

Use of Public Transport and Contraction of SARS-CoV-2 in a Large Prospective Cohort in Norway.

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Abstract

Background: For many people public transport is the only mode of travel, and it can be challenging to keep the necessary distances in such a restricted space. The exact role of public transportation and risk of SARS-CoV-2 transmission is not known.

Methods: Participants (n=121 374) were untested adult Norwegian residents recruited through social media who in the spring of 2020 completed a baseline questionnaire on demographics and use of public transport. Incident cases (n=1069) had a positive SARS-CoV-2 polymerase chain reaction test registered at the Norwegian Messaging System for Infectious Diseases by January 27, 2021. We investigated the association between use of public transport and SARS-CoV-2 using logistic regression. Odds ratios (ORs) with 95% confidence intervals (CIs) adjusted for age, calendar time, gender, municipality, smoking, income level, fitness and underlying medical conditions were estimated. Frequency of use of public transport was reported for 2 week-periods.

Results: Before lockdown, those who tested positive on SARS-CoV-2 were more likely to have used public transport 1-3 times (OR =1.28, CI 1.09-1.51), 4-10 times (OR=1.49, CI 1.26-1.77) and ≥ 11 times (OR=1.50, CI 1.27-1.78, p for trend<0.0001) than those who had not tested positive.

Conclusion: Use of public transport was positively associated with contracting SARS-CoV-2 both before and after lockdown.

Introduction

The SARS-CoV-2 virus has affected more than 200 countries and there are 226 million confirmed cases worldwide including 4.6 million deaths¹. Respiratory viruses can be transmitted through surface, droplets and airborne transmission². Public transport is sometimes the only mode of travel for many people and constitute confined spaces where people mix for extended periods of time and contains surfaces that are frequently touched that may promote transmission of infectious diseases³. There are several studies on microbial infections in train environments⁴⁻⁷. One study reported low risk of SARS-CoV-2 transmission by fomites⁴ and other studies found an increased risk of airborne transmission during train commute⁵⁻⁷. A systematic review of 65 studies on SARS-CoV-2 cluster infections (aggregation of cases) found that public transport (buses, flights, taxis, trains) was one of the major types of SARS-CoV-2 cluster infections⁸. A case-control study of 154 SARS-CoV-2 positive and 160 negative participants, however, found no association between public transport and risk of SARS-CoV-2⁹. The exact relationship between use of public transport and risk of SARS-CoV-2 transmission is not known. In a large cohort study in Norway, we investigated the association between use of public transport and SARS-CoV-2 acquisition.

Methods

In this prospective cohort study, participants were recruited between March 28 and April 17, 2020, through social media and nationwide media coverage. Eligible study participants were volunteers not tested for SARS-CoV-2 at the time of recruitment, who were 18 years or older, had a Norwegian identification number and electronic access to the secure national digital governmental identification service. All 122 453 participants signed an electronic consent form and completed an online baseline questionnaire detailing demographics, use of public transport and other possible risk factors for SARS-CoV-2 where use of public transport was one of many other questions on risk factors. The initial lockdown period in March 2020 lasted six weeks and involved closure of kindergartens, schools, gyms, bars, restaurants and major cultural and sports events. After that, there were no additional national school closures, and the population was, largely, only advised on social distancing, with restrictions reinstated from November 5, 2020.

Exposure

Use of public transport was defined as the use of public or commercial buses, trams, ferries and/or trains. All participants were asked how many times (1-3 times, 4-10 times and 11 times or more) during a two-week period they used public transport (Appendix). At baseline (March 28, 2020), there were separate questions regarding use of public transport before and after March 12, 2020, whether participants had been standing (due to lack of seats) and if they travelled during rush hour. Norway's initial lockdown started March 12, 2020.

Outcome

The outcome was a SARS-CoV-2 positive nasopharyngeal or oropharyngeal swab test determined by real-time polymerase chain reaction in any accredited Norwegian microbiology laboratory reported through the Norwegian Messaging System for Infectious Diseases (MSIS) at a time point later than the date of the baseline questionnaire and before 28 January, 2021. In Norway, it is mandatory to report all cases of SARS-CoV-2 infections to MSIS. The proportion of new positive SARS-CoV-2 tests by day in Norway at the different time points can be found in Supplementary Figure S2.

Potential confounders

We defined potential confounders to be age (5 years categories, missing), calendar time (date of questionnaire, continuous), sex (men, women, missing), income (NOK per household and year, below 299 999, 300 000-599 999, 600 000-1 000 000, more than 1 000 000, missing), fitness (very fit, fairly fit, in bad shape, missing), smoking (never, former, current, missing), underlying medical conditions (no, yes, missing), municipality (358 different municipalities, missing).

Missings

We excluded participants with missing on use of public transport at baseline. Missing on covariates was included as a separate category in each covariate.

Bias

In the current study all participants were untested at baseline in order to avoid recall bias and self-selection bias (difference in agreement to participate) between SARS-CoV-2 positive and non-positive participants. Outcome status was obtained from accredited laboratories in order to avoid misclassification of the outcome.

Statistical analyses

Because of the small losses to follow-up and the low percentage of SARS-CoV-2 infected^{10,11}, cumulative incidence was used, and the association between use of public transport before and after the initial lockdown period and subsequent contraction of SARS-CoV-2 was investigated using logistic regression. All individuals who had not contracted SARS-CoV-2 by January 27, 2021, were included as controls. We estimated odds ratios (ORs) with 95% confidence intervals (CIs) adjusting for age, calendar time, gender, municipality, smoking, income level, fitness and underlying medical conditions. Trend test was performed by fitting ordinal values corresponding to exposure categories and testing whether the slope coefficient differed from zero. All analyses were performed using Stata (Stata Statistical Software, release 16, Stata Corp., College Station, TX) and R (version 3.6.2). A two-sided p-value of less than .05 was considered statistically significant. Sensitivity analyses were performed by employment area (health care workers vs. not) and by sex.

Results

Of the 122 453 untested volunteers, 1079 were excluded because of missing information on use of public transport (Supplementary Figure S1). The final study sample consisted of 121 374 untested participants at baseline, of which 1 069 were incident SARS-CoV-2 positive cases from March 28, 2020, to January 27, 2021.

Table 1 shows that SARS-CoV-2 positive cases were younger (Mean age (Standard deviation (SD))= 43 (13.7)) than controls (Mean age (SD)=46 (13.7), Mann Whitney test $p < 0.0001$), and participants reporting no underlying medical conditions were more likely to acquire SARS-CoV-2 than controls. There were no differences between SARS-CoV-2 positive cases and controls regarding the possible confounders sex, income, fitness or smoking. There was a clear association between use of public transport before lockdown and subsequent testing positive to SARS-CoV-2. The ORs of SARS-CoV-2 were elevated in those who used public transport 1-3 times (OR =1.28, CI 1.09-1.51), 4-10 times (OR=1.49, CI 1.26-1.77) and ≥ 11 times in 2 weeks (OR=1.50, CI 1.27-1.78, p for trend < 0.0001 , Figure 1, Supplementary Table S1). After lockdown, use of public transport was still associated with elevated ORs of SARS-CoV-2 both for use of public transport 4-10 times (OR=1.55, CI 1.21-1.99) and ≥ 11 times in 2 weeks (OR=1.77, CI 1.30-2.42, likelihood-ratio test comparing before and after lockdown $p = 0.004$). Calculations of the population attributable fraction showed that before lockdown 19% of the SARS-CoV-2 positive cases could have been avoided if no one used public transport (Supplementary Table S1). Whereas after lockdown, 7% of

the SARS-CoV-2 positive cases could have been avoided. There was no significant difference for use of public transport during rush hour before and after lockdown (likelihood-ratio $p=0.08$, Figure 1). When we stratified the analyses by sex, there was no difference in the association between use of public transport and SARS-CoV-2 (results not shown). When stratifying for health care professionals the results remained the same (Figures 2 and 3). In health care workers, there was also a higher OR of SARS-CoV-2 for use of public transport after lockdown compared to before lockdown (likelihood-ratio $p=0.005$).

Discussion

Taking a bus or a train was associated with SARS-CoV-2 acquisition both before and after establishment of lockdown measures to prevent such transmission. There was some evidence of a dose-response association between the frequency with which Norwegians travelled on public transport and SARS-CoV-2 acquisition, even after controlling for other risk factors. Furthermore, morning and afternoon congestion on public transport seem to be a risky endeavor.

This study is a large prospective cohort study on SARS-CoV-2. The majority of participants were women, were younger than 50 years old, and had a higher income. This makes the results less generalizable to men, older than 50 years with a lower income. However, when we stratified the analyses by sex, there were no large differences in the association between use of public transport and SARS-CoV-2. Many of the participants were health professionals who had very easy access to tests from the beginning of the pandemic. Stratifying the analysis into health professionals and non-health professionals, use of public transport was positively associated with contraction of SARS-CoV-2, both in health care workers and in non-health care workers. We do not know the reason why we observed slightly higher ORs among health care workers than non-health care workers both before and after lockdown, but it is possible that health care workers were more likely to take public transport. A high proportion (38%) of the participants had a high income (>1 000 000 NOK per household per year). Although we adjusted for income, we cannot preclude the possibility of residual confounding or unmeasured confounding by socioeconomic status. Although there is high computer literacy in Norway, the proportion of participants with high income was likely due to the online recruitment method. Therefore, the results may not be generalizable to the general adult population in Norway

The baseline questionnaire was administered prior to SARS-CoV-2 diagnosis. The SARS-CoV-2 positive status was obtained from the registry of infectious disease (MSIS), where the results were reported by accredited laboratories in Norway. This makes the study less prone to misclassification of the outcome. However, we cannot exclude the possibility that some individuals could have been asymptomatic, therefore never tested and misclassified, but this misclassification would probably be non-differential because the misclassification of the SARS-CoV-2 status is not related to use of public transport.

Consistent with our finding of an association between use of public transport and transmission of SARS-CoV-2, a systematic review on SARS-CoV-2 cluster infections concluded that public transport was one of the important cluster infection⁸. Similarly, studies of train passengers in China indicated that there was a

transmission risk of SARS-CoV-2 among passengers, and that the relative risk depended on the seat location and travel duration ^{12,13}. SARS-CoV-2 transmission was identified during a bus journey early in the pandemic in China ¹⁴ and another study of case reports in 320 municipalities in China identified 318 outbreaks with three or more cases and reported that all were associated with indoor environment and that transport based outbreaks were the second most frequent category ¹⁵.

One limitation of the current study is that we only asked about the use of public transport and did not take any air or surface samples of the participants. However, it is important to elucidate the routes of transmission. A review on 14 experimental studies reported a strong likelihood of airborne transmission of SARS-CoV-2 in indoor air ¹⁶. Another cross-sectional study from Iran on 28 SARS-CoV-2 air samples on subways, buses and trains concluded that vehicles were contaminated with SARS-CoV-2 ¹⁷. Further, a case study on 244 individuals in China, reported of airborne transmission on a bus trip ¹⁸.

In contrast to the current study, a study in outpatient health care facilities in Nashville, the United States, found no association between public transport and risk of SARS-CoV-2 ⁹. That study was much smaller than the current study and the controls were symptomatic, indicating exposure to others (with any infection) in both groups. Four intervention studies found that risk of viral transmission was reduced with improved ventilation on public transport ¹⁹. In Norway, people generally did not use face masks during the first part of the pandemic and were therefore potentially more exposed to SARS-CoV-2 transmission through air. However, from August 14, 2020, public health authorities recommended face masks during public transport if social distancing (1 meter) was impossible, and from November 2020 it was commonly used.

In the current study we found a relative higher OR of SARS-CoV-2 infection after lockdown compared to before lockdown. This could indicate that there was a higher transmission rate in the general population after lockdown. Explanations of this difference could be that “the before lockdown” period was shorter (two weeks before March 12) than “the after lockdown” period (the two previous weeks), and that testing was more extensive after lockdown than before lockdown. We also observed that fewer participants used public transport after lockdown compared to before lockdown which is in line with the finding in a study from Australia ²⁰ and from the UK ²¹ asking about travel activity at different time points during the pandemic.

Conclusion

The current study found that use of public transport is positively associated with contraction of SARS-CoV-2. We cautiously suggest that interventions could lessen the risk of SARS-CoV-2 on public transport.

Declarations

Ethics approval and consent to participate

The study was approved by the Norwegian ethics committee (REK 124170) and is in line with the Declaration of Helsinki as revised in 2013. All participants signed informed consent forms and were given information about their right to withdraw from the study at any time.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Competing interests

There are no conflicts of interest to declare. Age Labs had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication.

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Authors' contributions

Arne Søråas designed the study. Karl Trygve Kalleberg, Mette Istre, Eyrún F. Kjetland and Arne Søråas collected the data. Merete Ellingjord-Dale did the statistical analyses and Merete Ellingjord-Dale and Arne Søråas drafted the manuscript. Karl Trygve Kalleberg, Mette Istre, Anders B. Nygaard, Sonja H. Brunvoll, Linn M. Eggesbø, John Arne Dahl, Eyrún F. Kjetland and Giske Ursin critically reviewed the manuscript for important intellectual contents. All authors read and approved the final manuscript.

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All statistical analyses were run in Services for Sensitive Data (TSD) which is a platform for collecting, storing and analyzing sensitive data in accordance with the Norwegian confidentiality regulations. SARS-CoV-2 positivity results were obtained from the Messaging System for Infectious Diseases which is a central health register that monitors infectious diseases in Norwegian population.

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Tables

Table 1. Descriptive statistics (N /%) on covariates in SARS CoV-2 positive cases (n=1069) and non-positive SARS CoV-2 participants (n=120 305) ^a.

Variable	SARS-CoV-2 positive cases		Non-positive SARS-CoV-2	
	Mean	SD	Mean	SD
Age (years)	43	13.7	46	13.7
	n	%	n	%
P-value ^b	<0.0001			
18-25	129	12	6151	5
26-30	117	11	10237	8
31-35	116	11	13313	11
36-40	114	11	13989	12
41-45	123	12	14728	12
46-50	130	12	15595	13
51-55	126	12	14168	12
56-60	101	9	10712	9
61-65	54	5	9076	8
66-70	26	2	6722	6
>70	30	3	5300	4
Missing	3	0	314	0
Calendar time (date)	31.03.2020	9.5	01.04.2020	12.5
	n	%	n	%
Sex				
men	318	30	36460	30
women	749	70	83552	70
Missing	2	0.2	293	0.2
P-value ^c	0.86			
Income (NOK per household and year)				
Below 299 999	47	4	4058	3
300 000-599 999	165	15	19969	17

600 000-1000 000	272	26	31305	26
More than 1000 000	401	38	44251	37
Missing	184	17	20722	17
P-value ^c	0.35			
Fitness				
Very fit	390	36	39709	33
Fairly fit	599	56	69641	58
In bad shape	80	8	10864	9
Missing	0	0	91	0
P-value ^c	0.04			
Smoking				
Never	577	54	63044	52
Former	406	38	45549	38
Current	61	6	9111	8
Missing	25	2	2602	2
P-value ^c	0.14			
Underlying medical conditions ^d				
No	626	59	63425	53
Yes	283	26	36792	30
Missing	160	15	20088	17
P-value ^c	0.001			

^a The statistical analyses were also adjusted for municipality (358 different municipalities).

^b Mann-Whitney test comparing equality of medians.

^c Chi-squared test.

^d Chronic heart disease, high blood pressure, chronic lung disease (not asthma), asthma, diabetes, receiving immunodeficiency treatment, cancer (under treatment).

Figures

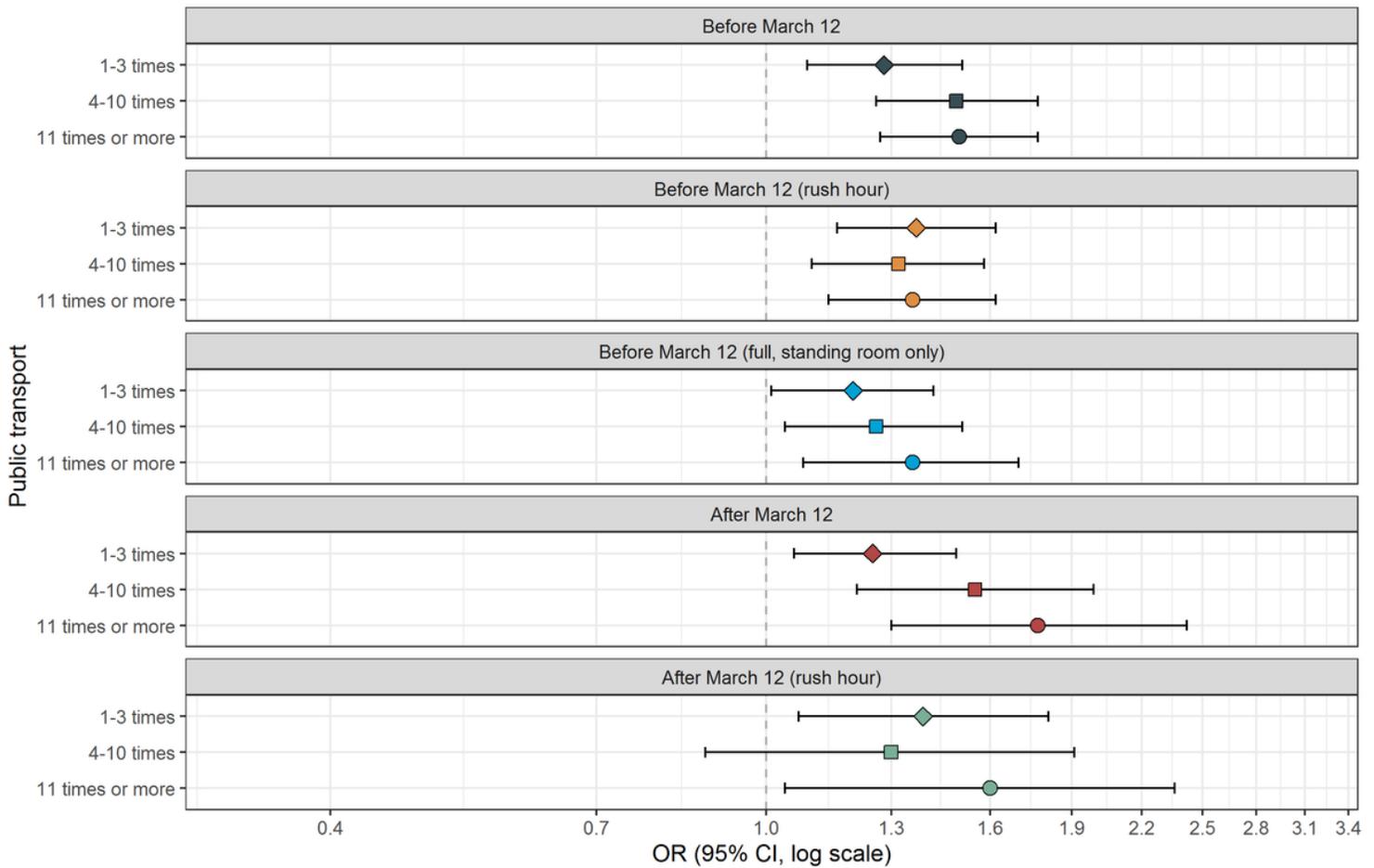


Figure 1

Adjusted odds ratios (OR) and 95% confidence intervals (CI) for the association between use of public transport and risk of SARS-CoV-2 a. a Adjusted for age (5-years categories, missing), calendar time (continuous) gender (men/women, missing) smoking (never, ever, missing), municipality (358 different, missing) income level per household (< 299 999, 300 000-599 999, 600 000-1000 000, >1000 000 NOK, missing) fitness (very fit, fairly fit, in bad shape, missing), underlying medical condition (no, yes, missing). Likelihood ratio test comparing a model with use of public transport before lockdown with a model with use of public transport after lockdown p=0.004.

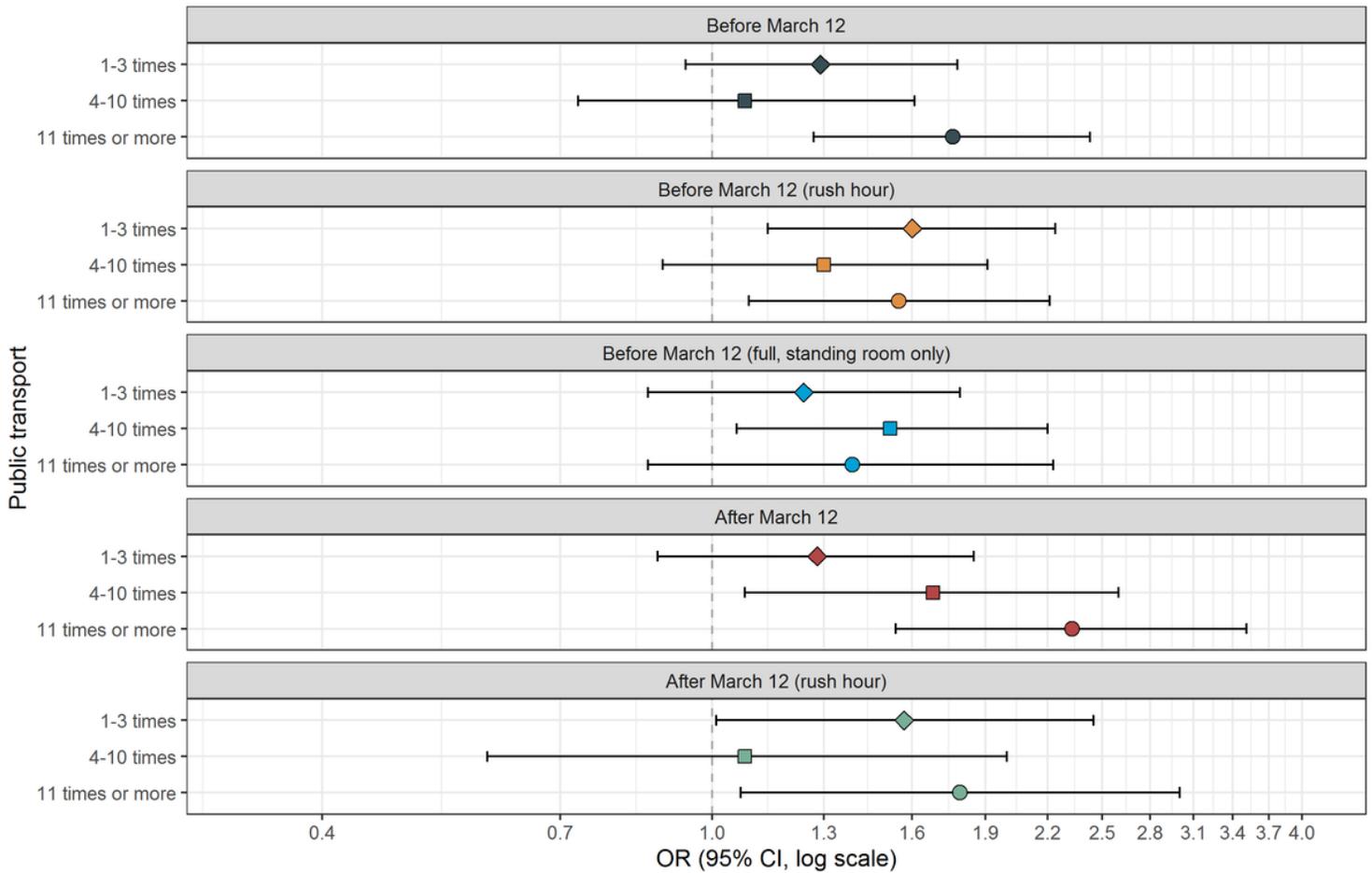


Figure 2

Adjusted odds ratios (OR) and 95% confidence intervals (CI) for the association between use of public transport and risk of SARS-CoV-2 among health care workers (n=22 037) a. a Adjusted for age (5-years categories, missing), calendar time (continuous) gender (men/women, missing) smoking (never, ever, missing), municipality (358 different, missing) income level per household (< 299 999, 300 000-599 999, 600 000-1000 000, >1000 000 NOK, missing) fitness (very fit, fairly fit, in bad shape, missing), underlying medical condition (no, yes, missing). Likelihood ratio test comparing a model with use of public transport before lockdown with a model with use of public transport before and after lockdown p=0.005.

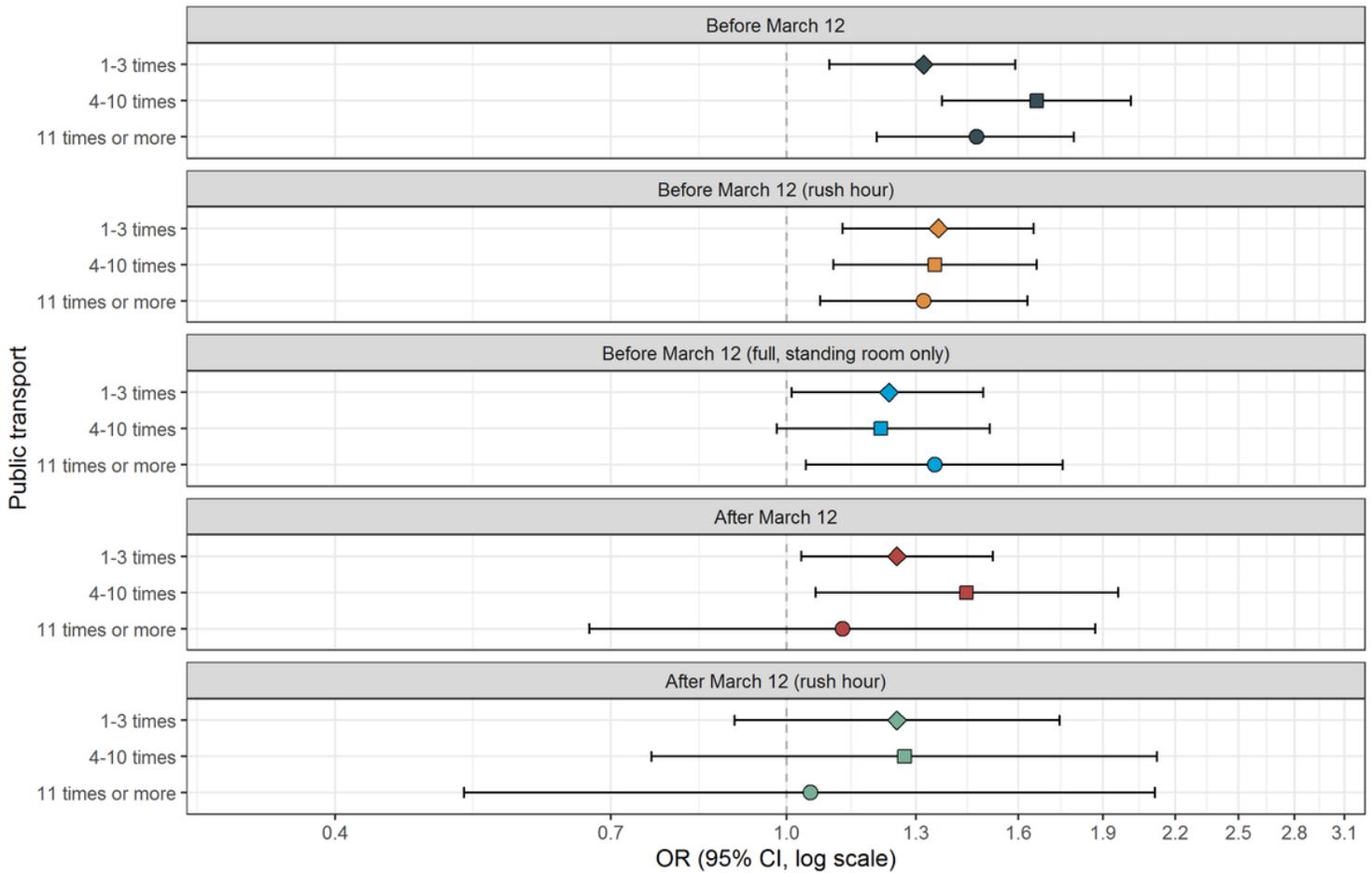


Figure 3

Adjusted odds ratios (OR) and 95% confidence intervals (CI) for the association between use of public transport and risk of SARS-CoV-2 among non-health care workers (n=97 962) a. a Adjusted for age (5-years categories, missing), calendar time (continuous) gender (men/women, missing) smoking (never, ever, missing), municipality (358 different, missing) income level per household (< 299 999, 300 000-599 999, 600 000-1000 000, >1000 000 NOK, missing) fitness (very fit, fairly fit, in bad shape, missing), underlying medical condition (no, yes, missing).

Supplementary Files

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