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The contribution of SARS-CoV-2 to the burden of acute respiratory infections in winter season 2022/2023: results from the DigiHero study

Nadine Glaser[1], Sophie Diexer[1], Bianca Klee[1], Oliver Purschke[1], Mascha Binder[2,3], Thomas Frese[4], Matthias Girndt[5], Jessica Höll[6], Irene Moor[7], Jonas Rosendahl[8], Michael Gekle[9], Daniel Sedding[10], Rafael Mikolajczyk[1,*], Cornelia Gottschick[1]

[1] Institute for Medical Epidemiology, Biometrics and Informatics (IMEBI), Interdisciplinary Centre for Health Sciences, Medical Faculty of the Martin Luther University Halle-Wittenberg, Halle (Saale), Germany
[2] Department of Internal Medicine IV, Oncology/Hematology, Martin Luther University Halle-Wittenberg, Halle (Saale), Germany
[3] Medical Oncology, University Hospital Basel, Basel, Switzerland
[4] Institute of General Practice and Family Medicine, Interdisciplinary Centre for Health Sciences, Medical Faculty of the Martin Luther University Halle-Wittenberg, Halle (Saale), Germany
[5] Department of Internal Medicine II, Martin Luther University Halle-Wittenberg, Halle (Saale), Germany
[6] Paediatric Haematology and Oncology, Martin Luther University Halle-Wittenberg, Halle (Saale), Germany
[7] Institute for Medical Sociology, Martin Luther University Halle-Wittenberg, Halle (Saale), Germany
[8] Department of Internal Medicine I, Martin Luther University Halle-Wittenberg, Halle (Saale), Germany
[9] Julius-Bernstein-Institute of Physiology, Medical Faculty of the Martin Luther University Halle-Wittenberg, Halle (Saale), Germany
[10] Mid-German Heart Centre, Department of Cardiology and Intensive Care Medicine, University Hospital, Martin Luther University Halle-Wittenberg, Halle (Saale), Germany

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A B S T R A C T

Objectives: In winter of 2022/2023 SARS-CoV-2 had developed into one of many seasonal respiratory pathogens, causing an additional burden of acute respiratory infections (ARIs). Although testing was still widely used, many positive tests were not reported for the official statistics. Using data from a population-based cohort, we aimed to investigate the contribution of SARS-CoV-2 to the burden of ARI.
Methods: Over 70,000 participants of the German population-based DigiHero study were invited to a questionnaire about the number and time point of ARI and SARS-CoV-2 test results in winter 2022/2023. We calculated the incidence of non-severe acute respiratory syndrome (SARS) ARI, the additional contribution of SARS-CoV-2, and extrapolated the age-specific estimates to obtain the total burden of SARS-CoV-2 in Germany.
Results: For the winter of 2022/2023, 37,708 participants reported 54,813 ARIs, including 9358 SARS-CoV-2 infections. This translated into a cumulative incidence of 145 infections/100 persons for all ARIs, 120 infections/100 persons for non-SARS ARI, and 25 infections/100 persons for SARS ARI (+21%).
Conclusions: Our estimate for ARI related to SARS-CoV-2 is consistent with the difference in all ARI between pre-pandemic years and 2022/2023. This additional burden should be considered, particularly, with respect to the implications for the work force.

Introduction

At the beginning of September 2022, 3 years after the detection of the first SARS-CoV-2 case, the World Health Organization worldwide had registered over 600 million confirmed cases and over 6.4 million deaths due to an infection with SARS-CoV-2 [1]. By the end of the winter season in March 2023, those numbers had risen to

* Corresponding author: Tel.:+49 345 557 3571.
E-mail address: rafael.mikolajczyk@uk-halle.de (R. Mikolajczyk).

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over 761 million confirmed cases and over 6.8 million deaths [2]. Our World in Data reported an even higher number of deaths of 8.6 million [3].

On May 3, 2023, the president of the World Health Organization declared the end of the COVID-19 pandemic [4]. Onward, the number of deaths and severe courses of infection requiring hospitalization or intensive care until treatment gradually decreased [3]. SARS-CoV-2 became endemic and one of the seasonal pathogens causing respiratory infections, resulting in consultations or sick leaves [5,6]. Still, these mild respiratory infections are known to cause a substantial societal burden, with effects on work force and subsequently the national economy, such as an increased number of absence days and reduced productivity [7,8]. Decision-makers need to be aware of this burden to adapt and create new policies with the goal of reducing infection incidences, for example, by establishing new strategies on vaccinations.

There are several approaches to estimating the burden of respiratory infections. The Centers for Disease Control and Prevention (CDC) use a multiplier-approach to estimate influenza incidences based on hospitalization numbers [9]. However, the multiplier-approach is only suitable for infections for which the number of mild cases per severe case are known and stable. However, these data are still lacking for SARS-CoV-2 and the uncertainty regarding the effects of immunity and the distribution of immunity in the population have to be considered. Protection levels of improved vaccines are still being studied, especially regarding effects of possible persisting immunity levels from previous infections with SARS-CoV-2. In the wake of the pandemic, some countries such as Germany and the UK still report registered SARS-CoV-2 cases [10–12].

By the beginning of September 2022, the Robert Koch Institute (RKI) had registered over 32 million SARS-CoV-2 infections [13]. By the end of March 2023, this number had risen to over 38 million cases, seeing an increase of about 6 million infections [14]. Although in Germany, reporting is still required for positive test results for both polymerase chain reaction and self-testing, particularly, self-testing is likely not to be reported. Furthermore, a sick leave mandated by a medical doctor does not require a pathogen test. Therefore, it is likely that less severe cases are often not registered. To assess the burden of respiratory infections in the society, the number of medical consultations can be used and if the proportion of infected seeking medical attentions is known, this could also be used in a multiplier method. Still, this number also does not include all acute respiratory infections (ARIs) because individuals not requiring treatment or an official sick leave might not visit a medical doctor. A direct approach to estimate the burden of ARIs at population level is, therefore, asking about self-reported ARIs and is, for example, used by the GrippeWeb portal [10,11]. One can assume that the burden of ARIs will increase with the presence of a new pathogen, as in this case SARS-CoV-2. Because testing for SARS-CoV-2 was still common in 2022 and 2023, we used this opportunity to estimate the incidence of ARIs caused by SARS-CoV-2. This can inform about the expected additional burden of ARIs in the subsequent years, which can aide decision-makers in adapting and creating new strategies to reduce the societal strain.

Methods

Study design and questionnaires

We used data from a questionnaire applied in the German population-based cohort for digital health research (DigiHero, DRKS Registration-ID: DRKS00025600). The design of DigiHero was described elsewhere [15]. In brief, recruitment was done via letters, with addresses obtained directly from German registration offices. This was carried out in all administrative districts in middle Germany (Saxony, Saxony-Anhalt, and Thuringia), whereas a stratified random selection of administrative districts was performed for the remaining federal states. We obtained informed consent from all participants during the process of the online-based registration. In DigiHero, data collection takes place via web-based questionnaires created via the free online-tool LimeSurvey. The ethics committee of the Medical School of the Martin Luther University Halle-Wittenberg has approved DigiHero (2020-076).

On March 22, 2023, we sent an online-survey about ARIs during the last 7 months to all 70,538 registered participants of DigiHero in 13 different federal states in Germany. We included questions about the number of infections since September 1; month they occurred; duration of symptoms and number of days spent in bed during sickness; hospitalization; whether a SARS-CoV-2 test was performed; and about vaccination status regarding influenza, pneumococci, and SARS-CoV-2. An analysis on vaccination data can be found elsewhere [16]. Participants were first asked about their total number of ARIs and, in the next step, for more detailed information on each of the reported ARIs (up to 10).

The collected data on ARI were merged with information on sociodemographic characteristics obtained via the baseline questionnaire of DigiHero. Using the International Standard Classification of Education, we categorized the levels of education into low, medium, and high [17]. In the baseline questionnaire, participants reported their net household income in Euro in seven income categories. We used those categories to calculate the net household equivalent income. Therefore, we calculated household weights as follows: 1 = weight for the first adult, 0.5 = all other adults (aged 14 years and above), and 0.3 = children. After, we determined the mean of each income category and divided this by the sum of the household weights. According to the result, we then assigned one of the initial seven income categories. Furthermore, we classified individuals according to social classes using the Winkler Index [18]. This score includes data on education level, income, and occupational status, each with assigned points from 1 to 7, with seven being the highest. For the missing occupational status, an estimation was calculated via forming the average of the other two factors as recommended in the study by Lampert and Kroll [19]. The total score combined the points for education, income, and occupational status, resulting in a number between 3 and 21. Social classes were assigned accordingly: lower class (3-8 points), middle class (9-14 points), high class (15-21).

Statistical analysis

We determined the monthly incidence and cumulative incidence (for the 7-month period from September 2022 to March 2023) of ARIs per 100 persons: first, for the total population and, second, stratified by age. As the questionnaire was first sent on March 22, we excluded this month in all monthly analyses. However, in March reported infections were included in all cumulative analyses. We distinguished between non-severe acute respiratory syndrome (SARS) ARI (when respondents reported either not having conducted a SARS-CoV-2 test or the test was negative) and SARS ARI with positive tests. We calculated the excess ARIs related to SARS by dividing the number of SARS ARIs by the number of non-SARS ARIs (considered as proxy for the number of ARIs before the pandemic) and report it as +X%. We conducted three analyses: a lower boundary estimate based on the number of ARIs with positive SARS-CoV-2 tests, an upper boundary estimate assuming that all ARIs without a test are related to SARS-CoV-2, and a mid-estimate assuming that in ARIs during which a SARS-CoV-2 test was not conducted, there was the same proportion of SARS ARIs as among those who reported testing. These analyses were repeated for the cumulative number of days with symptoms and for days spent in bed during sickness.

In the next step, we extrapolated the data on incidence of ARIs to the German adult population using the age distribution for Germany from 2022 available from the Federal Bureau of Statistics [20]. Therefore, we calculated incidences for 5-year age groups for the total number of ARI and SARS ARI and multiplied those by the sizes of these age groups in the German population. A similar analysis was conducted using incidences of three predefined age groups (15-34, 35-59, and 60 years and older) for pre-pandemic years, provided by GrippeWeb [21].

We also studied how the incidence of ARIs was associated with sociodemographic factors, such as sex, age, number of people living in a household, and social class, additionally adjusting for the federal state of residence in Germany as random effect in a mixed negative binomial model. To check for potential bias in our results due to differences in testing for SARS-CoV-2, we examined the likelihood of testing depending on the aforementioned sociodemographic factors using a mixed logistic regression before conducting a sensitivity analysis. All statistical analyses were conducted in R version 4.2.2 using the base functions and the additional packages “DescTools,” “MASS,” “lme4,” “epiR,” and “sjPlot”.

Results

We received 43,211 questionnaires between March and April 2023, corresponding to a response of 61%. After exclusion of incomplete data, responses of 37,708 participants were analyzed. The comparison of sociodemographic characteristics revealed some differences between responders and non-responders (Table 1). The response was slightly lower in males; younger people; and individuals with a lower level of education, income, or social class.

Although 10,638 individuals (28%) reported no infection, the remaining participants reported a total number of 54,813 ARIs for the winter season of 2022 and 2023. There were 45,455 ARIs without a positive SARS-CoV-2 test; for 11,699 of those, no SARS-CoV-2 test was available and for the others, there was a negative test. A total of 9358 (25% of the final sample) participants reported having had a positive SARS-CoV-2 test. The number of SARS-positive ARIs yielded an estimated lower boundary of 21% excess ARI. Adding all infections for which no test was conducted as SARS ARI, we found 62% excess ARI related to SARS-CoV-2 as the upper boundary. Using the proportion of positive tests among all conducted tests (21%) to estimate the number of SARS ARIs among the ARIs without a test (2457 ARIs), we found a mid-estimate of 27% excess infections due to SARS-CoV-2. The analysis by age group revealed a higher estimate of excess SARS ARI for older age groups (Supplementary Material 1).

The estimated cumulative incidence for the total number of ARI occurring in the period September until March was 145 infections per 100 persons, 120 infections/100 persons for non-SARS ARIs, and 25 infections/100 persons for SARS ARIs. The highest incidence for all ARI was observed in December 2022, with 26 infections per 100 persons (Figure 1a). For SARS ARIs, the highest incidence was in November 2022, with six infections per 100 persons. Stratified by age group, we observed a decreasing cumulative incidence with increasing age (Figure 1b). The age group 30-39 years displayed the highest cumulative incidence with 208 infections per 100 persons for the 7 months. Monthly incidences followed the same trend in all age groups (Supplementary Material 1).

For symptom duration and days spent in bed during sickness, a cutoff of 30 days was chosen. Infections exceeding this limit were excluded from further analyses. The distributions of symptom duration and number of days spent in bed during sickness for non-SARS ARIs and SARS ARIs can be viewed in Supplementary Material 2.

SARS ARIs were observed to cause symptoms for a longer time than non-SARS ARIs (mean 9.7 [9.5-9.9] vs 8.8 days [8.7-8.8]) (Table 2). This was similar for days spent in bed because individuals with a positive SARS-CoV-2 test stayed 1 day longer in bed during their infection than individuals with a negative or no SARS-CoV-2 test. Investigating the possible influence of recall time, we compared the variances and means by month, which revealed no distinct time trend for the number of days with symptoms and days spent in bed (data not shown). A total of 11,665 individuals reported more than one non-SARS ARI during the studied 7 months. In comparison, in this period, a maximum of one SARS ARI was reported per individual.

We observed an excess of 24.83 ARI per 100 persons due to SARS-CoV-2 (considering only positive SARS-CoV-2 tests). The extrapolation to the German adult population of about 68.4 million people resulted in an estimate of at least 17 million SARS-CoV-2 infections. Estimates for the number of general ARI in the last winter season yielded a total number of 150.58 million ARI in the German adult population. Estimations for pre-pandemic years based on GrippeWeb data are presented in Supplementary Material 3.

Consistent with the incidences of ARIs, the highest total cumulative number of days with symptoms was reported for December 2022, with 239 days per 100 persons, and among individuals aged between 30 and 39 years, with 1424 days per 100 persons (Figure 2a and b). Further stratification by age revealed similar trends in all age groups, agreeing well with previous results (Supplementary Material 1). SARS ARIs caused an additional burden of days with symptoms and days spent in bed during sickness of 11% and 15%, respectively. The proportion of days spent in bed among all days with symptoms was higher for SARS ARIs than for non-SARS ARIs (0.46 vs 0.31). However, the proportion decreased with age for both groups. The decrease resulted from the increasing symptom duration with age with relatively stable numbers of days spent in bed during infection in older age groups.

Male sex was associated with a lower risk of SARS ARI and non-SARS ARI (Table 3). A younger age was associated with a higher frequency of non-SARS and SARS ARI; however, the association was stronger for non-SARS ARI. Although, for SARS ARI, only living in a two-member household lead to an increased chance of infection, the chance to get infected increased steadily with the number of household members for non-SARS ARI. A lower social class was associated with a slightly higher chance of infection for non-SARS ARI; for SARS ARI, lower social class was associated with a risk reduction.

We saw a minor reduced likelihood of testing for SARS-CoV-2 for males, participants aged 70 years and older, individuals with a higher number of household members, and those belonging to a lower social class (Supplementary Material 4).

Discussion

Our analysis showed a cumulative incidence of 145 ARI episodes per 100 persons during September 2022 to March 2023, with 25% of the study population reporting an SARS ARI. These numbers resulted in an excess of 24.83 ARIs per 100 persons due to SARS-CoV-2 (+21%) as a lower boundary.

Our results showed similar calendar trends to what has been reported by the RKI’s GrippeWeb, which saw a steep increase in ARI beginning in October of 2022 and reaching its maximum in December [21]. Similar to our data, ARI numbers dropped in the beginning of the new year but remained higher than in October 2022. Furthermore, GrippeWeb data also indicated lower incidences in elderly individuals than younger age groups [21].

An extrapolation to the 2022 German adult population of about 68.4 million people revealed 17 million SARS ARIs. This number was almost three times higher than an estimation calculated using age-stratified 7-day incidences of the period September 2022 to March 2023 provided by the RKI, which resulted in 5.8 mil-

Table 1
Sociodemographic characteristics of responders and non-responders.

Characteristic	Value	Responders N (n = 37,708)	Responders % (95% CI)	Non-responders N (n = 33,639)	Non-responders % (95% CI)
Sex	Female	22,957	60.9 (60.4; 61.4)	17,467	51.9 (51.4; 52.5)
	Male	14,453	38.3 (37.8; 38.8)	15,003	44.6 (44.1; 45.1)
	Diverse	31	0.1 (0.1; 0.1)	76	0.2 (0.2; 0.3)
	NA	267	0.7 (0.6; 0.8)	1093	3.2 (3.1; 3.4)
Age group	18-29	2563	6.8 (6.5; 7.1]	5085	15.1 (14.7; 15.5)
	30-39	5151	13.7 (13.3; 14.0)	6089	18.1 (17.7; 18.5)
	40-49	6234	16.5 (16.2; 16.9)	5431	16.1 (15.8; 16.5)
	50-59	9183	24.4 (23.9; 24.8)	6299	18.7 (18.3; 19.1)
	60-69	9004	23.9 (23.5; 24.3)	5547	16.5 (16.1; 16.9)
	≥70	5239	13.9 (13.5; 14.2)	4020	12.0 (11.6; 12.3)
	NA	334	0.9 (0.8; 1.0)	1168	3.5 (3.3; 3.7)
Household members	1	6841	18.1 (17.8; 18.5)	5373	16.0 (15.6; 16.4)
	2	18,635	49.4 (48.9; 49.9)	14,953	44.5 (43.9; 45.0)
	3	5781	15.3 (15.0; 15.7)	5693	16.9 (16.5; 17.3)
	4	4666	12.4 (12.0; 12.7)	4665	13.9 (13.5; 14.2)
	5	1093	2.9 (2.7; 3.1)	1325	3.9 (3.7; 4.2)
	>5	269	0.7 (0.6; 0.8)	368	1.1 (1.0; 1.2)
	NA	423	1.1 (1.0; 1.2)	1262	3.8 (3.6; 4.0)
Education[a]	Low	1057	2.8 (2.6; 3.0)	2145	6.4 (6.1; 6.6)
	Medium	11,100	29.4 (29.0; 29.9)	10,306	30.6 (30.1; 31.1)
	High	23,704	62.9 (62.4; 63.4)	18,509	55.0 (54.5; 55.6)
	NA	1847	4.9 (4.7; 5.1)	2679	8.0 (7.7; 8.3)
Net household equivalent income[b]	<1250€	3678	9.8 (9.5; 10.1)	4980	14.8 (14.4; 15.2)
	1250 - <1750€	8014	21.3 (20.8; 21.7)	7387	22.0 (21.5; 22.4)
	1750 - <2250€	5170	13.7 (13.4; 14.1)	4385	13.0 (12.7; 13.4)
	2250 - <3000€	9292	24.6 (24.2; 25.1)	7160	21.3 (20.8; 21.7)
	3000 - <4000€	7723	20.5 (20.1; 20.9)	5091	15.1 (14.8; 15.5)
	4000 - <5000€	299	0.8 (0.7; 0.9)	198	0.6 (0.5; 0.7)
	≥5000€	219	0.6 (0.5; 0.7)	165	0.5 (0.4; 0.6)
	NA	3313	8.8 (8.5; 9.1)	4273	12.7 (12.3; 13.1)
Social class[c]	Lower class	3772	10.0 (9.7; 10.3)	4544	13.5 (13.1; 13.9)
	Middle class	17,326	45.9 (45.4; 46.5)	15,162	45.1 (44.5; 45.6)
	High class	12,527	33.2 (32.7; 33.7)	8799	26.2 (25.7; 26.6)
	NA	4083	10.8 (10.5; 11.1)	5134	15.3 (14.9; 15.7)
Born in Germany	Yes	36,297	96.3 (96.1; 96.4)	31,007	92.2 (91.9; 92.5)
	No	1154	3.1 (2.9; 3.2)	1546	4.6 (4.4; 4.8)
	NA	257	0.7 (0.6; 0.8)	1086	3.2 (3.0; 3.4)
Living in a city >100.000	Yes	11,087	29.4 (28.9; 29.9)	12,927	38.4 (37.9; 39.0)
	No	26,066	69.1 (68.7; 69.6)	20,041	59.6 (59.0; 60.1)
	NA	555	1.5 (1.4; 1.6)	671	2.0 (1.8; 2.2)
Federal state	Baden-Württemberg (only city of Stuttgart)	469	1.2 (1.1; 1.4)	516	1.5 (1.4; 1.7)
	Bavaria	3415	9.1 (8.8; 9.4)	3647	10.8 (10.5; 11.2)
	Berlin	486	1.3 (1.2; 1.4)	455	1.4 (1.2; 1.5)
	Brandenburg	3306	8.8 (8.5; 9.1)	2484	7.4 (7.1; 7.7)
	Hamburg	519	1.4 (1.3; 1.5)	503	1.5 (1.4; 1.6)
	Lower Saxony	1839	4.9 (4.7; 5.1)	1011	3.0 (2.8; 3.2)
	Mecklenburg-Western Pomerania	2080	5.5 (5.3; 5.8)	1494	4.4 (4.2; 4.7)
	Rhineland-Palatinate	4433	11.8 (11.4; 12.1)	3689	11.0 (10.6; 11.3)
	Saarland	1139	3.0 (2.9; 3.2)	585	1.7 (1.6; 1.9)
	Saxony	7660	20.3 (20.0; 20.7)	7286	21.7 (21.2; 22.1)
	Saxony-Anhalt	9535	25.3 (24.8; 25.7)	10,076	30.0 (29.5; 30.4)
	Schleswig-Holstein	2180	5.8 (5.5; 6.0)	1154	3.4 (3.2; 3.6)
	Other	92	0.2 (0.2; 0.3)	68	0.2 (0.2; 0.2)
	NA	555	1.5 (1.4; 1.6)	671	2.0 (1.8; 2.2)

CI, confidence interval

[a] Levels of education were categorized into low, medium and high, using the International Standard Classification of Education (ISCED-97) [15].

[b] In the baseline questionnaire, the net household income in Euro was inquired and sorted into seven income categories. These were converted into net household equivalent income. Therefore, household weights were calculated as follows: 1 = weight for the first adult; 0.5 = all other adults (aged 14 and above), and 0.3 = children. After, the mean of each income category was determined and divided by the sum of the household weights. According to the result, one of the initial seven income categories was assigned.

[c] Social class was determined according to the Winkler-Index. A score ranging from 3 to 21 was calculated according to the individual's levels of education, income, and occupational status. Individuals were assigned one of three social classes accordingly: lower class (3-8 points), middle class (9-14 points), and high class (15-21) [16,17].

lion COVID-19 cases [22]. This is most likely due to underreporting of positive tests to health authorities. Several studies have voiced concerns that although SARS-CoV-2 self-testing is of greater convenience and more accessible to the individual, it also enhances the risk of underreporting of cases due to requiring the initiative to report a positive test result to health authorities [23–25]. Although willingness for reporting a positive test result was high initially during the pandemic, it is unknown whether this changed as the perceived risk of SARS-CoV-2 decreased over time [26]. There also might be differences in test reporting behavior for different groups, although no differences have been found between men and women [26]. Furthermore, it is well known that mild diseases are

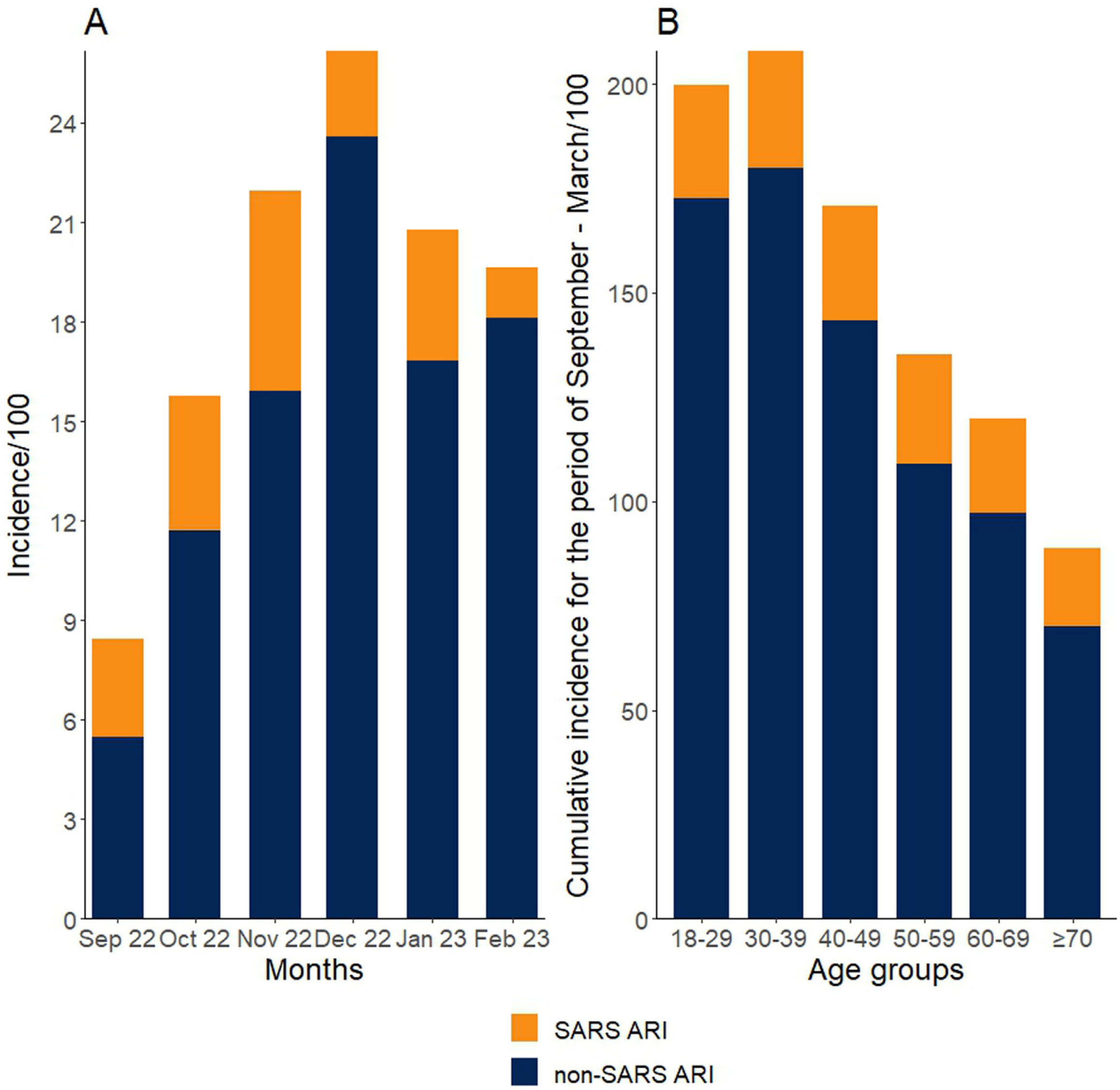

Figure 1. Incidence of acute respiratory infections with a positive test for SARS-CoV-2 and without in winter season of 2022/2023 (a) by month and (b) by age group. ARI, acute respiratory infections.

Table 2
Individual burden of self-reported acute respiratory infections in the winter season of 2022/2023. Analysis includes all infections with available reported days with symptoms and days in bed with the number of included infections in brackets.

	Mean number of days with symptoms (95% CI)	Median number of days with symptoms (95% CI)	Mean number of days in bed (95% CI)	Median number of days in bed (95% CI)
SARS ARI (n = 4239)	9.7 (9.5; 9.9)	7 [7,8]	3.0 (2.9; 3.1)	2 [2]
Non-SARS ARI (n = 41,465)				
Per episode[a]	8.8 (8.7; 8.8)	7 [7]	2.0 (1.9; 2.0)	1 [1]
Cumulative for seven months[b]	15.7 (15.6; 15.9)	12 [12]	3.7 (3.6; 3.7)	2 [2]

ARI, acute respiratory infections; CI, confidence interval
[a] The mean number of days with symptoms and days in bed per episode was calculated for all reported non-SARS ARI in the study period.
[b] For individuals reporting several ARI episodes in the study period, the number of days with symptoms and days in bed were summed up as a cumulative number and afterward included in the analysis of mean and median numbers of infection durations in the sample.

less likely to be reported, partly because individuals are less likely to seek health care in these cases [27,28]. Our data includes SARS-CoV-2 infections detected via self-testing, hence including mild cases which might have not been reported to health authorities. Therefore, our estimation is closer to the true number of COVID-19 cases in the German population than the data provided by the RKI and still is an underestimation of all SARS-CoV-2 infections, given that not all persons tested themselves, some tests might have been false negative, and SARS-CoV-2 infections can be very mild or even asymptomatic (i.e. not captured by our ARI definition).

Another extrapolation with DigiHero data was done for the number of all ARIs in the last winter season, which resulted in a

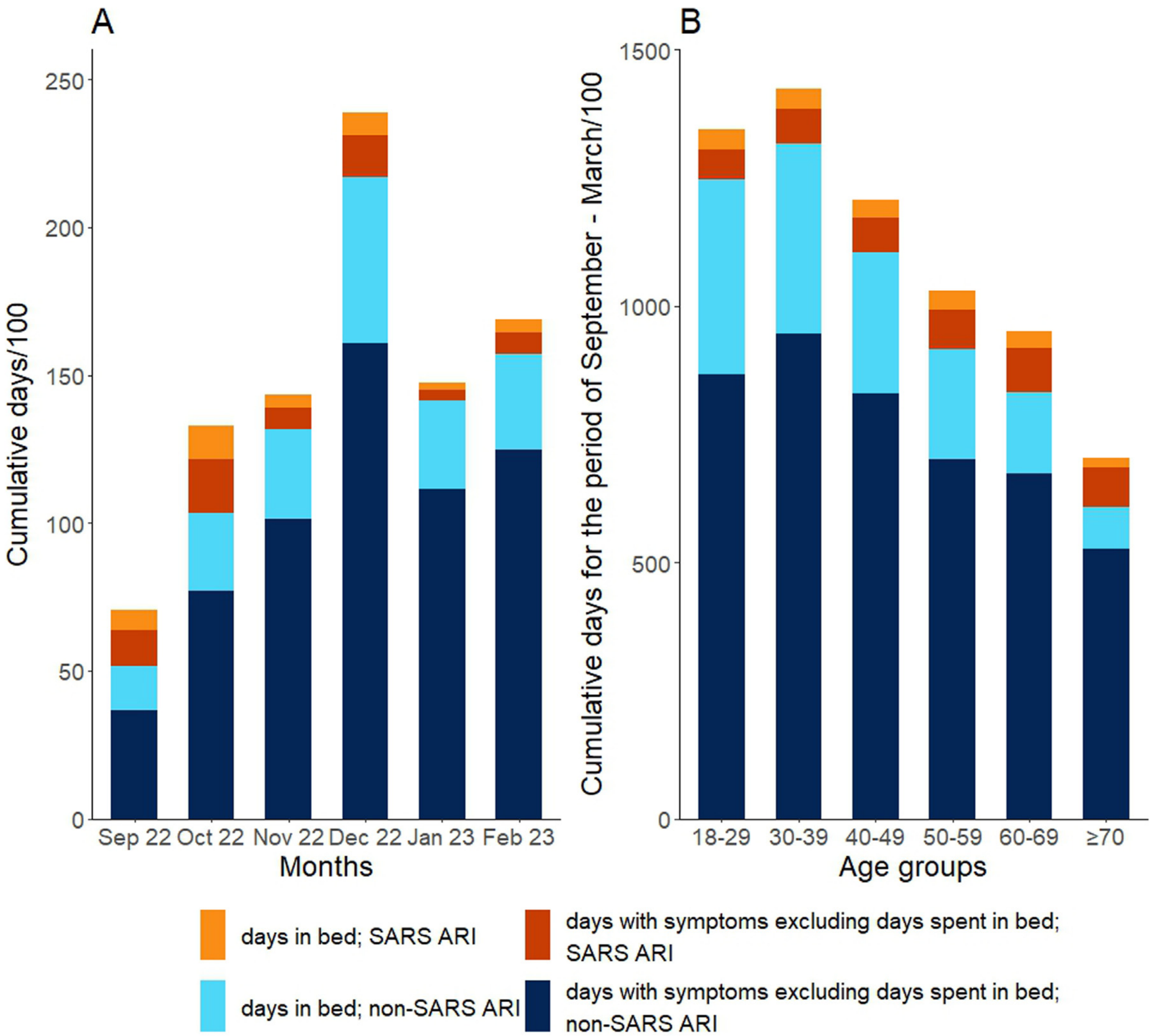

Figure 2. Cumulative number of days spent in bed and days with symptoms (excluding the former) for ARI with positive SARS-CoV-2 test and without in winter season of 2022/2023 (a) by month and (b) by age group. ARI, acute respiratory infections.

Table 3
Effects of sociodemographic variables on burden of acute respiratory infections with a positive test for SARS-CoV-2 and without in winter season of 2022/2023.
Incidence rate ratios for ARI from the respective multivariable mixed negative binomial regression with federal state as random effect and adjusted for all displayed variables. After exclusion of individuals with missing data on any of the sociodemographic variables, 32,754 individuals were included in the analysis. Size of the individual groups in brackets.

Characteristic	Value (n = 32,754)	Crude incidence/100 (95% CI)		Adjusted incidence rate ratio (95% CI)	
		Non-SARS ARI	SARS ARI	Non-SARS ARI	SARS ARI
Sex	Female (Ref.) (n = 19,881)	125.7 (122.3; 129.2)	26.1 (25.7; 26.5)	1.00	1.00
	Male (n = 12,873)	92.1 (91.8; 92.5)	22.7 (22.1; 23.2)	0.80 (0.78; 0.82)	0.89 (0.85; 0.93)
Age group	18-29 (Ref.) (n = 2163)	161.3 (156.8; 165.8)	27.7 (25.4; 29.1)	1.00	1.00
	30-39 (n = 4734)	166.8 (161.0; 172.6)	27.9 (26.7; 29.1)	1.00 (0.95; 1.05)	1.02 (0.92; 1.12)
	40-49 (n = 5514)	136.7 (132.7; 140.7)	27.4 (26.3; 28.5)	0.78 (0.74; 0.82)	1.03 (0.93; 1.13)
	50-59 (n = 7926)	102.7 (101.7; 103.6)	25.8 (24.9; 26.7)	0.64 (0.61; 0.67)	0.95 (0.87; 1.04)
	60-69 (n = 7783)	89.5 (88.9; 90.1)	22.7 (21.8; 23.5)	0.61 (0.58; 0.64)	0.83 (0.75; 0.91)
	≥70 (n = 4634)	61.2 (59.9; 62.5)	18.9 (17.8; 20.0)	0.43 (0.41; 0.46)	0.70 (0.63; 0.78)
Number of household members	1 (Ref.) (n = 6,197)	99.2 (99.0; 99.4)	23.2 (22.2; 24.1)	1.00	1.00
	2 (n = 16,345)	95.4 (95.2; 95.7)	24.7 (24.4; 25.2)	1.06 (1.02; 1.09)	1.10 (1.04; 1.17)
	3 (n = 5017)	141.4 (137.2; 145.7)	26.1 (25.0; 27.3)	1.30 (1.25; 1.35)	1.05 (0.98; 1.14)
	4 (n = 4046)	153.0 (148.1; 157.8)	25.5 (24.3; 26.8)	1.35 (1.29; 1.41)	1.02 (0.94; 1.11)
	5 (n = 937)	162.7 (157.9; 167.5)	24.9 (22.2; 27.7)	1.41 (1.32; 1.51)	1.00 (0.87; 1.15)
	>5 (n = 212)	145.8 (140.8; 150.7)	22.6 (17.0; 28.3)	1.36 (1.19; 1.55)	0.95 (0.71; 1.26)
Social class	Lower class (n = 3659)	118.0 (115.6; 120.4)	21.1 (19.9; 22.4)	1.04 (1.00; 1.08)	0.78 (0.72; 0.85)
	Middle class (n = 16,859	114.8 (112.3; 117.2)	23.7 (23.2; 24.1)	1.04 (1.01; 1.06)	0.88 (0.84; 0.92)
	High class (Ref.) (n = 12,236)	107.9 (106.2; 109.6)	27.3 (26.7; 28.0)	1.00	1.00

ARI, acute respiratory infections; CI, confidence interval.

total number of 150.58 million ARIs in the German adult population. This number is similar to an estimate based on GrippeWeb data, which yielded 144.4 million ARIs for September 2022 to March 2023 [21]. These numbers were higher than the estimated 129.0 million (2016/2017), 130.4 million (2017/2018), 119.7 million (2018/2019), and 120.6 million (2019/2020) infections for the pre-pandemic winters [21]. Given a mean of 124.9 million ARIs per winter season for the years 2017-2020, GrippeWeb estimates implicate a gap of almost 20 million infections (+16%) between pre- and post-pandemic winters. This agrees well with our lower boundary estimate of 21% excess ARI related to SARS-CoV-2 infections. The upper boundary and our mid-estimate would require a reduction of non-SARS ARI for the post-pandemic winter compared with pre-pandemic ones. Although it is possible that a higher awareness of respiratory infections reduced their overall number compared with the pre-pandemic years, this effect is probably not very strong. Because infections without test were shorter and resulted in less days spend in bed than those with a positive test, the fraction of SARS-CoV-2 infections among those was probably lower. This would suggest that the true incidence was between the lower boundary and the mid-estimate. Although the overall burden of ARI in the winter 2022/2023 could have also been increased after the preceding years with lockdowns, our data do not indicate this effect. As stated previously, this could be counteracted by a higher awareness of the population toward ARI. Nevertheless, SARS-CoV-2 is an additional pathogen, which was not present before, and is, hence, causing an additional burden of disease.

We further observed the mean symptom duration of SARS ARI to be longer than for non-SARS ARI. This is resulting from the fact that SARS-CoV-2 is more likely to cause occasional rather long-lasting symptoms than the established pathogens. The median number of days with symptoms in the DigiHero sample was 7 days (confidence interval 7-8). This was higher than the reported median symptom duration for Omicron infections (5 days [interquartile range 3-9]) in a study by Menni et al. [29]. However, they included individuals who had recovered within 21 days, whereas our criterion was a recovery within 30 days. Although individuals reported several ARIs within the winter season of 2022 and 2023, no more than one positive SARS-CoV-2 test per person was reported. This resulted in an overall higher burden of days with symptoms and days spent in bed during sickness due to ARIs caused by other pathogens than SARS-CoV-2. However, we observed an additional burden of 11% and 15% for both outcomes, respectively, due to COVID-19.

The analysis of possible risk factors revealed male sex and a higher age being associated with a lower incidence of both ARI types. One reason for lower infection rates in males and the elderly might have been the difference in number and intensity of contacts between the groups. Previous studies have shown that women tend to have longer duration contacts than men, often with physical interaction and especially with children [30,31]. A total of 28% of the infected in our sample reported living together with at least one child, with most of these individuals being women (69%). This could explain part of the elevated infection rates. Similarly, the number and duration of contacts is shown to decrease with higher age, hence lowering the risk of infection for retired people, especially those living alone [31–34]. This effect might have been amplified by the general knowledge of the elderly being at risk for severe SARS-CoV-2 infections, which might have led to further isolation of individuals with a high age to prevent them from being infected with the virus. A high proportion of physical contacts happens in home settings. More intense contacts such as this have a higher risk of transmission [33–35]. As the number of household members increases, so does the number of intimate contacts, explaining the increasing risk for non-SARS ARI for individuals living in a bigger household. The lower effect of household size on SARS ARI could be due to a higher risk awareness to COVID-19 in the population. With a detected SARS-CoV-2 case in the household, people might be more inclined to take measures to lower the transmission risk than they would for a common cold. In our sample, individuals of a lower social class had a smaller risk for SARS ARI. People with higher education and income were shown to have more and longer duration contacts. Moreover, they spent more time on social and leisure activities, associated with higher intensity contacts and a higher risk for infection [32,33]. Individuals belonging to lower social classes were slightly less likely to test for SARS-CoV-2. Hence, it is possible that a higher number of untested ARIs was misclassified as non-SARS ARI for these groups. This might explain the slightly increased risk for non-SARS ARI. Further supporting this, a sensitivity analysis, excluding all untested ARIs, showed no remaining effect of social class on the risk for non-SARS ARI, whereas all other effects remained largely unchanged (Supplementary Material 4).

Our study has several limitations. First, it includes only persons who can participate online. This restriction is also similar for GrippeWeb. However, in a previous study, we demonstrated that offering the possibility of paper-based participation did not change the estimations for many outcomes, including retrospectively reported infections [36]. Data were obtained retrospectively, introducing a possible recall bias when asking individuals to recount the number and duration of their respiratory infections in the 6 previous months. A separate analysis of variances and means of the reported days with symptoms and in bed (data not shown) revealed no distinct time trend. As reported, we did not find indications of problems in the data. Further, we demonstrated in a previous study comparing prospective and retrospective reporting of infections that short retrospective intervals can be recalled well [37]. Hence, we assume that recall time had only a minor effect on our results. Furthermore, we classified ARI according to the availability of a SARS-CoV-2 test result. However, we did not inquire whether the result was obtained via a polymerase chain reaction or a rapid antigen self-test. Especially self-testing holds a certain risk of delivering false-positive or false-negative results, also depending on the individual performing the test. Hence, misclassification of ARI episodes cannot be ruled out. However, including results from SARS-CoV-2 self-testing is also a strength of this study because it allows accounting for underreporting of less severe diseases compared with official data. Another strong point is our big sample size representing large parts of the general German population, although our results are possibly less representative for lower social classes, including less wealthy and educated individuals.

Conclusion

We estimated the excess ARIs related to SARS-CoV-2 at 21%, well in line with the difference in all ARIs between pre-pandemic years and the winter of 2022/2023. As SARS-CoV-2 is developing into a seasonal pathogen, we demonstrated the possible additional future burden on the population level. Although the risk of severe SARS-CoV-2 infections is reduced due to the achieved immunity in the population, we will likely face a higher burden of ARIs than before the pandemic, even if no new SARS-CoV-2 variants will appear. This additional burden of ARIs must be considered, particularly, with respect to the implications for the work force.

Declarations of competing interest

The authors have no competing interest to declare.

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Ethical approval

This study was approved by the ethics committee of the Martin Luther University Halle-Wittenberg (registration number 2020-076). Informed consent was obtained from all participants.

Author contributions

Sophie Diexer, Bianca Klee, Cornelia Gottschick, and Rafael Mikolajczyk developed the questionnaire. Nadine Glaser conducted the analyses, and drafted the manuscript. Oliver Purschke was responsible for data curation and validation. Mascha Binder, Thomas Frese, Matthias Girndt, Jessica Höll, Irene Moor, Jonas Rosendahl, Michael Gekle, Daniel Sedding, and Rafael Mikolajczyk developed the design of the DigiHero study. All authors provided comments on the manuscript and all authors accepted the final version.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijid.2024.107057.

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