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STUDY OF COMMUNITY FACE COVERINGS AND COMMERCIALLY AVAILABLE FACE MASKS USING A MODIFIED VIRAL FILTRATION METHOD

V. TSVETKOV, D. TODOROV*, A. HINKOV,
K. SHISHKOVA AND S. SHISHKOV

*Laboratory of Virology, Sofia University "St. Kliment Ohridski", Sofia, Bulgaria,
Dragan Tsankov Blvd. [8], [1164] Sofia, Bulgaria*
** Corresponding author: dani_todorov@biofac.uni-sofia.bg*

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Abstract: During the current COVID-19 Pandemic the humanity was faced with an increased need for an effective, cheap and available face mask to suppress the spread of the virus especially in the larger city communities. In a lot of them – homemade face masks were the only option due to the decrease of the supply chain worldwide. At the same time, a lot of fabric production facilities were diverted to the production of Personal protective equipment with variable quality. Even with no certification – the need and from there - the distribution of these products was high. In this situation research laboratories diverted their capacities into testing giving at least some information for the quality of the products. In this study, 15 different masks – both community face coverings and commercially available face masks, were tested for viral filtration efficacy (VFE). The results showed that even non-certified products can offer a good level of consumer protection, but also showed the need for some control over the small business that offers personal protection equipment (PPE) to the general public.

INTRODUCTION

Airborne viruses are a common cause of infectious diseases acquired indoors, as they are easily transmitted, especially in poorly ventilated environments (Verreault, Moineau and Duchaine 2008, Barker, Stevens and Bloomfield 2001). Respiratory pathogens are excreted by the infected person through speech, sneezing, coughing and are included in aerosol droplets. These droplets travel some distance before reaching surfaces where viruses can remain contagious for hours or days (Brady, Evans and Cuartas 1990, Bhardwaj and Agrawal 2020). Survival of viruses on surfaces is affected by temperature, humidity, pH and exposure to ultraviolet light. On the other hand, the viruses contained in the released aerosol droplets can be transported considerable distances by air currents to be inhaled by a susceptible host (Das et al. 2020). Once in the environment, the spread of viruses is a process involving many factors: the mechanism and rate at which droplets are excreted by the infected person, the concentration of viruses in respiratory secretions, environmental factors, room ventilation, and so on. Indoors, especially with poor ventilation, pose a greater risk of transmitting the viral infection. Human behaviour and their environment affect the susceptibility, severity and tolerability of respiratory viral diseases. Determining how viruses are transmitted in different circumstances and whether transmission requires close contact is important, as such information will influence the choice of infection control measures (La Rosa et al. 2013).

Coronavirus Infectious Disease 2019 (COVID-19) is a new respiratory disease caused by coronavirus 2 (SARS-CoV-2) virus (Sifuentes-Rodríguez and Palacios-Reyes 2020). The virus causes the severe acute respiratory syndrome. As with other diseases caused by respiratory viruses, measures to prevent their spread are recommended, including - handwashing, social distancing. Another extremely important factor in preventing infection with respiratory viruses, including SARS-CoV-2, is the wearing of personal protective equipment that filtrates inhaled air – face masks. The use of face masks is also recommended due to the presence of asymptomatic carriers of the virus capable of transmitting the infection (Worby and Chang 2020). Due to the scale of the pandemic and the consequent shortage of masks (Drewnick et al. 2021), a good approach is to use sufficiently reliable reusable masks (Liu, Leachman and Bar 2020).

Aim

In this study we have examined 15 different protective products with method based on the international standard for medical face masks. The object is to get conclusive results on the protective equipment ability to filter viral particles with easy to obtain and use laboratory equipment.

MATERIALS AND METHODS

MATERIALS

A. *Testing materials*

Table 1. Samples

Product	Number of layers	fabric
CFC 1	2	Cotton
CFC 2	1	Synthetic
CFC 3	2	Cotton
CFC 4	2	Cotton
CFC 5	3	2 cotton + 1 synthetic
CFC 6	1	Synthetic
CFC 7	2	Cotton
CFC 8	2	Synthetic
CFC 9	2	Synthetic
CFC 10	3	2 cotton + 1 synthetic
Face mask FFP2 1	3	2 cotton + 1 synthetic
Face mask FFP2 2	3	2 cotton + 1 synthetic
Face mask FFP2 3	3	2 cotton + 1 synthetic
Face mask FFP3 1	3	2 cotton + 1 synthetic
Face mask FFP3 2	3	2 cotton + 1 synthetic

B. Cell culture

The cell line MDBK (Madin-Darby Bovine Kidney) was supplied by National Cultural Cell Bank.

C. Virus

Human alphaherpesvirus type 1, strain F, (HHV-1) was supplied by NCIPD, Bulgaria.

D. Six stage cascade Andersen Impactor

Six stage Andersen impactor model FSC-A6 manufactured by Honri Airclean Technology Co., Ltd. was used with diameters on the stages shown in Table 2. The first stage lit was modified with additional insulation to compress the edge of the test material and at the same time to prevent leakage along the end.

Table 2. Range of particles sizes collected by each stage

Stage	Hole size [mm]	Captured particle size
1	1,18	>7 µm
2	0,91	4,7-7 µm
3	0,71	3,3-4,7 µm
4	0,53	2,1-3,3 µm
5	0,34	1,1-2,1 µm
6	0,25	0,65-1,1 µm

E. Intranasal Mucosal Atomization Device

Teleflex® MAD Nasal™ product spray atomizes the viral suspension into a fine mist of particles 30-100 microns in size.

METHODS

Viral filtration efficiency (VFE)

Method is based on EN 14683:2019 + AC:2019 (ECS 2019). Filtration efficiency was measured using the Human alphaherpesvirus and DMBK cell culture as the host. The viral suspension was aerosolized in a MAD nebulizer during each test were used with a challenge of 3x106 infectious doses 50 (CCID50) in 3 ml of DMEM for 2 min. The virus aerosol is a media droplet containing the pathogen. The aerosol sample was drawn through a chamber clamped into the top of a 6-stage Andersen sampler with plates on each stage. The flow rate was maintained at 28.3 L/min. Both test samples and positive control were obtained as described for the VFE method. Negative control with no virus in the airstream was performed to determine the background challenge in the glass aerosol chamber prior to testing. The filtration efficiency was calculated by determining the surviving infectious titers on every stage in CPE assay using the method of Reed and Muench (Reed and Muench 1938).

RESULTS

Our methodology was used to determine the viral filtration efficiency of two categories of face masks – community face coverings (CFC) and filtering facepiece (FFP) levels 2 and 3 (according to EN 149:2001), consisting of a different number of layers made of cotton or synthetic material. Masks belonging to the CFC category having only one layer of synthetic material (CFC 2 and 6, table 3) when placed on the path of the virus, they reduce its titter by only 0.17 decimal logarithms (compared to that of the virus control) and show only 33.00%

viral filtration efficiency (Table 3). When the number of layers increases, whether they are made of cotton (as in CFC 1,3,4 and 7, table 3) or synthetic material (as in CFC 8 and 9, table 3) the titter of the virus used decreased in the range between 0,34- 0.67 decimal logarithms (compared to that of the virus control, table 3). Viral filtration efficiency varies between 55.00% and 79.00%. However, in the tests with the three-layer CFC masks (CFC 5 and 10, see table 3), the titter decreased by 2 decimal logarithms (compared to that of the virus control). The viral filtration efficiency of CFC 5 and 10 is 99.00% (Table 3).

All standardized FFP2 and 3 masks are made of three layers. Placed in the path of the virus Face mask FFP2-1 and FFP2-3 reduce its titter (compared to that of the virus control) by approximately 2 decimal logarithms (VFE = 99.0%, table 3), and Face mask FFP2-2 and FFP3-2 by approximately 3 decimal logarithms (VFE = 99.9%, table 3). For Face mask FFP3-1 was even found that no infectious virus particles had passed through it. Its viral filtration efficiency is 100% (Table 3).

Table 3. Viral filtration efficiency

Product	VFE [%]	VC [log]	Sample [log]
CFC 1	33,0%	5,67	5,5
CFC 2	33,0%	5,67	5,5
CFC 3	79,0%	5,67	5
CFC 4	55,0%	5,67	5,33
CFC 5	99,0%	5,67	3,67
CFC 6	33,0%	5,67	5,5
CFC 7	90,0%	5,67	4,67
CFC 8	55,0%	5,67	5,33
CFC 9	55,0%	5,67	5,33
CFC 10	99,0%	5,67	3,67
Face mask FFP2 1	99,0%	5,67	3,67
Face mask FFP2 2	99,9%	5,67	2,67
Face mask FFP2 3	97,9%	5,67	4
Face mask FFP3 1	100,0%	5,67	0
Face mask FFP3 2	99,99%	5,67	2,67

DISCUSSION

In this study we try to determine and to compare the viral filtration efficiency of two categories of face masks – CFC and FFP levels 2 and 3 (according to EN 149:2001), consisting of a different number of layers made of cotton or synthetic material using a quick and reliable methodology. A community face covering is any material that covers the nose and mouth. It can be secured to the head with ties or straps or simply wrapped around the lower face. It can be made of a variety of materials, such as cotton, silk, or linen. A CFC may be factory-made or sewn by hand or can be improvised from household items such as scarves, bandanas, T-shirts, sweatshirts, or towels (www.pvhmc.org 2021). A filtering facepiece (used for protection against bioaerosols and dust) is defined in 29 CFR 1910.134(b) as "a negative pressure (the flow of air through the filter is achieved via inhalation) particulate respirator with a filter as an integral part of the facepiece or with the entire facepiece composed of the filtering medium) (Galassi 2011).

Single-layer masks (made of synthetic material (CFC 2 and 6, table 3)) belonging to the CFC category showed the lowest viral filtration efficiency (only 33.00%) (Table 3) skipping a large amount of the sprayed viral suspension. For double-layer masks, whether layers are made of cotton (as in CFC 1,3,4 and 7, table 3) or synthetic material (as in CFC 8 and 9, table 3) viral filtration efficiency increased slightly (varied between 55.00% and 79.00%), but the amount of the retained sprayed viral suspension was also little. The single-layer and double-layer masks (regardless of the material from which they are made) showed low filtration efficiency. However, in the tests with the three-layer CFC masks (CFC 5 and 10, see table 3) things were different. They reached 99.00% of viral filtration efficiency (Table 3) stopping a large amount of the sprayed viral suspension.

All standardized FFP2 and 3 masks are three-layer. All of them showed high viral filtration efficiency reaching values of 99.0% and above (Table 3). They stopped almost all of the amount of the sprayed viral suspension. For Face mask FFP3-1 was even found that no infectious virus particles had passed through it (Table 3).

According to the results the most effective were the three-layer masks from CFC category and all standardized masks from FFP category, levels 2 and 3. The values obtained in the tests with the three-layer masks in the CFC category are comparable with the lowest values obtained in the tests with the masks in the FFP category. The degree of protection provided by the mask depends mainly on the number of layers of which it is composed, and not so much on the material from which the respective layer is made.

CONCLUSION

Comparing the results obtained when the two categories of masks were tested, it is clearly seen that the single-layer and double-layer CFC masks (regardless of the material from which the respective layer is made) have low viral filtration efficiency. The values of viral filtration efficiency and the reduction of the viral infectious titter obtained in the tests with the three-layer masks in the CFC category are comparable with the lowest values established for the masks in the FFP category. This unequivocally shows that the degree of protection provided by the mask depends mainly on the number of layers of which it is composed, and not so much on the material from which the respective layer is made. This means that single-layer and double-layer CFC masks (regardless of the material from which the respective layer is made) are the least effective, which automatically makes them an unreliable protection stuff. In order for a mask from the CFC category to be effective, it must be three-layered. The category of masks FFP2 и 3 remains the most effective as protective equipment.

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