Respiratory Virus Shedding in Exhaled Breath and Efficacy of Face Masks

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Research Article

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Abstract

There are few studies describing the presence of respiratory viruses in respiratory droplets and aerosols in the exhaled breath of infected persons, and the efficacy of facemasks as a source control to prevent respiratory virus transmission. Here, we recruited children and adults with acute respiratory illness and collected respiratory droplets and aerosols, with and without surgical facemasks. We identified human coronaviruses, influenza virus and rhinovirus from both respiratory droplets and aerosols. Surgical face masks reduced detection of coronavirus RNA in both respiratory droplets and aerosols, but only respiratory droplets and not aerosols for influenza virus RNA. Our results provide mechanistic evidence that surgical facemasks could prevent transmission of human coronavirus and influenza virus infections if worn by symptomatic individuals.

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Introduction

Respiratory viruses are responsible for hundreds of thousands of infections (and the concomitant economic losses through sick leave, doctor consultations) as well as thousands of hospitalizations and deaths every year[1,2]. These viruses often result in a broad and overlapping spectrum of symptoms collectively referred to as acute respiratory virus infections (ARIs), or more commonly the “common cold”, which although mostly mild sometimes these ARIs can cause severe disease and death[3,4]. Among all ARIs, the greatest morbidity and mortality impact is thought to accrue from respiratory syncytial virus (RSV) infections in infants, and influenza virus infections in all ages, but there is also a considerable morbidity burden of other common respiratory virus infections[5,6] such as coronaviruses and rhinoviruses. Moreover, newly emerging respiratory viruses may have epidemic or pandemic potential with varying degree of severity, as exemplified by the Severe Acute Respiratory Syndrome epidemic in 2003 and the recent emergence[7] and global spread of the disease called COVID–19 by the virus named SARS-CoV–2.

Possible modes of respiratory virus transmission include contact, respiratory droplets (including larger droplets that fall rapidly near the source as well as coarse aerosols with aerodynamic diameter >5μm) and fine particle aerosols (droplets and droplet nuclei with aerodynamic diameter ≤5μm)[8,9]. Although hand hygiene and use of face masks, primarily targeting contact and respiratory droplet transmission, have been suggested as important mitigation strategies against influenza virus transmission[10], little is known about the relative importance of these modes in the transmission of other common respiratory viruses[8,9,11]. Uncertainties similarly apply to the transmission of SARS-CoV–2, where understanding on the relative importance of different modes of transmission of SARS-CoV–2, especially of the importance of the droplet and aerosol modes of transmission, is urgently needed for effective and timely control of COVID–19[12].

The use of surgical face masks is often suggested as one of the personal non-pharmaceutical interventions to reduce respiratory disease transmission in healthcare settings as well as in the

community[10,13]. Surgical face masks were originally introduced to protect participants from wound infection and contamination from surgeons (the wearer) during surgical procedures, and were later adopted to protect healthcare workers against acquiring infection from their patients[14]. Most of the existing evidence on the filtering efficacy of face masks and respirators as come from in vitro experiments with non-biological particles[15–17] or experimentally generated viruses[18] which may not be generalizable to infectious respiratory virus droplets. There is very little information on the efficacy of face masks in filtering respiratory viruses and reducing viral release from an individual with respiratory infections[13,19], with much of the research focusing on influenza[20,21].

In the present study we aimed to explore the importance of respiratory droplet and aerosol routes of transmission with a particular focus on coronaviruses, influenza viruses and rhinoviruses, by quantifying the amount of respiratory viruses in exhaled breath of participants with medically attended acute respiratory illnesses and determining the potential efficacy of surgical face masks to prevent respiratory virus transmission.

Methods

Study design

Participants were recruited year-round from March 2013 through March 2016 in a general outpatient clinic of a private hospital in Hong Kong. Participants attending the clinic were screened regardless of the purpose for the visit and those who reported ≥2 signs/symptoms of an ARI, within 3 days of illness onset and ≥11 years of age were eligible to participate. Individuals unable to provide informed consent (or parental consent for those 11–17 years of age) were ineligible. After explaining the study and obtaining informed consent, a rapid influenza diagnostic test, the Sofia Influenza A+B Fluorescent Immunoassay Analyzer (Cat #20218, Quidel, San Diego, CA), was used to identify influenza A or B virus infection as an incentive to participate. In the first phase of the study from March 2013 to February 2014 (‘Influenza Study’), the result of the rapid test was used to determine eligibility for further participation in the study and exhaled breath collection; while in the second phase of the study from March 2014 to March 2016 (‘Respiratory Virus Study’), the rapid test did not affect eligibility. All participants provided a nasal swab for the rapid test, and an additional nasal swab and a separate throat swab for subsequent virologic confirmation at the laboratory. Eligible participants also completed a questionnaire to record basic information including age, sex, symptom severity, medication, medical conditions and smoking history. Eligible participants were then invited to provide an exhaled breath sample collected by a bioaerosol collecting device, the Gesundheit-II (G-II), for 30 minutes in the same clinic visit.

Prior to the exhaled breath collection, each participant was randomly allocated in a 1:1 ratio to either wearing a surgical face mask (Cat #62356, Kimberly-Clark, Roswell, Georgia) or not during the collection. To mimic the real-life situation, under the observation by the study staff participants were asked to attach the surgical mask themselves, but instruction on how to wear the mask properly was given when the participant wore the mask incorrectly. Participants were instructed to breathe as normal during the

collection, but (natural) coughing was allowed and the number of coughs was recorded by study staff. Participants were then invited to provide a second exhaled breath sample of the alternate type (e.g. if the participant was first assigned to wearing a mask he/she would then provide a second sample without a mask), but most participants did not agree to stay for a second measurement because of time constraints. Participants were compensated for each 30-minute exhaled breath collection with a supermarket coupon worth approximately US$30 and all participants were gifted a tympanic thermometer worth approximately US$20.

Ethical approval

Written informed consent was obtained from all participants ≥18 years of age, and written informed consent was obtained from parents or legal guardians of participants 11–17 years of age in addition to their own written informed consent. The study protocol was approved by the Institutional Review Board of The University of Hong Kong and the Clinical and Research Ethics Committee of Hong Kong Baptist Hospital.

Collection of swabs and exhaled breath particles

Nasal swabs and throat swabs were collected separately, placed in virus transport medium (VTM), stored and transported to the laboratory at 2–8C, and the VTM were aliquoted and stored at −70C until further analysis. Exhaled breath particles were captured and differentiated into two size fractions, the coarse fraction containing particles with aerodynamic diameter >5μm (referred to here as 'respiratory droplets') included droplets up to approximately 100 μm in diameter) and the fine fraction with particles ≤5μm (referred to here as 'aerosols') by the "G-II" bioaerosol collecting device[21–23]. In the G-II device, exhaled breath coarse particles >5μm were collected by a 5.0μm slit inertial Teflon impactor, and the remaining fine particles ≤5μm were condensed and collected into about 170ml of 0.1%BSA/PBS. Both the impactor and the condensate were stored and transported to the laboratory at 2–8C. The virus on the impactor was recovered into 1ml, and the condensate was concentrated into 2ml of 0.1% BSA/PBS, aliquoted and stored at −70C until further analysis. In a validation study, the G-II was able to recover over 85% of fine particles >0.05μm in size, and had comparable collection efficiency of influenza virus as the SKC BioSampler[22].

data-xsweet-outline-level="1">Laboratory testing

Nasal swab samples were first tested by a diagnostic-use viral panel, xTAG Respiratory Viral Panel (Abbott Molecular, Illinois, USA), to detect qualitatively twelve common respiratory viruses and subtypes including coronaviruses (NL63, OC43, 229E and HKU1), influenza A (non-specific, H1 and H3) and B viruses, respiratory syncytial virus (RSV), parainfluenza virus (types 1–4), adenovirus, human metapneumovirus, and enterovirus/rhinovirus. After one or more of the candidate respiratory viruses was

detected by the Viral Panel from the nasal swab, all the samples from the same participant, i.e. the nasal swab, throat swab, the respiratory droplets and aerosols, were then tested with reverse transcriptase real-time polymerase chain reaction (RT-PCR) specific to the candidate virus(s) for determination of virus concentration in the samples. Infectious influenza virus was identified by viral culture using MDCK cells as described previously[24], while viral culture was not done for coronavirus and rhinovirus.

Statistical analyses

The primary outcome of the study was the virus generation rate in the tidal breathing of participants infected by different respiratory viruses, and the efficacy of face mask in preventing virus dissemination in exhaled breath, separately considering the respiratory droplets and aerosols. The secondary outcomes were the correlation between viral shedding in nose swabs, throat swabs, respiratory droplets and aerosols, and factors affecting viral shedding in respiratory droplets and aerosols.

We identified three groups of respiratory viruses with highest frequency of infection as identified by RT-PCR, namely coronavirus (including NL63, OC43, HKU1 and 229E), influenza virus, and rhinovirus, for further statistical analyses. We defined viral shedding as $\log_{10}$ virus copies per sample, and plotted viral shedding in each sample, i.e. the nasal swab, throat swab, respiratory droplets and aerosols, the latter two stratified by the mask intervention. As a proxy for the efficacy of face masks in preventing transmission of respiratory viruses via the respiratory droplet and aerosol routes, we compared the number of respiratory droplet and aerosol samples containing detectable viral shedding between participants wearing face mask or not, and tested for significant differences by Fisher's exact tests and by comparing viral shedding by Tobit regression. We used univariate Tobit regression to investigate factors affecting viral shedding in respiratory droplets and aerosols without mask use, for example age, days since symptom onset, prior influenza vaccination, current medication and number of coughs during exhaled breath collection. We investigated the correlations between viral shedding in nasal swab, throat swab, respiratory droplets and aerosols with scatterplots and calculated the Spearman's rank correlation coefficient between any two types of samples. We imputed 0.3 $\log_{10}$ virus copies/ml for the undetectable values before transformation to virus copies per sample. All analyses were conducted with R version 3.6.0[25] and the *VGAM* package[26].

Results

Between March 2013 and February 2014, we screened 1,374 participants, 416 (30%) participants were eligible, 188 (45%) were tested for influenza by the Sofia rapid test, and 37 (20%) were test positive for influenza by the Sofia rapid test and agreed to provide exhaled breath samples. One additional participant in that study tested negative on the rapid test but also proceeded for exhaled breath collection. Between March 2014 to March 2016, we screened 1,989 participants, 769 (39%) participants were eligible and 208 (27%) participants were recruited and provided exhaled breath samples (Supplementary Figure 1). Together from these 246 participants, 122 (50%) participants were randomized

to not wearing a face mask during the first exhaled breath collection and 124 (50%) participants randomized to wearing a face mask. 49 (20%) voluntarily provided a second exhaled breath collection of the alternate type. Therefore, we analyzed data from 147 sets of without-mask and 148 sets of with-mask exhaled breath samples from 246 participants.

Across the whole study period, infections by at least one respiratory virus were confirmed by RT-PCR in any samples from 123/246 (50%) participants, among whom without-mask exhaled breath samples were collected from 75 participants and with-mask exhaled breath samples from 77 participants, including 29 participants who provided samples both with and without a mask. Of the 123 participants with a detected virus, 111 (90%) were infected by one of coronavirus, influenza virus, or rhinovirus, while the remaining were by human metapneumovirus, parainfluenza virus, respiratory syncytial virus and adenovirus where only a small number of each of those infections was identified (Supplementary Figure 1, Supplementary Figure 2). Therefore, further analyses were performed only for participants with either coronavirus, influenza virus or rhinovirus infection.

Rhinovirus infections were detected with the highest frequency with 54 participants, followed by 43 participants infected with influenza virus, and 17 participants with coronavirus (including 8 with NL63, 1 with 229E, 5 with OC43 and 4 with HKU1, of which one was a co-infection of OC43 and HKU1). There were some differences in characteristics of participants with the different viruses (Table 1). Overall, most participants were younger adults and 5% were age 11–17 years, but there were more children with influenza virus and no children in the subgroup with coronavirus infection. Overall, 59% were female, but there were more females among the subgroup with coronavirus infection. The majority of participants did not have underlying medical conditions and overall 9% had received influenza vaccination for the current season but only 2% among those with influenza virus infection. The majority of participants were sampled within 24–48 or 48–72 hours of illness onset. 24% of participants had a measured fever ≥37.8ºC, with influenza patients more than twice as likely than coronavirus and rhinovirus-infected patients to have a measured fever. Coronavirus-infected participants coughed the most with an average of 17 (SD 30) coughs during the 30-minute exhaled breath collection. The profile of the participants randomized to with-mask vs without-mask groups were similar (Supplementary Table 1).

We tested viral shedding (in terms of viral copies per sample) in the nasal swabs, the throat swabs, the respiratory droplet samples, and the aerosol samples, and compared the latter two between the samples collected with or without a face mask (Figure 1). On average the (log) viral shedding were higher in the nasal swabs than the throat swabs for each of coronavirus (median 8.1 vs. 3.9), influenza virus (6.7 vs. 4.0) and rhinovirus (6.8 vs. 3.3) respectively. Viral RNA was identified from both respiratory droplets and aerosols for all three viruses, including 30%, 26% and 28% of the respiratory droplets, and 40%, 35% and 56% of the aerosols collected while not wearing a face mask, from coronavirus, influenza virus and rhinovirus-infected participants respectively (Table 2). In particular for coronavirus, we identified OC43 and HKU1 from both respiratory droplets and aerosols, but only identified NL63 from aerosols but not from respiratory droplets (Supplementary Table 2, Supplementary Figure 3).

In terms of the efficacy of face masks in reducing viral dissemination, for coronavirus, we detected virus in respiratory droplets and aerosols in 3/10 (30%) and 4/10 (40%) of the samples collected without face masks, respectively, but did not detect any virus in respiratory droplets or aerosols either collected from participants wearing face masks, this difference being significant in aerosols (Table 2). For influenza virus, we detected virus in 6/23 (26%) and 8/23 (35%) of the respiratory droplet and aerosol samples collected without face masks, respectively. There was a significant reduction by wearing face masks to 1/27 (4%) in detection of influenza virus in respiratory droplets, but no significant reduction in detection in aerosols (Table 2). Moreover, among the 8 participants who had influenza virus detected by RT-PCR from without-mask aerosols, 5 were tested by viral culture with 4 culture positive; while among the 6 participants who had influenza virus detected by RT-PCR from with-mask aerosols, 4 were tested by viral culture with 2 culture positive. For rhinovirus, there were no significant differences between detection of virus with or without face masks, both in respiratory droplets and in aerosols (Table 2). Conclusions were similar in comparisons of viral shedding (Table 2). In addition, we found a significant reduction in viral shedding (Supplementary Table 2) in respiratory droplets for OC43 (Supplementary Figure 4) and influenza B virus (Supplementary Figure 5), and in aerosols for NL63 (Supplementary Figure 4).

In coronavirus-infected participants, moderate positive correlations were observed between throat swabs and respiratory droplets (r = 0.69) and aerosols (r = 0.66), but weak correlation between respiratory droplets and aerosols (r = 0.19) (Supplementary Figure 6). For influenza virus, there were in general moderate positive correlations between different samples and in particular high positive correlation between respiratory droplets and aerosols (r = 0.91) Supplementary Figure 7). For rhinovirus, there were in general very weak correlations between viral loads in the various sample types (Supplementary Figure 8).

We plotted viral shedding data by time since illness onset, identifying declines in viral loads in nasal and throat swabs with time for influenza virus but not for coronavirus or rhinovirus (Figure 2). In univariable analyses of factors associated with detection of respiratory viruses in various sample types, we did not identify significant association in viral shedding with days since symptom onset (Supplementary Table 3) for respiratory droplets or aerosols (Supplementary Tables 4–6). We identified slight increases in shedding in respiratory droplets for coronavirus and influenza virus, and in aerosols for influenza virus only, when participants coughed more during the exhaled breath collection (Supplementary Tables 4–6).

A subset of participants (72/246, 29%) did not cough at all during at least one exhaled breath collection, including 37/147 (25%) during the without-mask and 42/148 (28%) during the with-mask breath collection. In this subset for coronavirus (n = 4), we did not detect any virus in respiratory droplets or aerosols from any participants. In the subset for influenza virus (n = 9), we detected virus in aerosols but not respiratory droplets from one participant. For rhinovirus (n = 17), we detected virus in respiratory droplets from 3 participants, and we detected virus in aerosols in 5 participants.

Discussion

We identified coronavirus, influenza virus, and rhinovirus RNA in the respiratory droplets and in particular aerosols from ARI patients recruited from an outpatient clinic, therefore indicate that aerosol transmission is a potential mode of transmission for coronaviruses as well as influenza viruses. Published studies have demonstrated the detection of respiratory viruses[27–29] such as influenza[21,23] and rhinovirus[30] from exhaled breath, and the detection of SARS-CoV and MERS-CoV from air samples (without size fractionation) collected from hospitals treating SARS[31] and MERS[32] patients, but ours is the first to demonstrate detection of coronaviruses in human exhaled breath, including the detection of OC43 and HKU1 from respiratory droplets, and NL63, OC43 and HKU1 from aerosols. Whether SARS-CoV–2 (which belongs to the same genus betacoronavirus as OC43, HKU1, MERS-CoV and SARS-CoV[33]) can transmit via aerosols remains to be determined. An important point to note is that detection of virus in aerosols in exhaled breaths or coughs is necessary but not sufficient to confirm that aerosol transmission occurs. The stronger correlations observed between throat swabs and respiratory droplets for coronavirus-infected participants may indicate viral load based on throat swabs would be a better indicator of transmission potential for respiratory droplet transmission of coronaviruses.

Surgical masks are one of the non-pharmaceutical measures considered for use in influenza epidemics and pandemics, with masks being used both as a measure of source control in ill persons and to prevent against infection[10]. Our findings indicate that surgical masks can efficaciously reduce the emission of influenza virus particles into the environment in respiratory droplets, but not in aerosols. This is consistent with the previous study by Milton et al. in which surgical masks reduced viral copies by 25 fold in respiratory droplets but only 2.8 fold in aerosols[21]. Here, we also demonstrated the efficacy of surgical masks to reduce coronavirus detection and viral copies in large respiratory droplets and in aerosols (Table 2). This has important implications for control of COVID–19, suggesting that surgical face masks could be used by ill persons to reduce onwards transmission of SARS-CoV–2. In addition, because of the concern over infectiousness in the absence of symptoms (i.e. pre-symptomatic transmission and asymptomatic transmission), our results indicate that universal wearing of face masks might further reduce transmission in the general community by preventing onwards transmission from asymptomatic infections. However, our study only included symptomatic individuals and common coronaviruses RNA was not identified from respiratory droplets or aerosols of the small number of infected individuals who did not cough, suggesting that for common coronaviruses the aerosols were primarily generated in the proximal airways via shear forces and likely in the 2 to 4 μm size range. If distal small airway reopening events contribute to aerosol generation[34] and viral load in fine aerosols in SARS-CoV–2 infection with evidence of pulmonary involvement, especially in the absence of cough, the viral aerosols might be in the submicron size range and behave more like influenza virus than the common human coronaviruses.

Among the samples collected without a face mask, we found that the majority of participants with influenza virus and coronavirus infection did not shed detectable virus in respiratory droplets or aerosols, while for rhinovirus we detected virus in aerosols in 19/34 (56%) participants. Among the exhaled breath samples that virus was detected the viral shedding tended to be low (Figure 1). Given the high collection efficiency of the machine[22], and given that each exhaled breath collection was done for 30 minutes, this

might imply that prolonged close contact would be required for transmission to occur, even if transmission was primarily via aerosols as has been described for rhinovirus colds[35]. Our results also indicate that there could be considerable heterogeneity in contagiousness of individuals with coronavirus and influenza virus infections.

The difference in the filtration efficiencies of the three viruses by surgical masks may suggest the size distribution of virus-laden respiratory droplets vary for different respiratory viruses, for example our results might suggest the exhaled virus-containing particles might be significant smaller for participants with influenza virus compared to coronavirus infections, which might signal a higher potential for aerosol transmission for influenza. The size of exhaled particles depends on the site of their origin (upper respiratory tract, lower respiratory tract or alveolar regions) in the lungs[36]. The sizes of particles that contain both viruses are unknown, but existing studies indicate that fine particles (<1μm) released by influenza patients may dominate[37]. It is perhaps surprising that we observed no effect of face masks on dissemination of rhinovirus in respiratory droplets (Table 2), given that the surgical mask was able to block virus in respiratory droplets for influenza virus in the present study and in the previous study by Milton et al[21], and for coronavirus in the present study. It may be possible that rhinovirus was more common in smaller droplets just above the 5μm cut-off, and these were not blocked by the surgical mask but were captured by the 5μm impactor and classified as respiratory droplets. Further experiments could help to explain this phenomenon, especially on the droplet generation for different respiratory virus infection and during different stages of infection or illness, where such data are minimal at present[38].

The major limitation of our study was the large proportion of participants with undetectable viral shedding in exhaled breath for each of the viruses studied. We could have increased the sampling duration beyond 30 minutes to increase the viral shedding being captured, at the cost of acceptability in some participants. An alternative approach would be to invite participants to perform forced coughs during exhaled breath collection[21]. However, it was the aim of our present study to focus on recovering respiratory virus in exhaled breath in a real-life situation, and we expected some individuals during an acute respiratory illness would not cough much or at all. Indeed, we identified virus RNA in a small number of participants who did not cough at all during the 30-minute exhaled breath collection, which would suggest droplet and aerosol routes of transmission are possible from individuals with no obvious signs or symptoms. Another limitation is that we did not confirm infectivity of coronavirus or rhinovirus detected in exhaled breath. While the G-II device was designed to preserve viability of viruses in aerosols[22], and in the present study we were able to identify infectious influenza virus in aerosols, we did not attempt to culture coronavirus[39] or rhinovirus[40] from the corresponding aerosol samples.

In conclusion, we identified viral shedding in respiratory droplets and aerosols for coronavirus, influenza virus and rhinovirus, confirming that both respiratory droplets and aerosols could be potential modes of transmission for these infections. In addition, we showed that surgical face masks can effectively block the dissemination of coronavirus and influenza virus into the environment in exhaled breath droplets, and can even block the dissemination of common human coronaviruses into the environment in exhaled

breath aerosols. Our findings provide mechanistic evidence to support the use of surgical face masks as a source control for coronavirus and influenza virus transmission.

Declarations

DATA AVAILABILITY

Anonymized raw data and R syntax to reproduce all the analyses, figures, tables and supplementary tables in the published article are available at: [Dryad link pending].

CONTRIBUTORS

All authors meet the ICMJE criteria for authorship. The study protocol was drafted by NHLL and BJC. Data were collected by NHLL, EYCS and BJPH. Laboratory testing was done by DKWC and KHC. Statistical analyses were done by NHLL. NHLL and BJC wrote the first draft of the manuscript, and all authors provided critical review and revision of the text and approved the final version.

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DECLARATION OF INTERESTS

BJC consults for Roche and Sanofi Pasteur. The authors report no other potential conflicts of interest.

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Tables

Table 1. Characteristics of individuals with coronavirus, influenza virus and rhinovirus infection by RT-PCR identified in any samples collected (nasal swab, throat swab, respiratory droplets and aerosol samples).

	All who provided exhaled breath (N = 246)	Coronavirus (N = 17)	Influenza virus (N = 43)	Rhinovirus (N = 54)
	n (%)	n (%)	n (%)	n (%)
Female	144 (59)	13 (76)	22 (51)	30 (56)
Age group (in years)				
11-17	12 (5)	0 (0)	8 (19)	4 (7)
18-34	114 (46)	10 (59)	11 (26)	24 (44)
35-50	79 (32)	2 (12)	16 (37)	18 (33)
51-64	35 (14)	4 (24)	8 (19)	5 (9)
≥ 65	6 (2)	1 (6)	0 (0)	3 (6)
Chronic medical conditions				
Any	49 (20)	5 (29)	5 (12)	10 (19)
Respiratory	18 (7)	0 (0)	4 (9)	3 (6)
Influenza vaccination				
Ever	94 (38)	6 (35)	15 (35)	20 (37)
Current season	23 (9)	2 (12)	1 (2)	4 (7)
Prior season only	71 (29)	4 (24)	14 (33)	16 (30)
Ever smoker	31 (13)	1 (6)	6 (14)	6 (11)
Time since illness onset, hours				
<24	22 (9)	0 (0)	5 (12)	2 (4)
24-48	100 (41)	9 (53)	13 (30)	25 (46)
48-72	85 (35)	8 (47)	18 (42)	20 (37)
72-96	39 (16)	0 (0)	7 (16)	7 (13)
History of measured fever ≥37.8ºC	58 (24)	3 (18)	17 (40)	8 (15)
Measured fever ≥37.8ºC at presentation	36 (15)	2 (12)	18 (42)	2 (4)
Measured body temperature (˚C) at enrolment (Mean, SD)	36.8 (0.8)	36.9 (0.8)	37.4 (0.9)	36.6 (0.7)
Symptoms at presentation				
Feverishness	111 (45)	10 (59)	27 (63)	16 (30)
Cough	198 (80)	15 (88)	40 (93)	44 (81)
Sore throat	211 (86)	15 (88)	31 (72)	49 (91)
Runny nose	200 (81)	17 (100)	36 (84)	48 (89)
Headache	186 (76)	13 (76)	30 (70)	38 (70)
Myalgia	176 (72)	12 (71)	31 (72)	34 (63)
Phlegm	176 (72)	9 (53)	34 (79)	41 (76)
Chest tightness	64 (26)	3 (18)	12 (28)	9 (17)
Shortness of breath	103 (42)	6 (35)	14 (33)	25 (46)
Chills	100 (41)	8 (47)	29 (67)	16 (30)
Sweats	95 (39)	5 (29)	18 (42)	20 (37)
Fatigue	218 (89)	16 (94)	38 (88)	48 (89)
Vomiting	19 (8)	2 (12)	5 (12)	2 (4)
Diarrhea	17 (7)	2 (12)	1 (2)	6 (11)
Number of cough during exhaled breath collection (Mean, SD)	8 (14)	17 (30)	8 (11)	5 (9)

Table 2. Efficacy of surgical facemasks in reducing detection of virus and viral shedding of coronavirus, influenza virus and rhinovirus in exhaled breath droplets and aerosols.

Virus type	Droplets >5µm			Aerosols ≤5µm		
	Without surgical face mask	With surgical face mask	*p*	Without surgical face mask	With surgical face mask	*p*
	DETECTION OF VIRUS					
	No. Positive / No. Total (%)	No. Positive / No. Total (%)		No. Positive / No. Total (%)	No. Positive / No. Total (%)	
Coronavirus	3/10 (30)	0/11 (0)	0.09	**4/10 (40)**	**0/11 (0)**	**0.04**
Influenza virus	**6/23 (26)**	**1/27 (4)**	**0.04**	8/23 (35)	6/27 (22)	0.36
Rhinovirus	9/32 (28)	6/27 (22)	0.77	19/34 (56)	12/32 (38)	0.15
	VIRAL LOAD (Virus copies per sample)					
	Median (IQR)	Median (IQR)		Median (IQR)	Median (IQR)	
Coronavirus	0.3 (0.3, 1.2)	0.3 (0.3, 0.3)	0.07	**0.3 (0.3, 3.3)**	**0.3 (0.3, 0.3)**	**0.02**
Influenza virus	**0.3 (0.3, 1.1)**	**0.3 (0.3, 0.3)**	**0.01**	0.3 (0.3, 3.0)	0.3 (0.3, 0.3)	0.26
Rhinovirus	0.3 (0.3, 1.3)	0.3 (0.3, 0.3)	0.44	1.8 (0.3, 2.8)	0.3 (0.3, 2.4)	0.12

Note: Fisher's exact test was used for comparing the detection of virus, and Tobit regression used for comparing log10(viral load), between the two groups. Undetectable values were imputed as 0.3 $\log_{10}$ virus copies per sample.

Figures

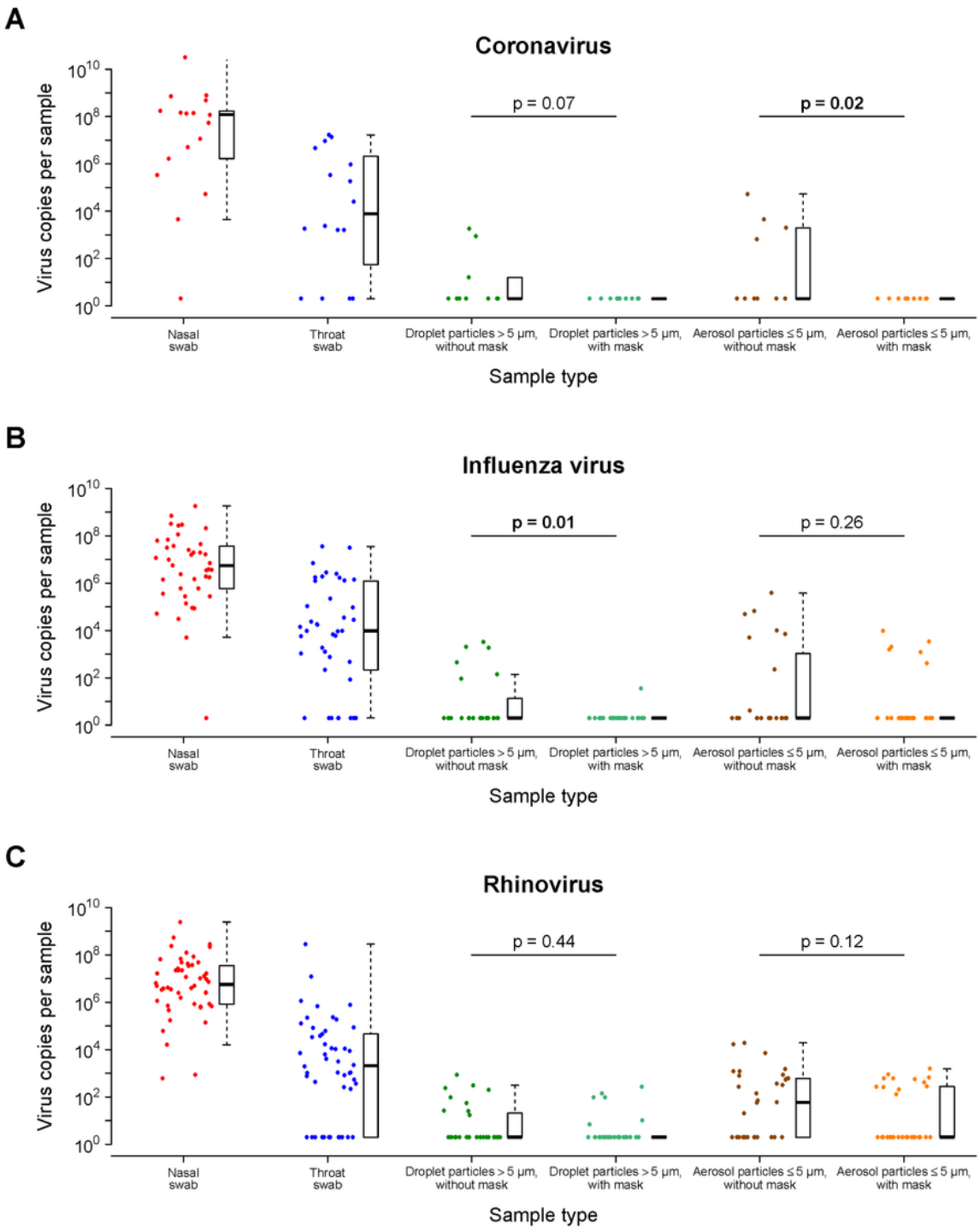

Figure 1

Virus copies in different samples (nasal swab, throat swab, or respiratory droplets and aerosols without or with use of a surgical face mask) in participants who were RT-PCR positive in any samples for coronavirus, influenza virus or rhinovirus.

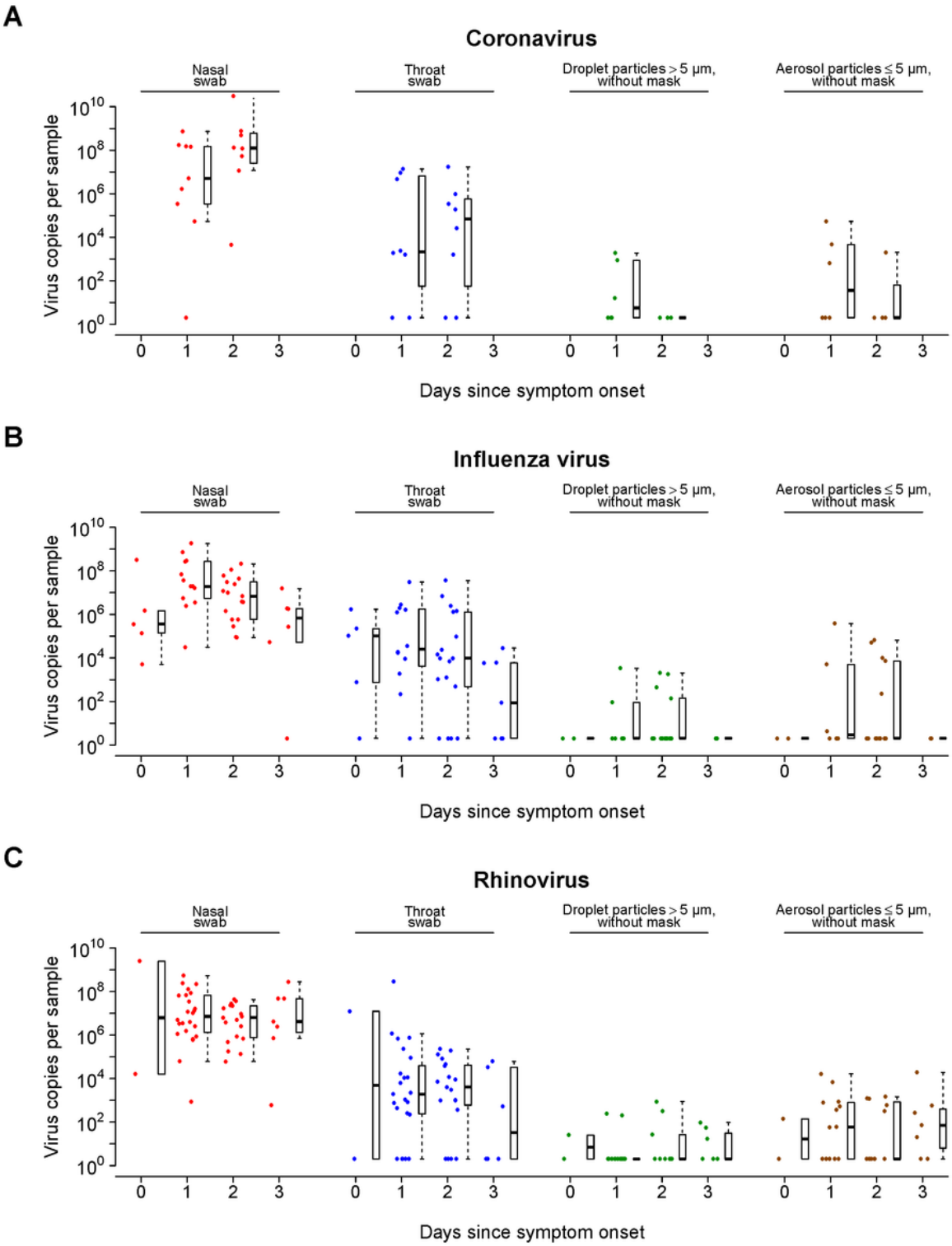

Figure 2

Viral shedding of coronavirus, influenza virus and rhinovirus in respiratory droplets and aerosols by day since symptom onset.

Supplementary Files

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- Supplementaryfiguresandtables.pdf