COVID

Article

Students in Dormitories Were Not Major Drivers of the Pandemic during Winter Term 2020/2021: A Cohort Study with RT-PCR and Antibody Surveillance in a German University City

Christian Rafael Torres Reyes [1,*], Eike Steinmann [2], Nina Timmesfeld [3], Hans-Joachim Trampisch [3], Julien Stein [3], Christian Schütte [1], Marina Skrygan [4], Thomas Meyer [4], Türkan Sakinc-Güler [5], Renate Schlottmann [1], Yannick Brüggemann [2], Daniel Todt [2,6], Andreas Walker [7], Nadine Lübke [7], Daniel Robert Quast [1,†] and Wolfgang Ekkehard Schmidt [1,5,*,†]

[1] Department of Medicine I, St. Josef-Hospital Bochum, Ruhr University Bochum, 44791 Bochum, Germany; christian.schuette@klinikum-bochum.de (C.S.); renate.schlottmann@rub.de (R.S.); daniel.quast@rub.de (D.R.Q.)
[2] Department of Molecular & Medical Virology, Ruhr University Bochum, 44801 Bochum, Germany; eike.steinmann@rub.de (E.S.); yannick.brueggemann@rub.de (Y.B.); daniel.todt@rub.de (D.T.)
[3] Department of Medical Informatics, Biometry and Epidemiology, Ruhr University Bochum, 44789 Bochum, Germany; timmesfeld@amib.ruhr-uni-bochum.de (N.T.); trampisch@amib.ruhr-uni-bochum.de (H.-J.T.); Julien.Stein@amib.ruhr-uni-bochum.de (J.S.)
[4] Department of Dermatology, Venerology and Allergology, St. Josef-Hospital, Ruhr University Bochum, 44791 Bochum, Germany; m.skrygan@klinikum-bochum.de (M.S.); thomas.meyer@klinikum-bochum.de (T.M.)
[5] Central Laboratory, St. Josef Hospital, Ruhr University Bochum, 44791 Bochum, Germany; tuerkan.sakinc-gueler@klinikum-bochum.de
[6] European Virus Bioinformatics Center (EVBC), 07743 Jena, Germany
[7] Institute of Virology, University Hospital Düsseldorf, Heinrich-Heine Universität, 40225 Düsseldorf, Germany; Andreas.Walker@med.uni-duesseldorf.de (A.W.); nadine.luebke@med.uni-duesseldorf.de (N.L.)
* Correspondence: christian.torresreyes@rub.de (C.R.T.R.); wolfgang.e.schmidt@rub.de (W.E.S.); Tel.: +49-234-509-6853 (C.R.T.R.); +49-234-509-2310 (W.E.S.); Fax: +49-234-509-2309 (C.R.T.R.)
† Both authors contributed equally.

check for updates

Citation: Torres Reyes, C.R.; Steinmann, E.; Timmesfeld, N.; Trampisch, H.-J.; Stein, J.; Schütte, C.; Skrygan, M.; Meyer, T.; Sakinc-Güler, T.; Schlottmann, R.; et al. Students in Dormitories Were Not Major Drivers of the Pandemic during Winter Term 2020/2021: A Cohort Study with RT-PCR and Antibody Surveillance in a German University City. *COVID* **2021**, *1*, 345–356. https://doi.org/10.3390/covid1010029

Academic Editor: Roger Frutos

Received: 13 July 2021
Accepted: 30 August 2021
Published: 3 September 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract: The role of educational facilities, including schools and universities, in the SARS-CoV-2 pandemic is heavily debated. Specifically, the risk of infection in student dormitories has not been studied. This cohort study monitored students living in dormitories in Bochum, Germany, throughout the winter term of 2020/2021. Over the course of four months, participants were tested repeatedly for SARS-CoV-2 infections using RT-PCR from gargle samples and serological testing. An online questionnaire identified individual risk factors. A total of 810 (46.5% female) students participated. Of these, 590 (72.8%) students participated in the final visit. The cross-sectional antibody prevalence was n = 23 (2.8%) in November 2020 and n = 29 (4.9%) in February 2021. Of 2513 gargle samples analyzed, 19 (0.8%) tested positive for SARS-CoV-2, corresponding to 14 (2.4%) infections detected within the study period. Gargle samples available of cases with confirmed present infection were always positive. The person-time incidence rate was 112.7 (95% CI: 54.11–207.2) per 100,000 person weeks. The standardized incidence ratio was 0.9 (95% CI 0.51–1.46, p = 0.69). In conclusion, students living in student dormitories do not appear to be major drivers of SARS-CoV-2 infections. RT-PCR from gargle samples is a patient-friendly and scalable surveillance tool for detection of SARS-CoV-2 infections.

Keywords: SARS-CoV-2; student dormitory; gargle sample; cohort study; antibody testing

1. Introduction

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the resulting coronavirus disease 2019 (COVID-19) have become a rapidly increasing major health issue worldwide [1]. With a hospitalization rate of up to 18% and a significant rate of patients requiring intensive care, COVID-19 represents a key concern to public health [2,3]. Importantly, a large percentage of transmissions are caused by mild or pre-symptomatic SARS-CoV-2 cases [4–6]. Since pre- or asymptomatic transmissions may be more significant in younger ages, educational facilities, including schools and universities, may be an important factor to sustain epidemic growth in the pandemic [7,8]. Living in dense areas like student dormitories could potentially increase the risk of secondary transmissions. Higher rates of transmission have been described within other congregate settings (e.g., long-term care facilities, workers in meat and poultry processing facilities, and homeless shelters) [9–12]. Although the characteristics of the population in these settings may considerably differ from student dormitories (e.g., student dormitories are mainly composed of healthy persons while long-term care facilities usually are not) and SARS-CoV-2 is known for a heterogeneous transmission dynamic [13], it is unclear whether a higher transmission rate may also be observed in student dormitories. Nonetheless, educational institutions and accommodation providers have implemented measures to reduce the infection risk. Furthermore, most academic institutions closed their campuses and launched or extended online learning platforms. However, this transition is reported to have significantly affected the mental health and wellbeing of students [14,15].

Infections with SARS-CoV-2 are usually identified by real-time reverse transcriptase polymerase chain reaction (RT-PCR) of viral RNA or rapid SARS-CoV-2 antigen detection devices, both using pharyngeal or nasal swabs [16–18]. Recently, non-invasive gargling with 10 mL of saline solution has been established as an almost equi-sensitive and equi-specific sample collection method, compared to pharyngeal swabs [19–24].

The aim of the present prospective cohort study was to evaluate the incidence of SARS-CoV-2 infections among students accommodated in student dormitories of a major university city in the urban central Ruhr area in Germany. Furthermore, the present study aimed to evaluate the feasibility of large-scale testing for the identification of SARS-CoV-2 infections using gargle samples.

2. Materials and Methods

2.1. Study Design

Academic institutions in the city of Bochum provide education for approximately 58,000 students, of which 5559 (9.5%) live in student dormitories. The local council of student affairs in Bochum (Akademisches Förderungswerk, AKAFOE) supervises most student dormitories, providing accommodation for 4043 (72.7%) students in Bochum. All students living in dormitories managed by AKAFOE were contacted using their registered e-mail and various social media channels. This included information regarding the purpose of the study and an invitation to actively participate in the study.

During the study period, strict hygiene measures were mandated within the dormitories by AKAFOE. These included compulsory wearing of a face mask when indoors, the closure of study and recreational rooms, and a ban on any social gatherings (e.g., parties). Adherence to hygiene measures was not assessed systematically, but regular check rounds by AKAFOE staff were implemented. According to the AKAFOE, most students complied with these regulations and no events of noncompliance with hygiene rules were reported by students or AKAFOE personnel during the study period.

A total of four study visits were conducted during the winter term from November 2020 to February 2021. Study visits were conducted monthly (every four weeks) and students from all AKAFOE facilities in Bochum were recruited on-site at five different student dormitories, close to the academic institutions of the Ruhr University Bochum. At each of the four monthly visits, students were asked to provide a gargle sample for RT-PCR testing and to fill out an online questionnaire sent by e-mail. Blood samples were collected for anti-SARS-CoV-2 antibody detection at baseline (November 2020) and at the final study visit after a period of four months (February 2021). Participants were informed of their test results via e-mail.

All participants provided written informed consent. The present study was approved by the Ethical Committee of the Medical Faculty, Ruhr University Bochum (registration number: 20-7074).

2.2. Detection of Anti-SARS-CoV-2 Antibodies

At baseline and visit 4, blood samples (5 mL serum) were collected. Samples were transported to the laboratory within five hours and analyzed immediately. Antibody testing was conducted using a commercial immunoassay. The assay uses a recombinant protein representing the nucleocapsid (N) antigen in a double-antigen sandwich assay format and does not detect antibody responses after vaccination against SARS-CoV-2 [25].

2.3. SARS-CoV-2 Detection by RT-PCR

Samples for RT-PCR were self-collected by the study participants. On each visit, participants received a 50-mL test tube containing 10 mL 0.9% saline solution and were informed on how to collect a gargling sample using step-by-step instruction. Additionally, an instructional video (uploaded to YouTube®, available in the online supplement) was provided. Participants were required to gargle for 30–60 s in their own room or outdoors.

Primary processing was performed without cell enrichment according to a modified method based on the Vienna COVID-19 Detection Initiative [14]. Commercial kits and test systems were applied for RNA extraction, RT-PCR, and analysis (online supplement).

In case of an invalid test result, RT-PCR was repeated and, if amplification failed again, regarded as invalid. Participants were then informed on the unsuccessful testing and instructed to seek medical advice in case of COVID-19 symptoms. In all other cases, results were automatically sent to the individual participant by e-mail. Participants with positive results were additionally informed in person and the cases were reported to local health authorities. Positive test results from the final study visit were screened for variants of concern, including the SARS-CoV-2 spike gene N501Y mutation, by melting curve analysis [26]. Virus sequencing was performed for infections identified within a dormitory if they occurred in the same time frame and the infection chain was not retraceable by other means. The used method for sequencing has been previously described [27].

2.4. Data Management and Statistical Analysis

On each visit, an online questionnaire (available in the online supplement) was sent to each participant by e-mail. Data were collected and managed using an electronic data capture system. Commercial software was used for statistical analysis and figure creation (specifications are detailed in the online supplement).

The incidence rate was calculated by dividing the number of detected SARS-CoV-2 cases by the sum of the study groups' individual time at risk. The individual time at risk was determined from the date of recruitment until final participation or date of positive RT-PCR result, respectively. Participants with a past or present infection at baseline were excluded from this calculation, as they were not considered to be at risk.

For calculation of the standardized incidence ratio (SIR), expected incidences were determined from the publicly available number of cases in Bochum (Robert Koch Institute (RKI) database). The population's data were weighted for each age group from publicly available data of Bochum from the year 2020 [28,29]. For this analysis, only participants with an antibody measurement on visit 4 were included. The SIR was determined by dividing the observed incidence by the expected incidence. For analysis of possible infection risk factors, hazard ratios were estimated with a 95% confidence interval using uni- and multivariant cox regression models including only infections acquired during the study (infections before recruitment were included).

3. Results

3.1. Study Population

A total of 810 participants were included in the present study. Figure 1 provides detailed information on attendance and data acquired during the visits. The final follow-up visit in February 2021 was attended by 590 (72.8%) students. Key characteristics of the study cohort at baseline are presented in detail in Table 1. Before and during the study period, none of the study participants were vaccinated against SARS-CoV-2.

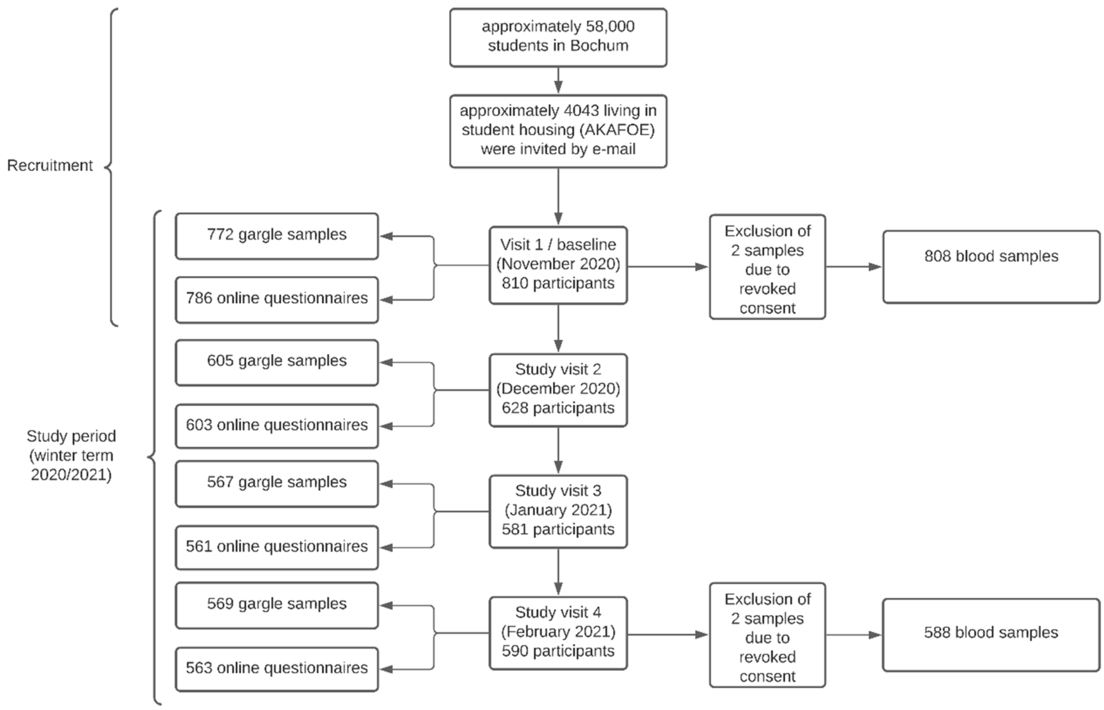

Figure 1. Flowchart of the recruitment into the study Flowchart depicting an overview of the recruitment process and details of study visits, including number of collected samples. AKAFOE: Akademisches Förderungswerk.

Table 1. Characteristics of all participants and students who attended the final study visit, data collected from online questionnaire at baseline.

Total	All Participants n = 810	Attended Final Visit n = 590
Personal information		
Age [years]	23.7 (±3.4) [810]	23.5 (±3.2) [590]
Females	377 (46.5%) [810]	283 (48.0%) [590]
BMI [kg/m^2]	23.3 (±3.8) [771]	23.2 (±3.68) [574]
Living conditions		
Single apartment	299 (39.4%) [779]	198 (34.6%) [572]
Shared apartment	480 (61.6%) [779]	374 (65.3%) [572]
No. of roommates, mean (SD) (n = 478)	3.2 (±2.2) [478] min. 0, max. 14	3.0 (±1.9) [372] min. 0, max. 14

Table 1. *Cont.*

Total	All Participants n = 810	Attended Final Visit n = 590
Health information		
Nicotine consumption	113 (14.7%) [767]	73 (12.9%) [565]
Alcohol consumption	369 (48.1%) [767]	297 (52.7%) [564]
Chronic disease	112 (14.3%) [782]	82 (14.3%) [573]
Bronchial asthma	36	30
Metabolic disease	23	16
Psychiatric	17	12
Regular medication	213 (27.4%) [778]	165 (28.8%) [574]
Contraceptives	126	103
Thyroid drugs	31	24
Antidepressants	20	13
Analgesics	17	12
Regular sports activities	500 (64.5%) [775]	378 (66.3%) [570]
Country of birth		
Germany	572 (73.1%) [783]	456 (79.0%) [577]
Iran	37 (4.7%) [783]	17 (3.0%) [577]
Russia	30 (3.8%) [783]	21 (3.6%) [577]
Italy	12 (1.5%) [783]	8 (1.4%) [577]
Other	132 (16.9%) [783]	75 (13.0%) [577]

Data is presented as means (±SD) or number (% of total). Data was derived from online questionnaires. "Attended final visit" was defined as participants that attended the baseline and last follow-up visit. Total numbers of students attending baseline and final visit are presented in bold. Number of available data is presented in squared brackets.

3.2. Cross-Sectional Prevalence of Infection with SARS-CoV-2 at Baseline

Based on the number of reported cases from RKI in Bochum, the expected incidence was calculated as 1.14% at baseline. Eight (0.99%) students reported being aware of a past SARS-CoV-2 infection. Anti-SARS-CoV-2 antibodies were detected in 23 (2.8%) participants (Table 2). Additionally, one participant reported a history of COVID-19 diagnosed by RT-PCR. However, no antibody response was detectable in this patient. This resulted in a total of 24 (3.0%) students with a history of SARS-CoV-2 infection. This corresponds to a 2.71 higher rate of SARS-CoV-2 infections compared to the expected number of cases. Six cases (0.74%) had a positive RT-PCR result at baseline.

Table 2. Number of unreported cases at baseline based on online questionnaire and antibody status.

Have You Ever Been Tested Positive for SARS-CoV-2 Infection?	Anti-SARS-CoV-2 Antibody Status	
	Positive	Negative
Total number	**23**	**785**
Yes	7 (30.4%)	2 † (0.25%)
No	15 (65.2%)	760 (96.7%)
No answer	1 (4.3%)	23 (30.5%)
Ratio reported to unreported case ‡	1:2	

Data describes the relation between measured antibody response and history of COVID-19 as acquired through online questionnaire. Data is presented as n (% of total). † Including one case diagnosed within the study period at an early stage of infection without seroconversion. ‡ Including one presumably unreported case that did not answer the questionnaire and one reported case without positive antibody response.

3.3. SARS-CoV-2 Incidence Rates in Bochum, Germany during the Study Period

Until the end of the study (21 February 2021), a total of 10,412 infections were reported in Bochum, with 7616 infections being recorded during the study period. The 7-day incidence rate (according to RKI data) per 100,000 inhabitants during the study visits was 167/100,000 (visit 1, November 2020), 210/100,000 (visit 2, December 2020), 94/100,000 (visit 3, January 2021), and 55/100,000 (visit 4, February 2021), respectively.

Due to the increasing incidence rates, measures for infection control were mandated by local government (partial lockdown from 2 November 2020, full lockdown from 16 December 2020). Following the full lockdown, the campus was completely closed for educational purposes and all teaching was conducted online only.

3.4. Incidence of SARS-CoV-2 Infections within the Study Period

During the study period, 14 (2.4%) of the 590 students that attended the baseline and final visit had either RT-PCR or serological evidence of a new SARS-CoV-2 infection. This corresponds to an incidence of 2.47% (n = 567) over the study period (excluding cases with history of past infection and missing serological follow up). The expected incidence for the study population in the same period was calculated (weights adjusted) from the RKI data for Bochum at 2.74%. The standardized incidence ratio was 0.9 (95% CI 0.51–1.46, p = 0.69). Figure 2 depicts a timeline of the study period with the SARS-CoV-2 incidence of the study cohort and the general population in Bochum.

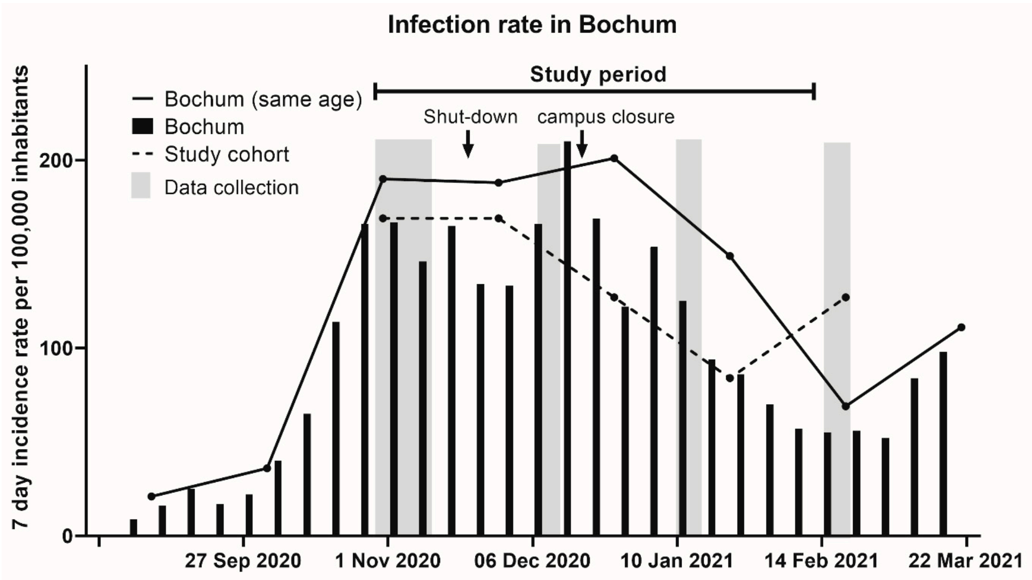

Figure 2. Incidence of SARS-CoV-2 during the study period Displayed are the 7-day incidence rates per 100,000 inhabitants in Bochum for the general population (total and aged 17 to 34) and the study cohort. Data was retrieved from publicly available databases of the RKI. The mean 7-day incidence rate per 100,000 inhabitants of the study cohort and age-matched control group of the general population was calculated from the number of infections per 28 days during the study period. Periods of sample collection (study visits) are marked in grey rectangles.

Infections were mostly identified with RT-PCR testing, which proved to be positive in 13 (92.9%) of the detected cases (including one case diagnosed by local health authorities without having provided a gargle sample at time of diagnosis). Antibody testing was positive in 12 (85.7%) of the detected cases. In two (14.3%) cases, the infection had not yet reached the stage of seroconversion at diagnosis in the final round. Asymptomatic infections were identified in three (21.4%) participants through the follow-up questionnaire. Of the 14 SARS-CoV-2 infections, six (42.9%) were first diagnosed in the context of the present study. All cases were mildly affected without the necessity of hospitalization. Using telephone interviews and contact tracing, no infection clusters were identified by our study group or local health authorities. However, two cases with a positive RT-PCR result within the same dormitory but without a retractable infection chain were detected in the last visit. After sequencing of the viral genome with characterization as lineage B.1.177.62, a very high genetic similarity was detected, hence indicating an infection cluster (Figure 3). No variant of concern was detected after examination of the three positive results (16.7%) from the final study visit.

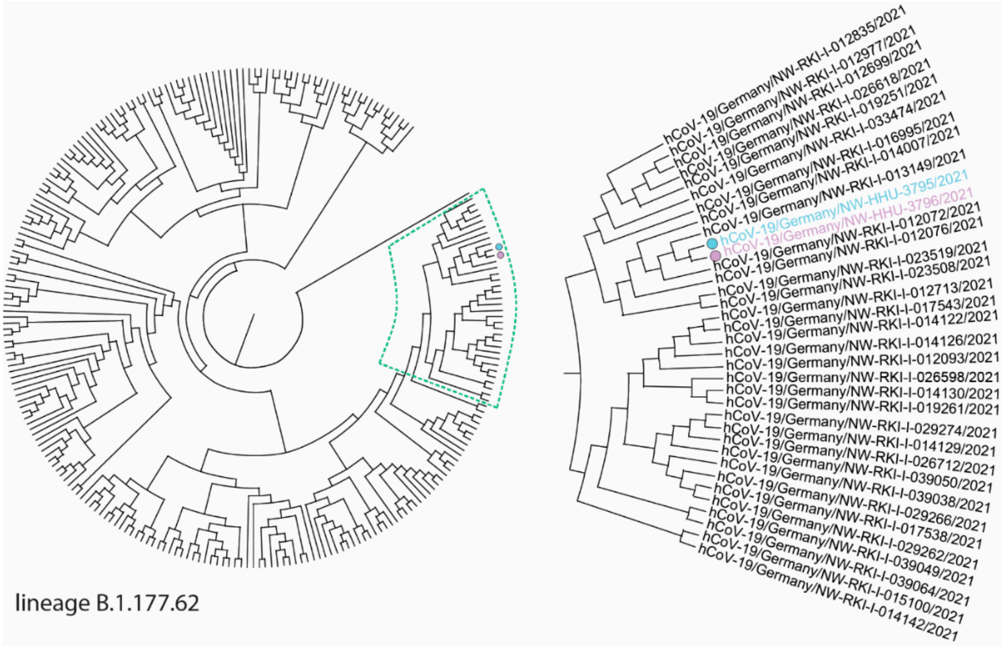

Figure 3. Lineage of sequenced viral genomes from the suspected infection cluster within the dormitory (B1.177.62) The figure depicts the cladogram of lineage B.1.177.62. Represented are all sequenced genomes acquired during the study period in North Rhine-Westphalia that were deposited at the Global Initiative on Sharing All Influenza Date (GISAID). At study visit 4, two participants from the same dormitory tested positive in the same time frame but without a traceable infection chain. To analyze the possibility of an undetected infection cluster, both viral genomes were sequenced. The dots mark the two genome sequences originating from these participants and exhibit a high phylogenetic similarity.

After exclusion of all cases with past or present infection at baseline, data from 684 (84.4%) students were used for the calculation of person-time incidence rate, resulting in 170 person years under observation. In this group, 10 (14.6%) new infections were observed. The person-time incidence rate of infection with SARS-CoV-2 was 112.7 (95% CI: 54.1–207.2) per 100,000 person weeks over the course of the study period.

3.5. RT-PCR Results and Gargle Sample as a Surveillance Tool

A total of 2513 gargle samples were collected, corresponding to a 96.3% overall return rate. Due to invalid results, 230 (9.2%) samples were excluded. Of the remaining 2283 (90.8%) samples, 2264 (99.2%) tested negative for SARS-CoV-2 RNA (Table 3). Positive results were found in 19 (0.8% positivity rate) samples deriving from 14 (1.9%) participants (duplicates due to persistently positive results with high cycle threshold *(ct)* values > 33 in three cases). Two cases of positive RT-PCR results at baseline were associated with past infections (>2 weeks disease onset, positive antibody results).

Of 12 cases of documented seroconversion, 10 (83.3%) were detected by analysis of gargle samples. In total, 12 (85.7%) of the documented cases detected within the study period were found using RT-PCR in a gargle sample. In both other cases, no sample was provided at time of infection. Hence, gargle samples available from cases with present infection were always RT-PCR positive (100%).

Table 3. Results of RT-PCR and antibody analysis per study visit.

	No. of Samples	Positive Results	Negative Results
Baseline/visit 1 (November 2020)			
Participants	810		
Collected gargle samples	772 (95.3%)		
Valid † RT-PCR results	727 (89.8%)	6 (0.8%)	721 (99.2%)
Anti-SARS-CoV-2 IgG/IgM	808 (99.8%)	23 (2.9%)	785 (97.2%)
Visit 2 (December 2020)			
Participants	628		
Collected gargle samples	605 (96.3%)		
Valid † RT-PCR results	513 (81.7%)	7 (1.4%)	506 (98.6%)
Visit 3 (January 2021)			
Participants	581		
Collected gargle samples	567 (97.6%)		
Valid † RT-PCR results	497 (85.5%)	3 (0.6%)	494 (99.4%)
Visit 4 (February 2021)			
Participants	590		
Collected gargle samples	569 (96.4%)		
Valid † RT-PCR results	546 (92.5%)	3 (0.6%)	543 (99.5%)
Anti-SARS-CoV-2 IgG/IgM	588 (99.7%)	29 (4.9%)	559 (95.1%)

† In total 230 out of 2,513 RT-PCR samples analysis remained invalid after repeating the test (9.2%). Data is presented as *n* (% of total).

In three (0.1% of total samples) cases, we suspected a false-positive result (only E gene positive with *ct*-values > 34, asymptomatic, no risk-contact). In these cases, control with pharyngeal swab (RT-PCR) and serological testing five days after initial testing were negative, hence indicating a false-positive initial result. However, in one of these cases, the participant tested positive in the context of a new exposure in the participant's family four weeks after the initial false-positive result. In the other cases, no seroconversion was observed in the final visit.

3.6. Impact of the Housing Situation on Infection Risk and Risk Factor Analysis

Participants at baseline feature a larger proportion of students living in shared apartments compared to the total capacity of AKAFOE facilities (61.6% vs. 51.4%, Supplementary Materials Figure S1). Within the six dormitories with the highest number of participants, the participation rate in facilities with mainly shared apartments was higher than in facilities with mainly single apartments (48.5% vs. 19.3%). Of the overall 38 detected cases with evidence of SARS-CoV-2 infection, 20 (52.63%) lived in a shared apartment. No statistically significant difference was found in relation to the housing form with regards to incidence rate. Further analysis to investigate the determinants and predictors of a positive SARS-CoV-2 test result (risk factor analysis) yielded no significant results (Supplementary Materials Figure S5).

4. Discussion

To our knowledge, the present study is the first to report on the incidence of infection with SARS-CoV-2 within student dormitories using sequential antibody and RT-PCR testing of a study cohort. The primary findings of the present study indicate that students living in student dormitories do not appear to contribute to the COVID-19 pandemic in Germany, provided appropriate hygiene measures are used. Furthermore, the large-scale use of gargle sampling proved to be an effective and reliable method to collect patient samples for SARS-CoV-2 RNA detection.

Cases of COVID-19, suggesting higher rates of secondary transmission, have been observed in other congregate settings, including long-term care facilities, acute care hospitals, correctional facilities, homeless shelters, and crowded conditions for workers in meat and poultry processing facilities [11]. Although limitations regarding the comparability of the present cohort with these studies are obvious, the present study investigated an important population within a common and dense living situation. Furthermore, the study cohort represents a relevant proportion of students living in student dormitories in Bochum (14.6%). In general, about 13.9% of students in Germany live in student dormitories [30]. We believe that the present cohort is representative of the living conditions in university dormitories in Germany. Hence, the results of the present study might be applicable to similar living situations in other countries, but detailed studies should be performed to replicate the present results. Further studies need to provide evidence to evaluate if the results can also be applied to students living outside of student dormitories or to cohorts that have been vaccinated.

The study period overlapped with the second wave of SARS-CoV-2 infection in Germany, presenting an optimal time of examination. In Bochum, the overall incidence rate as reported by the RKI was sequentially reduced under the strict lockdown measures mandated by German authorities in December 2020 (167 at baseline to 55 cases per 100,000 inhabitants on visit 4). The incidence of infection within the study cohort was numerically lower in comparison to the general population of the same age, although not significantly different (2.47% vs. 2.74%, SIR 0.9, 95% CI 0.51–1.46, $p = 0.69$). The officially reported cases of SARS-CoV-2 infections most likely do not include a considerable number of undetected oligo- or asymptomatic infections, as the general population was usually only tested if symptoms are present or in the context of outbreak management [31,32]. Furthermore, the incidence from reports by the Robert-Koch-Institute was calculated without exclusion of cases with past infection. Considering these unaccounted factors, a higher incidence may reasonably be assumed for the general population. For the period before baseline, the incidence of reported cases within the study group and same age control group was also observed at a slightly lower level (0.99% vs. 1.14%). Transmission of SARS-CoV-2 is known to spread in clusters, yet only two cases were identified as a possible infection cluster within the study cohort. This indicates that most transmissions of detected cases did not occur within the study cohort. At the final study visit, 29 (4.9%) cases with positive antibody results were identified. A Germany-wide seroprevalence study from blood donors reported an approximate 6% adjusted seroprevalence of the general population in February 2021 (with a higher percentage for <30 years age) [32]. Based on these findings and calculations, students living in a dormitory do not appear to be major drivers of SARS-CoV-2 infections in the context of the pandemic when appropriate measures are used.

The use of gargle samples for RT-PCR detection of SARS-CoV-2 in this study was accompanied by technical challenges that require consideration. Gargle samples contain PCR inhibitors. Due to inhibition from these substances, the RT-PCR results often returned invalid requiring repetition of the analysis. Ultimately, the rate of invalid test results was reduced to 4.0% in the analysis of samples from the final study visit 4 by dilution of the RNA extract.

The gargling method provided several advantages. Present infections were always detected by RT-PCR from gargle samples. Compared to conventional swabs, the gargling sample can be obtained with minimal infection risk for healthcare staff. Furthermore, the acceptance and compliance of participants was very high (96.3% return rate). Six SARS-CoV-2 infections were first diagnosed in the context of the study. At-home self-testing with antigen-tests has disadvantages, such of lower sensitivity and specificity, due to the assay method. Hence, RT-PCR testing of gargle samples might present an ideal method for conducting large-scale studies in public health or for outbreak management without the downside of lower diagnostic performance.

The strengths of the present study lie in the longitudinal examination of a representative cohort with a unique living situation, which is often overlooked in the context of the pandemic. Furthermore, the use of a rather neglected and user-friendly testing approach was implemented. However, several limitations need to be considered. Due to the study design, a selection bias of those participating in the study cannot be excluded. Gargle samples were not validated head-to-head against the current gold-standard of pharyngeal swabs, although this validation has been performed in the past [19,22]. Federal and regional lock-down measures applied during the study period may have differently affected students' daily lives as compared to the general population, resulting in a reduced comparability for infection risk assessment. Differences in lock-down measures and implementation of intramural hygiene concepts within dormitories may limit the transferability of the present results to other settings. Further information on the SARS-CoV-2 attack rate among the included dormitories was not available from local health authorities due to statutory rules. Furthermore, as no virus variants of concern were detected, the influence of such variants on infection chains in student dormitories cannot be assessed with the present data.

A strong correlation between socio-economic factors and infection over the course of the pandemic was reported [24,33]. Especially, city districts with lower socio-economic structure have been more afflicted by COVID-19-caused deaths [34]. Respectively, considering the higher educational status of the study cohort, a lower incidence rate compared to the public seems to be plausible.

In conclusion, we have found convincing evidence that students living in student dormitories were not a major contributor to transmission of SARS-CoV-2 infections in an urban population during the winter term of 2020/2021.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/covid1010029/s1, Figure S1: Capacity of AKAFOE facilities in Bochum, Figure S2: Overview of positive results and identification of individual cases of infection, Figure S3: Ct values of positive RT-PCR results, Figure S4: Results of antibody response from participants, Figure S5: Hazard ratio for all detected cases of SARS-CoV-2 infections according to variables from online questionnaire, Table S1: Dormitories from AKAFOE, Table S2: Specification of used commercial software and test systems, Video S1: Technique for gargling of RT-PCR sample, Appendix S1: Online questionnaire.

Author Contributions: Conceptualization, C.R.T.R., E.S., N.T., H.-J.T., R.S., D.R.Q. and W.E.S.; Data curation, C.R.T.R. and J.S.; Formal analysis, C.R.T.R., N.T., D.T. and J.S.; Funding acquisition, E.S., N.T. and W.E.S.; Investigation, C.R.T.R., J.S., C.S., M.S., T.M., T.S.-G., A.W. and N.L.; Methodology, N.T., D.R.Q. and W.E.S.; Project administration, C.R.T.R., E.S., N.T., J.S., Y.B. and W.E.S.; Supervision, E.S., D.R.Q. and W.E.S.; Validation, C.R.T.R., N.T. and J.S.; Visualization, C.R.T.R., D.T., D.R.Q. and W.E.S.; Writing—original draft, C.R.T.R. and D.R.Q.; Writing—review and editing, C.R.T.R., E.S., N.T., H.-J.T., Y.B., D.T., C.S., T.M., D.R.Q. and W.E.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the German Federal Ministry of Education and Research (BMBF, Award Number: 01KX2021) as part of the B-FAST (German: Bundesweites Forschungsnetz Angewandte Surveillance and Testung) within the NUM (German: Netzwerk Universtitätsmedizin). The funder had no role in study design, data collection, data analysis, data interpretation nor writing of the report.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the Medical Faculty, Ruhr University Bochum (registration number: 20-7074).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data collected for the study contain information that could compromise the privacy of research participants. Data sharing restrictions imposed by national and trans-national data protection laws prohibit general sharing of data. Data can be made available upon approval by the principal investigator of this study, the Ethics Committee of the Ruhr University Bochum and the data protection officer of Katholisches Klinikum Bochum. Proposal can be submitted to the principal investigator.

Acknowledgments: We thank Marvin Pogoreutz, Department of Molecular & Medical Virology, Ruhr University Bochum, Friederike Lemm and Bernadette Kaup, Institute of Hospital Hygiene, St. Josef-Hospital Bochum and Michaela Knapp, AKAFOE Bochum, for invaluable support in conducting the study. We acknowledge the contribution of numerous employees from AKAFOE Bochum.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Cucinotta, D.; Vanelli, M. WHO Declares COVID-19 a Pandemic. *Acta Biomed.* **2020**, *91*, 157–160. [CrossRef]
2. Richardson, S.; Hirsch, J.S.; Narasimhan, M.; Crawford, J.M.; McGinn, T.; Davidson, K.W.; Barnaby, D.P.; Becker, L.B.; Chelico, J.D.; Cohen, S.L.; et al. Presenting Characteristics, Comorbidities, and Outcomes Among 5700 Patients Hospitalized With COVID-19 in the New York City Area. *JAMA* **2020**, *323*, 2052. [CrossRef]
3. Schilling, J.L.A.; Schumacher, D.; Ullrich, A. al DMe. Krankheitsschwere der ersten COVID-19-Welle in Deutschland basierend auf den Meldungen gemäß Infektionsschutzgesetz. *J. Health Monit.* **2020**, *11*, 1–20. [CrossRef]
4. Böhmer, M.M.; Buchholz, U.; Corman, V.M.; Hoch, M.; Katz, K.; Marosevic, D.V.; Böhm, S.; Woudenberg, T.; Ackermann, N.; Konrad, R.; et al. Investigation of a COVID-19 outbreak in Germany resulting from a single travel-associated primary case: A case series. *Lancet Infect. Dis.* **2020**, *20*, 920–928. [CrossRef]
5. Ferretti, L.; Wymant, C.; Kendall, M.; Zhao, L.; Nurtay, A.; Abeler-Dorner, L.; Parker, M.; Bonsall, D.; Fraser, C. Quantifying SARS-CoV-2 transmission suggests epidemic control with digital contact tracing. *Science* **2020**, *368*. [CrossRef] [PubMed]
6. Ganyani, T.; Kremer, C.; Chen, D.; Torneri, A.; Faes, C.; Wallinga, J.; Hens, N. Estimating the generation interval for coronavirus disease (COVID-19) based on symptom onset data, March 2020. *Eurosurveillance* **2020**, *25*. [CrossRef] [PubMed]
7. Levinson, M.; Cevik, M.; Lipsitch, M. Reopening Primary Schools during the Pandemic. *N. Engl. J. Med.* **2020**, *383*, 981–985. [CrossRef]
8. Hyde, Z. COVID-19, children and schools: Overlooked and at risk. *Med. J. Aust.* **2020**, *213*, 444. [CrossRef] [PubMed]
9. He, X.; Lau, E.H.Y.; Wu, P.; Deng, X.; Wang, J.; Hao, X.; Lau, Y.C.; Wong, J.Y.; Guan, Y.; Tan, X.; et al. Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nat. Med.* **2020**, *26*, 672–675. [CrossRef] [PubMed]
10. McMichael, T.M.; Clark, S.; Pogosjans, S.; Kay, M.; Lewis, J.; Baer, A.; Kawakami, V.; Lukoff, M.D.; Ferro, J.; Brostrom-Smith, C.; et al. COVID-19 in a Long-Term Care Facility—King County, Washington, February 27–March 9, 2020. *MMWR Morb. Mortal Wkly. Rep.* **2020**, *69*, 339–342. [CrossRef] [PubMed]
11. Dyal, J.W.; Grant, M.P.; Broadwater, K.; Bjork, A.; Waltenburg, M.A.; Gibbins, J.D.; Hale, C.; Silver, M.; Fischer, M.; Steinberg, J.; et al. COVID-19 Among Workers in Meat and Poultry Processing Facilities—19 States, April 2020. *MMWR Morb. Mortal. Wkly. Rep.* **2020**, *69*. [CrossRef]
12. Mosites, E.; Parker, E.M.; Clarke, K.E.N.; Gaeta, J.M.; Baggett, T.P.; Imbert, E.; Sankaran, M.; Scarborough, A.; Huster, K.; Hanson, M.; et al. Assessment of SARS-CoV-2 Infection Prevalence in Homeless Shelters—Four, U.S. Cities, March 27–April 15, 2020. *MMWR Morb. Mortal. Wkly. Rep.* **2020**, *69*, 521–522. [CrossRef] [PubMed]
13. Meyerowitz, E.A.; Richterman, A.; Gandhi, R.T.; Sax, P.E. Transmission of SARS-CoV-2: A Review of Viral, Host, and Environmental Factors. *Ann. Intern. Med.* **2021**, *174*, 69–79. [CrossRef] [PubMed]
14. Khan, A.H.; Sultana, M.S.; Hossain, S.; Hasan, M.T.; Ahmed, H.U.; Sikder, M.T. The impact of COVID-19 pandemic on mental health & wellbeing among home-quarantined Bangladeshi students: A cross-sectional pilot study. *J. Affect. Disord.* **2020**, *277*, 121–128. [CrossRef]
15. Radu, M.C.; Schnakovszky, C.; Herghelegiu, E.; Ciubotariu, V.A.; Cristea, I. The Impact of the COVID-19 Pandemic on the Quality of Educational Process: A Student Survey. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7770. [CrossRef] [PubMed]
16. WHO. Antigen-Detection in the Diagnosis of SARS-CoV-2 Infection Using Rapid Immunoassays: Interim Guidance; 11 September 2020 (Geneva: World Health Organization). Available online: https://www.who.int/publications/i/item/antigen-detection-in-the-diagnosis-of-sars-cov-2infection-using-rapid-immunoassays (accessed on 2 May 2021).
17. WHO. Laboratory Testing for 2019 Novel Coronavirus (2019-nCoV) in Suspected Human Cases: Interim Guidance; WHO Headquarters, WHO Worldwide: 19 March 2020. Available online: https://www.who.int/publications/i/item/10665-331501 (accessed on 2 May 2021).
18. Wölfel, R.; Corman, V.M.; Guggemos, W.; Seilmaier, M.; Zange, S.; Müller, M.A.; Niemeyer, D.; Jones, T.C.; Vollmar, P.; Rothe, C.; et al. Virological assessment of hospitalized patients with COVID-2019. *Nature* **2020**, *581*, 465–469. [CrossRef] [PubMed]
19. Bennett, S.; Davidson, R.S.; Gunson, R.N. Comparison of gargle samples and throat swab samples for the detection of respiratory pathogens. *J. Virol. Methods* **2017**, *248*, 83–86. [CrossRef] [PubMed]
20. Saito, M.; Adachi, E.; Yamayoshi, S.; Koga, M.; Iwatsuki-Horimoto, K.; Kawaoka, Y.; Yotsuyanagi, H. Gargle Lavage as a Safe and Sensitive Alternative to Swab Samples to Diagnose COVID-19: A Case Report in Japan. *Clin. Infect. Dis.* **2020**, *71*, 893–894. [CrossRef]
21. Malecki, M.; Lusebrink, J.; Teves, S.; Wendel, A.F. Pharynx gargle samples are suitable for SARS-CoV-2 diagnostic use and save personal protective equipment and swabs. *Infect. Control Hosp. Epidemiol.* **2020**, 1–2. [CrossRef]
22. Mittal, A.; Gupta, A.; Kumar, S.; Surjit, M.; Singh, B.; Soneja, M.; Soni, K.D.; Khan, A.R.; Singh, K.; Naik, S.; et al. Gargle lavage as a viable alternative to swab for detection of SARS-CoV-2. *Indian J. Med. Res.* **2020**, *152*, 77–81. [CrossRef] [PubMed]
23. Guo, W.-L.; Jiang, Q.; Ye, F.; Li, S.-Q.; Hong, C.; Chen, L.-Y.; Li, S.-Y. Effect of Throat Washings on Detection of 2019 Novel Coronavirus. *Clin. Infect. Dis.* **2020**, *71*, 1980–1981. [CrossRef] [PubMed]
24. Willeit, P.; Krause, R.; Lamprecht, B.; Berghold, A.; Hanson, B.; Stelzl, E.; Stoiber, H.; Zuber, J.; Heinen, R.; Köhler, A.; et al. Prevalence of RT-qPCR-detected SARS-CoV-2 infection at schools: First results from the Austrian School-SARS-CoV-2 prospective cohort study. *Lancet Reg. Health Eur.* **2021**, *5*, 100086. [CrossRef] [PubMed]

25. Meyer, B.; Torriani, G.; Yerly, S.; Mazza, L.; Calame, A.; Arm-Vernez, I.; Zimmer, G.; Agoritsas, T.; Stirnemann, J.; Spechbach, H.; et al. Validation of a commercially available SARS-CoV-2 serological Immunoassay. *Clin. Microbiol. Infect.* **2020**. [CrossRef]
26. Public Health England. Guidance: Investigation of Novel SARS-CoV-2 Variants of Concern. Technical Breefing Document on Novel SARS-CoV-2 Variant. Available online: https://www.gov.uk/government/publications/investigation-of-novel-sars-cov-2-variant-variant-of-concern-20201201 (accessed on 21 December 2020).
27. Walker, A.; Houwaart, T.; Wienemann, T.; Vasconcelos, M.K.; Strelow, D.; Senff, T.; Hülse, L.; Adams, O.; Andree, M.; Hauka, S.; et al. Genetic structure of SARS-CoV-2 reflects clonal superspreading and multiple independent introduction events, North-Rhine Westphalia, Germany, February and March 2020. *Eurosurveillance* **2020**, *25*. [CrossRef]
28. BOStatIS. Bochumer Statistischen Informations-SystemStadt Bochum. 2020. Available online: https://duvatools.bochum.de/asw/asw.exe?aw=/Bevoelkerungspyramide_2020_tbl.ini (accessed on 2 May 2021).
29. RKI. Robert Koch-Institut: SurvStat@RKI 2.0. 2021. Available online: https://survstat.rki.de/Content/Query/Create.aspx (accessed on 2 May 2021).
30. Berghoff, H. Studentisches Wohnen 2003 und 2018: Wo Studierende Unterkommen—Gerstern und Heute. 2019. Available online: https://www.che.de/wp-content/uploads/upload/Im_Blickpunkt_Studentisches_Wohnen_2003_und_2018.pdf (accessed on 2 May 2021).
31. RKI. Nationale Teststrategie—Wer Wird in Deutschland auf das Vorliegen Einer SARS-CoV-2 Infektion Getestet? 2020. Available online: https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Teststrategie/Nat-Teststrat.html (accessed on 2 May 2021).
32. RKI. Serologische Untersuchungen von Blutspenden auf Antikörper Gegen SARS-CoV-2 (SeBluCo-Studie). 2021. Available online: https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Projekte_RKI/SeBluCo_Zwischenbericht.html (accessed on 2 May 2021).
33. Mourad, A.; Turner, N.A.; Baker, A.W.; Okeke, N.L.; Narayanasamy, S.; Rolfe, R.; Engemann, J.J.; Cox, G.M.; Stout, J.E. Social Disadvantage, Politics, and Severe Acute Respiratory Syndrome Coronavirus 2 Trends: A County-level Analysis of United States Data. *Clin. Infect. Dis.* **2020**. [CrossRef] [PubMed]
34. Plümper, T.; Neumayer, E. The pandemic predominantly hits poor neighbourhoods? SARS-CoV-2 infections and COVID-19 fatalities in German districts. *Eur. J. Public Health* **2020**, *30*, 1176–1180. [CrossRef]