Why the mask? The effectiveness of face masks in preventing the spread of respiratory infections such as COVID 19 – a home testing protocol

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Abstract

Since the start of the COVID 19 pandemic there has been much debate in the media on whether masks should be worn to stop the spread of the virus. There are two ways in which they could work. Firstly, to protect the person wearing the mask, and secondly, to reduce the likelihood of the person wearing the mask passing the disease on to anyone else. This is not an easy issue to address and many factors come into play such as droplet size, aerosol transmission and the viral load, as well as the specific properties of any given mask. The method used in this study was to measure the change in relative humidity when wearing a mask, compared to no mask, in various scenarios, based on the assumption that as the virus is air-borne the smaller the increase in humidity the less the spread of the virus. The results above show that the use of a mask, excluding some simple home-made ones, significantly reduces the spread of humidity. However their effectiveness is device specific and needs to be considered in greater detail for each type of mask, especially the direction of escaping air when forward flow is blocked.

Introduction

Since the start of the COVID 19 pandemic there has been much debate in the media on whether masks should be worn to stop the spread of the virus. There are two ways in which they could work. Firstly, to protect the person wearing the mask, and secondly, to reduce the likelihood of the person wearing the mask passing the disease on to anyone else. This is not an easy issue to address and many factors come into play such as droplet size, aerosol transmission and the viral load required for transmission as well as the specific properties of any given mask. (1,2)

During this time a textile orthotics company, AngelMed, with whom the author was working on a totally different project, asked if it was possible to test some masks they were making to try and help with the COVID 19 pandemic. As for many people, any laboratory facilities have been reduced to the dining room table over the past few weeks, equipment limited to a calibrated temperature/relative humidity meter that happened to be at home, and the author, family and neighbours as volunteers. The mask was evaluated by comparing it to a variety of existing, prototype and home-made masks.

A brief literature search showed that Porton Down (3) had done some work on home-made masks a few years ago in preparation for a pandemic. Based on their work, a section of vacuum cleaner bag (Numatic) and two thicknesses of standard kitchen roll were chosen as filters for use in the home-made sock masks.

Method

The principle of the evaluation was to measure the change in relative humidity when wearing the masks, compared to no mask, in various scenarios with the humidity meter placed directly in front of the volunteer. This is based on the assumption that the virus is carried by air-borne moisture and that reduction in the increase in relative humidity when wearing a mask will limit the spread of the virus.

Background relative humidity was measured over a period of at least two minutes until a stable reading was maintained before each test. Four people participated in the testing. All were experienced NHS staff and so familiar with wearing masks with the author undertaking the majority of the testing.

The masks tested consisted of the prototype mask from AngelMed, a standard NHS clinical mask and a FFP2V (SureProtec) mask used for spraying chemicals. (4) The opportunity was also taken to look at some other materials that people were using as 'home-made' masks. A standard t-shirt, doubled Buff (5), sock masks, both with and without paper filters (6), and another proposed design, a home-made mask designed to enable lip reading (7), were also tested

Three scenarios were tested. Hard breathing from 65cms, quiet breathing from 20cm and hard breathing from 20cm. For the hard breathing tests each person exhaled at the sensor as hard as possible, 20 times. For the quiet breathing the person was asked to breathe normally for two minutes. The humidity meter was placed in a stand directly in front of the volunteer, its distance from the mouth varied accordingly and the percentage change in relative humidity recorded (RH). Between readings RH was allowed to return to the baseline value. This procedure was repeated without any mask, with a NHS mask, FFP2V mask and the AngelMed mask. Ten complete sets of data were recorded. The tests on the home made masks were tested to the same protocol but with fewer repetitions, merely for comparative purposes.

Results

The results obtained on the three masks and the control readings are shown in Table 1. and in Figs 1a, 1b and 1c.

	Control	NHS Mask	FFP2V	AngelMed
20 Hard Breaths 65cm	4.8	0.4	0.2	0.4
SD	1.8	0.6	0.4	0.3
Quiet breathing 20cm – 2 mins	1.4	0.4	0.1	0.1
SD	1.1	0.7	0.1	0.2
20 Hard Breaths 20cm	22.1	0.2	4.0	1.3
SD	7.2	0.7	2.6	1.0

Table 1 Percentage changes in Relative Humidity RH

Tests on a single thickness of t-shirt and doubled Buff (5) from 65 cm gave percentage changes in RH of 5.4% and 5.1% respectively. Tests of a two layer sock mask from 20 cm gave an increase of RH of 8.5% and 9.5% depending on the cut of the mask. A single layer sock mask gave an increase in RH of 15.3%. Inclusion of a filter such as a section of vacuum cleaner bag or two thicknesses of kitchen roll did however reduce this to a level too small to measure (<0.1%). The home-made lip reading mask also prevented any increase in relative humidity, even with the hard breathing tests from 20cm.

Discussion

The results above show that the use of a mask, not including the home-made ones, significantly reduces the spread of humidity and presumably in an infected person, the spread of that infection. This was true in all three test scenarios. Even the home-made ones were effective in reducing the increase spread of humidity, but only if a filter such as a section of vacuum cleaner bag or doubled kitchen roll, was included. The use of a t-shirt or a doubled walking Buff made very little difference for hard breathing at 65cm which questions their efficacy in preventing the spread of any infection.

One interesting fact was that when measurements were made during the hard breathing tests at 20cm, the FFP2V mask did not perform so well. This is due to the fact that the mask has a valve designed to stop the user breathing in harmful chemicals. This is a one-way valve which closes on inhaling. Hence when the user breathes out, the valve opens. This also brings into question what happens to the flow of air when the user breathes out with any mask. The air has to escape somewhere. This problem has been addressed recently by researchers at Edinburgh University using far more sophisticated equipment than what was available in these tests. (8) They showed that although the mask blocks the flow of air forward it does produce jets of expelled air in other directions. In the case of the FFP2V mask this is largely downwards. For many other masks, especially those fitting poorly around the nose, this is largely upwards, hence the common occurrence of the users' glasses steaming up. For those not fitting well around the side of the face these jets will be lateral. Obviously the direction of these jets is important. If you are standing talking to a seated person there is a strong chance that you will be directing your exhaled air over them if your mask fits poorly around your chin or contains a valve. Coughing is also interesting as it is instinctive to turn your head to the side when coughing near another person. This could make the situation far worse as an occlusive mask will block the forward flow of air and channel that air sideways or upwards depending upon the fit.

The tests on the lip reading mask are worthy of note. This mask was made of a much thicker material and also included a clear window to enable lip reading. As such it did provide an effective barrier. However the main problem of the mask is the compression of the nose and the inherent restriction to breathing. Sitting quietly for approximately 10 minutes while wearing the mask reduced SpO2 in one user from 97% to 93% as measured by a Pulse Oximeter. As a result the mask was uncomfortable and did force the user to take deeper breaths. Another user went for a walk whilst wearing the lip reading mask and found that his SpO2 dropped from 97% to 89%. He also felt that breathing was harder and that he had to take deeper breaths. Hence an important feature of any mask is that not only must it provide a barrier, it should also not restrict breathing. Air has to be able to get into and out of the mask.

The design of the AngelMed mask was interesting in that it did not contain a valve, but fitted very securely due to a wide mouldable nose piece. The mask was made from two layers of ‘spacer’ material which is commonly used in orthotics. As a result the 20cm hard breathing tests did show a slight increase in humidity compared to the NHS mask, but not so great as for the FFP2V mask. Further tests with the nose piece not so well fitted did show a significant reduction in RH, however glasses did then steam up. This indicates that the air has to go somewhere and although increasing near the mouth, its direction is at least known. (9). More detailed tests on the spread of that air would be interesting, but are beyond the scope of this paper. Reading at 65cm were however comparable to the NHS and FFP2V masks.

Conclusions

From these limited tests it appears that a well-fitting mask can stop the spread of humidity and hence possibly infection. It is interesting that in countries where wearing masks is more common such as SE Asia and Japan, infection rates have been lower (2) In Taiwan, population 24 million, they had their first case of COVID 19 on 21 January, they did not implement a lockdown and had only 441 cases and 7 deaths. They did however have a pandemic plan in place established as a result of SARS in 2002-4. Compare this with New York, population approx.. 20 million, first case 1st March 2020 who as of 21 May 2020, had 353,000 cases and 24,000 deaths.

The final question is, ‘Is wearing a mask is a good idea?’ At the start of this work the author was sceptical, but having completed it, is of the opinion that wearing a mask should be mandatory when in a confined space where a two metre separation is not possible, such as on public transport, or for close team working etc.. It is not a total solution and the limitations of the particular mask used need to be considered. As such their efficacy in stopping the wearer catching any infection is not known, especially using a simple NHS or home-made mask. However they do reduce the sphere of influence of the person wearing the mask and hence do have a role to play, but only if included as part of a total pandemic prevention package, including; basic hygiene, social distancing and an efficient track and trace system.

However this work has shown that what at first seems to be a simple piece of equipment, a face mask, becomes a complicated medical device once all the factors concerning its use are considered. Therefore further studies are urgently needed on the efficacy of different designs of mask and the role they play in preventing the spread of airborne infections. To quote the late Heinz Wolff ‘We need more research into URINE technology – Unexciting Research Into Necessary Equipment.’ A challenge to all Bioengineers.

Limitations

It is realised that this work is severely limited and as such the results provide only a guide. One particular limitation was that change in humidity has only been measured in a forward direction and so when wearing a mask the direction and extent of any upward, downward or lateral jets was not determined. This work did not consider the efficacy of any of the masks tested in protecting the wearer from airborne infection. Further useful information can be obtained from looking at the references quoted.

Conflict of Interest

The author was originally inspired to undertake this work as a result of contact from AngelMed, but this work is independent and no payment has been received.

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References

(1) Raymond Tellier , Yuguo Li , Benjamin J Cowling , Julian W Tang
Recognition of Aerosol Transmission of Infectious Agents: A Commentary BMC Infect Dis 2019 Jan 31;19(1):101. doi: 10.1186/s12879-019-3707-y

(2) Kimberly A. Prather1, Chia C. Wang, Robert T. Schooley
Reducing transmission of SARS-CoV-2 Kimberly A. Prather1 , Chia C. Wang, 2,3 Robert T. Schooley4 Science 10.1126/science.abc6197 (2020).

(3) Anna Davies, BSc, Katy-Anne Thompson, BSc, Karthika Giri, BSc, George Kafatos, MSc, Jimmy Walker, PhD, and Allan Bennett, MSc Testing the Efficacy of Homemade Masks: Would They Protect in an Influenza Pandemic? Disaster Med Public Health Preparedness. 2013;7:413-418

(4) https://www.hse.gov.uk/pubns/priced/hsg53.pdf

(5) https://www.buffwear.co.uk/

(6) https://www.youtube.com/watch?v=angxHfwS-6E –version 1

(7) https://www.salisburyjournal.co.uk/news/18442950.salisbury-volunteer-launches-lip-reading-masks-help-vulnerable-groups/

(8) https://www.dropbox.com/sh/fvp131tsqxccqol/AACe8jA5iwrfsZTtCbTRKznSa?dl=0&preview=Paper.pdf

(9) https://www.4dflexisport.com/collections/face-masks

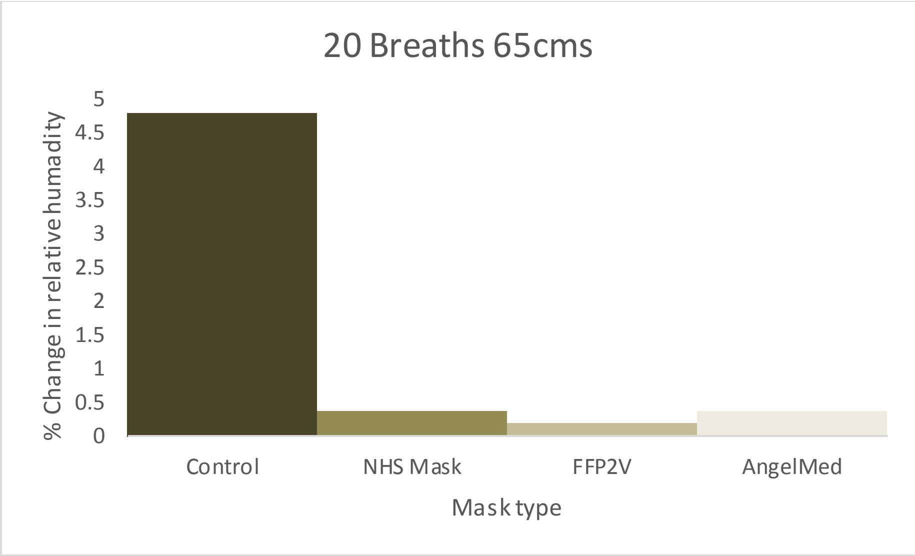

Fig 1a Relative change in humidity - 20 breaths from 65cms

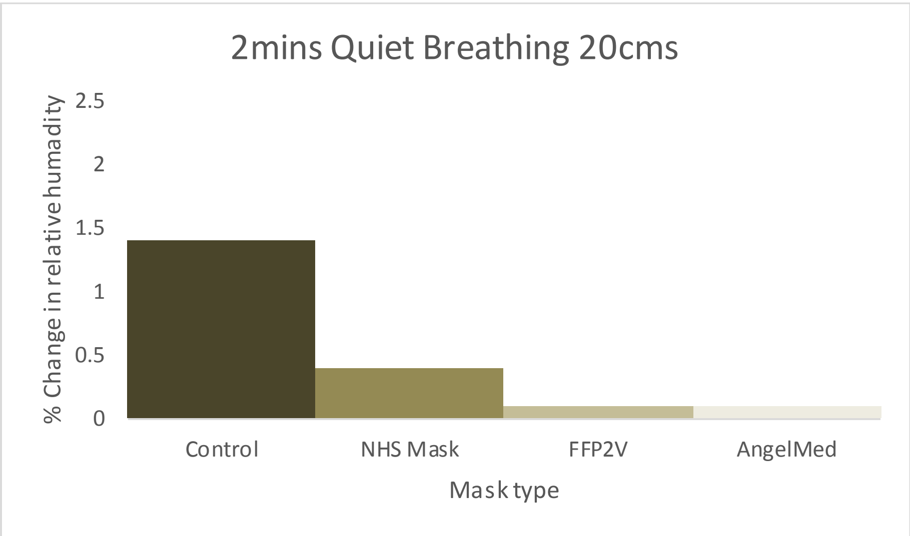

Fig 1b Relative change in humidity - 2mins quiet breathing from 20cms

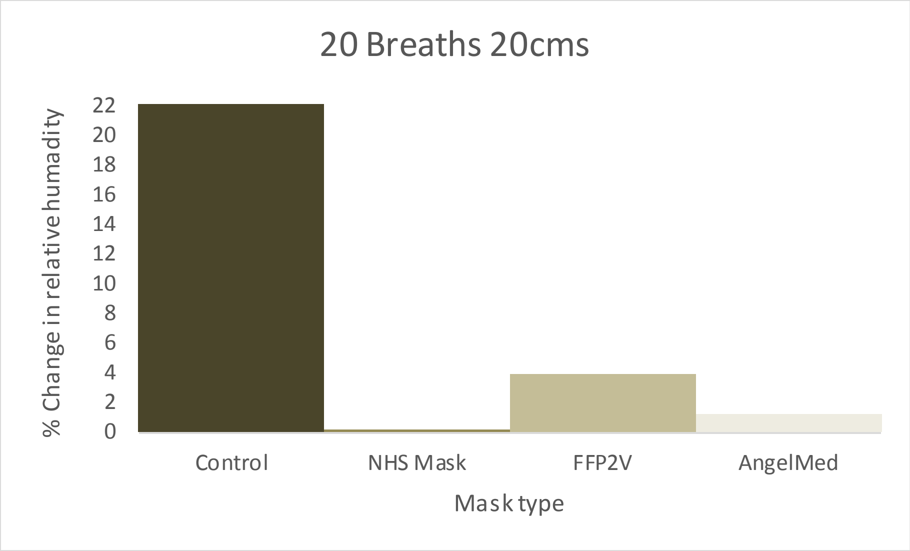

Fig 1 Relative change in humidity - 20 breaths from 20cms