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A COmfortably Vented, Indigenously Designed (COVID) Fabric Helmet to Curb Infection Spread in Education, Healthcare and Other Community Settings

***Ashish Karn, *Shashank Singh Deo, **Raman Kumar Singh and *Abhay Kumar**

*Department of Mechanical Engineering, School of Engineering, University of Petroleum and Energy Studies, Dehradun, Uttarakhand, India-248007; *E-mail: ashish.karn@alumni.iitd.ac.in.
**Department of Management Studies, Indian Institute of Technology Delhi, New Delhi, India-110016.

Associate Editor: Dr. S. Rao, Reader, Department of Reproductive Bio-Medicine, NIHFW, New Delhi-110067.

Reviewers:
Dr. Chetna Chouhan, CMO, NIHFW, New Delhi-110067.
Dr. Rajesh Kumar, Assistant Professor, Department of Reproductive Bio-Medicine, NIHFW, New Delhi-110067.

Abstract

Considering the current scenario of Coronavirus outbreak and the post-pandemic situation, the need for protective gears such as face-masks assumes utmost importance for the common populace, as well as in the areas of concern such as the community and healthcare settings. Earlier reported researches show that although masks' usage may help curb the infection spread, a major issue stems from the lack of adherence to proper ways of wearing/taking off masks. The users touch their face, ears, eyes, nose, etc. after taking off the masks, ultimately making themselves more susceptible to infection and thus, reducing the efficacy of the suggested measure of using face-masks. The existing masks are quite inadequate. It covers only the nose and mouth, leaving room for the users to touch their face, ears, nose, and eyes, all the vulnerable gates for infection transmission. The masks are uncomfortable and require regular adjustment, there are problems of humidity build-up inside the masks, high chances of leakage, problems with breathing, and one even needs to take off the mask for ingesting liquids, food, medicine, etc. even if one is in a community setting or a crowded region. Further, since these masks provide insufficient protection, there is an additional burden on the supply chain requirements for other personal protective gear. The researchers have designed a low-cost COmfortably Vented, Indigenously Designed (COVID) fabric helmet to address these limitations of the commercially available masks. It is designed so that usage of this cheap helmet, along with the usually worn cloth, is enough to provide complete protection to an individual. The fabric helmet is integrated with many innovative design features that will not only address the concerns of the users but will also be comfortable, cheap, and ease pressure on the requirement for expensive and already scarce personal protective equipment; and thus, greatly curtail the COVID-19 infection spread in the country. Most importantly, the design will serve as a very effective device in protecting the pediatric population in the educational institutions and in residential and healthcare settings, as situations spring back to normalcy in communities around the globe.

Keywords: COVID-19, Coronavirus, Facemask, Mask, PPE, Infection spread, Helmet.

Introduction

In an emerging outbreak of an infectious disease such as the current COVID-19 scenario, non-pharmacological measures such as an adequate hand hygiene program, respiratory precautions and proper coughing etiquette, contacts control, use of personal protective equipment such as face-masks and respirators are one of the few most promising means of protection available, particularly in the face of a dearth of a clear-cut pharmacological intervention such as a vaccine. Literature suggests that the possible modes of transmission of the virus, such as SARS-CoV-2, are via droplets through respiratory route[1] and possibly through feco-oral routes. Evidence further suggests that COVID-19 could be transmitted before the onset of symptoms, and thus community spread of infection could be drastically reduced if everyone, including asymptomatic contagious individuals, wears masks[2]. Various personal protective equipment used in healthcare and community settings worldwide can be broadly categorized into three divisions: cloth, cotton, or gauze masks (i.e., cloth or non-surgical masks); medical, surgical, or procedure mask (i.e., medical masks); and respirators of filtering facepiece respirators such as N95, N99, etc.[3] Cloth masks (hereafter "face-masks") are designed to prevent the spread of infection from wearers to others or vice-versa and are made of one or two layers of cotton fabric material, and these vary widely in their filtration efficacy[4]. The surgical masks can further be subdivided into two-layered or three-layered masks, depending upon its structure. A triple-layer mask consists of an outer hydrophobic non-woven layer that repels droplets, blood, water, etc., an intermediate melt-blown filter layer, and an inner soft non-absorbent layer. The two-layered surgical masks do not contain a filter layer, which reduces its effectiveness against bacteria and viruses compared to the triple-layer masks[5]. However, even these triple-layered masks are quite ineffective in blocking the very small particles which are formed as a result of aerosol-generating procedures such as swab collection, intubation, and laboratory processing of specimens in healthcare settings. These airborne contaminants are removed, however, in respirators which contain a mechanical filter and filter particles through interception. The prior literature has few reported findings that conclusively corroborate the efficacy of different kinds in preventing the spread of infectious diseases, particularly in a variety of community settings[6].

Jefferson et al., in his systematic reviews published in BMJ on the physical interventions to interrupt or reduce the spread of respiratory viruses, found that medical masks halted the spread of respiratory viruses from likely infected patients[7,8]. In particular, studies conducted during the 2003 outbreak of SARS-CoV reported that masks alone were 68 percent effective at preventing the virus[7,8]. More specifically, the recent work of McIntyre and Chungtai[4] investigated the mask usage among people in community settings, particularly colleges and households. Their findings indicate that wearing a mask protected people from infections, especially when coupled with an adequate hand hygiene protocol. However, a major problem was compliance: the common populace was found to be inept at wearing masks, which reduced their effectiveness considerably. But, the authors concluded that if the masks are used early and consistently in a proper way, they are indeed efficacious in protection against infection. Apart from the reported findings in the literature, it is a prevalent notion that wearing a mask may reduce one's chances of infection through viruses that are airborne or are carried through fine droplets or aerosols. However, according to the recently released guidelines from the Center for Disease Control and Prevention (CDC), USA, in the wake of the Coronavirus pandemic, this fact needs a closer examination. According to CDC, in the event of one fidgeting with one's mask, and especially if one touches one's face in the process, the chances are high that one may infect himself with virus-containing droplets intercepted by the mask. The CDC offers some tips for how to properly use a mask, and among all the guidelines issued, the primary ones are to not touch the mask or parts of the face, especially eyes, mouth, and nose, which are vulnerable to infection. People touching their face and nose inadvertently is; thus, it becomes an important mode of transmission. An average person touches his face 16 to 24 times an hour, and this fact poses a potential risk in undermining the efficiency of infection prevention using a mask[9]. A protective mask may reduce the chances of infection spread but cannot completely eliminate the risk, especially if the disease has more than a single means of transmission. Thus, every mask, irrespective of its efficiency, has to be used in conjunction with a host of other preventive measures and etiquettes such as respiratory etiquettes, hand hygiene, and physical distancing[10].

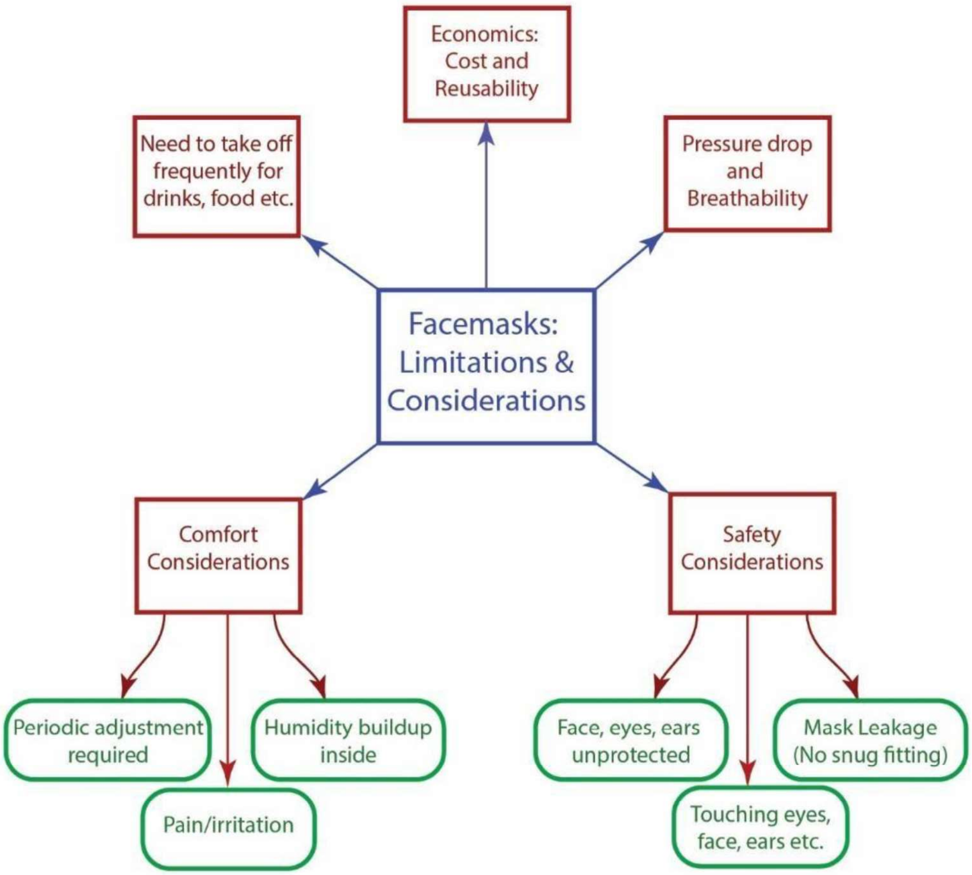
This is clearly a matter of concern from many standpoints. Firstly, in the event of huge supply chain disruptions, the procurement of personal protective equipment is a challenge[2]. The general populace even stands unclear of the exact requirements for protection against infection spread for visiting a healthcare setting– a face visor, a coverall, or a mask. Secondly, as life springs back to normalcy in many countries post lifting of nation-wide lockdowns, the safety of school children and others raises disconcerting questions. Are children expected to solemnly follow the social distancing norms? Can the children be expected to religiously understand and adhere to the etiquette of masking their eyes, face, and nose? Can they be expected to manage the face-masks well, and above all, not touch their faces? Can they don the conventional face-masks for an extended period of time? Finally, choices of personal protective gear viz. face-masks for the pediatric section of the population are very limited, and the adult respirators are not recommended for them because of the underlying risks of asphyxiation, injury, and the inability of the children to wear these due to high breathing resistance[11]. Clearly, there is a gap that needs to be filled with suitable engineering design intervention, considering the smooth transition from the current phases of lockdowns to normalcy, and simultaneously ensuring the proper protection of the pediatric population, and to quell the fears and apprehensions of the community in general. The current paper presents a novel engineering design of a COmfortably Vented and Indigenously Designed (COVID) Fabric helmet, which can possibly play a major role in ensuring the smooth transition of community living to normalcy and curb the infection spread in community settings such as education and healthcare. The next section of this paper summarily provides a description of the problems with the existing face-masks. Subsequently, it presents an innovative fabric helmet design of protective face-mask with a description of its several features outlining its superiority over a conventional face-mask. The authors also present an array of variants of manufactured prototype designs. This is followed by a conclusive assessment of the potential impact of the fabric helmet design upon implementation.

Existing Problem with Conventional Masks and Better Alternative Designs

In spite of the widespread usage of masks worldwide, the commercially available masks (both cloth as well as medical masks) have fundamental limitations, which may significantly reduce their efficacy in control and spread of the Coronavirus (or any other viral) pandemic. While Figure 1 presents a schematic diagram of the various limitations of the existing face-masks as well as important considerations in the design of adequate protective equipment, Figure 2 depicts the cons of the masks that are currently used widely. These limitations/considerations can broadly be categorized under five main divisions: Safety considerations, comfort considerations, pressure drop, and breathability, and the need to take off the masks frequently to ingest drinks, food, etc. First, there are three important factors with respect to safety which are worth considering: most of the commercially available masks in the market cover only the nose and mouth; leaving eyes, ears, head, and other portions of the face bare, making it susceptible to infection by virus/ fine droplets/aerosols. These masks don't provide sufficient protection, and there is an additional requirement of Personal Protective Equipment (PPE) if an individual wishes to enter into infected areas/ hospitals, etc. Also, the current masks do not feel snugly over the nose and mouth, and the chances of leakage are high, and so is the probability of infection spread when worn by an infected patient. Even in the case of fit-tested masks and respirators, the presence of facial hair may substantially increase the magnitude of leakage through the device[5]. Finally, there are chances that an individual may end up touching his/her eyes, ears, face, etc. and thus, may acquire infection. Secondly, comfort considerations are extremely crucial in the design of a face-mask, particularly considering the pediatric population, and may further be attributed to three primary reasons. Many conventional face-masks are fastened at the back of ears or are tied at the back of the head and require regular adjustment or removal after regular periods of time due to pain or irritation. Users of most of the cloth masks complain of a humidity build-up near the nose and the mouth and thus an irritating sensation after a while. Another important cause of concern is that one needs to frequently take off these masks in case of drinking liquids or minor food/ medicine, even if one is in a community setting or in a place where social distancing is not possible. Lastly, many face-masks (such as cloth masks) constrict the nasal passage, which is a cause of concern for those who have respiratory ailments or have short breaths. In general, the tighter the fabric structure, the better the potential for filtration. However, with the increasing tightness of the structure, the pressure drop or breathing resistance increases, affecting user comfort[5]. Another important consideration stems out from economics: the initial cost and reusability of the face-masks. One or more of the above-mentioned factors may pose a serious limitation on the usage or effectiveness of the masks in providing protection.

Figure 1

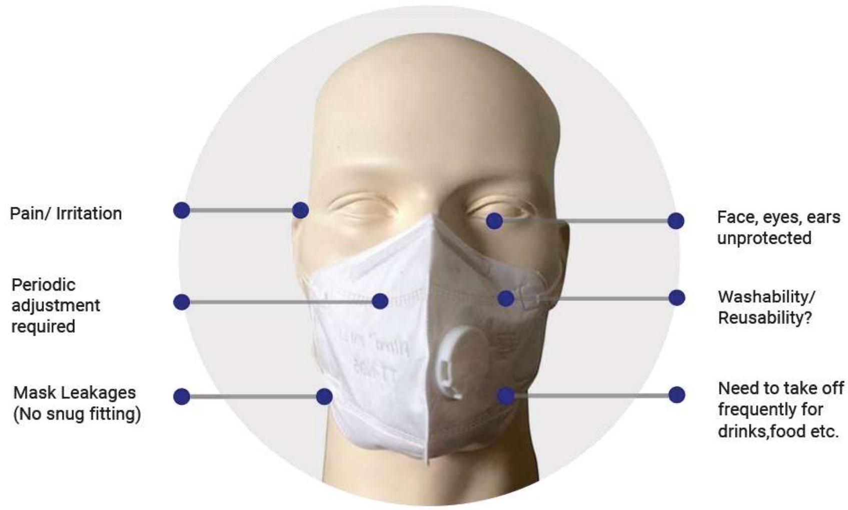
Limitations of the Existing Face-masks



In the event of a virus-based pandemic like the COVID-19, many sick individuals are expected to be quarantined or treated at home. Thus, caregivers and other family members stay in close proximity to the infected patient and face the same risk of exposure as experienced by the healthcare workers[5]. Apart from the household settings, extra protection is required for healthcare workers, people visiting healthcare facilities, and a large pediatric population post-pandemic lockdown. Prior literature has suggested that the children's tolerance of a protective wear is negatively affected by a host of psychophysical factors such as moisture and heat build-up, breathing resistance, facial pressure as well as a dearth of parental and societal pressure and persuasion[12]. In order to suitably address all the limitations as indicated in Figure 2, an alternative design of a protective gear is absolutely imperative to cater to these requirements.

Figure 2

Cons of the Masks being Currently Used Widely



The Proposed Innovation and Its Novelty

In order to circumvent these issues faced by the users, a COmfortably Vented and Indigenously Designed (COVID) fabric helmet has been designed which not only circumvents these problems, but adds further to the safety of its users, as well as, comes at an economical price (around INR 200, or < $3). Figure 3 summarizes the novel features of the currently proposed design of a fabric helmet.

Figure 3

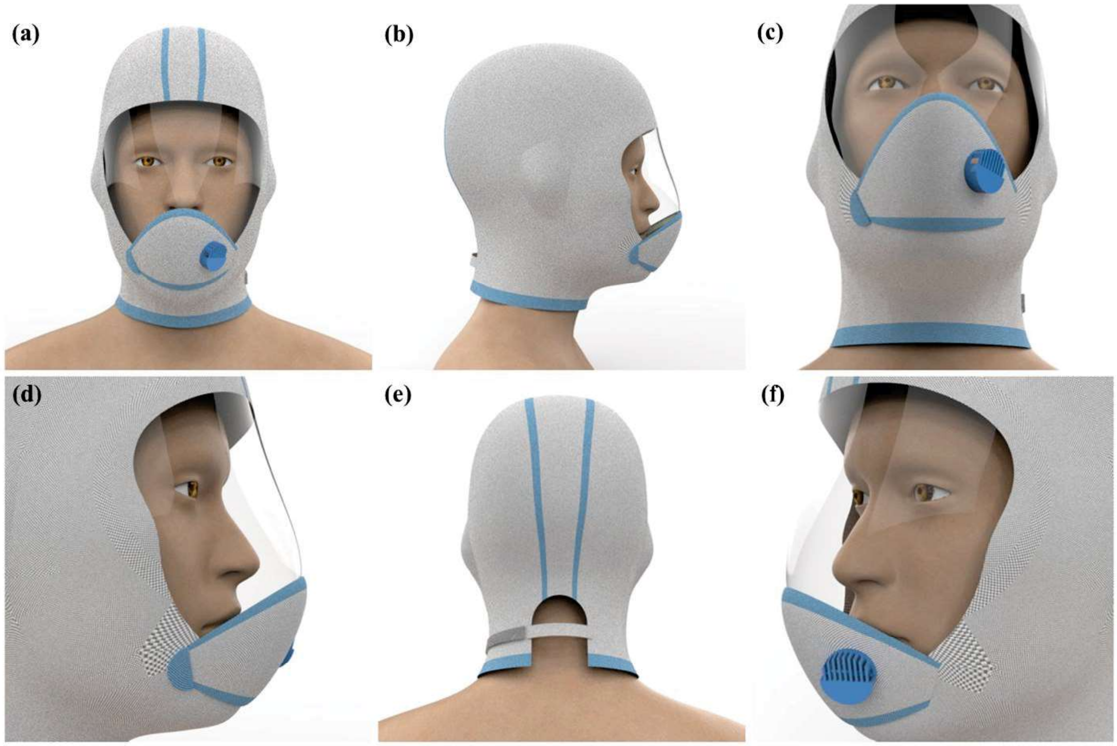
A Schematic of the Different Features of Fabric-Helmet

First, true to its name and its intended user base (among others, the pediatric population in schools and colleges), An air-breathing cloth above the head and around the sides ensures that there is a proper vent for the air and the body heat to escape, making the users feel comfortable over a longer period of time (Figure 4. It is worth pointing out that different grades of the air-venting fabric have been tested, experimented and used, and the subjects have reported that the fabric helmets are extremely comfortable to wear. Second, as shown in Figure 4 b, unlike the conventional masks, the fabric helmet sits around the head, is sturdy, does not require frequent adjustment, and it does not cause any pain at the back of the ears. Third, Figures 4 a-4 c suggest that this fabric-based soft-helmet provides complete protection to the entire face, including the hair, eyes, ears, nose, and head, minimizing vulnerability to infection. Unlike the currently-used masks, it does not allow the users to inadvertently touch the nose, ears, eyes, face, etc. thus minimizing the chances of infection. The air that is inhaled passes through an N95 mask cloth over the nose, and there exists a snug fit reducing all possibility of leakage, as depicted in Figure 4 d. Fourth, additional comfort is facilitated by the presence of a one-sided air vent guarantees that only the exhaled air goes out of the mask, whereas the inhaled air enters only through the N95 mask cloth. This air vent, shown in Figure 4 e, ensures that there is no humidity build-up inside the mask, and thus, the user may feel comfortable over longer periods of time. It should be pointed out that several design variants are typically possible as far as the location of the one-way air vent is considered. However, the governing consideration is that the vent should be placed as close to the mouth as possible. It is worth noting that the exhalation valves bypass the filter media and significantly reduce the effort required to exhale and increases comfort by significantly reducing heat and moisture build-up[5]. As shown in the back-side view in Figure 4 e, some space has been provided at the back for ventilation, and the 'lifted nose' design of the transparent fabric shield ensures that the visor does not touch the nose. Overall, these different factors add greatly to the comfort of wearing this fabric helmet over extended durations.

Next, as far as the economics of the fabric helmet is concerned, the cost may vary depending upon the different variants of the basic proposed design. In our study, we have fabricated three different designs for healthcare, household, and educational settings. Typically, these designs can be marketed under a low and high price segment, the basic difference being the presence of an N95 face-mask embedded in the case of an expensive version. Yet, these fabric helmets are cheap, costing merely around INR 200-250 (i.e., < $3) in India. Further, these masks are completely washable and reusable after sterilization or disinfection, as long as due care is taken while washing. It is recommended that these fabric helmets be washed and dried separately for longer life. It is worth pointing out that the fabric helmet comes with a unique feature of cheek-velcro as shown in Figure 4 f (in some design variants), wherein a velcro placed over the cheek may be engaged/ disengaged in case the wearer needs to sip water, ingest medicine or some light foodstuff, particularly in a crowded or community setting, thereby significantly reducing chances of infection spread. It should be reiterated that the velcro has necessarily been placed on the cheek so as to ensure that the user does not touch the areas close to the nose and mouth, which are more susceptible to contamination. In addition, the question of proper fit and adjustability is worth emphasizing. The fabric helmet comes with thin elastic straps/velcro that sits over the neck as well as on the head and allows users with a variety of head/neck sizes to comfortably wear it. The transparent visor is made of a flexible material, pressed at its top end, in such a way that it leaves some gap over the nose, thus facilitating breathing as compared to the cloth wrapped around the nose (particularly for people with respiratory problems). Finally, complete visibility is ensured by the usage of transparent grade Polystyrene/ Polycarbonate plastic with an anti-fogging coating, thus keeping it lightweight, comfortable and wearable over long durations.

Figure 4

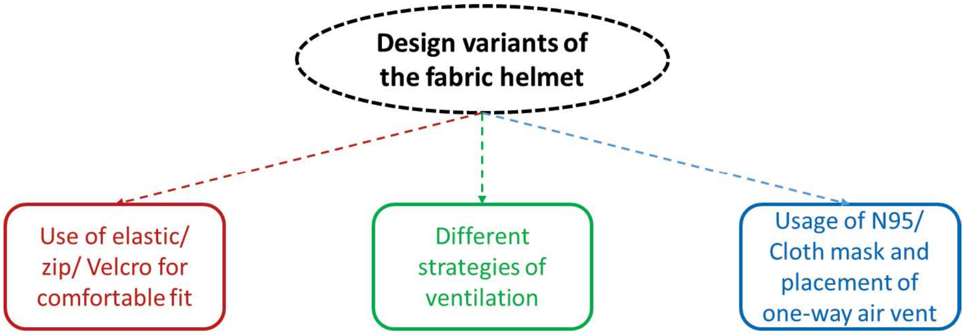
Different Views of the Proposed Protective COVID Fabric Helmet



(a) Front view (b) Side view (c) Bottom view (d) a close right-side view showing the cheek velcro (represented by blue colored section), (e) back-side view, and (f) a close left-hand view showing the one-way air vent. The black strips indicate an elastic/Velcro

Figure 5

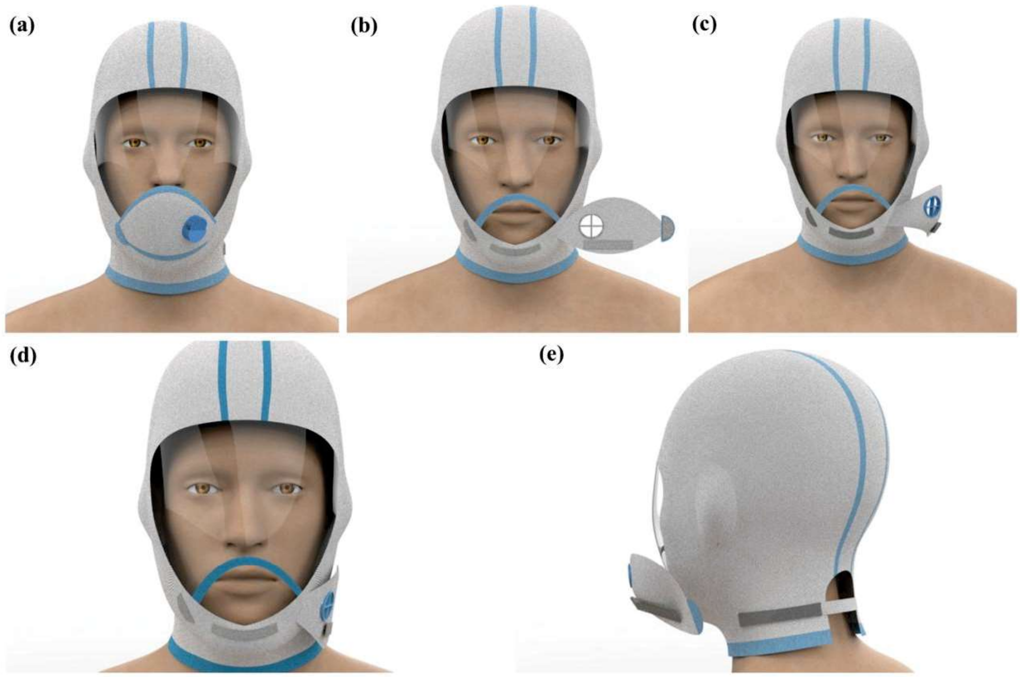
Strategies for the Preparation of Some Design Variants of the COVID Fabric Helmet



Typically, infectious diseases spread through droplets, respiratory aerosols, or contact with contaminated surfaces. Large particles such as droplets (>5 μm), which are emitted during sneezing or coughing, can be efficiently filtered out by medical masks, whereas aerosol particles (< 5 μm) can remain suspended in the air for several hours and are intercepted only by a respirator. It is expected that the proposed fabric helmet provides protection against multiple modes of transmission, including airborne, droplet, and hand to mouth/nose transmission, and is thus very effective in curbing infection. However, the effectiveness and wearability of these fabric helmets over long durations can be significantly enhanced significantly by incorporating some minor design modifications.

Figure 6

Stages in Food/Water Intake by Removing Cheek-Velcro



(a) Cheek Velcro closed, (b) Velcro detached, (c) Velcro taken backward, (d) Velcro fastened near the neck, and (e) the back-side view showing how the Velcro can also be attached to the back during the ingestion process

To improve the effectiveness and wearability of this fabric helmet, different fabric helmet variant design prototypes were fabricated for testing in order to cater to the needs arising in the pandemic and the post-pandemic situation. As shown in Figure 7, the different strategies for the fabrication of these different design variants are as follows: first, to ensure proper comfort to the users with respect to the fit, an elastic band or a Velcro was used to account for different head shapes and hairstyles. Second, a set of design variants were created, keeping different ventilation strategies in mind, and finally, the usage of an N95 mask or a cloth mask that is embedded in the fabric helmet and the location of the one-way air vent.

Finally, the suitability of the integration of cloth masks vis-à-vis N95 respirators with fabric helmets is worth pointing out. A recent study in this regard published in the American Chemical Society reports that the filtration efficiency of many common fabrics and their results with regard to the efficacy of the cloth masks are quite promising. In fact, the best part is that these hybrid three-layered cloth masks are superior to N95 for particles smaller than 300 nm, which is roughly the size of Coronavirus (80~120 nm). Figure 6 shows plots of filtration efficiency for different cloth masks as compared to N95 masks, and also the effect of 1 percent gap on the filtration efficiency. As evident from Figure 7 (A), N95 respirators, although has a high filtration efficiency in the size range greater than 300 nm, it drops down considerably in the smaller size range. Table 1 shows that the N95 masks provide an average filtration efficiency of 85 percent for particle size less than 300 nm. However, with a leakage gap as less as 1 percent, the average filtration efficiency drastically drops down to a mere 34 percent, which is quite low and unsafe in community settings. Also, as pointed earlier in this paper, a leakage gap of more than 1 percent is not unexpected during the usage of N95 respirators. In fact, the filter efficiency as reported by most of the face-masks in the market are for particles in the size range of 3 microns, which is much larger than the size of any virus, and thus the reported high filter efficiencies do not hold much relevance in the present context with respect to viral load protection. Since the chances of leakage with respect to snug-fitting over the nose is negligible in the COVID fabric helmet because of its design, these fabric helmets will invariably operate in the high-efficiency range and thus may prove more effective for protection from infection spread.

Figure 7 shows different views of the fabric helmet with the three-layered cloth masks (although three-layers are not visible in the figures). Based on the filter efficiencies data as observed from Table 1, four different design variants are fabricated by varying mask cloths and overhead fabric specifications. Table 2 provides detail of these design variants.

Figure 7

Filtration Efficiency of Cloth Masks vis-à-vis N95 Respirators with and without Gap of One Percent as a Function of Particle Size (Reproduced from[13])

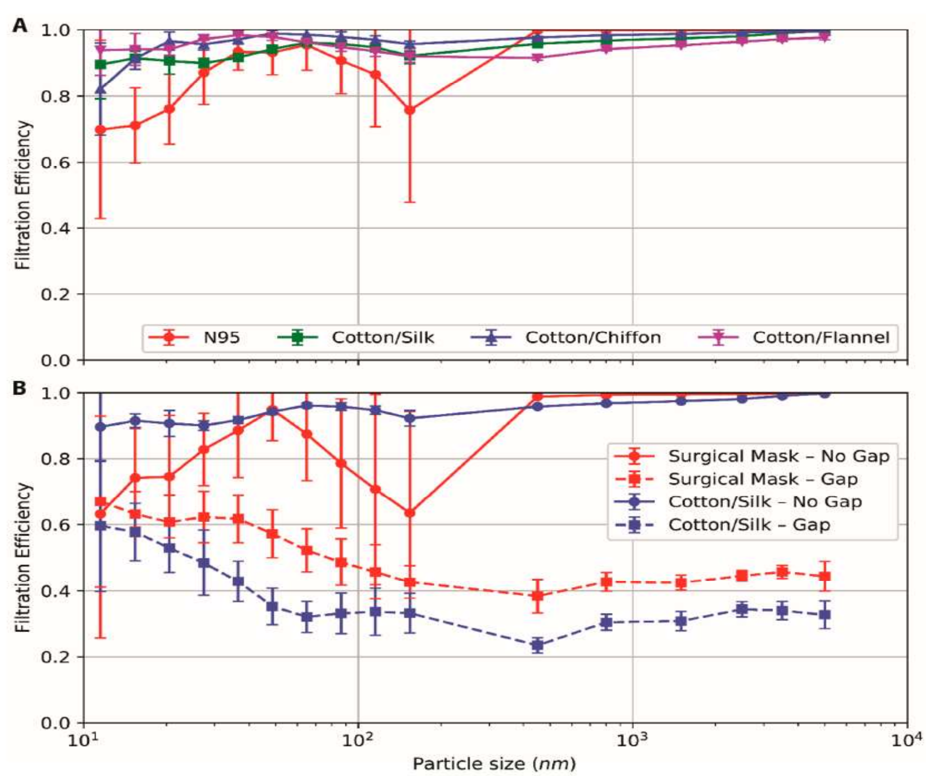


Table 1

Filtration Efficiencies of Various Test Specimens at a Flow Rate of 1.2 CFM and the Corresponding Differential Pressure (ΔP) across the Specimen (Reproduced from [13]).

Sample/fabric	Flow rate: 1.2 cfm		
	Filter efficiency (%)		Pressure differential
	<300 nm particles	>300 nm particles	Δp (Pa)
N95 (no gap)	85 ± 15	99.9 ± 0.1	2.2
N95 (with 1% gap)	34 ± 15	12 ± 3	2.2
Surgical mask (no gap)	76 ± 22	99.6 ± 0.1	2.5
Surgical mask (with a gap)	50 ± 7	44 ± 3	2.5
Cotton quilt	96 ± 2	96.1 ± 0.3	2.7
Quilter's cotton (80 TPI), 1 layer	9 ± 13	14 ± 1	2.2
Quilter's cotton (80 TPI), 2 layers	38 ± 11	49 ± 3	2.5
flannel	57 ± 8	44 ± 2	2.2
Cotton (600 TPI), 1 layer	79 ± 23	98.4 ± 0.2	2.5
Cotton (600 TPI), 2 layers	82 ± 19	99.5 ± 0.1	2.5
Chiffon, 1 layer	67 ± 16	73 ± 2	2.7
Chiffon, 2 layers	83 ± 9	90 ± 1	3.0
Natural silk, 1 layer	54 ± 8	56 ± 2	2.5
Natural silk, 2 layers	65 ± 10	65 ± 2	2.7
Natural silk, 4 layers	86 ± 5	88 ± 1	2.7
Hybrid 1: cotton/chiffon	97 ± 2	99.2 ± 0.2	3.0
Hybrid 2: cotton/silk (no gap)	94 ± 2	98.5 ± 0.2	3.0
Hybrid 2: cotton/silk (gap)	37 ± 7	32 ± 3	3.0
Hybrid 3: cotton/flannel	95 ± 2	96 ± 1	3.0

Table 2

Filtration Efficiencies of Various Test Specimens at a Flow Rate of 1.2 CFM and the Corresponding Differential Pressure (ΔP) across the Specimen

Variant-1	Anti-fogging visor	600 μm PET (food grade quality)
	Cloth Mask Specifications	Cotton quilt first layer – 120 TPI, pure cotton second layer – 95% cotton, 5% polyester third layer – 120 TPI, pure cotton
	Fabric (overhead) Specifications	Two layers of anti-microbial coating
Variant-2	Anti-fogging visor	600 μm PET (food grade quality)
	Cloth Mask Specifications	Hybrid 1 first layer – 600 TPI, pure cotton second layer – 90% polyester, 10% spandex third layer – 90% polyester, 10% spandex
	Fabric (overhead) Specifications	Two layers of anti-microbial coating
Variant-3	Anti-fogging visor	600. μm PET (food grade quality)
	Cloth Mask Specifications	Hybrid 2 first layer – 600 TPI, pure cotton second layer – pure silk third layer – pure silk
	Fabric (overhead) Specifications	Two layers of anti-microbial coating
Variant-4	Anti-fogging visor	600. μm PET (food grade quality)
	Cloth Mask Specifications	Hybrid 3 first layer – 600 TPI, pure cotton second layer – 65% cotton, 35% polyester
	Fabric (overhead) Specifications	Two layers of anti-microbial coating

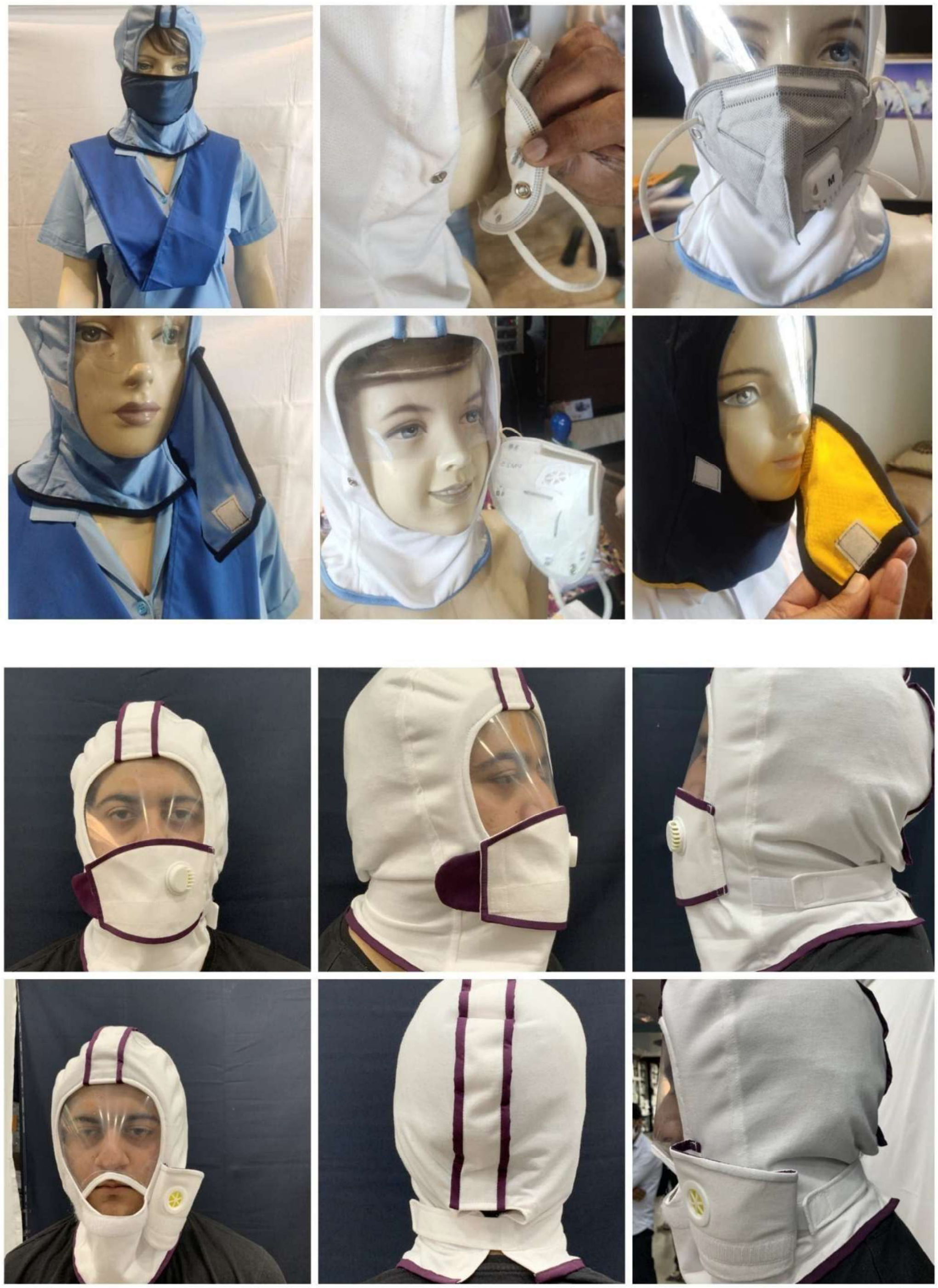
Finally, we present some of the designs we have tried to fabric these comfortably vented fabric helmets. Figure 8 (a) shows three basic designs of these fabric helmets on mannequin models, primarily intended for school/college students. As Figure 4 a-f shows, the designs differ in the use of chit buttons/velcros to engage/disengage the masks and whether an N95 or a cloth mask has been embedded in the fabric helmet. There are indeed several such designs possible, and it is hoped that the proposed idea of a soft fabric helmet during the pandemic and post-pandemic situation will be a very helpful low-cost contribution to the nations across the globe as they prepare to spring back to normalcy post the lockdown situation. Figure 8 (b) presents different views of a typical design of such a fabric helmet on an individual. The proposed COVID fabric helmet can be used not only in schools and colleges but also in air-conditioned offices, buses and trains, and also in hospitals and other pathological labs and testing facilities.

Figure 8

Designs of Fabric Helmets for Students

(a)

(b)



(a) Mannequin models wearing different prototype designs of COVID fabric helmets designed for school children during the testing phase, and (b) different views of one of the prototype models as worn by an individual

Conclusions: Potential Impact of the Proposed Innovation

The proposed innovation (COVID Fabric Helmet), if implemented, will greatly improve the safety of people in community settings or in situations where social distancing is difficult. It will also significantly improve the user comfort in wearing masks and encourage people to wear masks for significantly larger periods of time, particularly in places such as a workplace, during travel, etc. without worrying about adjusting. Thus, the current innovation will also greatly improve the efficacy of masks in curtailing the spread of COVID infection. This mask can be manufactured easily and also used in hospitals and other public places. This fabric helmet will reduce the need for coveralls and PPEs (which are getting scarce in the market, currently) because apart from covering the body with the cloth, the current masks are insufficient in covering the head and face. This proposed innovation will bridge that gap and reduce the need for expensive PPEs. Particularly, in developing countries, the requirement of providing PPE to all the healthcare workers (doctors, nurses, ICU technicians, lab technicians, support staff, etc.), infected and non-infected patients, relatives of patients, police and security personnel, etc. poses an immense burden on the economy. This adds to the immense healthcare burden, and so the need to design low-cost and simple PPE is the need of the hour to prevent the spread of COVID-19. Moreover, the designed intervention does not only cater to the healthcare settings but may also serve as a useful tool in addressing the post-COVID scenario in the nation, particularly in community settings such as educational institutions, where the health and safety of the pediatric population is a matter of great concern. It is hoped that educational institutions worldwide may get initial ideas for proper protective equipment to safeguard children around the world. Other institutions, such as offices, hospitals, pathological labs, and other testing facilities, may also benefit from this low-cost fabric helmet design. Further, professionals who are required to come in close proximity with other individuals/customers during their profession, such as dentists, barbers, etc. may also benefit from this design of fabric helmet.

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References

1. MacIntyre CR, S Cauchemez, DE Dwyer, H. Seale, P. Cheung, G. Browne, M. Fasher, J. Wood, Z. Gao R. Booy and N. Ferguson.Face mask use and control of respiratory virus transmission in households. Emerg Infect Dis, 2009;15(2): p 233-41.
2. Khan M.M. & S.R. Parab.Simple Economical Solution for Personal Protection Equipment (Face Mask/Shield) for Health Care Staff During COVID 19. Indian J Otolaryngol Head Neck Surg, 2020; p 1-5.
3. Feng S., C. Shen, N. Xia, W. Song, M. Fan & B.J. Cowling, Rational use of face masks in the COVID-19 pandemic. The Lancet Respiratory Medicine, 2020.
4. MacIntyre C.R. & A.A. Chughtai. Face-masks for the prevention of infection in healthcare and community settings. BMJ, 2015. 350: p h694.

5. Bailar, J., D.S. Burke, L. Brosseau, H. Cohen, E. Gallagher & K. Gensheimber.Reusability of face-masks during an influenza pandemic. Institute of Medicine, National Academies Press, Washington DC, 2006.
6. Naveed H., Y. Scantling-Birch, H. Lee & M.A. Nanavaty.Controversies regarding mask usage in ophthalmic units in the United Kingdom during the COVID-19 pandemic. Eye (Lond), 2020.
7. Jefferson T., R. Foxlee, C. Del Mar, L. Dooley, E. Ferroni, B. Hewak, A. Prabhala, S. Nair & A. Rivetti.Physical interventions to interrupt or reduce the spread of respiratory viruses: systematic review. BMJ, 2008; 336(7635): p. 77-80.
8. Jefferson T., C. Del Mar, L. Dooley, E. Ferroni, L.A. Al-Ansary, G.A. Bawazeer, M.L. van Driel, R. Foxlee & A. Rivetti.Physical interventions to interrupt or reduce the spread of respiratory viruses: systematic review. BMJ, 2009;339: p. b3675.
9. Ramakrishnan D. COVID-19 and Face Masks – To Use or Not to Use! Indian Journal of Community Health. 32(2): p. 240-242.
10. Davies A., K.A. Thompson, K. Giri, G. Kafatos, J. Walker & A. Bennett, *Testing the efficacy of homemade masks: would they protect in an influenza pandemic?* Disaster Med Public Health Prep, 2013;7(4): p. 413-8.
11. Guha S., A. Mejia-Alfaro, P. Hariharan & M.R. Myers.Effectiveness of face-masks for pediatric populations against submicron-sized aerosols. Am J Infect Control, 2015;43(8): p. 871-7.
12. Roberge R. Facemask use by children during infectious disease outbreaks. Biosecure Bioterror, 2011; 9(3): p. 225-31.
13. Konda A., A. Prakash, G.A. Moss, M. Schmoldt, G.D. Grant & S. Guha.Aerosol filtration efficiency of common fabrics used in respiratory cloth masks. ACS nano, 2020; 14(5): p. 6339-6347.