Original Research

SARS-CoV-2 seroprevalence and determinants of infection in young adults: a population-based seroepidemiological study

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ABSTRACT

Objectives: Most SARS-CoV-2 seroprevalence studies have focussed on adults and high-risk populations, and little is known about young adults. The objective of the present study was to provide evidence on the SARS-CoV-2 seroprevalence among young adults in Germany and to explore determinants associated with seropositivity in general and, specifically, with previously undetected infections.
Study design: This was a population-based SARS-CoV-2 seroprevalence study.
Methods: In November 2020, a population-based study on SARS-CoV-2 seroprevalence in young adults (aged 18–30 years) was conducted in a large German city. Serum samples were obtained to analyse the SARS-CoV-2 antibody status using the Elecsys Anti-SARS-CoV-2 immunoassay. Descriptive statistics and odds ratios (ORs) of seropositivity and of previously undetected infections in relation to different determinants were calculated.
Results: Among 2186 participants, SARS-CoV-2 antibodies were detected in 72 individuals, equalling a test performance-adjusted seroprevalence of 3.1% (95% confidence interval [CI]: 2.4–4.0). Based on reported COVID-19 cases to the public health authority, a moderate underascertainment rate of 1.7 was calculated. Seropositivity was higher among individuals who sought COVID-19-related information from social media (OR: 1.83, 95% CI: 1.2–3.1), and undetected COVID-19 infections were more prevalent among men and those not adhering to social distancing.
Conclusions: The results show a substantial underascertainment of SARS-CoV-2 infections among young adults and indicate that seroprevalence is likely to be much higher than the reported COVID-19 prevalence based on confirmed COVID-19 cases in Germany. Preventive efforts should consider the heterogeneity of risk profiles among the young adult population.

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Introduction

In Germany, the new coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus type 2 (SARS-CoV-2), first appeared in January 2020. At the beginning of the pandemic, high incidence rates were primarily reported among the elderly population; however, the age distribution of those infected with COVID-19 began to shift when numbers started to increase significantly among the younger population in late summer 2020.[1–3] Since the start of the pandemic, there have been ongoing debates about COVID-19 susceptibility in young adults; however, empirical evidence remains scarce and often inconclusive.[4–6]

In this context, the use of seroprevalence studies, which assess the number of people in a population who test positive for a specific disease based on blood serum, can help to determine the number of infections at the population level and to identify the magnitude of undetected cases. Currently, however, most SARS-CoV-2 seroprevalence studies have focussed on the general population or on specific high-risk groups (e.g. hospital staff),[7,8] and only a few studies have considered young adults.[4] In some studies, the sample size was too small to enable age group–specific evaluations, and in

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the larger studies, young adults were frequently not considered as a separate group.[9–11] In studies that did evaluate young adults, only descriptive analyses were conducted;[8,12] for example, findings from Europe determined the seroprevalence for individual age groups and found that it was highest among 20- to 34-year-olds.[8,12] To the best of our knowledge, to date, more in-depth studies among young adults have not been carried out.

Many previous studies were conducted during the first pandemic wave, at a time when the COVID-19 incidence was relatively low among young people. From a public health perspective, data on SARS-CoV-2 seroprevalence among young adults are of great importance for several reasons, including (1) young adults are characterised by a high number of asymptomatic cases, which may contribute to the undetected transmissions of the disease;[13] (2) young adults are characterised by distinct determinants, including low-risk perception and high mobility;[13,14] and (3) although most young adults experience a mild disease course, there are increasing concerns of long-term adverse health effects[15] and identifying factors linked to infection risk (both detected and undetected) can help to understand SARS-CoV-2 transmission dynamics and consequently support the development of targeted prevention measures. The present study aims to provide evidence on SARS-CoV-2 seroprevalence among young adults in Germany in November 2020 (i.e. during the second pandemic wave in Germany) and to explore determinants associated with seropositivity in general and, specifically, with previously undetected infections.

Methods

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist for reporting cross-sectional studies was followed in the present study.[16]

Study design, population and sampling

SERODUS is a population-based, cross-sectional seroepidemiological study, which was conducted in Düsseldorf (Germany) between 2 and 27 November 2020. The sampling frame consisted of all individuals aged 18–30 years who were registered in Düsseldorf in October 2020 ($n = 106,449$). The study sample was selected via random sampling through the population registry (Fig. 1). The minimum sample size was calculated to be 1600–2000 individuals, with 95% confidence limits and assuming an anticipated seroprevalence of 1–6% or lower. The anticipated seroprevalence of 1–6% was chosen based on earlier reports that suggested a SARS-CoV-2 seroprevalence of between 1% and 6% in the general adult population.[17–19] To estimate even simple group differences with acceptable error intervals, the target corridor was a net sample of 2000 ± 400 individuals. Inclusion criteria were (1) permanent residence in Düsseldorf, (2) aged 18–30 years at that date when the serum sample was taken and (3) providing written informed consent. All potential participants were invited through written personal postal invitation letters (step 1) sent to their private mailboxes, including information about the study, a personal invitation number and a link to the study website. If interested in participation, an appointment could be made via the study hotline. Given the short recruitment phase of 14 days, reminder letters were sent out 5 days after the initial invitation (step 2).

Informed consent

Participants provided written and informed consent.

Measures

The primary study outcome was SARS-CoV-2 seroprevalence, and the secondary outcome was determinants associated with seropositivity. After providing written and informed consent, study participants completed a self-administered questionnaire, and a blood sample was taken.

Established survey instruments were used to obtain information on participants' sociodemographics (e.g. age and educational level), COVID-19-related symptoms (e.g. fever), chronic conditions (e.g. diabetes), exposure (e.g. participation in festivities) and behaviour-related factors (e.g. adherence to COVID-19 public health measures). Questions relating to sociodemographic characteristics were taken from the demographic standards defined by the German federal statistics office.[20] Questions concerning adherence to and support of COVID-19-related public health measures were taken from a COVID-19 questionnaire provided by the Robert Koch Institute, Germany's central public health authority.[21] General adherence to public health measures was assessed by asking respondents, "To what extent do you adhere to the coronavirus containment measures, which came into effect on March 18, 2020?" Specific public health measures investigated included social distancing (in private and public settings) and wearing a face mask in public. The type and frequency of the source used to retrieve COVID-19-related information were investigated by asking respondents, "How often do you use social media for COVID-19-related information?" All study material was provided in German, English, Turkish and Arabic languages.

Laboratory analysis and assays

Serum samples were tested for antibodies (including IgG, IgA and IgM) against the nucleocapsid antigen of SARS-CoV-2 (N) using the Elecsys Anti-SARS-CoV-2 immunoassay (Roche Diagnostics, Mannheim, Germany). The assay was performed on a Cobas e801 analyser (Roche Diagnostics, Mannheim, Germany) according to the manufacturer's instructions. The results showing a cut-off index (COI) of <1.0 were classified as negative, and a COI ≥1.0 was deemed positive for anti-SARS-CoV-2 antibodies (hereinafter referred to as seropositive). According to internal study data of Roche Diagnostics, the overall clinical specificity of the Elecsys Anti-SARS-CoV-2 immunoassay was 99.8% containing no cross-reactivity to the common cold coronaviruses, and additionally, a clinical sensitivity of 99.5% was calculated ≥14 days post polymerase chain reaction (PCR) confirmation. Serum samples with positive results were subject to SARS-CoV-2 neutralisation assay to detect SARS-CoV-2 neutralising antibodies with a titre of ≥1:10 being considered positive.[22]

Data analysis

Data analysis followed a three-step approach.

First, descriptive statistics, including the calculation of frequencies and percentages, were performed to describe the sample and the seroprevalence among young adults.

Second, the underascertainment rate of SARS-CoV-2 infections was calculated. This was based on the ratio of two population proportions: the proportion of SARS-CoV-2 infections calculated from our study and the cumulative incidence of non-fatal PCR-positive cases in the young adult population of Düsseldorf. These estimates were adjusted for test sensitivity (99.5%) and specificity (99.8%) of the Roche Cobas Elecsys Anti-SARS-CoV-2 test.[23]

Third, to investigate the association between seropositivity and possible risk factors, a series of logistic regressions to calculate odds ratios (ORs) were performed. Specifically, the OR for seropositivity was estimated separately for each main exposure of interest (e.g.
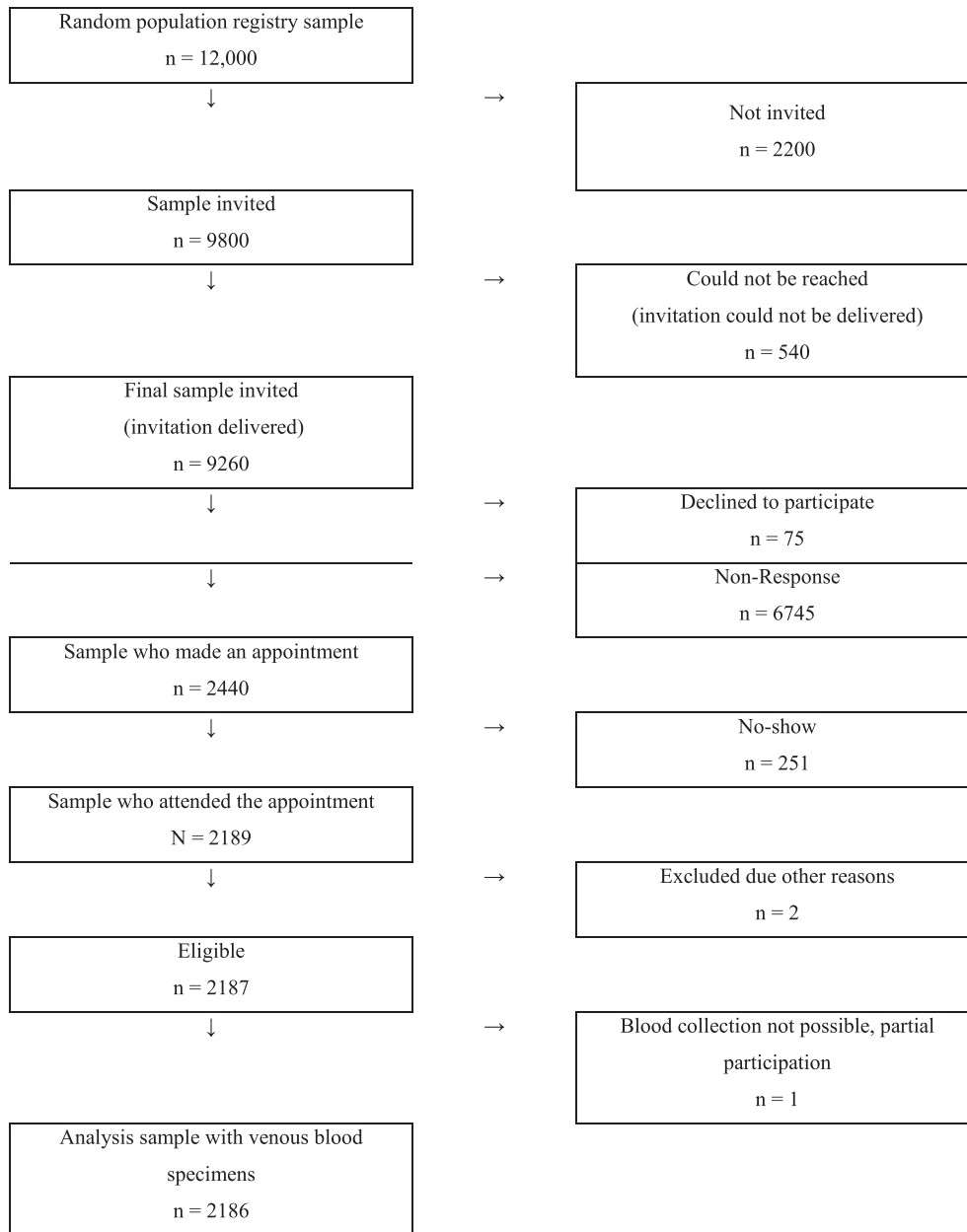
Fig. 1. Flow diagram of participant recruitment, enrolment, and study completion.

adherence to public health measures, travelling outside the European Union [EU] etc.; Model 1). In Model 2, each estimate was adjusted for age and sex (the estimate for age is adjusted only for sex, and the estimate for sex is adjusted only for age).

Analyses were performed using Stata version 15 (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC). All statistical models fit the data well according to the Hosmer–Lemeshow goodness-of-fit test (see supplementary material Table S1).

Results

A total of 2189 individuals attended the study centre (Fig. 1). Three observations were excluded because the individuals could not be tested (e.g. syncope). This yielded an analytic sample of 2186 individuals (24% of those invited) with complete records (i.e. informed consent, questionnaire and laboratory results; Fig. 1).

Sample characteristics

Table 1 shows the sociodemographic characteristics, and Table 2 shows the health- and behaviour-related characteristics of the study participants. Of 2186 participants, 60.7% were female, 37.2% were aged 20–25 years, and 16.9% had a migration background (Table 1). Most participants rated their health as good (81%) and chronic conditions were rare, with only 9.2% of participants reporting having one or more chronic conditions (Table 2).

Seroprevalence

Of 2186 young adults who participated in the present study, a total of 72 individuals were seropositive, representing a crude prevalence rate of 3.3% (95% confidence interval [CI]: 2.6–4.1) and a test-adjusted prevalence of 3.1% (95% CI: 2.4–4.0; Table 3). The

Table 1
Sociodemographic characteristics of study participants (n = 2186).

Characteristics	Participants, n (%)
Sex	
Female	1327 (60.7)
Male	857 (39.2)
Missing	2 (0.1)
Age group	
<20 years	139 (6.4)
20–25 years	813 (37.2)
26–30 years	1218 (55.7)
Missing	16 (0.7)
Household size	
1 person	575 (26.3)
2 persons	1027 (47.0)
≥3 persons	567 (25.9)
Missing	17 (0.8)
Educational level[a]	
Lower and middle	171 (7.8)
Higher	1921 (87.9)
Still a student or other type of education	81 (3.7)
Missing	13 (0.6)
Employment status	
Not working[b]	110 (5.0)
Part-time and short-term (reduced working hours)	164 (7.5)
Full time	1180 (54.0)
Student	703 (32.2)
Missing	29 (1.3)
Migration background	
Yes	370 (16.9)
No	1803 (82.5)
Missing	13 (0.6)

[a] Participants' education level was assessed according to the 2011 version of the International Standard Classification of Education (ISCED) and grouped into low/middle education (e.g. primary education) and higher education.
[b] This also includes pensioners and parents on maternity leave.

cumulative incidence of reported cases in the population aged 18–30 years was 1.8% (as of November 2020). Based on the estimated test-adjusted seroprevalence of 3.1% and the cumulative incidence of 1.8%, it is estimated that approximately 1.7-fold more infections occurred than were ascertained by confirmed case counts. Only 31 (43.1%) of individuals with antibodies had tested positive for COVID-19 by PCR before the present study. Consequently, the within-study 'true' rate of unreported COVID-19 cases in this population is 2.3. Among the 72 seropositive individuals, neutralising antibodies were detected in 66 individuals (91.7%; Table 3).

Determinants of a SARS-CoV-2 infection

Table 4 and Table S2 provide a detailed presentation of seroprevalence by sociodemographic and health-related characteristics. The proportion of men with positive SARS-CoV-2 antibodies (3.8%) was slightly higher than the proportion of women (2.7%). The odds of being seropositive was significantly higher among those with self-reported COVID-19 symptoms, such as loss of smell (OR: 55.6, 95% CI: 30.7–99.0), loss of taste (OR: 40.8, 95% CI: 23.0–75.5), fever ≥38 °C (OR: 5.06, 95% CI: 3.0–8.6), dyspnoea and shortness of breath (OR: 4.15, 95% CI: 2.1–7.6; Table S2). The odds of being seropositive were also almost two times higher for those who seek COVID-19-related information from social media (Table S2; OR: 1.83, 95% CI: 1.2–3.1). An increasing trend was seen in individuals who trust information from social media influencers (OR: 1.78, 95% CI: 0.9–3.3) and who do not support social distancing (Table S2; OR: 1.81, 95% CI: 0.9–3.7). Unexpectedly, we did not find evidence for a significant association between low self-reported general adherence to COVID-19 public health measures and seroprevalence (Table S2;

Table 2
Health-related characteristics and social determinants of study participants (n = 2186).

Characteristics	Participants, n (%)
Self-reported health	
Very good/excellent	1771 (81.0)
Fair/bad	385 (17.6)
Missing	30 (1.4)
Chronic condition	
No	1975 (90.3)
Yes	201 (9.2)
Missing	10 (0.5)
PCR test since February 2020	
Yes	784 (35.9)
No, no test needed	1126 (51.5)
No, but I thought about getting tested	194 (8.9)
No, I asked for a test but did not get one	72 (3.3)
Missing	10 (0.5)
Self-reported COVID-19	
Yes	46 (2.1)
No	728 (33.3)
I do not know	10 (0.4)
Symptoms since February 1[a]	
Fever ≥38 °C	225 (10.3)
Cough	648 (29.8)
Pneumonia	7 (0.3)
Dyspnoea/shortness of breath	121 (5.6)
Pain when breathing	112 (5.2)
Congested/running nose	848 (39.0)
Sore throat	854 (39.1)
Loss of smell or taste	100 (4.6)
No symptoms	511 (23.5)
Contact to a confirmed COVID-19 case	
No	1711 (78.3)
Yes, with a distance ≥1.5 m	179 (8.2)
Yes, with a distance <1.5 m	285 (13.0)
Missing	11 (0.5)
Other exposures[a]	
Working with patients	262 (12.0)
Working with customers	340 (15.6)
Participated in an event with ≥50 persons	850 (39.1)
Travelled outside the EU	246 (11.3)
Travelled within the EU	1068 (49.0)
General adherence to public health measures[b]	
Adheres completely to public health measures	1243 (56.9)
Adheres partly to public health measures	919 (42.0)
Adheres little to public health measures	9 (0.4)
Does not adhere to public health measures at all	0 (0.0)
Missing	15 (0.7)
COVID-19 information resource: social media	
Rarely/never	1488 (68.1)
Often/always	686 (31.4)
Missing	12 (0.5)
Trust in COVID-19 information from social media influencer	
Trust	277 (12.7)
No trust	1891 (86.5)
Missing	18 (0.8)
Supporting social distancing in private (contact restriction)	
Yes	1968 (90.0)
No	204 (9.4)
Missing	14 (0.6)
Supporting social distancing in public (at least 1.5 m distance)	
Yes	2126 (97.3)
No	488 (2.2)
Missing	12 (0.5)
Supporting wearing a face mask in public spaces	
Yes	2165 (99.0)
No	13 (0.6)
Missing	8 (0.4)
Supporting the travel restriction	
Yes	1991 (91.1)
No	169 (7.7)
Missing	26 (1.2)

PCR, polymerase chain reaction.
[a] Multiple replies were possible.
[b] In the following analyses, the categories "partly" and "little" were categorised as "partly, adherence to public health measures was assessed by asking respondents.

Table 3
Comparison of different prevalence measures of SARS-CoV-2 antibodies (n = 2186).

Prevalence measure	SARS-CoV-2 seroprevalence (unadjusted, n = 72), % (95% CI)]	SARS-CoV-2 seroprevalence (adjusted[a], n = 72), % (95% CI)	Participants with neutralising antibodies titres[b] (n = 66), % (95% CI)
Overall seroprevalence	3.3 (2.6–4.1)	3.1 (2.4–4.0)	3.0 (2.4–3.8)
Percentage of those who are seropositive and had a positive PCR before study	2.1 (1.6–2.8)	1.9 (1.4–2.6)	N/A
Percentage of those with neutralising antibody titres and a positive PCR before study	45.5 (34.0–57.4)	45.0 (34.1–57.6)	N/A

CI, confidence interval; N/A, not applicable.
[a] Adjusted for Roche Cobas Elecsys Anti-SARS-CoV-2 test sensitivity and specificity.
[b] Only in case of a positive Roche Cobas Elecsys Anti-SARS-CoV-2 test (n = 66) neutralising antibody titre assay was performed.

OR: 0.91, 95% CI: 0.5–1.5) or for participants who had travelled both within (Table S2; OR: 0.98, 95% CI: 0.6–1.6) and outside (Table S2; OR: 0.72, 95% CI: 0.3–1.8) the EU. Interestingly, no significant associations were found for those aged 20–25 years (OR: 1.27; 95% CI: 0.4–3.9), individuals with a secondary school education (OR: 1.15; 95% CI: 0.4–2.9) and those who worked with patients (OR: 1.12, 95% CI: 0.5–2.4) and customers (OR: 1.36, 95% CI: 0.78–2.38).

Determinants of an undetected SARS-CoV-2 infection

Table 4 and Table S2 also show a subgroup analysis of participants who were seropositive but did not report a prior SARS-CoV-2 infection (right column). Because of the small sample size, ORs were not calculated, and the interpretation is based exclusively on the 95% CIs. The analysis showed that undetected infections are about twice as likely in men (2.6%, 95% CI: 1.7–3.99) than in women

Table 4
SARS-CoV-2 seroprevalence in young adults and determinants of infection (n = 2186).

Characteristic	Distribution among seropositive participants	OR for being seropositive unadjusted	OR for being seropositive adjusted for age and sex[a]	Distribution among seropositive participants, but without prior self-reported SARS-CoV-2 infection (positive by PCR)[b]
	%[c] [95% CI]; n	OR [95% CI]	OR [95% CI]	%[c] [95% CI]; n
Sex				
Male	3.8% [2.7–5.3]; 34	Ref[d]	Ref	2.6% [1.7–3.9]; 23
Female	2.7% [1.9–3.7]; 38	0.70 [0.42–1.15]	0.70 [0.42–1.16]	1.3% [0.7–2.0]; 18
Missing (n)	0	–	–	0
Age group				
<20 years	2.7% [0.9–7.0]; 4	Ref	Ref	2.0% [0.6–6.2]; 3
20–25 years	3.4% [2.3–4.9]; 29	1.27 [0.4–3.9]	1.30 [0.6–2.0]	2.2% [1.13–3.5]; 19
26–30 years	2.9% [2.0–4.0]; 37	1.07 [0.4–3.3]	0.94 [0.4–2.0]	1.3% [0.8–2.2]; 18
Missing (n)	2	–	–	1
Household size				
1 person	3.1% [1.9–4.9]; 19	Ref	Ref	1.6% [0.8–3.1]; 10
2 persons	3.2% [2.3–4.6]; 35	1.03 [0.6–1.9]	1.06 [0.6–2.0]	1.8% [1.1–2.9]; 20
≥3 persons	2.8% [1.7–4.6]; 17	0.90 [0.4–1.8]	0.94 [0.6–2.0]	1.6% [0.8–3.1]; 10
Missing (n)	1	–	–	1
Educational level				
Lower/middle	2.7% [1.1–6.5]; 5	Ref	Ref	1.0% [0.1–4.2]; 2
Higher	3.2% [2.4–4.1]; 64	1.15 [0.4–2.9]	1.52 [0.50–4.63]	1.9% [1.2–2.5]; 37
Still a student/other degree	2.3% [0.5–8.4]; 2	0.83 [0.1–5.0]	1.10 [0.17–7.18]	2.3% [0.5–8.4]; 2
Missing (n)	1	–	–	0
Employment status				
Full time	3.1% [2.2–4.3]; 39	Ref	Ref	1.7% [1.1–2.7]; 22
Not working	5.3% [2.3–11.3]; 6	1.73 [0.7–4.3]	1.88 [0.7–4.7]	2.7% [0.8–8.1]; 3
Part-time or reduced working hours	4.1% [1.9–8.4]; 7	1.32 [0.6–3.1]	1.43 [0.6–3.4]	12
Student	2.2% [1.3–3.7]; 17	0.71 [0.4–1.32]	0.71 [0.4–1.3]	1.7% [0.9–3.1]; 13
Missing	3	–	–	4.4% [2.3–21.7]; 1
Migration background				
No	3.2% [2.4–4.1]; 60	Ref	Ref	1.6% [1.1–4.1]; 32
Yes	2.5% [1.3–4.7]; 10	0.79 [0.4–1.62]	0.81 [0.4–1.65]	1.8% [0.7–3.8]; 7
Missing (n)	2	–	–	2

CI, confidence interval; OR, odds ratio.
[a] The estimates for household size, education, employment status and migration background are adjusted for age and sex, the estimate for age is adjusted only for sex and the estimate for sex is adjusted for age only.
[b] For the analysis of subjects with antibodies but without self-reported SARS-CoV-2 infection, subjects with positive PCR test (n = 46) or unknown PCR result (n = 10) were excluded, resulting in a sample size of 2130 participants.
[c] This is the test-adjusted seroprevalence; row-percentages.
[d] Ref = reference category.

(1.3%, 95% CI: 0.7–2.0). The seroprevalence estimate was also considerably higher among individuals who did not adhere to social distancing (2.9%, 95% CI: 1.2–6.3) compared with individuals who adhered to social distancing (1.6%, 95% CI: 1.1–2.3) and among those who seek COVID-19-related information from social media (2.5%, 95% CI: 1.6–4.3) compared with those who did not seek COVID-19-related information from social media (1.3%, 95% CI: 0.8–2.1). The seroprevalence estimate was also higher in individuals who had considered SARS-CoV-2 testing in the past but ultimately did not go ahead with testing. Specifically, while 1.7% of total participants had an undetected infection, 5.0% (95% CI: 2.6–9.1) of those who had considered being tested and 5.4% (95% CI: 2.0–13.3) of those who had not received a test despite requesting one were seropositive. Higher prevalence estimates were also found for individuals who attended an event with >50 people (2.4%, 95% CI: 1.6–3.8) and who travelled outside the EU (2.3%, 95% CI: 0.9–5.1).

Discussion

In the present study, a test-adjusted SARS-CoV-2 seroprevalence of 3.1% and an underascertainment factor of 1.7 were found among young adults in Germany. Factors significantly associated with SARS-CoV-2 seroprevalence included self-reported symptoms (e.g. loss of smell) and seeking COVID-19-related information from social media. Factors significantly associated with an undetected SARS-CoV-2 infection were being male, not adhering to social distancing and seeking COVID-19-related information from social media.

Compared with estimates from previous national and international studies, the reported seroprevalence and underascertainment rate in the present study are lower than in the general adult population.[24,25] For example, a study from the United States determined a test-adjusted seroprevalence as high as 23% in some counties,[24] and in Germany, Neuhauser et al. reported an underascertainment factor between 2 and 6.[25] There are at least two possibilities that might explain the observed differences. First, most studies focussed on different age groups and specific population groups, such as healthcare personnel.[7,26,27] Furthermore, younger people often experience an asymptomatic or mild SARS-CoV-2 infection, which is associated with lower serum titres.[28] Consequently, it is possible that younger individuals have titres that fall below the threshold of serological assays, and therefore, previous infection may be less frequently detected. Second, the majority of studies were conducted at different times of the pandemic and often in hotspot areas;[10,17,29,30] it should be noted that the timing of the study is crucial, as seroprevalence rates may vary between different pandemic phases. Specifically, many previous seroprevalence studies were performed during the first pandemic wave in spring 2020. In Germany, during this time, significantly fewer PCR tests were performed than during the second wave (starting in November 2020), and therefore, it is likely that at the beginning of the pandemic, a much higher rate of COVID-19 cases remained undetected. Furthermore, it is important to note that to correct the seroprevalence for test sensitivity and specificity, this study applied a conservative approach by using very high sensitivity and specificity values; thus, the corrected seroprevalence is lower than the uncorrected seroprevalence. However, if sensitivity and specificity were below the manufacturer's specification, seroprevalence would be higher and the underreporting rate more distinct. In addition, it has been suggested that antibody titres decline over time.[31] We cannot exclude the possibility that some antibody responses no longer existed by the time of the survey, which would consequently underestimate the seroprevalence.

Potential determinants for seropositivity and undetected infection included self-reported symptoms and seeking COVID-19-related information from social media.

The findings regarding self-reported symptoms are in line with previous reports, which show that a loss of smell and taste, as well as a fever $\geq$38 °C were the most strongly associated factors with SARS-CoV-2 seropositivity.[26,32,33] Martínez et al.,[33] for instance, found that fever was among the most frequently described symptoms by seropositive individuals.

The results regarding social media use are novel. Currently, most studies investigating social media use in times of COVID-19 focussed on preventive behaviour in general[34,35] but have not associated it with the actual SARS-CoV-2 seropositivity. Nonetheless, the results are somewhat contradictory to the findings of the present study. For example, Mahmood et al.[34] found that social media use predicts self-efficacy and perceived threat of COVID-19, which, in turn, predicts preventive behaviour. However, in the present study, participants who sought COVID-19-related information from social media were found to be significantly more likely to be seropositive, and undetected cases in this group were almost twice as likely. It is possible that seropositive individuals in the present study viewed content that downplayed the COVID-19 infection risk, which may have led to lower adherence levels to public health measures. However, this remains speculative, as these interrelations could not be detected in the present study. Furthermore, it is important to note that these results may vary over time, might be wave sensitive (i.e. severity of this specific pandemic wave) and depend on information available and consequent knowledge about COVID-19. Nevertheless, social media platforms can play a critical role in the spread of information, particularly in times of crisis, and might impact adherence to public health recommendations.[36,37] Furthermore, given that social media platforms are often the main vehicle for communication among young adults, understanding the dynamics between content consumption and social behaviour may help design more effective communication strategies.

No statistically significant results were found for the association between general adherence to COVID-19 public health measures and seropositivity. However, there was a tendency for seropositivity among individuals who reported that they were in support of social distancing. This may seem surprising at first but could be explained by the fact that adherence to prevention measures was retrospectively assessed. Therefore, information, recall bias and social desirability bias cannot be ruled out.[27] Nonetheless, given that social distancing effectively reduces the risk of transmission and that young adults, despite their often mild disease course, can still spread the virus, they represent a subgroup of the population requiring additional attention from public health campaigns.[38]

The findings suggest that large-scale COVID-19 testing can help to detect more COVID-19 cases. The expansion and continuous development of testing are recommended to secure the containment of the pandemic. Furthermore, vaccination is also essential in younger age groups, especially as recent cross-sectional data from adolescents and young adults found evidence of new or persisting COVID-19 symptoms, such as fatigue, insomnia, headache, concentration difficulties, exercise intolerance and chest pain, 1-month postdiagnosis.[39,40] Vaccinating young adults may, therefore, help prevent the long-term health effects of COVID-19. Furthermore, recent evidence also suggests that vaccination can help reduce the transmission of the disease.[41] Given the high mobility of young adults, increasing immunisation in this population group can help prevent transmission, thereby also protecting vulnerable groups, such as the elderly.

The present study has some limitations that must be noted.

First, we aimed to explore the association between specific (social) determinants and seropositivity, but the subgroups were relatively small, which unfortunately precluded detailed and robust statistical analysis.

Second, the response rate of 24% was lower than that of other seroprevalence studies[17,25] but higher than an epidemiological study conducted in Germany (i.e. NAKO).[42] Nonetheless, the response rates of the other seroprevalence studies are only comparable to a limited extent because different groups were investigated and many studies focussed on hotspot areas.[30] The recruitment period of the present study was short (14 days), resulting in a limited number of individuals being available to participate (i.e. recruitment could not be fully completed in every format [e.g. telephone recruitment attempts]); however, it did enable calculation of SARS-CoV-2 seroprevalence at a specific point in time.

Third, it is impossible to gauge whether study participants were subject to systematic bias because contact could not be established with some invitees. A comparison with the age and gender structure of the population reveals that the net sample is well represented in terms of age, but not gender. Similar to other seroprevalence studies, men were underrepresented.[10,43] However, because men often have a higher seroprevalence and more undetected infections, it is possible that the overall seroprevalence is underestimated in the present study.

Finally, sampling bias may have also occurred. Specifically, the prevalence of COVID-19 infection was higher in this study than the officially reported cumulative prevalence. While the official reported cumulative prevalence among young adults was 1.8%, in the present study, 2.1% of participants reported a prior COVID-19 infection. It is likely that individuals with a prior infection were more sensitised and had an increased interest in participating.

In conclusion, the findings of this study suggest that the SARS-CoV-2 seroprevalence is likely to be much higher than the reported prevalence rates based on confirmed COVID-19 cases. The results further suggest that social media play an important role in young adults' risk perception. Given the limited amount of seroepidemiological data for young adults, a follow-up study to improve the understanding of SARS-CoV-2 seroprevalence and to better identify determinants of a SARS-CoV-2 infection is needed.

Author statements

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.03.009.

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