Healthcare use in 700 000 children and adolescents for six months after covid-19: before and after register based cohort study

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ABSTRACT

OBJECTIVES

To explore whether and for how long use of healthcare services is increased among children and adolescents after covid-19.

DESIGN

Before and after register based study.

SETTING

General population of Norway.

PARTICIPANTS

Norwegians aged 1-19 years (n=706 885) who were tested for SARS-CoV-2 from 1 August 2020 to 1 February 2021 (n=10 279 positive, n=275 859 negative) or not tested (n=420 747) and were not admitted to hospital, by age groups 1-5, 6-15, and 16-19 years.

MAIN OUTCOME MEASURES

Monthly percentages of all cause and cause specific healthcare use in primary care (general practitioner, emergency ward) and specialist care (outpatient, inpatient) from six months before to about six months after the week of being tested for SARS-CoV-2, using a difference-in-differences approach.

RESULTS

A substantial short term relative increase in primary care use was observed for participants during the first month after a positive SARS-CoV-2 test result compared with those who tested negative (age 1-5 years: 339%, 95% confidence interval 308% to 369%; 6-15 years: 471%, 450% to 491%; 16-19 years: 401%, 380% to 422%). Use of primary care for the younger age groups was still increased at two months (1-5 years: 22%, 4% to 40%; 6-15 years: 14%, 2% to 26%) and three months (1-5 years: 26%, 7% to 46%, 6-15 years: 15%, 3% to 28%), but not for the oldest group (16-19 years: 11%, −2% to 24% and 6%, −7% to 19%, respectively). Children aged 1-5 years who tested positive also showed a minor long term (≤6 months) relative increase in primary care use (13%, −0% to 26%) that was not observed for the older age groups, compared with same aged children who tested negative. Results were similar yet the age differences less pronounced compared with untested controls. For all age groups, the increase in primary care visits was due to respiratory and general or unspecified conditions. No increased use of specialist care was observed.

CONCLUSION

Covid-19 among children and adolescents was found to have limited impact on healthcare services in Norway. Preschool aged children might take longer to recover (3-6 months) than primary or secondary school students (1-3 months), usually because of respiratory conditions.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Reports mention persistent symptoms in children and adolescents after infection with SARS-CoV-2

The duration and reasons for a potentially increased use of healthcare after covid-19 are unknown for young people of different ages

WHAT THIS STUDY ADDS

A sudden increase in primary, but not specialist, care, was observed in children and adolescents who tested positive for SARS-CoV-2, but not in those who tested negative or were not tested

1-5 year olds accessed healthcare services for longer after covid-19 than 6-19 year olds (3-6 months *v* 1-3 months)

Respiratory conditions as well as general and unspecified conditions were the main reasons for the increase in primary healthcare visits

Introduction

The content, duration, and impact of post-covid syndrome (long covid) has been described for adults in several studies. We recently showed that adults with severe covid-19 might experience symptoms for 3-6 months after initial infection with SARS-CoV-2, mainly related to respiratory and circulatory conditions.[1] These findings are in accordance with a range of other reports showing increased risk of complications after serious covid-19 among adults, implying that severe disease has a considerable impact on long term use of healthcare.[2-6] Less is known about the potential long term sequelae after mild infection.[5]

Except for the occurrence of the rare multisystem inflammatory syndrome in children (MIS-C) after initial SARS-CoV-2 infection[7] and a good prognosis in terms of disease severity and death,[8 9] far less is known about the impact of the disease on post-covid health and healthcare use among children. Existing studies are case reports and analyses of small populations (5-33 children) mostly with severe initial covid-19, with similar long term problems observed in children as in adults.[10 11] In a study of children with covid-19, more than half of 129 participants with mean age 11 years reported at least one persisting symptom 120 days after the initial infection.[11] This finding contrasts with that of two other studies, which reported persistent symptoms for at least three to four weeks after the initial infection in only 4% of 171 children of median age 3 years and 4% of 1734 children aged 5-17 years.[12 13] Neither of these studies are informative about the development and implementation of policies during the pandemic

owing to their size, narrow selection criteria, or lack of a comparison group.

Large scale, population based and prospective studies are needed to determine the magnitude, duration, and impact of long term symptoms of covid-19 among children. Little is also known about whether healthcare use among children and adolescents is increased after initial disease, and how long the increase might persist for young compared with older children. A long term increase in specialist care visits after SARS-CoV-2 infection would imply that post-covid symptoms are severe for certain age groups, whereas a short term increase restricted to primary care would imply milder symptoms. Such knowledge could be used to upscale or downscale health services. We explored the short term (0-3 months) and long term (4-6 months) effects of potentially long lasting symptoms of SARS-CoV-2 infection on the basis of healthcare use among children and adolescents aged 1-5, 6-15, and 16-19 years. Because covid-19 is usually less severe in young people, we hypothesised that healthcare use in children and adolescents would be less increased and shorter than observed among adults.[1 14]

Methods

Design and data sources

To estimate the long term impacts of testing positive for SARS-CoV-2 on healthcare use among children and adolescents we used population wide longitudinal registry data from Norway in a nationwide before and after register based cohort study. BeredtC19 is an emergency preparedness register that aims to rapidly disseminate knowledge about the pandemic, including impacts of measures to limit the spread of SARS-CoV-2 on health and use of healthcare services.[15] BeredtC19 compiles daily updated individual level data from several registers, including the Norwegian surveillance system for communicable diseases (all testing for SARS-CoV-2), the Norwegian Patient Register (electronic patient records from all hospitals in Norway), and the Norway Control and Payment of Health Reimbursement database (consultations with general practitioners and emergency primary healthcare) as well as the National Population Register (age, sex, country of birth, date of death). BeredtC19 therefore includes the dates of testing and results for polymerase chain reaction (PCR) tests for SARS-CoV-2 reported by laboratories throughout Norway to the surveillance system for communicable diseases and electronic patient records from primary care as well as hospital based outpatient and inpatient specialist care. The establishment of an emergency preparedness register forms part of the legally mandated responsibilities of the Norwegian Institute of Public Health during epidemics.

Study population

Our population included residents of Norway aged 1-19 years on 1 January 2020 and who later were tested for SARS-CoV-2 by a PCR test and had a positive or negative test result. We also included untested children and randomly assigned to them a hypothetical test date. To account for temporal changes in testing intensity, the hypothetical test date was assigned so that the fraction of untested children with a test date in each calendar week was the same as the fraction of tested children with an actual test date in the same calendar week. Because testing intensity differed by age groups over time, this assignment was done separately for age group 1-5 years (preschool age), 6-15 years (primary and lower secondary school age), and 16-19 years (upper secondary school age). Because at the beginning of the pandemic (March-July 2020) children and adolescents were not included in test criteria, they were less frequently tested. We therefore restricted our study to the period 1 August 2020 to 1 February 2021, when PCR tests were widely available and the second wave of SARS-CoV-2 infection was at its beginning in Norway. Testing criteria during our study period indicated testing for everyone with acute respiratory tract infection or other symptoms of covid-19, close contacts of people with confirmed covid-19 (as a part of contact tracing), people arriving in Norway, people being admitted to certain healthcare institutions, and anyone who suspected they had covid-19. Specific advice for children and adolescents implied they should be tested in consultation with their parents and that those with a runny nose as the only symptom (without other signs of a newly arisen respiratory tract infection) were not in need of a test. Testing was free for residents, and test capacity was sufficient from August 2020.

Because parents might be more likely to test offspring with pre-existing conditions than healthy offspring, and because many tests were performed as a routine before hospital visits, we excluded children and adolescents who received hospital based outpatient or inpatient specialist care during the test week and during the first or second week after the test week in the main analyses. For consistency we used similar exclusion criteria for the group of untested participants. In a supplementary analysis, we studied all children and adolescents with covid-19 who did or did not receive hospital based outpatient or inpatient specialist care during the test week and during the first or second week after the test week. With outcome data from 1 February 2020 to 1 May 2021, we could follow participants in the different age groups from six months before to at least three months after the test date.

Study groups

We studied all children and adolescents who were tested and not tested for SARS-CoV-2 in Norway, divided into three mutually exclusive groups:

Covid-19 group—Participants with one or more positive PCR test results (using the first available test date with a positive result) who were not admitted to hospital with covid-19 (and, in a supplementary analysis, who were admitted to hospital).

No covid-19 group—Participants with one or more negative PCR test results (first comparison group), with one of the test dates randomly chosen for participants

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with several negative test results. Participants in this group had no previous positive PCR test results. By choosing one of the test dates randomly in place of the first available test date, we could achieve a more balanced study panel in terms of observable pre-test and post-test healthcare use.

Untested group—Participants with no PCR test result, who we randomly assigned to a hypothetical test date (second comparison group). Thus, participants in this group had no previous positive or negative PCR test results.

Outcomes

We studied all cause healthcare use in primary care (patient records from the Norway Control and Payment of Health Reimbursement database) and specialist care (patient records from Norwegian Patient Register database), from six months before to around six months after the test week. The categorical outcome variable for primary care was set to 1 if the participant had visited primary care (general practitioners or emergency wards) at least once during a week (otherwise 0), and the categorical outcome variable for specialist care to 1 if the participant had received hospital based outpatient or inpatient specialist care at least once during a week (otherwise 0). Similarly, cause specific healthcare use was studied, as described in supplementary S-Table A1 (digestive; circulatory; respiratory; endocrine, metabolic, or nutritional; genitourinary; eye or ear; musculoskeletal; mental; skin; blood; and general or unspecified conditions). Observations for our selected outcomes were censored from the week we could no longer observe healthcare use.

Statistical analyses

We first explored descriptive data by age group, such as testing patterns (percentage of participants who had at least one PCR test result and percentage with a positive test result among those tested), sex, immigrant background (born in Norway or elsewhere), and comorbidities. Because we used administrative register data routinely collected when participants were in contact with health services, no observations were missing. Secondly, we studied the crude percentage of participants who used healthcare services at least once each week from six months before the test week to, on average, six months after the test week for participants who tested positive for SARS-CoV-2, participants who tested negative for SARS-CoV-2, and untested controls, by age group. Thus, we calculated the percentage of participants who used health services each calendar week and present averages over the six months before the test week and over post-test periods 1-4 weeks, 5-8 weeks, 9-12 weeks, and 13-~24 weeks. We also plotted the percentages by periods of four weeks after the test week, adjusted for potential confounders and estimated the groupwise percentages (with 95% confidence intervals calculated based on Wilson[16]) of participants who had different reasons for visits after the test week (see supplementary S-Table A1).

Finally, we used a generalised difference-in-differences approach to estimate how much larger or smaller the use of healthcare services was for participants who tested positive for SARS-CoV-2 versus those who tested negative or were not tested. These analyses evaluate the effect of an event by comparing the change in the outcome for the affected group before and after the event with the change over the same time span in a group not affected by the event.[17-19] In this study we compared the rate of healthcare use in the months before and after the PCR test for participants who tested positive (first difference) with the difference in the rate of healthcare use in the months before and after the PCR test for participants with a negative test result for SARS-CoV-2 or untested controls (second difference). The difference-in-differences estimate is the difference between these two differences, estimated using linear probability models with robust standard errors and presented as the difference in percentage points. Statistically, an interaction term (between before and after PCR tests and covid-19 group category) is used to derive the difference-in-differences estimate. By including calendar month fixed effects, this approach accounts for background trends such as seasonal variations in healthcare use.[17] The difference-in-differences estimate can be interpreted as the change in healthcare use that is related to covid-19, beyond any background calendar month trends. If no association is found between covid-19 and subsequent healthcare use, the difference-in-differences estimate would be zero.

We generalised this traditional difference-in-differences method by extending the post-test periods from one to four (1-4 weeks, 5-8 weeks, 9-12 weeks, and 13-~24 weeks), comparing with the three months before test week, and also including a separate parameter for the test week (groupings were decided based on expected and observable patterns in data). This is a standard way of allowing for time varying treatment effects,[18 19] which avoids having to impose a specific functional form on how time is modelled. This approach is implemented by including categorical variables for each of these extra periods and accompanying interaction terms. In this way, separate effects can be calculated for different post-test periods. In addition to the presentation of results as absolute differences in percentage points, we also present relative differences (in percentages) by dividing the absolute estimate (and corresponding lower and upper confidence interval bounds) for each of the post-test periods by the rate of healthcare use of the comparison group in the pre-test period (multiplied by 100).

The main advantage of the difference-in-differences approach compared with other methods for comparing groups (such as Poisson or Cox regression models) in our setting is that all information, including that in the denominator, is used and we can adjust for different levels of pre-test healthcare use by design.[18] Thus, it also adjusts for the characteristics of participants that stay constant over time, such as sex and country of birth (as could be observed here) and also unobservable

factors. Difference-in-differences models are used in two data situations, one where different individuals are studied before and after the event, and another, which is the case in the current study, where the same individuals are followed from before to after the event.[18] Although adjusting for individual characteristics that are constant over time can be important in the first type of data situation to account for changes in composition, it is less likely to affect our difference-in-differences estimates where the same individuals are followed over time (ie, an individual has the same sex in the pre-test period as in the post-test period). Composition might, however, also matter in our study as a result of censoring (ie, when a participant's healthcare use can no longer be observed). Adjusting might also improve precision.[18] We thus adjusted for several individual potential confounders: sex (male or female participants), number of comorbidities (0, 1, 2, or ≥3) based on risk conditions for severe covid-19 defined by an expert panel and as identified in data from the Norwegian Patient Register,[20] country of birth (Norway or elsewhere), and calendar month (12 categories, to account for seasonal variations in testing and healthcare use).

Models were run separately for each of the age groups 1-5 years, 6-15 years, and 16-19 years, as well as for the two outcomes of all cause healthcare use in primary care and all cause healthcare use in specialist care. We undertook four supplementary analyses. Firstly, for the outcomes that showed increased healthcare use after a positive test result for SARS-CoV-2 we repeated the analyses using cause specific outcomes (supplementary S-Table A1 and supplementary file part A). Secondly, we included all age groups in one difference-in-differences model (supplementary file part B). Thirdly, we studied the number of days of healthcare use in a week as outcome and ran a generalised linear model with a negative binomial distribution (supplementary file part C). Finally, we compared the participants who tested positive for SARS-CoV-2 who were admitted to or not admitted to hospital (supplementary file part D). In all our models we estimated 95% confidence intervals based on robust standard errors, accounting for observations for the same participant being correlated over time. All analyses were run in STATA MP v.16.

Patient and public involvement

No patients were involved in setting the research question, study design, outcome measures, or the conduct of the study. The study was based on deidentified data from Norwegian national registries.

Results

Of the about 1.3 million (n=1 288 232) Norwegian residents aged 1-19 years, 744 408 had been tested (n=307 185) or not tested (n=437 223) for SARS-CoV-2 from 1 August 2020 to 1 February 2021; 543 824 were excluded because they were tested outside the study period (supplementary S-Figure A1). A further 37 523 were excluded because they had been admitted to hospital (inpatient or outpatient) during the test week or the first or second week after the (hypothetical) test week (usually routine testing before hospital visits) (supplementary S-Figure A1). After exclusions, the main study sample comprised 706 855 participants: 10 279 (1.5%) who tested positive for SARS-CoV-2, 275 859 (39.0%) who tested negative, and 420 747 (59.5%) who were untested controls (supplementary S-Figure A1). Everyone could be observed for the first three months after the test week, 544 278 (77.0%) could be observed for the first six months, and 204 988 (29.0%) could be observed for six to nine months. The mean (standard deviation) follow-up time from the test week was 5.9 (1.6) months (range 3-9 months). Thus, some individuals will be censored during the period 4-6 months (13-~24 weeks) after the test week and some will have a longer follow-up that will be embedded in the ~24 weeks—that is, 25-36 weeks of observations.

The 328 participants who tested positive for SARS-CoV-2 and were admitted to hospital with SARS-CoV-2 were excluded from the study sample (supplementary S-Figure A1). However, they were included in a supplementary analysis comparing healthcare use of children and adolescents who tested positive and were admitted to hospital versus not admitted to hospital (supplementary file part D).

Figure 1 shows that, on average, over the study months, participants in the youngest age group (1-5 years) were tested less frequently than those in the oldest age group (16-19 years). The percentage who tested positive, however, was similar for the different age groups and increased by the same extent throughout the study period (fig 1). Because the percentage who tested positive reflects the underlying transmission in society (and impacts on all the study groups), further testing is not likely to have affected the findings.

Participants who tested positive for SARS-CoV-2 and the two comparison groups were similar for age and sex (table 1). Participants who tested negative, however, were more often born in Norway compared with untested participants (with their randomly assigned test date) and with those who tested positive (table 1), which might reflect differences in socioeconomic status between people born in Norway and those born elsewhere, as well as other factors, such as travelling and the effectiveness of test, trace, and isolate.[21] Furthermore, a larger percentage among participants being tested had two or more comorbidities (table 1).

Crude groupwise change in percentages of healthcare use following test week

In total 2.9% and 3.3% of participants aged 1-19 years with a positive SARS-CoV-2 test result used primary care in the 24-13 and 12-1 weeks before being tested, which increased to 41% in the test week before declining steadily by weeks 1-4 (16.1%), 5-8 (3.9%), 9-12 (3.9%), and 13-24 (2.9%) after test week (crude, unadjusted estimates) (table 2). Thus, by 9-12 weeks and 13-~24 weeks, the percentage of participants who used primary care after a positive test

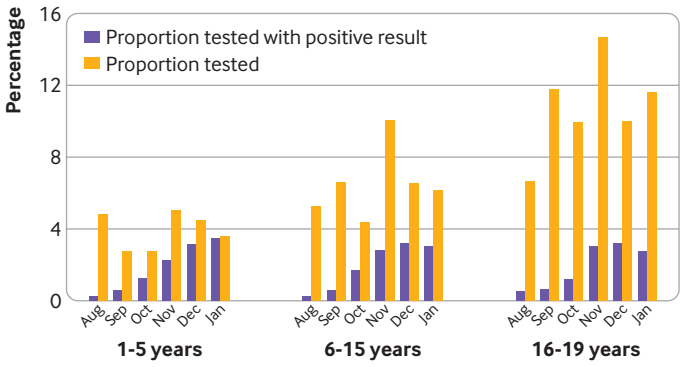

Fig 1 | Percentage of population (n=1 288 232) tested for SARS-CoV-2 using polymerase chain reaction, August to December 2020 and January 2021, and percentage testing positive each month, by age group

result had declined to similar levels to those observed before the positive test result. For children who tested negative, the increase in the test week was less steep and returned to pre-test levels more rapidly (table 2). For untested participants, use of primary care was similar from six months before to six months after the (hypothetical) test week (table 2).

No increased use of specialist care was observed among the study groups (table 2). Because only children and adolescents with mild disease after initial SARS-CoV-2 infection (not admitted to hospital (inpatient or outpatient) in test week or in one or two weeks after test week) were studied, the zero specialist consultations observed in the test week (table 2) are a result of deliberate construction of the study population.

Similar patterns—a steep rise in primary care but not specialist care use after a positive SARS-CoV-2 test result were confirmed in age specific plots (1-5, 6-15, and 16-19 years) adjusted for sex, country of birth, comorbidities, and calendar month (fig 2).

Table 1 | Characteristics of participants by age group and SARS-CoV-2 test status. Values are numbers (percentages) unless stated otherwise

Characteristics by age group	Positive SARS-CoV-2 result	Negative SARS-CoV-2 result		Not tested	
		Estimates	P value	Estimates	P value
1-5 years					
Participants*	1336	41 124		104 629	
Mean (SD) age (years)	3.2 (1.4)	3.0 (1.4)	<0.001	3.1 (1.4)	<0.001
Female participants	628 (47)	19 328 (47)	0.8	51 268 (49)	0.2
Born outside Norway	80 (6)	1234 (3)	<0.001	4185 (4)	<0.001
≥2 comorbidities	<5 (<0.37)	49 (0.12)	0.8	63 (0.06)	0.2
6-15 years					
Participants*	5414	150 685		241 055	
Mean (SD) age (years)	11.1 (2.8)	11.2 (2.8)	0.1	10.2 (2.8)	<0.001
Female participants	2653 (49)	73 836 (49)	0.5	118 117(49)	0.9
Born outside Norway	866 (16)	10 548 (7)	<0.001	21 695 (9)	<0.001
≥2 comorbidities	11 (0.24)	301 (0.21)	0.6	241 (0.1)	0.002
16-19 years					
Participants*	3529	84 050		75 063	
Mean (SD) age (years)	17.5 (1.1)	17.5 (1.1)	<0.001	17.5 (1.1)	0.02
Female participants	1694 (48)	42 866 (51)	0.009	33 028 (44)	<0.001
Born outside Norway	776 (22)	8405 (10)	<0.001	9758 (13)	<0.001
≥2 comorbidities	<5 (<0.14)	177 (0.21)	0.2	120 (0.16)	0.5

SD=standard deviation.
*Not admitted to hospital during test week or 1-2 weeks after (hypothetical) test week. Participants admitted to hospital with covid-19 were only included in supplementary analyses (supplementary file part B).

Reasons for healthcare visits after test week

Respiratory conditions were the most common reason for post-test primary care visits, particularly in the youngest participants (1-5 years) (fig 3). Participants who tested positive for SARS-CoV-2 had a high probability of visiting primary care for respiratory conditions (53% (95% confidence interval 51% to 56%) for ages 1-5 years, 47% (46% to 48%) for 6-15 years, and 57% (5% to 58%) for 16-19 years). This was 2-3 times higher than for participants who tested negative in the same age group (28% (28% to 28%) for ages 1-5 years, 12% (12% to 12%) for 6-15 years, and 17% (17% to 17%) for 16-19 years), and 5-10 times higher than in untested controls in the same age group (11% (11% to 11%) for ages 1-5 years, 4% (4% to 4%) for 6-15 years, and 4 (4% to 4%) for 16-19 years) (fig 3).

Participants who tested positive for SARS-CoV-2 had the same probability of visiting primary care for general and unspecified conditions as those who tested negative (both groups ~15%), yet a 1.5-2 times higher probability than untested controls (~8%) (fig 3, supplementary S-Tables A2-A5). For primary care visits related to other causes, participants who tested positive for SARS-CoV-2 were not, or only to a small extent, overrepresented (fig 3).

Mental disorders and general and unspecified conditions were the most common reasons for visits to specialist care, more so among the older age groups (6-15 and 16-19 years; fig 4). The probability of different cause specific visits to specialist care did not differ or showed only minor differences between the three study groups (fig 4). Supplementary S-Tables A2-A5 show the numbers and percentages with corresponding 95% confidence intervals for visits to primary and specialist care for all causes.

Short term (0-3 months) effects on healthcare use compared with participants without SARS-CoV-2

When the difference-in-differences models were applied and the within group changes over time compared statistically with each other (adjustment for confounders), a substantial short term relative increase in primary care use was observed for participants during the first 1-4 weeks after a positive SARS-CoV-2 test result compared with participants with a negative result (339% for ages 1-5 years, 471% for 6-15 years, 401% for 16-19 years; table 3). At 5-8 weeks post-test, there was still an increase in primary care use of ~14-22% for ages 1-5 years and 6-15 years who tested positive for SARS-CoV-2 compared with those who tested negative (table 3). However, at 5-8 weeks when the oldest participants who tested positive were compared with the oldest children who tested negative, the difference-in-differences estimate was not significantly different from zero (β=0.34, 95% confidence interval −0.06 to 0.75) implying no group difference in change in primary care use over time for the oldest participants (table 3).

The tendency towards younger children having a lengthier increase in healthcare use after SARS-CoV-2

Table 2 | Percentage of participants aged 1-19 years who visited primary or specialist care during study weeks according to SARS-CoV-2 status

	Pre-test weeks		Test week	Post-test weeks			
	24-13	12-1		1-4	5-8	9-12	13-~24*
Primary care							
Positive for SARS-CoV-2	2.9	3.3	41.5	16.1	3.9	3.9	2.9
Negative for SARS-CoV-2	2.8	3.1	19.1	4.1	3.4	3.4	2.9
Untested controls	1.7	1.7	1.7	1.7	1.8	1.8	1.6
Specialist care							
Positive for SARS-CoV-2	1.4	1.6	0.0	1.2	1.7	1.8	1.9
Negative for SARS-CoV-2	1.5	1.5	0.0	1.1	1.7	1.9	2.2
Untested controls	0.9	0.9	0.0	0.6	1.0	1.1	1.2

Estimates are crude (not based on models or adjusted for confounders).
*Includes observations from weeks 25-36 for some individuals (both numerator and denominator).

was observed in groupwise comparisons at 9-12 weeks after testing. Participants aged 1-5 and 6-15 years who tested positive for SARS-CoV-2 had a 26% and 15% relative increase in primary care use compared with participants of the same age who tested negative, respectively (table 3). Use of primary care at 9-12 weeks was not increased in participants aged 16-19 years who tested positive compared with those of the same age who tested negative (table 3). Similar results were observed in the age interaction model (supplementary file part B) and in the analyses using number of days of healthcare use as the outcome, as well as in the generalised linear model with negative binomial distribution (supplementary file part C). For all age groups, primary care visits for respiratory conditions, and to a smaller extent for general and unspecified conditions, showed groupwise pre-test and post-test patterns like those observed for primary care use for all causes (supplementary S-Figure A2). Participants who tested positive for SARS-CoV-2 had an increased use of primary care for respiratory conditions at four weeks after the test week, which was not observed for participants who tested negative. No group differences could be observed for primary care visits for other causes (supplementary S-Figure A2).

No short term (1-4, 5-8, or 9-12 weeks) increase in specialist care use was observed for any of the age groups with a positive SARS-CoV-2 test result compared with any of the age groups with a negative test result (table 3).

Short term (0-3 months) effects on healthcare use compared with untested controls

A similar pattern was observed when the analyses were repeated using untested controls who were assigned a hypothetical test date, although the short term differences in groupwise change were generally larger than when participants who tested negative were used as a control group (table 3, table 4). A large immediate increased use of primary healthcare was observed

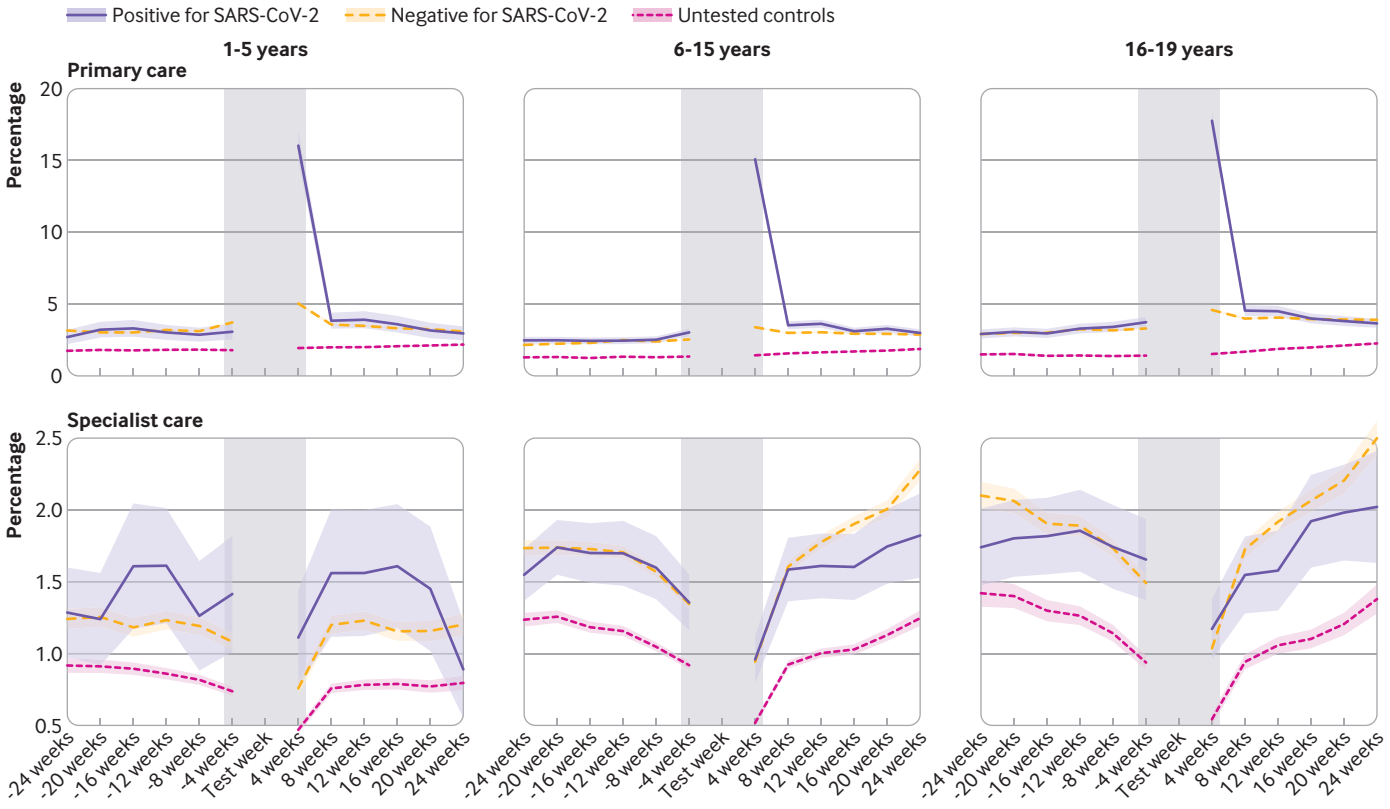

Fig 2 | Estimated percentages (95% confidence intervals) of young people using primary or specialist care (inpatient and outpatient) per week, from six months before to about six months after the week of a polymerase chain reaction test for SARS-CoV-2 for those who tested positive, tested negative, and were untested controls, by age groups. Estimates adjusted for age, sex, comorbidities, country of birth, and calendar month. The dip for specialist care around the test week is a mechanical result owing to the exclusion of participants who were admitted to hospital with covid-19 in the test week and two subsequent weeks. Estimates beyond 24 weeks include observations from weeks 25-36 for some individuals (both numerator and denominator)

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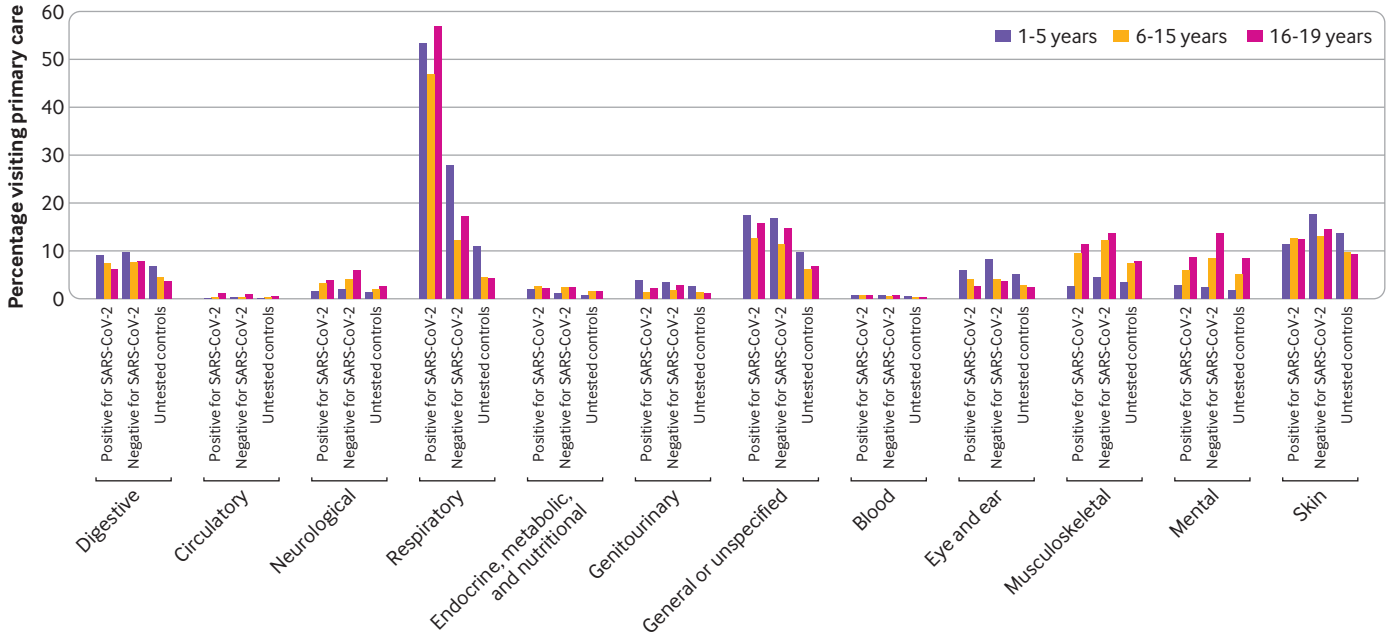

Fig 3 | Reasons for primary care visits from first week after being tested for SARS-CoV-2 for participants who tested positive, tested negative, and were untested controls with a hypothetical test week, by age group

during the first month after a positive test result for all age groups (relative increases: 615% for ages 1-5 years, 917-851% for 6-19 years; table 4). The increase was still considerable 5-8 weeks and 9-12 weeks after a positive test result—that is, participants in all age groups who tested positive showed increased use of primary healthcare compared with untested controls in the same age group (relative increase 30-43%; table 4). Similar results were observed in the age interaction model (supplementary file part B) and in the analyses using number of days of healthcare use as outcome, as well as in the generalised linear model with negative binomial distribution (supplementary file part C). Participants who tested positive for SARS-CoV-2 showed an increased use of primary care for respiratory conditions at four weeks after the test week, which was not seen for untested controls (supplementary S-Figure A2). No group differences could be observed for primary care visits for other causes (supplementary S-Figure A2).

No short term increase in use of specialist care was observed at 1-4, 5-8, or 9-12 weeks for any of the

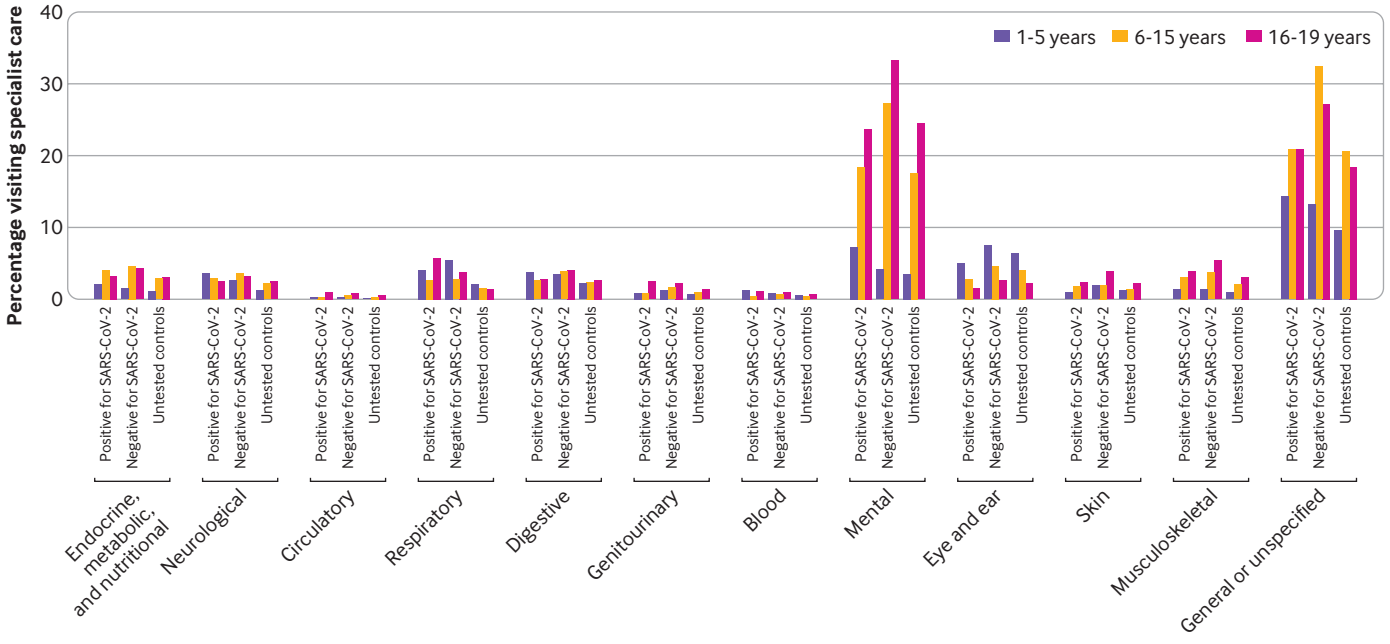

Fig 4 | Reasons for specialist care visits from first week after being tested for SARS-CoV-2 for participants who tested positive, tested negative, and were untested controls with a hypothetical test week, by age group

Table 3 | Difference-in-differences estimates (in percentage points) for change in percentage of participants using healthcare service after the week of a positive polymerase chain reaction test result for SARS-CoV-2, with participants who tested negative as comparison group

Age group and weeks after test result	Primary care		Specialist care	
	Percentage points difference in weekly rate of use: β* (95% CI)	% relative difference* (95% CI)	Percentage points difference in weekly rate of use: β* (95% CI)	% relative difference* (95% CI)
1-5 years				
1-4	11.35 (10.33 to 12.37)	339 (308 to 369)	0.12 (−0.24 to 0.49)	4 (−7 to 15)
5-8	0.74 (0.15 to 1.33)	22 (4 to 40)	0.08 (−0.35 to 0.52)	3 (−10 to 15)
9-12	0.88 (0.23 to 1.53)	26 (7 to 46)	0.08 (−0.36 to 0.51)	2 (−11 to 15)
13-24†	0.42 (−0.02 to 0.86)	13 (−0 to 26)	0.11 (−0.45 to 0.24)	−3 (−14 to 7)
6-15 years				
1-4	11.42 (10.92 to 11.92)	471 (450 to 491)	0.18 (−0.03 to 0.38)	7 (−1 to 16)
5-8	0.34 (0.04 to 0.64)	14 (2 to 26)	0.07 (−0.16 to 0.30)	3 (−6 to 13)
9-12	0.37 (0.07 to 0.67)	15 (3 to 28)	−0.12 (−0.36 to 0.12)	−5 (−15 to 5)
13-24†	0.01 (−0.20 to 0.22)	0 (−8 to 9)	−0.40 (−0.62 to −0.17)	−16 (−25 to 5)
16-19 years				
1-4	12.57 (11.91 to 13.23)	401 (380 to 422)	0.17 (−0.09 to 0.43)	6 (−3 to 14)
5-8	0.34 (−0.06 to 0.75)	11 (−2 to 24)	−0.19 (−0.46 to 0.09)	−6 (−15 to 3)
9-12	0.20 (−0.21 to 0.60)	6 (−7 to 19)	−0.41 (−0.71 to −0.10)	−13 (−23 to −3)
13-24†	−0.32 (−0.60 to −0.04)	−10 (−19 to −1)	−0.46 (−0.77 to −0.15)	−15 (−25 to −5)

All models included categorical variables for healthcare use in weeks 13-24 before test week, test week, age, sex, calendar month, country of birth, and comorbidities.
*Adjusted for confounders. Compared with rate of use during 1-12 weeks before the test for participants who tested negative.
†Includes observations for weeks 25-36 for some participants.

age groups after a positive test result for SARS-CoV-2 compared with untested controls (table 4).

Long term (4 to ~6 months) effects on healthcare use, both comparison groups

When the within group changes were compared over a longer time span, results were consistent across age and comparison groups, generally implying no long term (13-~24 weeks) effects on use of primary or specialist care. Participants aged 1-5 years who tested positive, however, still showed a relative increase in primary care use of 13% (95% confidence interval −0% to 26%) at 13 to ~24 weeks compared with participants of the same age who tested negative (table 3). No such increase was observed compared with untested children aged 1-5 years (table 4). For participants aged 6-15 and 16-19 years, no long term increase in use of primary or specialist care after a positive test result for SARS-CoV-2 was observed for any of the age groups, independent of whether the comparison group was the untested controls or participants with a confirmed negative result (table 3, table 4). When the numbers of days of healthcare use per week were counted and when a generalised linear model with negative binomial distribution was run, a similar pattern of age differences in length of increased primary healthcare use was observed (supplementary file part C). The age interaction model of participants with a positive test result versus those with a negative result showed that participants aged 16-19 years had

Table 4 | Difference-in-differences estimates (in percentage points) for change in percentage of participants using healthcare service after the week of a positive polymerase chain reaction test result for SARS-CoV-2, with untested controls as comparison group

Age group and weeks after test result	Primary care		Specialist care	
	Percentage points difference in weekly rate of use: β* (95% CI)	% relative difference* (95% CI)	Percentage points difference in weekly rate of use: β* (95% CI)	% relative difference* (95% CI)
1-5 years				
1-4	12.77 (11.76 to 13.79)	615 (566 to 664)	0.02 (−0.34 to 0.38)	2 (−45 to 50)
5-8	0.62 (0.04 to 1.21)	30 (2 to 58)	0.14 (−0.29 to 0.56)	18 (−39 to 74)
9-12	0.67 (0.03 to 1.31)	32 (1 to 63)	0.13 (−0.30 to 0.56)	17 (−40 to 73)
13-24†	−0.11 (−0.54 to 0.32)	−5 (−26 to 16)	−0.14 (−0.48 to 0.20)	−18 (−63 to 27)
6-15 years				
1-4	12.07 (11.57 to 12.56)	817 (783 to 851)	0.04 (−0.16 to 0.25)	4 (−17 to 26)
5-8	0.59 (0.28 to 0.87)	39 (19 to 59)	0.19 (−0.035 to 0.42)	20 (−4 to 45)
9-12	0.635 (0.34 to 0.93)	43 (23 to 63)	0.08 (−0.16 to 0.32)	9 (−17 to 34)
13-24†	−0.03 (−0.24 to 0.17)	−2 (−16 to 12)	−0.05 (−0.27 to 0.17)	−5 (−29 to 18)
16-19 years				
1-4	13.55 (12.89 to 14.21)	851 (810 to 893)	0.02 (−0.24 to 0.28)	2 (−21 to 25)
5-8	0.63 (0.23 to 1.03)	40 (14 to 65)	−0.05 (−0.32 to 0.22)	−4 (−29 to 20)
9-12	0.45 (0.05 to 0.85)	28 (3 to 54)	−0.19 (−0.49 to 0.11)	−17 (−44 to 10)
13-24†	−0.50 (−0.77 to −0.22)	−31 (−48 to −14)	−0.10 (−0.41 to 0.21)	−9 (−36 to 19)

All models included categorical variables for healthcare use in weeks 13-24 before test week, test week, age, sex, calendar month, country of birth, and comorbidities.
*Adjusted for confounders. Compared with rate of use during 1-12 weeks before the test for participants who tested negative.
†Includes observations for weeks 25-36 for some participants.

a statistically significantly lower use of primary care than participants aged 1-5 years during weeks 13 to ~24 weeks (β −0.75, 95% confidence interval −1.27 to −0.23, supplementary file part B). No such age differences were observed in the age interaction model that compared participants with a positive test result versus untested controls.

Discussion

In 706 885 children and adolescents who were or were not tested for SARS-CoV-2 in Norway, we found that those aged 1-19 years had symptoms severe enough to increase their use of primary, but not specialist, care after a positive test result. The length of increased primary care use depended on age. Preschool aged participants (1-5 years) showed a longer increased use of primary healthcare services (~3-6 months) than 6-19 year olds (~1-3 months).

By including all children and adolescents tested and not tested for SARS-CoV-2 in Norway, our study provides a detailed picture of the post-covid healthcare use for the different age groups. Using routinely collected registry data and applying modern regression techniques, we found that the main effect of covid-19 on healthcare use in children and adolescents aged 1-19 years is likely limited to an increased use of primary care dependent on age. The findings suggest that SARS-CoV-2 infection does not lead to severe long term health problems in children and adolescents, at least not problems that require follow-up by specialist care. These findings are important in the consideration of whether or not to vaccinate children and adolescents against SARS-CoV-2 infection and whether measures to control the virus are still required when adults have been vaccinated.

Interpretation and comparison with related studies

We found that the post-covid increase in primary care visits were of a longer duration for younger participants. More specifically, and when compared with children with a negative SARS-CoV-2 test result, the relative increase in primary care use in the youngest age group (1-5 years) at 9-12 weeks after a positive test result was four times the relative increase in primary care use in the oldest age group (16-19 years) in the same period (table 3). Also, 1-5 year olds represented the only age group with a long term (13-~24 weeks) increase in primary care use (table 3). The trend towards younger children showing a longer impact of SARS-CoV-2 infection were confirmed in our analyses using an age interaction model and count outcomes or models (supplementary file parts B and C), however, was less evident in analyses using untested children as the comparison group (table 4, supplementary file parts B and C). Our findings therefore suggest that after a positive SARS-CoV-2 test result, 1-5 year olds have an increased use of primary care for 3-6 months, 6-15 year olds for three months, and 16-19 year olds for 1-3 months. For all age groups, the increase was mainly related to respiratory symptoms (fig 3, fig 4, supplementary S-Figure A2). Because the youngest patients may experience more long lasting symptoms after other respiratory infections,[22] the prolonged increase in primary healthcare use due to respiratory conditions may be expected. However, considering previous reports that SARS-CoV-2 infection might lead to both short term and long term problems in a wide range of body systems (eg, digestive, cardiovascular, musculoskeletal) in adults,[1 14 23] the findings of limited impact on other systems than the respiratory system in children is important new knowledge, for example, for general practitioners, who will deal with most of the children with post-covid problems.

Our findings also shed new light on previous reports of post-covid problems in children. For example, a study of 129 children with mean age 11 years reported at least one persisting symptom at 120 days after covid-19.[11] Typical signs and symptoms were fatigue, muscle and joint pain, headache, insomnia, respiratory problems, and palpitations.[11] Other studies, of 171 participants of median age 3 years and 1734 aged 5-17 years, report findings that are more in line with our findings—that symptoms persist in a small proportion (4%) for at least 3-4 weeks after the initial SARS-CoV-2 infection and that the symptoms are limited to persistent cough, fatigue, headache, and anosmia.[12 13] In our study, we found that respiratory problems and other general or unspecified post-covid symptoms are likely to result in an increase in healthcare use but limited to primary care. Our findings could thus imply that because no specialist care was needed the severity of post-covid symptoms is limited in children. Thus, the findings shed important light on existing studies in other study populations and using different methodologies and raises several new research questions.

Topics for future study

Given our findings, we believe it will be important to learn more about post-covid health using more detailed diagnostic codes as well as patient reported outcome measures. More information is needed on how the respiratory conditions and general and unspecified conditions, which we found were the most common reasons for healthcare visits among children with a positive test result for SARS-CoV-2, are experienced by patients and their doctors. Also, considering the differing estimates of duration of increased primary care use among the youngest children (table 3, table 4) and that we could only observe a few individuals for more than six months after a positive result, further study might be needed to determine the exact duration of post-covid problems in the youngest age group.

Our data could not fully answer the important research question of what happens to the few children with SARS-CoV-2 who were admitted to hospital. Our supplementary study shows that such children do not access healthcare more than children with covid-19 who were not admitted to hospital (supplementary file part D). These findings should be interpreted with care, however, given that the number of participants admitted to hospital was low, and the appropriateness of the comparison group (children with a positive

SARS-CoV-2 test result not admitted to hospital can be questioned as the children might be recovered enough by discharge to not require further healthcare). Probably a more important research question in the future will be how health after covid-19 compares with that after influenza, particularly among children who are admitted to hospital. We were unable to estimate this in our study because of a zero prevalence of influenza-like illnesses in Norway during 2021.[24] Influenza viruses will, however, probably start to recirculate along the fewer public health measures taken and along the higher vaccination coverage in the adult population, enabling such a study design in the future. Finally, important topics for further study will be the post-covid health of infants (0-1 years, not included here because of excess healthcare use during birth and throughout the maternity period) as well as the identification of what characterises children who are in need of prolonged healthcare after covid-19 (eg, studying the joint effects of country of birth, socioeconomic status, and number and type of comorbidities using a prediction or classification model).

Strengths and limitations of this study

Important strengths of our study are its sample size, the inclusion of young people with a confirmed positive or negative polymerase chain test result for SARS-CoV-2, and the use of two comparison groups. Another strength is the use of routinely collected data from registers that are mandated by law and cover the entire population of Norway. Our methodological approach of studying healthcare use both before and after the week of testing for SARS-CoV-2 is also a major strength. This approach allowed us to form a detailed picture of what happens to children and adolescents after covid-19, independent of time invariant confounders. Because factors such as the underlying transmission in society, testing patterns over time, including the increased testing during our study period (see fig 1) and healthcare use, as well as public health measures will impact on all three study groups to the same extent, these factors will be adjusted for by design. Such important strengths ensure the representativeness of our study and that our findings might be used to inform actions to control SARS-CoV-2 in Norway and comparable countries. One limitation is that healthcare use cannot always be used as a proxy for a population's health or medical conditions. Rather, it may be used as a marker for healthcare seeking behaviour. Thus, symptoms could persist that are not dealt with in primary or specialist care.

Other important limitations are the methodological challenges arising because of the differences in age specific testing patterns (fig 1) and potential selection bias in the construction of comparison groups. For example, parents might decide that their 2 year old child should be tested based only on non-verbal information, whereas teenagers to a larger extent might book a test using their own initiative. Although recommendations for testing have included all people with symptoms, parents might be more likely to test their children with pre-existing conditions and younger children, rather than their healthy and older children (a negative test result was a requirement for several healthcare activities including hospital visits). These issues could result in different selection criteria for age groups in those who tested positive or negative for SARS-CoV-2. We used three measures to circumvent this selection issue of those participants at risk or in need of healthcare being tested more often. Firstly, to increase the representativeness of our study we randomly assigned the untested population—presumably a generally healthy group—to a hypothetical test date. Secondly, we excluded all children and adolescents who had an inpatient or outpatient hospital stay during the test week or the 1-2 weeks after the test week, since such people might be tested because of seeking medical treatment. Excluding these individuals ensures that the group who tested negative is more similar for pre-test and post-test healthcare use to the group who tested positive. Thirdly, we only studied children and adolescents who were tested after 1 August 2020, when testing was widely available for all population groups (not only healthcare workers and those deemed to be at risk).

The selection criteria could have led to an underestimation of the effect of covid-19 in the analyses that compared participants with a positive SARS-CoV-2 test result versus those with a negative result, because young people who require a test are more likely to be tested owing to poor pre-existing health, such that the participants who tested negative might be less healthy than the optimal comparison group. However, we may have overestimated the effect of covid-19 in the analyses that compared participants positive for SARS-CoV-2 with untested controls, because untested children and adolescents might be healthier than the optimal comparison group. The true effect of SARS-CoV-2 on post-covid healthcare use may therefore be somewhere between the estimates from the two comparison groups. We therefore believe that the measures taken to combat selection for PCR testing, and the similar findings across two different comparison groups—one possibly healthier (untested) than the one with people who tested positive for SARS-CoV-2 and one similarly healthy (negative for SARS-CoV-2), as well as across different age groups—strengthen the validity and representativeness of our findings. In that regard, our findings can be generalisable to countries with equal and free access to healthcare and PCR testing for SARS-CoV-2 for all the inhabitants. Our findings, however, will not be representative for countries that largely rely on home testing or antigen testing, as both these were almost not performed in Norway in our study period. Finally, we cannot be certain that the temporal pattern in healthcare use of children and adolescents without covid-19 or those who were untested are reasonable counterfactuals for the patterns in healthcare use of the children and adolescents with covid-19. However, the similar trends in healthcare use in the months before the test week (fig 2) accord with the common trend assumption of the difference-in-differences method.[19]

Conclusion

Covid-19 among children and adolescents has a limited impact on healthcare services. Preschool aged children might take longer to recover (~3-6 months) than primary or secondary school students (~1-3 months), usually because of respiratory conditions. The limited impact of covid-19 on the health of young people is important information in the consideration of whether children and adolescents should be vaccinated to protect themselves and others.

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Contributors: KT and KM designed the study. KDS, DTK, KT, and KM had access to all the data in the study and take full responsibility for the integrity of the data and the accuracy of the data analysis. They are the guarantors. KDS and DTK performed the statistical analyses. KM drafted the manuscript. KT, PS, KS, and MG-I critically evaluated the stages of the research process. All authors contributed to data acquisition, conceptual design, analyses, and interpretation of results, and drafting the article or critically revising it for important intellectual content. All authors gave final approval for the version to be submitted. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: The establishment of an emergency preparedness register forms part of the legally mandated responsibilities of the Norwegian Institute of Public Health during epidemics. The Ethics Committee of South-East Norway confirmed (4 June 2020, #153204) that external ethical board review was not required.

Data sharing: Data are not publicly available.

The manuscript's guarantors (KDS, DTK, KT, and KM) affirm that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Dissemination to participants and related patient and public communities: We plan to disseminate the findings to the public through the dissemination programme of the Norwegian Institute of Public Health.

Provenance and peer review: Not commissioned; externally peer reviewed.

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Supplementary information: supplementary material parts A-D