlled, phase 2 trial. Lancet. 2021;398:2258–76.
27. Tsang JS, Dobaño C, VanDamme P, Moncunill G, Marchant A, Othman RB, et al. Improving vaccine-induced immunity: can baseline predict outcome? Trends Immunol. 2020;41:457–65.
28. Koerber N, Priller A, Yazici S, Bauer T, Cheng C-C, Mijočević H, et al. Dynamics of spike-and nucleocapsid specific immunity during long-term follow-up and vaccination of SARS-CoV-2 convalescents. Nat Commun. 2022;13:153.
29. Notarte KI, Ver AT, Velasco JV, Pastrana A, Catahay JA, Salvagno GL, et al. Effects of age, sex, serostatus, and underlying comorbidities on humoral response post-SARS-CoV-2 Pfizer-BioNTech mRNA vaccination: a systematic review. Crit Rev Clin Lab Sci. 2022;59(6):373–90.
30. Ward H, Whitaker M, Flower B, Tang SN, Atchison C, Darzi A, et al. Population antibody responses following COVID-19 vaccination in 212,102 individuals. Nat Commun. 2022;13:907.
31. Zintel S, Flock C, Arbogast AL, Forster A, Wagner CV, Sieverding M. Gender differences in the intention to get vaccinated against COVID-19: a systematic review and meta-analysis. J Public Health. 2022;1–10. https://doi.org/10.1007/s10389-021-01677-w.
32. Nassiri-Ansari T, Atuhebwe P, Sika Ayisi A, Goulding S, Johri M, Allotey P, et al. Shifting gender barriers in immunisation in the COVID-19 pandemic response and beyond. The Lancet. 2022;400(10345):24.
33. Naruse H, Ito H, Izawa H, Sarai M, Ishii J, Sakaguchi E, et al. Immunogenicity of BNT162b2 mRNA COVID-19 vaccine in patients with cardiovascular disease. J Clin Med. 2021;10:5498.
34. Lee SW, Moon J-Y, Lee S-K, Lee H, Moon S, Chung SJ, et al. Anti-SARSCoV-2 Spike protein RBD antibody levels after receiving a second dose of ChAdOx1 nCov-19 (AZD1222) vaccine in healthcare workers: lack of association with age, sex, obesity, and adverse reactions. Front Immunol. 2021;12:779212.
35. Milne G, Hames T, Scotton C, Gent N, Johnsen A, Anderson RM, et al. Does infection with or vaccination against SARS-CoV-2 lead to lasting immunity? Lancet Respir Med. 2021;9:1450–66.

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