Prevalence, incidence and longevity of antibodies against SARS-CoV-2 among primary healthcare providers in Belgium: a prospective cohort study with 12 months of follow-up

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ABSTRACT

Objectives To estimate the prevalence, incidence and longevity of antibodies against SARS-CoV-2 among primary healthcare providers (PHCPs).

Design Prospective cohort study with 12 months of follow-up.

Setting Primary care in Belgium.

Participants Any general practitioner (GP) working in primary care in Belgium and any other PHCP from the same GP practice who physically manages (examines, tests, treats) patients were eligible. A convenience sample of 3648 eligible PHCPs from 2001 GP practices registered for this study (3044 and 604 to start in December 2020 and January 2021, respectively). 3390 PHCPs (92.9%) participated in their first testing time point (2820 and 565, respectively) and 2557 PHCPs (70.1%) in the last testing time point (December 2021).

Interventions Participants were asked to perform a rapid serological test targeting IgM and IgG against the receptor binding domain of SARS-CoV-2 and to complete an online questionnaire at each of maximum eight testing time points.

Primary and secondary outcome measures The prevalence, incidence and longevity of antibodies against SARS-CoV-2 both after natural infection and after vaccination.

Results Among all participants, 67% were women and 77% GPs. Median age was 43 years. The seroprevalence in December 2020 (before vaccination availability) was 15.1% (95% CI 13.5% to 16.6%), increased to 84.2% (95% CI 82.9% to 85.5%) in March 2021 (after vaccination availability) and reached 93.9% (95% CI 92.9% to 94.9%) in December 2021 (during booster vaccination availability and fourth (delta variant dominant) COVID-19 wave). Among not (yet) vaccinated participants the first monthly incidence of antibodies against SARS-CoV-2 was estimated to be 2.91% (95% CI 1.80% to 4.01%). The longevity of antibodies is higher in PHCPs with self-reported COVID-19 infection.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Prospective cohort study with good response during 12 months of follow-up.
⇒ Rapid serological test (RST) measuring the presence of antibodies against SARS-CoV-2 after infection and vaccination, without distinction.
⇒ Timely and comparable estimates of the prevalence of antibodies against SARS-CoV-2 among primary healthcare providers.
⇒ Large sample size permitting precise estimates at national and regional level.
⇒ Convenience sample, missing data points and potentially lower actual RST accuracy limiting the study validity.

Conclusions This study confirms that occupational health measures provided sufficient protection when managing patients. High uptake of vaccination resulted in high seroprevalence of SARS-CoV-2 antibodies in PHCPs in Belgium. Longevity of antibodies was supported by booster vaccination and virus circulation.

Trial registration number NCT04779424.

INTRODUCTION

As of 8 June 2022, SARS-CoV-2 has caused over 530 million infections worldwide (4,164,698 in Belgium) and caused over 6.3 million deaths from coronavirus disease (COVID-19) worldwide (over 31,000 in Belgium).1 COVID-19 can be a lethal respiratory tract infection (RTI), but often presents with mild symptoms or remains asymptomatic.

Since the start of the COVID-19 pandemic, SARS-CoV-2 seroprevalence estimates have provided essential information about population exposure to infection and helped predict...
the early course of the epidemic.\textsuperscript{2,3} When setting up this study, seroprevalence studies in Iceland\textsuperscript{4} and Spain\textsuperscript{5} showed different levels of population antibody positivity, lasting up to at least 4 months in Iceland. In addition, early cohort studies have suggested waning of antibody levels in individuals is associated with, for example, illness severity, age and comorbidities.\textsuperscript{6-8} Meanwhile, other seroprevalence studies showed antibody positivity lasting up to 9 months.\textsuperscript{9,10} Additionally, after vaccination, longevity of antibody positivity could differ depending on the type of vaccination and vaccination regime.\textsuperscript{11,12} For Belgium, Sciences (the Belgian national institute of public health, www.sciensano.be) performs national seroprevalence studies of SARS-CoV-2 antibodies in the general population\textsuperscript{13} and several relevant populations including school-aged children and school staff,\textsuperscript{14} hospital staff,\textsuperscript{15} nursing homes residents and their staff.\textsuperscript{16,17} These results are publicly available and regularly updated on an online dashboard.\textsuperscript{18}

This article focuses on the seroprevalence among primary healthcare providers (PHCPs).\textsuperscript{19} PHCPs manage the vast majority of patient contacts, including COVID-19 patients, and therefore, play an essential role in the efficient organisation of healthcare.\textsuperscript{20,21} Among the PHCPs, general practitioners (GPs) in particular, act as gatekeepers to the next levels of care. Therefore, preserving the capacity of GPs, together with that of their coworkers, throughout the COVID-19 epidemic is essential.\textsuperscript{22} In Belgium, this is particularly concerning given that the GP workforce consists of mainly older adults and is therefore at higher risk for COVID-19-related morbidity and mortality.\textsuperscript{23} In Italy, GPs represented up to 38% of the physicians who died from COVID-19 early in the epidemic.\textsuperscript{24}

Before the start of this study (December 2020), data on how many PHCPs in Belgium had been infected by SARS-CoV-2 was not readily available,\textsuperscript{25} and effective vaccines for PHCPs were not anticipated to be available in the near future.

During the COVID-19 crisis rapid serological tests (RSTs) have been developed to identify the presence of antibodies to SARS-CoV-2. Compared with laboratory tests, a valid easy-to-use RST could speed up the availability of the test results for both the participants and the national health authorities.\textsuperscript{25} Furthermore, by using RSTs in this study, PHCPs got the opportunity to become more familiar with this type of technology.

Sciences has validated five RSTs using finger prick blood, identifying one test with appropriate sensitivity (92.9%) and specificity (96.3%) for use in seroprevalence studies.\textsuperscript{26} We used this RST for this study. It targets IgM and IgG against the receptor binding domain (RBD) of SARS-CoV-2 and could therefore also provide valuable information in a vaccinated population.

Given the availability of vaccines for PHCPs soon after the start of this study, we now report on the prevalence of antibodies against SARS-CoV-2 among a cohort of PHCPs in Belgium followed-up for 12 months, and on the incidence and longevity of those antibodies both after natural infection and after vaccination.

\section*{Methods}
This study was a prospective cohort study. Data collection was performed according to the publicly available protocol, providing more details on the study methods.\textsuperscript{19}

\section*{Study population}
Any GP working in Belgium (including those in professional training) working in primary care and any PHCP from the same GP practice in a clinical role (clinical examination, testing or treating patients) were eligible if they were able to comply with the study protocol and provided informed consent to participate in the study. Staff hired on a temporary (interim) basis were excluded as follow-up over time would be compromised. Administrative staff or technical staff without any prolonged (longer than 15 min) face-to-face contact with patients and PHCPs who were not professionally active during the inclusion period were not eligible either.

PHCPs were recruited between 15 November 2020 and 15 January 2021. GPs working in clinical practice in Belgium were invited to register online for participation in this national epidemiological study and were asked to invite the other PHCPs in their practice to do the same. We emphasised that PHCPs who had already been diagnosed with COVID-19 were also eligible. Information about the study was disseminated to GPs and PHCPs via professional organisations (Domus Medica and Collège de Médecine Générale), university networks across the country and through professional media channels. We checked our convenience sample for representativeness in terms of geographic and demographic characteristics.\textsuperscript{23}

To assess the geographical representativeness of our sample, we compared the distribution by region and by province of active GPs in Belgium in 2020 (source www.ima-aim.be) with the distribution of participating GPs.

\section*{Data collection}
On inclusion in the study, participants were assigned a unique study code by the researchers and received testing material at their workplace through regular mail. At their first testing time point they received an invitation by email inviting them to autocollect a capillary blood sample and analyse it using the RST (OrientGene) and to complete a baseline questionnaire available in Dutch, French and English via a personalised link through a secured online platform hosted by Sciences (Limesurvey). The invitation email included links to both written and video instructions to perform the RST on yourself and on someone else.

The baseline questionnaire at the first testing time point asked for written informed consent and for information about the result of the RST, basic sociodemographic data (age, gender, composition...
of household—e.g., presence of school-aged children in the house), professional data (practice patient size), health status (pre-existing health conditions, regular medication use, presence of symptoms since the start of the epidemic, previous positive test results for COVID-19), professional exposure (contact with confirmed cases, use of infection prevention and control measures and the availability of personal protective equipment (PPE)) and practice organisational aspects (delayed care for non-urgent conditions) (see online supplemental file 1). A follow-up questionnaire was sent for each of the subsequent testing time points. In addition to the RST result, it collected information on the health status, including the presence of symptoms, COVID-19 testing and results, vaccination status (date of vaccination, type of vaccine, number of doses, presence of side effects) and professional exposure (contact with confirmed cases, use of infection prevention and control measures) (see online supplemental file 2).

Follow-up
The study lasted 12 months, from December 2020 to December 2021, and included eight testing time points. Compared with the study protocol, the testing time point at the fifth month was skipped because of limited additional epidemiological value based on progressive insights from studies with similar protocols conducted by Sciensano that longer interval than 4 weeks between testing time point are suitable.

Sample size
This study aimed to include 5000 PHCPs with a ratio of 4 GPs to 1 other PHCP. The sample size considerations regarding the different objectives of the proposed study are described in more detail in the study protocol. For the objectives reported here, even half the sample size aimed for would allow for precise estimates of the prevalence, incidence and longevity of antibodies against SARS-CoV-2.

Data analysis
In the analysis, we included all PHCPs who provided informed consent and reported RST results at the testing time points. If in the questionnaire the entry for the date the RST was performed was missing or implausible, the date of completing the questionnaire was used instead. All analyses were conducted using R V.4.1.0 (www.R-project.org).

Prevalence
To assess the prevalence of antibodies against SARS-CoV-2, we calculated among the valid RST the proportion (95% CI) of positive RST for IgG and/or IgM, and for IgG and IgM separately (crude seroprevalences). In addition, we calculated the proportion (95% CI) of PHCPs that self-reported testing positive for SARS-CoV-2 (no test specified, so this includes both virus or antibody detection) since the outbreak of the COVID-19 pandemic (February 2020) and the proportion (95% CI) of PHCPs with any positive test, either a positive study RST or testing positive since the outbreak at their first testing time point. For any subsequent testing time points, we asked the participants to specify if self-reported testing positive for SARS-CoV-2 since the previous testing time point concerned virus or antibody detection.

We also estimated the prevalence of antibodies against SARS-CoV-2 (IgG and/or IgM) taking into account clustering of PHCPs within their practice as well as the distribution of PHCPs across the districts in Belgium (adjusted seroprevalences). Weights were calculated based on the differences between the actual distribution of GPs across districts and the distribution of participating GPs with RST results across districts. These weights were then extrapolated to all other PHCPs. The estimates are based on generalised estimating equations assuming a binomial distribution for the RST result, an identity link function and an independent working correlation matrix. In a similar way, we also estimated the adjusted prevalence of self-reported positive testing for SARS-CoV-2 since the start of the COVID-19 pandemic and the adjusted prevalence of these two tests results combined, either a positive study RST or testing positive since the outbreak for the first two testing time points.

Incidence
To assess the incidence of antibodies against SARS-CoV-2 (IgG and/or IgM) among participants not (yet) vaccinated, first we produced a Kaplan-Meier plot including participants providing a valid negative RST result at their first testing time point and not testing positive before, considering a positive RST during follow-up as event and censoring on vaccination or lost to follow-up. Second, we assessed the monthly incidence of antibodies against SARS-CoV-2 due to natural infection in those not yet vaccinated, by analysing the data collected during the testing time points after the first testing time point. We included participants providing valid RST results both at the testing time point assessed and the preceding testing time point. We excluded participants reporting a positive RST at the preceding time point or already vaccinated with a first dose. In addition, we corrected the estimates for clustering of participants in general practices.

To assess the incidence of antibodies against SARS-CoV-2 (IgG and/or IgM) due to vaccination in those vaccinated, we calculated the proportion of participants with antibodies against SARS-CoV-2 less than 7 days and 7 days or more after the first, the second and the third dose of a COVID-19 vaccine, respectively, and stratified by self-reported history of COVID-19 infection.

Longevity
To assess the longevity of antibodies against SARS-CoV-2 (IgG and/or IgM) among participants not (yet) vaccinated, first we produced a Kaplan-Meier plot including...
participants without a self-reported history of COVID-19 infection before their first testing time point that provided a valid positive RST results before receiving their first dose of a COVID-19 vaccine, considering a negative RST result during follow-up as event (= negative RST result followed by another negative RST result or missing data) and censoring on vaccination or lost to follow-up (midpoint and interval censoring). Second, we included participants not yet vaccinated, that provided a valid RST result at the testing time point assessed and a positive RST result at the previous testing time point. We estimated the proportion with a negative test result at the testing time point assessed and a positive RST result before receiving their first vaccine (2639 (81.8%) BNT162b2, 144 (4.5%) mRNA-1273 and 2 (0.1%) mRNA-1273 followed by BNT162b2). A total of 3415 (93.6%) PHCPs participated in at least one testing time point, 2909 (79.7%) participated in 6 and 2141 (58.7%) participated in all 8 testing time points. The number of PHCPs participating per testing time point is presented in online supplemental table S2.

To assess the longevity of antibodies against SARS-CoV-2 (IgG and/or IgM) after COVID-19 vaccination, we produced Kaplan-Meier plots by self-reported history of COVID-19 infection, including participants that provided a valid positive RST results at least 7 days after receiving their second dose of a COVID-19 vaccine, considering a negative RST result during follow-up as event (= negative RST result followed by another negative RST result or missing data) and censoring on booster vaccination (date of third dose) or lost to follow-up (midpoint and interval censoring).

Vaccination
The start of the vaccination of PHCPs during the study follow-up provided the opportunity to monitor its progress.

Patient and public involvement
Neither patients (or PHCPs in this specific study) nor the public were involved in the design of the study. During the study, the information shown in figure 1 was shared with the participants and the general population through the publicly available website of the Belgian health authorities (Sciensano) shortly after each testing—time point both for Belgium and its three regions, Brussels, Flanders and Wallonia.

RESULTS
Description of the study cohort
In total, 3648 eligible PHCPs from 2001 practices registered and were asked to provide informed consent of whom 3044 and 604 PHCPs were sent personal study materials to be able to collect data for their first testing time point starting on 24 December 2020 and 25 January 2021, respectively. A total of 3390 PHCPs participated in their first testing time point by completing the baseline questionnaire, among which 2597 GPs, 386 GPs in training and 407 other PHCPs (table 1).

Our sampling procedure resulted in the participation of a reasonably geographically representative sample of GPs at the level of the provinces (online supplemental table S1). At the level of the regions, there is about 8% overrepresentation of GPs in Flanders and corresponding underrepresentation of GPs in Wallonia.

Participant characteristics
Table 1 presents the characteristics of the 3390 PHCPs who participated in their first (baseline) testing time point. These PHCPs, mainly GPs, were relatively young, more often female and working more often in (large) group practices than in solo or duo practices. Table 2 shows how many testing time points PHCPs participated. A total of 3415 (93.6%) PHCPs participated in at least one testing time point, 2909 (79.7%) participated in 6 and 2141 (58.7%) participated in all 8 testing time points. The number of PHCPs participating per testing time point is presented in online supplemental table S2. While the response rate gradually decreased, still 2557 (77.2% of invited PHCPs) participated in the last testing time point.

Vaccination status
Overall, 3227 participants received a full primary vaccination. 2783 participants received two doses of an mRNA vaccine (2639 (81.8%) BNT162b2, 144 (4.5%) mRNA-1273 and 2 (0.1%) mRNA-1273 followed by BNT162b2). A total of 437 participants (13.5%) received two doses of
ChAdOx1-S and 5 (0.2%) participants one dose of Ad26.COV2.S.

At the final testing time point, 2211 of the participants had received a booster vaccination. A total of 1879 (85.0%) participants received a booster with BNT162b2 and 267 (12.1%) with mRNA-1273. 1 participant received ChAdOx1-S and another participant Ad26.COV2.S as third dose.

Prevalence

The prevalence of antibodies against SARS-CoV-2 among PHCPs in Belgium from December 2020 to December 2021 is shown in figure 1 and online supplemental table S3. Online supplemental table S3 also gives the number of eligible PHCPs, that is, those testing between the start and end date of the respective testing time point, as well as the regional differences. At the first testing time point (T1), among 2680 eligible PHCPs, 2629 provided valid test results, of which 366 (15.1%) were positive. Afterwards, the prevalence increased substantially up to 84.2% at T4, mainly due to vaccination (see online supplemental table S4). Six months later (T7) the prevalence was substantially lower (70.2%), while during the fourth COVID-19 wave (delta variant dominant) and after booster vaccination became available it increased again to 93.9% (T8).

Incidence

Among not (yet) vaccinated participants

The incidence of antibodies against SARS-CoV-2 among PHCPs in Belgium among participants that provided a valid negative RST result at their first testing time point, did not self-report a COVID-19 infection before and were not (yet) vaccinated is shown in figure 2. For the second testing time point (T2), the monthly incidence of antibodies against SARS-CoV-2 was estimated to be 2.91% (95% CI 1.80% to 4.01%; n=895), that is, the proportion of PHCPs not yet vaccinated at T2 and testing negative at T1, that tested positive at T2. For T3 and T4, it was estimated to be 3.93% (95% CI 2.04% to 5.82%; n=407) and 4.04% (95% CI 0.16% to 7.92%; n=99), respectively. As of T4, the sample size of eligible participants was too small for precise estimates.

Among vaccinated participants

The incidence of antibodies against SARS-CoV-2 among vaccinated PHCPs in Belgium according to their self-reported history of COVID-19 infection is shown in figure 3. The incidence of antibodies is higher in PHCPs with self-reported COVID-19 infection compared with PHCPs with no self-reported COVID-19 infection both less than 7 days and 7 days or more after the first and the
second dose, less than 7 days after the third dose, but not 7 days or more after the third dose.

Longevity

Among not (yet) vaccinated participants

The longevity of antibodies against SARS-CoV-2 among not (yet) vaccinated PHPCs in Belgium is shown in figure 4.

For T2 the positivity of antibodies against SARS-CoV-2 was estimated to be 18.54% (95% CI 12.84% to 24.24%; n=178) lower compared with T1, that is, the proportion of participants not yet vaccinated at T1 and testing positive at T1 for SARS-CoV-2 antibodies that tested negative for SARS-CoV-2 antibodies at T2. For T3 and T4 it was estimated to be 19.42% (95% CI 11.76% to 27.07%; n=103) and 12.50% (95% CI 0.99% to 24.01%; n=32), respectively. As of T4, the sample size of eligible participants was too small for precise estimates.

Among participants after full primary vaccination

The longevity of antibodies against SARS-CoV-2 among PHCPs in Belgium who have received their full primary vaccination, but not yet a booster vaccination, according to their self-reported history of COVID-19 infection is shown in figure 5. The longevity of antibodies is higher in PHCPs with self-reported COVID-19 infection compared with PHCPs without self-reported COVID-19 infection after full primary vaccination.
DISCUSSION

The prevalence of antibodies against SARS-CoV-2 among PHCPs in Belgium was 15.1% in December 2020, that is, before vaccination had started and right after the second Belgian COVID-19 wave that peaked beginning November 2020, and reached 93.9% in December 2021, i.e. after booster vaccination had started and after the fourth Belgian COVID-19 wave in which the Delta variant was dominant and that peaked beginning December 2021. The incidence of antibodies against SARS-CoV-2 within 2 weeks after COVID-19 vaccination with a first dose was higher in PHCPs with a self-reported history of COVID-19 infection compared with those with no self-reported history of infection. The longevity of antibodies was more pronounced in the former group of PHCPs than in those with no self-reported history of infection.

The seroprevalence in PHCPs before vaccination (15.1%) appeared to be lower than that among the general population (18.7%) and that among hospital healthcare workers (19.7%) in Belgium, in December 2020, when the Belgian healthcare system was approaching the end of the second COVID-19 wave. It should, however, be noted that the accuracy of the RST might be lower when used by many different PHCPs instead of a few trained and experienced staff (for validation) and lower than analysis of a serum sample in the lab (for seroprevalence in the general population and in hospital healthcare workers) using conventional lab-tests. This is suggested by the lower seroprevalence in this study for PHCPs in Flanders compared with that in an earlier prospective cohort study using dried blood spots (DBS) analysed in the lab. Not finding a higher seroprevalence among PHCPs, generally concerned about being at high risk of COVID-19 infections, compared with the general population might be explained by the availability and proper usage of PPE.

Most PHCPs in our study (94.49%) received a first vaccine dose in the period January–March explaining the increase in seroprevalence to 84.1% in April 2021. The monthly incidence of antibodies due to natural infection in those not yet vaccinated in the same time period was estimated to be around 4% in this study. Natural course of infection could, therefore, not have caused a similar rise in seroprevalence.

A gradual decrease in the prevalence of anti-SARS-CoV-2 antibodies among PHCPs was observed in the following months leading to a seroprevalence of 70.2% in September 2021. In December 2021 most PHCPs (86.5% of participants in testing time point 8) already received a booster dose of a COVID-19 vaccine resulting in a seroprevalence of 93.1% at the end of the study. Although also the circulation of Delta variant corona virus might have impacted this increase in seroprevalence. For example, the seroprevalence in mainly unvaccinated schoolchildren in Belgium almost doubled during the fourth COVID-19 wave (26.6% at 8 October 2021 vs 50.9% at 15 December 2021). Natural infection before vaccination did seem to limit waning of antibodies after vaccination. These findings strengthen the accruing evidence base for reduced protection from infection in vaccinated, but previously uninfected participants. The clinical significance is however still to be determined. A reduction in vaccine effectiveness against infection could increase transmission to and the risk of infection among high-risk persons who consult PHCPs, some of whom may have progression to severe disease. In addition, recent studies have shown that vaccination confers more durable protection against severe outcomes of hospitalisation and death than against mild symptomatic and asymptomatic infection.

At this point, studies suggest that a third or booster dose provides additional protection on top of simply reversing previous waning, but that the greatest protection from...
the worst clinical outcomes still remains heavily con-
centrated in the first two doses.\textsuperscript{32-36}

Although studies suggest prolonged protection, it
remains unclear to what extent the presence of antibodies
(against the RBD) is associated with protection against new
variants of the coronavirus.\textsuperscript{36,37} Neutrolising antibo-
dy titers measured in the laboratory remain the strongest
correlate of protection against symptomatic and severe
illness across multiple variants.\textsuperscript{38,39}

This large cohort study with 12 months follow-up
provided precise estimates of the prevalence and inci-
dence of antibodies against SARS-CoV-2 among PHCPs at
national and regional level. Another strength of this study
is the use of RSTs. This substantially improved the timeli-
ness of the test result availability and allowed the PHCPs
to immediately check their results, which was not the case
in our previous work that used DBS to assess the prev-
alence and incidence of antibodies against SARS-CoV-2
among PHCPs in Flanders.\textsuperscript{23} Consequently, the results
in PHCPs in Belgium could be compared much faster
to that of the general population and other population
groups, for example, healthcare workers in hospitals and
nursing homes.

In addition, the RST used in this study allowed us to
estimate the incidence and longevity of antibodies against
SARS-CoV-2 both after natural infection and after vacci-
nation. This, on the other hand, also limits seropreval-
ence studies like ours and others,\textsuperscript{16} using an RST not
able to distinguish antibodies after natural infection
(with new variants) from antibodies after vaccination,
to assess virus circulation once the target population is
highly vaccinated.

Lost to follow-up or missing data, reduced accuracy of
the RST in primary care and the use of a convenience
sample could also have limited the validity of the study
results. However, overall retention and response of
PHCPs in the study was good to excellent, we used the
best available RST to avoid under- and overestimation of
the presence of SARS-CoV-2 among PHCPs due to imper-
fect testing methods (imperfect sensitivity and speci-
ficity), and the estimates were corrected for clustering
and potential geographical misrepresentation of the
PHCPs. Still, the RST used is less accurate than the ELISA
and missing this reference test’s quantitative aspect.

Selection bias is possible, because the study started at
the end of the second COVID-19 wave: if all the most
vulnerable PHCPs had already been infected at the time
of the start of this study, then the incidence among the
remaining PHCPs may be lower (because better immune
system, more adherent to personal protection guidelines,
etc). Therefore, we explicitly asked for participation
regardless of previous SARS-CoV-2 testing and test results.

In conclusion, this national study confirms results from
an earlier study at regional level (Flanders only) that for
the PHCP's seroprevalence and incidence during the second
COVID-19 wave was similar to that of the general popu-
lation suggesting that the occupational health measures
implemented provided sufficient protection when
managing patients. A vaccination programme including
one booster increased the seroprevalence of antibodies
against SARS-CoV-2 leading to a seroprevalence of 93.9% in
December 2021. Between primary and booster vacci-
nation, longevity of antibodies was more pronounced in
PHCPs with a history of self-reported COVID-19 infect.
Therefore, continued monitoring of the seropreval-
ence in PHCPs after booster vaccination, with longer
time intervals, could be relevant, provided that the pres-
ence of antibodies is associated with protection.
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