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An engineering approach for fighting COVID-19
Pseudo herd immunity through the complete spread of the helmet-type masks

Yusaku Fujii[1,a,*], Akihiro Takita[1,b], and Seiji Hashimoto[1,c]

[1]School of Science and Technology, Gunma University, 1-5-1 Tenjin-cho, Kiryu City 376-8515, Japan

*Corresponding author

[a]<fujii@gunma-u.ac.jp>, [b]<takita@gunma-u.ac.jp>, [c]<hashimotos@gunma-u.ac.jp>

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Abstract. A simple engineering way of fighting COVID-19 is proposed. First, the possibility of mass production of an inexpensive helmet-type mask, whose shielding rate against virus invasion is almost 100%, is shown. Second, the possibility of obtaining a pseudo herd immunity by means of the numerical control of the wearing ratio of the helmet-type masks is shown.

1. Introduction

The world is in an intermittent lockdown state due to COVID-19 [1, 2, 3]. 'Herd immunity' is normally obtained either through vaccination or immunity developed through previous infection. WHO supports achieving 'herd immunity' through vaccination, not by allowing COVID-19 to spread through any segment of the population, as this would result in unnecessary cases and deaths [4].

The authors propose an alternative engineering way to achieve 'pseudo herd immunity' through the mass spread of the almost-perfect masks. This proposal is based on the following 3 simple ideas/hypothesis.

[a] Mass production of helmet-type masks, which shield viruses 100%, is easy with the modern technology.

[b] If every person wears the helmet-type mask all the time, anyone cannot be newly infected. And all the airborne infectious diseases, including COVID-19, will be shut down promptly.

[c] Considered in the same way as herd immunity, the mask wearing rate, which is required to converge the infection, is not necessarily 100%.

This research is the improved one from the previous researches by the authors [5, 6] based on the inventions made by the authors [7, 8].

2. Prototype of the helmet-type almost-perfect mask

Figure 1 shows a helmet-type mask (total mass: 664g, operational time: 8 hours, total cost of parts: 200USD) developed using commercially available parts. If it is mass produced, the price is estimated to be 100USD or less.

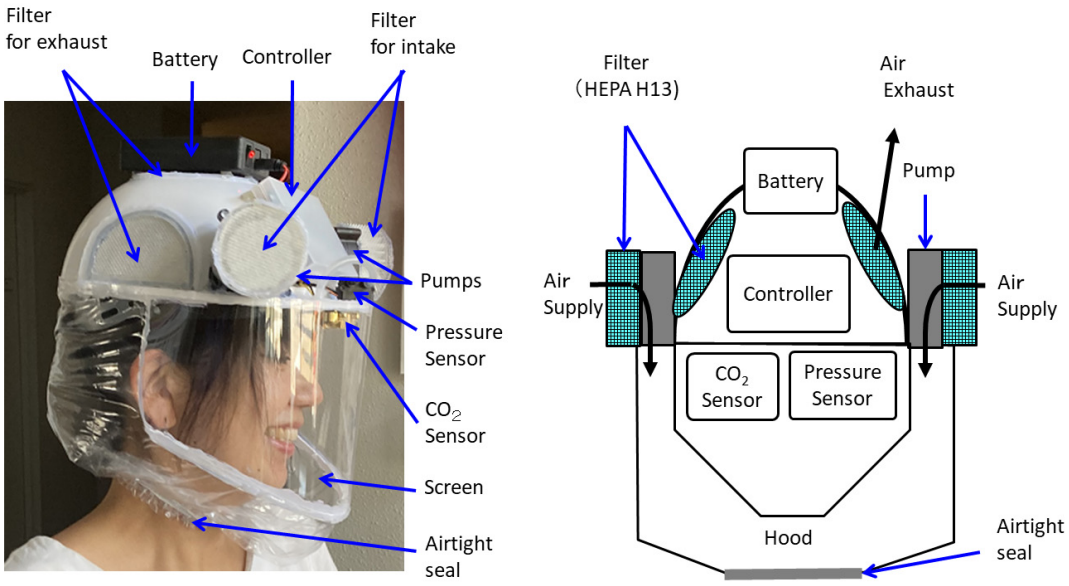
The features of the developed prototype are the following two points.

[a] Positive internal pressure

The pump power is controlled so that the flow rate is 100 L/min or larger, the carbon dioxide concentration is 2000 ppm or less and the internal pressure is 50 Pa or higher than the outside.

[b] Filtered air intake

Pumps make all the intake air filtered with a non-woven filter (HEPA H13 standard, 99.97% adsorption of particles up to 0.3 μm). Natural exhaust filtered with a non-woven filter (95% adsorption of particles around 0.1-0.3 μm) is realized due to the higher internal pressure.



(a) Photo of the mask (b) Schematic of the mask

Fig. 1. The prototype of the helmet-type mask (with $S_{r,in}$ = 1.0 and $S_{r,out}$ = 0.9)

The particles in a bio-aerosol are generally 0.3 to 100 μm in diameter [9], therefore, the adsorption rate of particles up to 0.3 μm can be considered as the virus shielding rate. Since the air invasion from the outside cannot occur due to the positive internal pressure, the aerosol/virus shielding rate of intake air $S_{r,in}$ is estimated to be approximately 1.00 (100%). The virus leakage to the outside mainly depends on the air tightness of the neck seal, and it is estimated to be 5% or less. Therefore, the aerosol/virus shielding rate of exhaust air $S_{r,out}$ is estimated to be approximately 0.90 (90%) or higher.

3. Infection control by means of the helmet-type masks

If all the people wears this mask ($S_{r,in}$ =1.0) all the time, no people can become newly infected and the spread of infection will be shut down immediately. However, with the concept of held immunity, not necessarily 100% people should wear the mask ($S_{r,in}$ =1.0) all the time to converge the spread of infection, as discussed below.

A susceptible person, who wears a mask that perfectly blocks the entry of the virus ($S_{r,in}$ =1.0), cannot become infected and then cannot infect others just like an immunized person. If the ratio W_r of all the people in a society wear the masks ($S_{r,in}$ =1) all the time, that means, the ratio W_r of all the susceptible people wear the masks and they cannot be infected. Then, the effective reproduction number R_t of COVID-19 of the society is reduced to the modified effective reproduction number R_{tm} as follows,

$$R_{tm} = (1- W_r)\, R_t \tag{1}$$

$$W_r = 1 - R_{tm}/R_t \tag{2}$$

By estimating the current effective reproduction number R_t and setting the target of the modified effective reproduction number R_{tm}, the required mask wearing ratio W_r can be calculated using the equation (2).

In the above discussion, the condition in which ratio W_r of all the susceptible persons wear the helmet-type masks all the time, can be replaced by the condition that all the susceptible persons wear the helmet-type masks at the ratio W_r of all the interpersonal physical contacts.

Table 1. Proposed social status for fighting COVID-19

	All the time		Concern of Infection Spread: Small → Large
Present Status	New lifestyle (Social Distancing, etc.) Recommended	+	Status of lockdown: Weak /Nothing → Strong
Proposed Status			Required wearing rate W_r of helmet-type masks: 0% → 100%

When lockdown is required due to the spread of infection, the government can take the following alternatives in lieu of lockdown as shown in Table 1.
[a] Every person is required to wear the helmet-type masks ($S_{r,in}$ = 1) when going out.
[b] The wearing rate W_r, which each person should follow, is shown.

By developing and introducing a system for measuring and managing the wearing rate of each individual, a society, in which each person is officially encouraged to make the interpersonal contact without the mask within the ratio of (1- W_r) for maintaining the health of the society, could be created.

As for evaluating the effective amount of the interpersonal physical contacts, various indicators can be considered, such as [a] the ratio of the time spent wearing the mask to the time spent going out, and [b] the ratio of the number of people contacted with the mask to the total number of people contacted. It is necessary to examine the validity and implementability of the indicators from the viewpoints of control of the infection spread.

Figure 2 shows the wearing rate W_r of the mask ($S_{r,in}$ = 1), which is required to realize the modified effective reproduction number R_{tm} =0.5 for the society with the current estimated value of the effective reproduction number R_t.

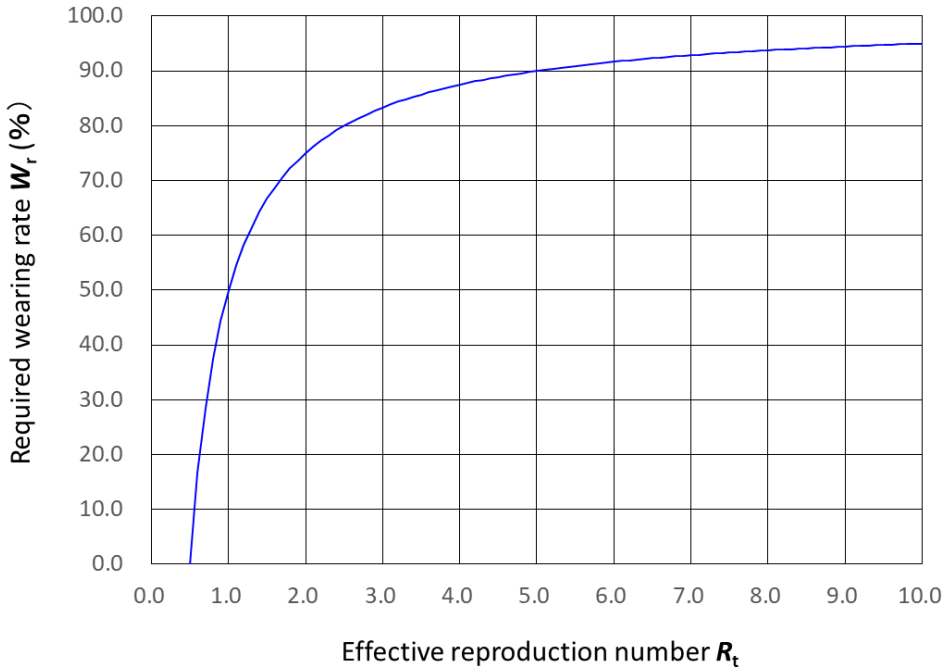


Figure 2 Wearing rate W_r required to realize R_{tm}=0.5
(using the helmet-type mask with $S_{r,in}$=1.0)

For an example, in order to realize R_{tm} = 0.5 and halve the number of infected people every infection period in a society under almost the worst infection situation of R_t = 5.0, the helmet-type mask with 100% intake shielding rate ($S_{r,in}$ = 1.0) should be worn by 90% (W_r = 0.9) of all the members of the society at all the time. Alternatively, all the members of the society should wear the masks in 90% of all the interpersonal contacts.

4. Discussions

Considering that infectious people, including asymptomatic infectious people, wear the helmet-type masks with a higher exhaust shielding rate $S_{r,out}$ than usual face masks, the modified effective reproduction number R_{tm} is considered to be lower than that derived from the equation (1).

If this proposal is taken by the society, then, the comfort, convenience, functionality and design of the helmet-type masks will be rapidly and significantly improved by the efforts of companies and governments.

As for “air” not like “water”, modern people, still like primitive people, breathe “natural air”. With the advent of very-comfortable and almost-perfect helmet-type masks, many people might prefer to wear the masks, regardless of the spread of virus infection or regardless the government order to wear them. This means the emergence of a society that is extremely resistant against all airborne infectious diseases.

5. Conclusions

If this proposal is taken, the society can take “order to wear the masks” instead of “lockdown”. The damage to the society can be minimized even under the worst infection status.

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