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Risk factors for SARS-CoV-2 infection and hospitalisation in children and adolescents in Norway: a nationwide population-based study

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ABSTRACT

Objective To determine risk factors for SARS-CoV-2 infection and hospitalisation among children and adolescents.

Design Nationwide, population-based cohort study.

Setting Norway from 1 March 2020 to 30 November 2021.

Participants All Norwegian residents<18 years of age.

Main outcome measures Population-based healthcare and population registries were used to study risk factors for SARS-CoV-2 infection, including socioeconomic factors, country of origin and pre-existing chronic comorbidities. All residents were followed until age 18 years, emigration, death or end of follow-up. HRs estimated by Cox regression models were adjusted for testing frequency. Further, risk factors for admission to the hospital among the infected were investigated.

Results Of 1 219 184 residents, 82 734 (6.7%) tested positive by PCR or lateral flow tests, of whom 241 (0.29%) were admitted to a hospital. Low family income (adjusted HR (aHR) 1.26, 95% CI 1.23 to 1.30), crowded housing (1.27, 1.24 to 1.30), household size, age, non-Nordic country of origin (1.63, 1.60 to 1.66) and area of living were independent risk factors for infection. Chronic comorbidity was associated with a slightly lower risk of infection (aHR 0.90, 95% CI 0.88 to 0.93). Chronic comorbidity was associated with hospitalisation (aHR 3.46, 95% CI 2.50 to 4.80), in addition to age, whereas socioeconomic status and country of origin did not predict hospitalisation among those infected.

Conclusions Socioeconomic factors, country of origin and area of living were associated with the risk of SARS-CoV-2 infection. However, these factors did not predict hospitalisation among those infected. Chronic comorbidity was associated with higher risk of admission but slightly lower overall risk of acquiring SARS-CoV-2.

Strengths and limitations of this study

- ► Nationwide register data provided information about comorbidity, country of origin and socioeconomic status of children and adolescents with and without COVID-19 infection.
- ► Risk of infections and risk of hospitalisation could be studied separately, showing that socioeconomic status and country of origin were associated with infections whereas comorbidity was the main risk factor for hospitalisation.
- ► The number of admissions was low and did not allow for further meaningful analyses of those hospitalised.

INTRODUCTION

The risk of severe COVID-19 increases with age, as shown by the proportion of hospitalisation and death by age categories.[1] A lower prevalence of antibodies in young children demonstrated in serology studies suggests that not only the risk of severe disease but also the risk of infection is lower in the youngest age groups.[2–4]

Exposure to infected household members is the primary source of infection,[5] in addition to exposure from other contacts, including peers in day care/school and leisure activities.[6] Little is known regarding socioeconomic risk factors, such as household crowding, household size and family income, for infection in children and adolescents.[5] Country of origin has been associated with an increased risk of hospitalisation, but it is unclear whether this is related to socioeconomic factors or increased susceptibility to the virus.[7–10]

Chronic conditions that affect children may increase the risk of infection due to exposure through health and care services, particularly for children living in special care with many close adult contacts. Chronic conditions may also increase the severity of COVID-19. In a European multicentre study, 25% of those included in a predominantly hospital-based sample had underlying medical conditions.[11] Chronic conditions were associated with an increased risk of admission to an intensive care unit (ICU). In the USA, the prevalence

of complex morbidity or neuromuscular disease was high among children admitted to ICU care.[12] However, data on the baseline occurrence of these conditions in the general child population were not available, so the risk for hospitalisation associated with comorbidities could not be determined. A systematic review summarised the findings regarding comorbidities in severe COVID-19,[13] but studies tend to capture emergency hospital visits and inpatients and lack data on the vast majority who are infected without hospital encounters.

Improved knowledge of the risk factors for infection and hospitalisation is relevant for mitigation and future vaccine strategies.

In this nationwide study covering the first 21 months of the pandemic, the aim was to determine risk factors for COVID-19 in the population<18 years and to study risk factors for hospitalisation in those infected with SARS-CoV-2.

MATERIAL AND METHODS

We investigated the epidemiology of SARS-CoV-2 infections in a nationwide, population-based study. In an open cohort, inhabitants <18 years living in Norway at any time from 1 March 2020 to 30 November 2021 were included. The end of follow-up was 30 November 2021, age 18 years or death, whichever occurred first.

Norway is a sparsely populated country, which has been less affected by the pandemic than most European countries.[14] The schools and kindergartens have been open with protective measures except for 6 weeks in March/April 2020.[15] The strategy is based on testing, isolation, contact tracing and quarantine. Testing strategies have been targeting symptomatic individuals and contacts of known cases. Since September 2021, screening strategies in schools in high-endemic areas in periods of high transmission has been added to the test policy. Vaccination was offered to children with severe comorbidities from June 2021 and to 16–17 and 12–15 year olds from August and September 2021, respectively.

Individual-level data were available from the BEREDT C19 registry, developed specifically for emergency preparedness to provide knowledge on the spread of the SARS-CoV-2 virus.[16] In the registry, the unique national identification number given to all citizens on birth or immigration was used to link vital sources of information (figure 1):

- The national population registry includes information on date of birth, sex, municipality and geographical region (south-east, west, central, north).
- Statistics Norway (SSB) provides data on socioeconomic factors: household size, household crowding, family income and country of origin.
- The Norwegian Patient Registry (NPR) is an administrative database that contains data on the activity at all publicly funded hospitals and clinics, including International Classification of Diseases (ICD-10) codes. Reporting to the NPR is mandatory and forms the basis for government reimbursements to specialist health services. The list of ICD-10 codes and their groups that were relevant for this study is provided in figure 2.
- The Norwegian Registry for Primary Health Care covers claims for reimbursement from primary health service providers to the state. For this study, the International Classification for Primary Care (ICPC-2) code for asthma (R96) was used to capture milder forms of asthma not receiving specialist care. The other chronic conditions in our study were cared for at the specialist level; thus, further ICPC-2 codes were not used.
- The Norwegian Surveillance System for Communicable Diseases (MSIS) includes results of all positive and negative PCR tests and rapid antigen tests for SARS-CoV-2. The dates of testing and test results are legally required to be reported from all laboratories to the MSIS. Some negative results could be missing before 1 April 2020, but all positive results are included. Serology results were not available, except for in suspected cases of multisystem inflammatory syndrome (MIS-C).

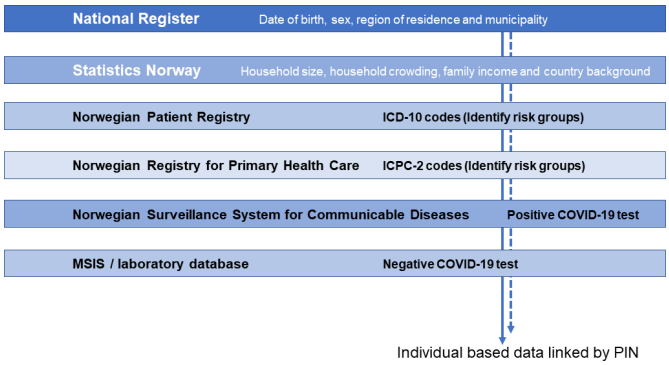

Figure 1 Flow of data and data sources for BEREDT C19. ICE-10, International Classification of Diseases; ICPC-2, International Classification for Primary Care.

Main outcomes

The main outcome was any infection by SARS-CoV-2, as confirmed by a PCR test or lateral flow (rapid test). To capture severe COVID-19, hospitalisation (admission>5 hours duration) with a primary or secondary diagnosis of COVID-19 (U07.1) and/or MIS-C (U10) was used. ICD-10 codes for admission with COVID-19 were extracted to classify the main presentation (MIS-C, respiratory, gastrointestinal, other symptoms and non-related diagnoses). We further explored the number of tests taken and the proportion of positive tests by month.

Exposures

To characterise risk factors for infection and hospitalisation, we included sex and age (at time of a positive test or at study entry) categorised into age groups (table 1). The region of living (south-east vs west/central/north) and size of the municipality (</≥50 000 residents) were further studied. Low family income was defined

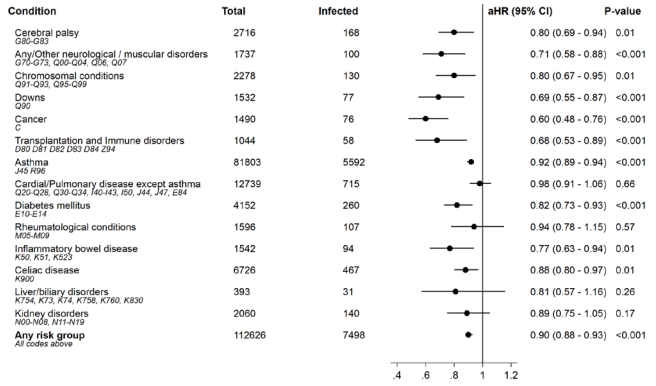

Figure 2 Pre-existing chronic condition in the population and in those infected with SARS-CoV-2 and adjusted HR for infection*. *Adjusted for age, sex, region, municipality size, household size, household crowding, low family income, testing frequency and country of origin. aHR, adjusted HR.

according to official statistics as <60% of the median income for Norway (last 3 years) for the family, weighted by the number of family members. Household crowding was defined by Statistics Norway as having fewer than one living room and<20 m^2 of living space per household member. The size of the household was categorised as shown in table 1. To study the potential impact of country of origin, we classified by the individuals', maternal/paternal and grandparents' country of birth, as described in detail at Statistics Norway.[17] Pre-existing chronic comorbidities were grouped according to diagnostic codes, as shown in figure 2.

Statistics

We performed summary statistics for categorical variables, summarising absolute numbers and percentages. Cox regression models were further used to estimate HRs for confirmed infection or hospitalisation before the end of follow-up. Cluster correction was applied using familial identification to account for dependency. Proportional hazards were assessed by log–log plots of survival. In the main analysis, we included the aforementioned sets of a priori selected covariates in multivariable models. To account for differences in testing practices and policies, the frequency of testing was adjusted for, with a maximum of one test recorded per week to account for clustered tests due to outbreak investigations.

The frequency of hospitalisation was low among those who were infected. In the analysis of hospitalisation risk, we dichotomised the country of origin and chronic comorbidities. We further explored hospitalisation for primary infection and with MIS-C separately to assess whether comorbidities were risk factors specific to these outcomes. In preplanned sensitivity analyses, we stratified our analyses for 2020 versus first and second half of 2021 because of the introduction of the alpha virus variant in January 2021 and the delta variant in July 2021 and increased test activity in 2021, which may have impacted detection rates. Analyses were further stratified by counties which had a higher spread of infection (Oslo and the surrounding county Viken) compared with the nine other counties in Norway.

Patient and public involvement

Patients were not involved in setting the research question or the outcome measures. No patients were asked to advise on interpretation or writing up of results. We will disseminate the results of the research to the general public.

RESULTS

During the observation period of 21 months, 82 734 of 1 219 184 inhabitants <18 years had a positive test for SARS-CoV-2, yielding a cumulative incidence of 67.9/1000 (table 1). The incidence increased by age category but did not differ by sex (figure 3). After adjustments, the risk of infection remained higher from age groups>5 years compared with the reference category of ≤5 years (table 1).

Of those infected, 241/82 734 (2.9/1000) were admitted to a hospital. MIS-C was recorded in 40, yielding an incidence of 0.5/1000 in those with known infection. Of the remaining 201 subjects who were hospitalised, 89 had respiratory codes, 22 had gastroenterological and 13 had respiratory/gastroenterological codes, and 30 had other symptom codes. Overall, 47 were admitted for reasons other than COVID-19. Interestingly, 13 were infected from first day of life. The median hospital stay length excluding cases with MIS-C and admissions for other reasons was 1 day and 93% were discharged within 7 days. Admission to intensive care (n=19) and death (n=2) were rare events, and these outcomes were not studied further.

Socioeconomic and demographic risk factors for infection

The incidence of infection was highest in the south-east region, and those living in municipalities with >50 000 inhabitants had a significantly higher risk compared with smaller municipalities (adjusted HR (aHR) 1.61, 95% CI 1.58 to 1.64, table 1). Living in households with more than two members compared with smaller households was associated with an increased risk and particularly increased with ≥6 in the household (aHR 1.53, 95% CI 1.47 to 1.60, table 1). Household crowding and low family income were independent and significant predictors for the risk of infection (p<0.001, table 1).

Country origin outside Nordic countries was associated with an increased risk (aHR 1.63, 95% CI 1.60 to 1.66). The risk estimates were highest for residents with family backgrounds from Africa, Asia and the Middle East/North Africa, whereas the estimates for North America/Oceania were similar as those observed for Nordic countries (table 1). Age category, region of living and municipality size, low income, household crowding and size, and country of origin were independent predictors for infection with SARS-CoV-2 in the adjusted model (table 1).

Table 1 Characteristics of Norwegian residents<18 years infected versus non-infected with SARS-CoV-2 from 1 March 2020 to 30 November 2021

	No SARS-CoV-2 recorded, n=1 136 450	SARS-CoV-2 positive, n=82 734 (6.8%)	HR (95% CI)	Adjusted HR (95% CI)*	P value
Age (years), n (%)†					
≤5	430 331 (37.9)	17 772 (21.5)	Ref.	Ref.	
6–11	354 372 (31.2)	33 012 (39.9)	2.65 (2.59 to 2.71)	1.95 (1.90 to 1.99)	<0.001
12–17	351 747 (31.0)	31 950 (38.6)	4.12 (4.03 to 4.22)	2.59 (2.52 to 2.65)	<0.001
Sex, n (%)					
Boys	583 390 (51.3)	42 178 (51.0)	Ref.	Ref.	
Girls	553 060 (48.7)	40 556 (49.0)	1.01 (1.00 to 1.03)	1.01 (1.00 to 1.02)	0.14
Geographical region, n (%)					
South-east	621 592 (54.8)	60 704 (73.4)	Ref.	Ref.	
West/central/ north	512 744 (45.2)	21 966 (26.6)	0.45 (0.44 to 0.46)	0.63 (0.62 to 0.65)	<0.001
Municipality size, n (%)‡					
<50 000	624 461 (55.0)	29 517 (35.7)	Ref.	Ref.	
≥50 000	509 875 (45.2)	53 153 (64.3)	2.15 (2.11 to 2.19)	1.61 (1.58 to 1.64)	<0.001
Household size, n (%)‡					
≤2	89 401 (8.5)	4 711 (6.0)	Ref.	Ref.	
3	228 730 (21.9)	12 080 (15.5)	0.97 (0.94 to 1.01)	1.04 (1.00 to 1.08)	0.03
4	431 561 (41.2)	31 608 (40.5)	1.31 (1.27 to 1.36)	1.14 (1.10 to 1.18)	<0.001
5	234 828 (22.4)	20 292 (26.0)	1.55 (1.49 to 1.60)	1.26 (1.21 to 1.31)	<0.001
≥6	88 310 (8.4)	11 623 (14.9)	2.35 (2.25 to 2.45)	1.53 (1.47 to 1.60)	<0.001
Overcrowded living condition‡					
n (%)	189 889 (16.7)	24 304 (29.4)	1.92 (1.88 to 1.96)	1.27 (1.24 to 1.30)	<0.001
Low family income‡					
n (%)	131 139 (11.5)	16 312 (19.7)	1.77 (1.73 to 1.82)	1.26 (1.23 to 1.30)	<0.001
Country of origin, (n, %)					
Nordic countries§	712 022 (62.7)	38 802 (46.9)	Ref.	Ref.	
Europe	150 954 (13.3)	14 682 (17.8)	1.71 (1.67 to 1.76)	1.54 (1.51 to 1.58)	<0.001
North America and Oceania	26 938 (2.4)	1 695 (2.1)	1.13 (1.07 to 1.20)	1.05 (0.99 to 1.11)	0.12
Latin America	19 970 (1.8)	1 517 (1.8)	1.35 (1.27 to 1.43)	1.21 (1.14 to 1.29)	<0.001
Middle East and North Africa	26 968 (2.4)	4 945 (6.0)	3.19 (3.06 to 3.32)	2.07 (1.99 to 2.16)	<0.001
Africa	46 729 (4.1)	7 874 (9.5)	2.93 (2.83 to 3.04)	2.22 (2.14 to 2.31)	<0.001
Asia	96 127 (8.5)	11 599 (14.0)	2.14 (2.08 to 2.20)	1.73 (1.68 to 1.78)	<0.001

*Adjusted for all covariates in the table and additionally for testing frequency.
†Age at inclusion in study. Children who died at birth and were born after 30 November 2021 were excluded. A total of 13 children who were SARS-CoV-2 positive at birth were included.
‡Missing region and municipality size n=2178, household size/low family income n=66 040, overcrowded living condition n=85 655 and country of origin n=58 362. The youngest children (born in 2020 and 2021) are predominantly missing in socioeconomic covariates and country of origin.
§Nordic countries: Norway, Sweden, Finland, Denmark, Iceland and Faroe Islands.

Chronic conditions as risk factors for infection

Of the total population, 112 626 (9.2%) had diagnoses of chronic conditions, as listed in figure 2. Overall, there was a slightly lower risk of being infected with SARS-CoV-2 in children and adolescents with chronic conditions (aHR 0.90, 95% CI 0.88 to 0.93, figure 2). None of the groups of chronic comorbidities had a significantly increased risk in unadjusted or adjusted analyses (figure 2). Notably, we found a lower risk of infection for all chronic comorbidities in the adjusted analyses, though not significant for all subgroups (figure 2).

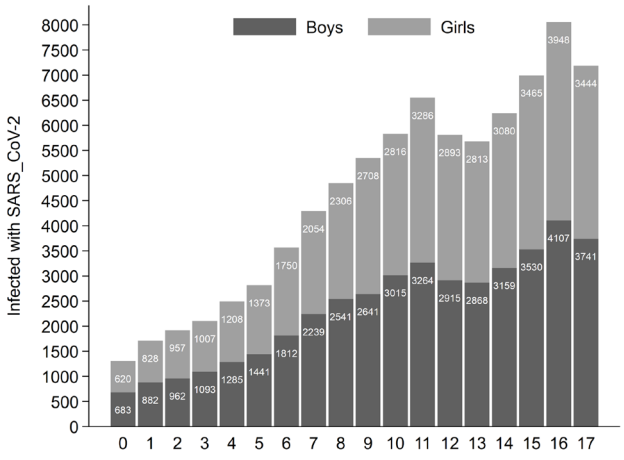

Figure 3 Age at time of positive test and sex of infected with SARS-CoV-2 (cumulative cases from 1 March 2020 to 30 November 2021).

Risk factors for hospitalisation

Among those infected with SARS-CoV-2, the risk of hospitalisation was lowest for the age group 6–11 years (table 2). Sociodemographic factors were not associated with the risk of hospital admission, with the exception of a reduced risk for those from households with ≥5 members. A non-Nordic country of origin was not a risk factor for hospitalisation among those infected (aHR 1.13, 95% CI 0.83 to 1.54, table 2). Among those admitted to a hospital, 55 of 241 (22.8%) had a chronic comorbidity, which was a strong risk factor for hospital admission (aHR 3.46, 95% CI 2.50 to 4.80). Asthma and other chronic cardiopulmonary conditions were the most prevalent, and the latter group was particularly associated with hospitalisation (table 2). When excluding those admitted with a diagnosis of MIS-C or admission unrelated to COVID-19, the risk estimates for chronic comorbidities were not substantially changed (aHR 3.67, 95% CI 2.44 to 5.52). Chronic comorbidity was also associated with increased risk of MIS-C (aHR 2.82, 95% CI 1.27 to 6.24).

Stratified analyses for risk factors for infection by time periods showed a larger difference for age categories and smaller differences for country of origin and socioeconomic factors in latter periods compared with 2020 (online supplemental table 1). Analyses stratified by geographical area did not indicate substantial differences between Oslo/Viken versus other counties (online supplemental table 2). Test activity increased throughout the period, and a total of 2.1 million tests have been registered (online supplemental file 1). The mean number of tests per individual was 1.9 for those with comorbidity versus 1.67 for those without.

DISCUSSION

The main risk factors for infection with SARS-CoV-2 among children and adolescents in the present study were socioeconomic determinants and country of origin, in addition to geographic region and municipality size. Hospitalisation for COVID-19 was very uncommon, but premorbid chronic conditions and young age were associated with increased risk. The country of origin and socioeconomic factors were not associated with the risk for hospitalisation among those infected.

Strengths and limitations of study

Among several strengths of the current study, sample size provided by the linkage of nationwide registers and avoidance of a selection bias, which is often encountered in hospital-based studies, are prominent. To the best of our knowledge, this is the first large study to determine socioeconomic characteristics and country of origin as risk factors of SARS-CoV2-infection across the range of severity in children and adolescents. The coverage of this nationwide study was high, likely capturing the majority of all infected, as suggested by seroprevalence studies indicating that the majority of cases in our country were detected by PCR.[14] However, the availability of testing was limited during the first months of the pandemic. This may have resulted in a higher proportion of undetected cases during the first period, particularly among children and adolescents.

Furthermore, the linkage to national diagnosis registers provides trustable detection of relevant chronic comorbidities. A recording of overweight/obesity was not available, and this factor has also been associated with COVID-19 severity in children and adolescents.[9 10 13] Risk factors for disease severity may be biased if chronic disease was part of the test criteria, which to some extent occurred during the early phases of the pandemic. Comorbidity and young age would likely lower the threshold for hospital admission, potentially inflating the observed associations.

Country of origin was the strongest predictor for the risk of infection. Notably, these risk estimates remained highly significant when adjusting for socioeconomic factors. This suggests that country of origin and socioeconomic status were independent factors for the distribution of SARS-CoV-2 in our population. A report from the USA showed a higher risk of infection in non-white ethnic groups, but did not account for socioeconomic factors.[18] How such factors confound associations with country of origin in societies with welfare systems that are different from the publicly funded healthcare system in Scandinavia should be studied further.

The higher rates of SARS-CoV-2 in non-Nordic groups has also been observed for adults in Norway.[19] Because family contacts are the main source of infection, a similar difference by country of origin is expected among children and adolescents. Factors related to a higher prevalence in these families are higher occupational exposure and contact with high-endemic areas by travel or visitors. Communication of the implemented strict infection control measures may not reach certain groups, and cultural differences in interpersonal contact may increase the vulnerability to infectious diseases.

Table 2 Risk for hospital admission among residents<18 years infected with SARS-CoV-2 (n=82 734)

Exposure	Hospitalised, n (%)		HR (95% CI)	Adjusted HR (95% CI)*	P value
	Yes (n=241)	No (n=82 734)			
Age category (years), (n,%)†					
≤5	126 (52.3)	17 646 (21.4)	Ref.	Ref.	
6–11	37 (15.4)	32 975 (40.0)	0.13 (0.09 to 0.19)	0.17 (0.11 to 0.26)	<0.001
12–17	78 (32.4)	31 872 (38.6)	0.23 (0.17 to 0.31)	0.35 (0.25 to 0.48)	<0.001
Sex, n (%)					
Boys	124 (51.5)	42 054 (51.0)	Ref.	Ref.	
Girls	117 (48.5)	40 439 (49.0)	0.97 (0.75 to 1.26)	1.04 (0.79 to 1.38)	0.77
Region, n (%)					
South-east	171 (71.3)	60 533 (73.4)	Ref.	Ref.	
Others	69 (28.8)	21 897 (26.5)	1.11 (0.83 to 1.48)	1.21 (0.88 to 1.65)	0.25
Municipality size, n (%)‡					
<50 000	82 (34.0)	29 435 (35.7)	Ref	Ref	
≥50 000	158 (65.6)	52 995 (64.2)	1.04 (0.79 to 1.37)	0.94 (0.70 to 1.25)	0.66
Household size, (n,%)‡					
≤2	26 (10.8)	4 685 (5.7)	Ref	Ref	
3	50 (20.)	12 030 (14.6)	0.89 (0.53 to 1.48)	0.86 (0.51 to 1.44)	0.51
4	70 (29.0)	31 538 (38.2)	0.48 (0.29 to 0.78)	0.60 (0.36 to 1.00)	0.051
5	35 (14.5)	20 257 (24.6)	0.38 (0.22 to 0.66)	0.45 (0.26 to 0.79)	0.005
≥6	29 (12.0)	11 594 (14.1)	0.56 (0.32 to 0.97)	0.54 (0.29 to 0.98)	0.04
Low family income, (n, %)‡	58 (24.1)	16 254 (19.7)	1.45 (1.06 to 1.98)	1.27 (0.90 to 1.81)	0.18
Overcrowded living conditions, (n, %)‡	71 (29.5)	24 233 (29.4)	1.22 (0.91 to 1.63)	1.24 (0.87 to 1.76)	0.23
Country background, (n, %)					
Nordic countries	84 (34.9)	38 718 (46.9)	Ref	Ref	
Non-Nordic	157 (65.1)	43 775 (53.1)	1.55 (1.19 to 2.03)	1.13 (0.83 to 1.54)	0.43
Chronic condition, (n, %)					
No	186 (77.2)	75 050 (90.7)	Ref	Ref	
Any	55 (22.8)	7 443 (9.0)	3.19 (2.35 to 4.32)	3.46 (2.50 to 4.80)	<0.001
Asthma§	25 (10.4)	5 567 (6.7)	1.69 (1.12 to 2.56)	2.02 (1.32 to 3.10)	0.001
Chronic cardiopulmonary except asthma‡	18 (7.5)	697 (0.8)	9.90 (6.12 to 16.04)	6.40 (3.76 to 10.89)	<0.001
Cerebral palsy/other neuromuscular/ Downs/other chromosomal¶	<5	166 (0.2)	4.13 (1.03 to 16.62)	4.92 (1.26 to 19.18)	0.02
Cancer, transplantation and immunodeficiencies§	7 (2.9)	124 (0.1)	20.51 (9.67 to 43.50)	24.40 (11.60 to 51.34)	<0.001
Liver/kidney disorders§	7 (2.9)	162 (0.2)	15.84 (7.47 to 33.60)	14.49 (6.45 to 32.51)	<0.001
Autoimmune disorders§¶	<5	885 (1.1)	0.78 (0.19 to 3.13)	1.20 (0.30 to 4.82)	0.80

*Adjusted for all other covariates in the table.
†Age at admission or positive test for SARS-CoV-2.
‡Missing municipality size n=1, household size, low family income and overcrowded living conditions n=31.
§These subanalyses were run separately without adjustment for other comorbidities.
¶Due to privacy guidelines, we are unable to show exact numbers in cells with fewer than five individuals.

Comparison with other studies

Country of origin was not a risk factor for hospitalisation in our study. This is important, as other studies have also raised concern for such an association in children, and this finding was in contrast to most previous studies among hospital-based cohorts of children and adolescents.[7–10] However, these studies did not provide data that separated the risk of infection from hospitalisation. The current data suggest that a skewed distribution of country of origin among hospitalised children was driven by differences in the spread of infection in society and not by susceptibility to severe disease, in line

with a recent US study on risk factors for severe COVID-19.[20] In adults, genetic susceptibility clearly influences the severity of COVID-19 infection,[21 22] which is attributed to gene variants that are differentially distributed across ethnic groups.[23] Such a genetic susceptibility remains to be proven for severe COVID-19 disease among children and adolescents.

The linkage to nationwide registers allowed us to study pre-existing comorbidities as a risk factor for infection and hospital admission. This differs from previous studies reporting whether children and adolescents who were admitted to hospital with a chronic comorbidity had an increased risk of ICU transfer or death.[7–10] Because a very low percentage of children and adolescents required admission (0.29%), our findings provide new information on risk factors for infection regardless of severity. None of the chronic comorbidities were associated with an increased risk of infection. The national policy during the pandemic was to keep schools and kindergartens open with infection control measures, and only children with severe chronic comorbidities were advised to stay home. Therefore, stricter infection control in vulnerable groups may have led to a somewhat lower risk of infection. Vaccination of adolescents with comorbidities (≥12 years age) started in March 2021 and could potentially affect our findings.

The excess risk for hospitalisation for children with any comorbidity of aHR 3.46 was in line with a large study from the CDC COVID-19-NET, including over 250 centres reporting an adjusted OR (aOR) of 3.55 (95% CI 3.14 to 4.01).[7] However, 88% in the CDC study were excluded due to missing data, which could bias the associations. Furthermore, chronic comorbidity was a risk factor for hospital admission among 454 children from Colorado (OR 2.73), of whom 15% were admitted due to symptomatic infection.[24]

Comorbidity was a risk factor for ICU admission or death among hospitalised children and adolescents in a multicentre study from the first wave in the UK, in which 42% of hospitalised children had at least one comorbidity and all who died (6/627) had a severe comorbidity.[9] Similarly, a European study and an American multisite study found increased risk for ICU admission in those with a chronic comorbidity (aOR 3.27 in both studies).[11 20] A complex comorbidity was not a significant risk factor for severity (aOR 1.51, 95% CI 0.51 to 4.42) in a US multicentre study, although four of the seven deaths occurred in such children.[10] Comorbidities were recorded in 65% of those with severe, compared with 25% of non-severe, infections in a large French hospital-based study (aOR 2.9, 95% CI 0.9 to 9.9).[25] MIS-C differed from other admissions characterised by a low occurrence of pre-existing comorbidity in the studies of hospitalised cases from the USA, the UK and France.[9 10 25] This contrasts our findings, however our study included few MIS-C cases and should be interpreted cautiously.

Asthma was the most prevalent comorbidity in our study. Children with asthma had a slightly lower risk of infection and a somewhat increased risk of hospital admission compared with children without asthma. Current asthma has been suggested to be negatively associated with the risk of hospitalisation for COVID-19 in children[26 27] and was not associated with hospitalisation in a study including both children and adults.[28] Similar to our study, other chronic cardiopulmonary conditions have been reported as risk factors for hospital admission and/or ICU transfer.[9 11 25] The current study had a limited number of hospitalised children, precluding precise estimates for less frequent comorbidities. Neurological and congenital disorders, malignancy, immunocompromised and gastrointestinal comorbidities have, to a varying extent, been associated with hospitalisation or ICU admission.[11 13 24 25]

Currently, the vaccine roll-out and discussions about whether children and adolescents should be vaccinated are ongoing. Groups of children and adolescents at risk of a severe course are important to identify, and determinants of a higher risk of infection are relevant if a targeted vaccination strategy is considered. Mitigation strategies in addition to vaccination could also focus on groups with an increased incidence of SARS-CoV-2 or severe complications. Socioeconomic disparities were recently demonstrated in Brazil[29] but should be further studied in high-income countries.

Through public health efforts, particularly with testing, contact tracing, quarantine and isolation, Norway succeeded in limiting the spread of SARS-CoV-2. A lower incidence of SARS-CoV-2 compared with most other countries may reduce the generalisability of our findings.

CONCLUSION

The results from the current study provide novel data on the socioeconomic determinants of infection. A strong association with country of origin suggests that non-pharmaceutical and pharmaceutical interventions targeted to minority groups of children and adolescents could mitigate further disease. Chronic comorbidity was associated with the risk of admission but not with the overall risk of acquiring SARS-CoV-2.

Contributors KS and GT coordinated the study, wrote the analysis plans and had the primary responsibility for writing the paper. GT and PL-DR did the statistical analysis and reviewed and commented on drafts. HLG was the guarantor, supervised the study, interpreted the data and reviewed and commented on all drafts. MG-I, PS and PKK reviewed the drafts and contributed in the interpretation of the findings.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants. An institutional review board was conducted. The Regional Ethics Committee of south-east Norway confirmed (4 June 2020, #153204) that an external ethical review board was not required for the use of BEREDT C19. The study was a nationwide register study using health-administrative data.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No additional data available.

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4 and 5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5 + 15/16
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	5
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, explain how loss to follow-up was addressed	5
		(*e*) Describe any sensitivity analyses	5
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	17
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7, 15/16 and 19
		(b) Indicate number of participants with missing data for each variable of interest	15/16, footnotes.
		(c) Summarise follow-up time (eg, average and total amount)	7
Outcome data	15*	Report numbers of outcome events or summary measures over time	7 and 15/16
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7 and 15/16/18
		(*b*) Report category boundaries when continuous variables were categorized	15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8 and Supplement
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	9-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.