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# Comparing Effect of Donning Different Types of Face Masks on Oxygen Saturation, Pulse Rate and Comforts among Healthy Wearers

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**Abstract**

Background: In facing the pandemic of COVID-19, the role of face mask is utmost important and has been considered the most basic personal protective equipment to be used against Corona virus. In spite of that, there are significant population disagree with wearing mask as they perceive wearing mask is unsafe, causing discomfort and may even compromise their health. This pose significant challenge in the battle against COVID-19. Thus, this study aims to determine the effect of different types of masking on oxygen saturation, pulse rate and comfort of the healthy wearers.

Methods: In this crossover method comparison study, four different types of mask were worn by ten (10) similar healthy adult participants, for an equal duration of time and perform the same set of activities within the range of typical sedentary routines. The oxygen saturation and pulse rate of each wearer was measured with pulse oximeter before masking, after 30 minutes and 1 hour of masking. The subjective symptoms of dizziness, pain around facial and ear region, tachypnea, itchiness, discomfort and fogginess (for subjects who wear spectacles) were also recorded. The masks consist of the most commonly used single surgical mask, double surgical mask, N95 mask and the stick-on mask Lekad.

Results: The results indicated no significant effect in oxygen saturation level changes between different types of masks worn by participants, however there was significant effect in pulse rate changes. Nonetheless, subjects wearing N95 masks experienced more dizziness, itchiness, tachypnea and discomfort compared with other mask. Stick-on mask Lekad reported less subjective symptoms and no fogginess for participants wearing spectacles and therefore was preferred for health professionals working in enclosed atmosphere.

Conclusion: It was indicated that regardless of types of mask, masking should be encouraged and continuously practiced in the public area to break the chain of virus transmission. The innovative stick-on mask Lekad seems to report a more stable oxygen saturation, pulse rate and experienced less subjective symptoms than other types of mask and has a good potential to emerge as a better mask to be used in a crowded and enclosed environment.

Keywords: face mask, surgical mask, N95 mask, oxygen saturation, respirator mask, corona virus, stick-on mask

**Introduction**

During the COVID-19 pandemic, uses of face masks including surgical masks, N95 mask and other types of masks are widely recommended by local and international authority through the enforcement of regulation (1, 2). Mask mandates have helped reduce the number of cases in the United States and in Germany as demonstrated in recent outbreak of COVID-19 (3, 4). A large survey conducted in 69 countries, found community mask adherence and community attitudes towards masks are associated with a reduction in COVID-19 cases and deaths (5).

Masks have been associated with a reduction in the infection rate among health care workers in a large hospital network (6). Evidence also substantiated that wearing surgical mask was not associated with a decline in oxygen saturation in older participants (7). In spite of evidence, many parties claim that masks can cause hypoxia and may compromise health, concerns have emerged about the safety of wearing face masks. However, mask is arguably the best weapon against COVID-19, but the world attention is mainly on vaccine. No doubt vaccine has its role but is associated with lots of uncertainty and risk. While the world hardly able to manage the problem of COVID-19, we are further facing threat of new virus variants. Even if every one of us is vaccinated, mask is still be needed. Research has clearly proven where compliance of mask is strong, COVID-19 in the region is better controlled (8). Not only mask saved life, it is also found to save economy. Despite all that, there are significant population not complied to masking. This pose significant challenge in the battle again COVID-19.

Although surgical and N95 masks are widely used by healthcare workers in atmospheric hostile environment but the impact of masking on physiological parameters has not been tested during and after physical activity. Thus, it is useful and timely for this study to determine the effect of different types of masking on oxygen saturation, pulse rate and comfort of the healthy wearers during and after physical activity.

**Methods**

This is a crossover method comparison study in which ten healthy adults were recruited from university nursing student population to participate in this study. Selection was based on inclusive and exclusive criteria. Eligibility criteria to include only non-smokers, age 20 - 30 years old. Those with known history of medical conditions such as heart diseases, cancer, diabetes, hypertension and smokers were excluded from study. Ten final year nursing students were randomly selected from a total of 350 nursing student population in AIMST University Malaysia. Four different types of mask were worn by ten similar healthy adult participants including one with no mask as a control. The study protocol was approved by AIMST University Human & Animal Ethics Committee (AUHEC:00234/01/21). Informed consent was taken from each participant before the study was undertaken.

To minimize variability, participants were provided with single 3-layer surgical masks (Medicos), double 3-layer surgical masks (Medicos), N95 masks (3M), stick-on masks (Lekad© 3C Co Ltd) and a portable pulse oximeter (Mindray©).

Participants were required to wear mask for an equal duration of 1 hour, at similar time of a day and perform the same set of activities within the range of typical sedentary routine.

Instruction was given on how to wear the mask correctly to ensure adequate fitting so the mask should cover the participant's nose and mouth appropriately. Participants were instructed to self-monitor and record SpO2 and pulse rate among themselves in 3 times interval at the start of activity, 30 minutes and at 1 hour times after activity. The time interval for recording was monitored by researchers to ensure participants conform to the protocol. They were offered opportunities to clarify the instructions if they didn't understand. Participants were also asked to answer the questionnaire given on subjective symptoms that they felt after the completion of research activity. Each participant was required to perform similar standard activities namely reading books or play with their phone for 15 minutes. Random walking in normal pace for 15 minutes. Continuous conversation with university friend for 15 minutes. Stairs climbing exercise continuously for 15 minutes. Recording were taken at first reading before activity start, second reading at 30 minutes' time and subsequently for third reading at 60 minutes' time. The primary outcomes are oxygen saturation level. Recording was taken using MINDRAY©DNP2 pulse oximeter. The normal oxygen saturation level is >95%, hypoxia may occur if SpO2 <95% (9), whereas for pulse rate, the normal reading for adult is 60 - 100 bpm. Tachycardia is interpreted when pulse rate >100 bpm, and bradycardia was considered if pulse rate is < 60 bpm.

**Results**

In the initial phase, a total of 12 university final year nursing students voluntarily participated in this study. However, 2 declined due to time planned for research conducted crashing with their clinical placement schedule. A total of 10 participants with mean age 20.1±0.3 years old, 9 female (90%) and 1 male were enrolled. Six (60%) participants were Chinese and 4 (40%) belong to Indian ethnicity (Table 1). All participants were healthy and no one had any medical comorbidity.

A total of 300 measurements on SpO2 and pulse rate were taken from participants who wore different types of mask plus readings taken for participants without mask. In term of subjective symptoms, a total of 70 symptoms self-reported by participants for each type of masks wore by them. Likewise, a total of 40 records for each symptom reported regardless of types of mask they wore.

Secondary outcomes are subjective symptoms experienced by participants which include shortness of breath (SOB), dizziness, aching, itchiness, discomfort, increase heart beat and spectacle's fogginess. These symptoms were measured with items in questionnaire adapted from Liu et al. (10) which participants need to score each item with rating scale from 0 which means totally no feeling of symptom to 5 with most unbearable symptom. However, one item on comfort was scored in reverse coding range from 0 with unbearable feeling to 5 with most comfortable.

Sample size of 10 participants was calculated using G*power version 3.1.9.7 (11). The estimation was based on F test with ANOVA repeated measures, within factors with desired effect size of 0.5, α level at 0.05, and power level (1-β) of 85%. As this was a cross over method comparison study with 3 repeated measurement for each group, 10 participants were considered appropriate.

The results of pooled SpO2 and pulse rate across 3 times interval were tabulated between 4 different types of mask and no masking was also taken as control. Participants wore single surgical mask recorded slight decrease (0.4%) of SpO2 with reading 99.3 before masking to 98.9 after completion of activity. Those on double surgical mask recorded decrease (1.6%) of SpO2 with reading 99.3 before masking to 97.7 after completion of activity. Participants who wore N95 also recorded decrease (1.6%) of SpO2 with reading 99.3 before masking to 97.7 after completion of activity. However, those wore stick-on mask Lekad recorded slight increase (0.2%) of SpO2 from 98.9 before masking to 99.1 after completion of activity. Whereas for participants who didn't put on mask recorded mild decrease (0.4%) of SpO2 from 99.1 before masking to 98.7 after completion of activity (Table 2).

In term of pulse rate, participants who wore single surgical mask reported increase pulse rate (22%) from 93.4 before masking to 114.4 after completion of activity. Those wore double surgical mask reported increase of pulse rate (32%) from 93.1 before masking to 122.8 after completion of activity. Participants on N95 reported increase of pulse rate (24%) from 95.6 before masking to 118.7 after completion of activity. Those wore stick-on mask Lekad recorded increase pulse rate (31%) from 85.5 before masking to 112.3 after completion of activity. Participants who didn't wear mask reported more increase pulse rate (37%) from 93 before masking to 127.6 after completion of activity.

The factorial ANOVA repeated measures results show there was no significant main effect in SpO2 changes between different types of masks worn by participants [$F(1,4)=2.418$, $\eta_p^2=0.177$, $p>0.05$]. However, there was a significant interaction effect between types of mask worn and time interval before masking and after activity on the changes in SpO2 [$F(8,90) =2.788$, $\eta_p^2=0.199$, $p=0.008$]. The interaction effect was depicted (Figure 1) particularly between stick-on mask and other types of mask including participants without mask.

Similarly, the factorial ANOVA repeated measures within- between effect were conducted for pulse rate. The results show there was a significant main effect in pulse rate changes between different types of masks worn by participants [$F(1,4)=2.744$, $\eta_p^2=0.196$, $p<0.05$]. However, there was no significant interaction effect between types of mask worn and time interval before masking and after activity on the changes in pulse rate [$F(6.751,75.950) =0.615$, $\eta_p^2=0.052$, $p>0.05$]. Figure 2 showed no obvious interaction effect between types of mask worn and time interval before masking and after activity on the changes in pulse rate.

**Table 1: Demographic characteristics of study samples**

| | **Frequency** | **Percentage (%)** |
|---|---|---|
| Gender | | |
| Male | 1 | 10 |
| Female | 9 | 90 |
| Age | | |
| ≤20 | 9 | 90 |
| >21 | 1 | 10 |
| Ethnicity | | |
| Chinese | 6 | 60 |
| Indian | 4 | 40 |

**Table 2: Results of distribution of SpO2, pulse rate between different types of masks**

| Parameter | Types of Mask | Time (minutes) | Mean | SE | 95% CI Lower | 95% CI Upper | P |
|---|---|---|---|---|---|---|---|
| SpO2 | Single surgical mask | Pre | 99.300 | 0.300 | 98.621 | 99.978 | 0.062 |
| | | T1 | 99.300 | 0.260 | 98.711 | 99.889 | |
| | | T2 | 98.900 | 0.233 | 98.372 | 99.428 | |
| | Double surgical mask | Pre | 99.300 | 0.213 | 98.817 | 99.782 | |
| | | T1 | 97.900 | 0.433 | 96.920 | 98.880 | |
| | | T2 | 97.700 | 0.539 | 96.482 | 98.918 | |
| | N95 | Pre | 99.300 | 0.260 | 98.711 | 99.888 | |
| | | T1 | 98.000 | 0.298 | 97.326 | 98.674 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | T2 | 97.700 | 0.396 | 96.805 | 98.595 | |
| | Stick-on mask Lekad | Pre | 98.900 | 0.276 | 98.274 | 99.526 | |
| | | T1 | 98.800 | 0.291 | 98.143 | 99.457 | |
| | | T2 | 99.100 | 0.180 | 98.694 | 99.506 | |
| | No mask | Pre | 99.100 | 0.314 | 98.389 | 99.811 | |
| | | T1 | 98.600 | 0.306 | 97.909 | 99.291 | |
| | | T2 | 98.700 | 0.396 | 97.805 | 99.595 | |
| Pulse rate | Single surgical mask | Pre | 93.400 | 3.585 | 85.291 | 101.509 | |
| | | T2 | 92.400 | 3.787 | 83.834 | 100..966 | |
| | | T3 | 114.400 | 5.564 | 101.813 | 126.987 | |
| | Double surgical mask | Pre | 93.100 | 3.466 | 85.260 | 100.940 | |
| | | T1 | 100.000 | 2.817 | 93.628 | 106.372 | |
| | | T2 | 122.800 | 8.136 | 104.395 | 141.205 | |
| | N95 | Pre | 95.600 | 2.409 | 90.150 | 101.050 | |
| | | T1 | 94.500 | 2.655 | 88.494 | 100.506 | 0.040* |
| | | T2 | 118.700 | 4.558 | 108.388 | 129.09 | |
| | Stick-on mask Lekad | Pre | 85.500 | 1.839 | 81.339 | 89.661 | |
| | | T1 | 89.400 | 3.600 | 81.256 | 97.544 | |
| | | T2 | 112.300 | 5.442 | 98.987 | 124.612 | |
| | No mask | Pre | 93.000 | 2.970 | 86.281 | 99.719 | |
| | | T1 | 100.600 | 3.128 | 93.525 | 107.675 | |
| | | T2 | 127.600 | 1.893 | 123.319 | 131.881 | |

Note: SE: Standard error; CI: confidence interval; *p<0.05

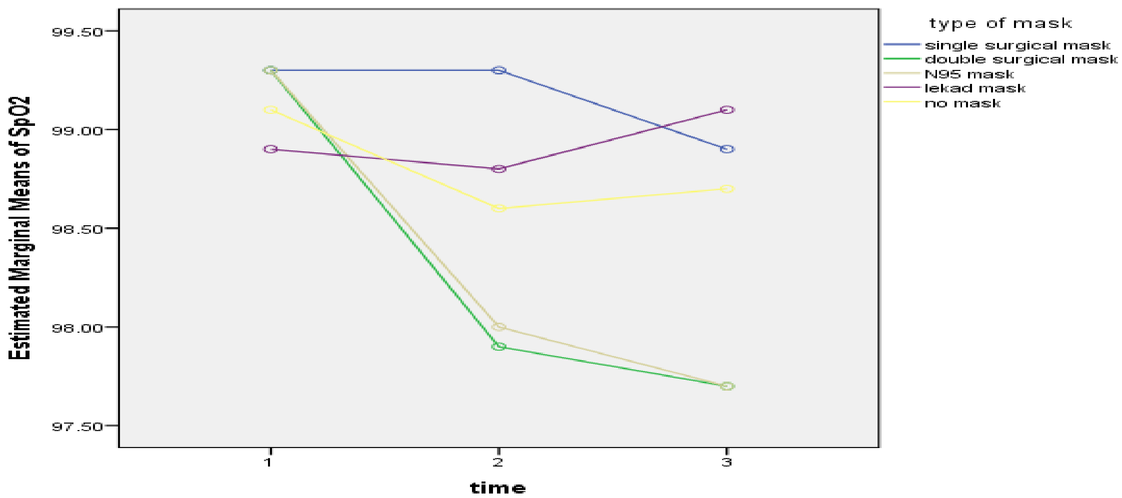



**Figure 1: Distribution of SpO2 on donning different types of masks**

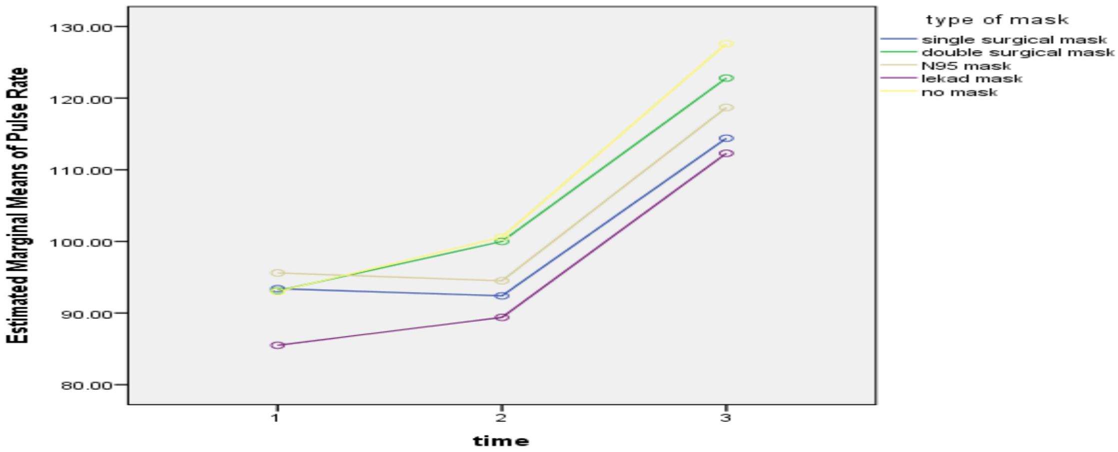



**Figure 2: Distribution of pulse rate on donning different types of masks**

The results from subjective symptoms elicited from questionnaire responded by participants after the activity. For shortness of breath, participants felt that N95 mask contributing the most with mean score of 2.90 and the least is double surgical mask with mean score of 0.28. N95 mask also causing the most in dizziness with mean score of 2.3 while the least is single surgical mask (mean:0.90). N95 also causing the most aching to the facial and ear region (mean: 2.4) compared to other types of mask and the least causing pain was stick-on mask Lekad (mean:0.30). N95 also causing more itchiness, increased heart rate than other types of mask. In term of comfort, single surgical mask was considered the most comfortable follows by double surgical mask and stick-on mask Lekad, while N95 seems to be the least comfortable. For those who wore spectacles, stick-on mask was considered the least that caused fogginess follows by N95 while single surgical mask causing the most fogginess for those who wore spectacles.

The subjective feeling data was performed with non-parametric test as it violates the required assumptions. The results of Kruskal Wallis test revealed that all subjective symptoms did not showed significant differences between four different types of masks worn by participants except the aching symptom [H(3)=16.913, p=0.001) (Table 3).

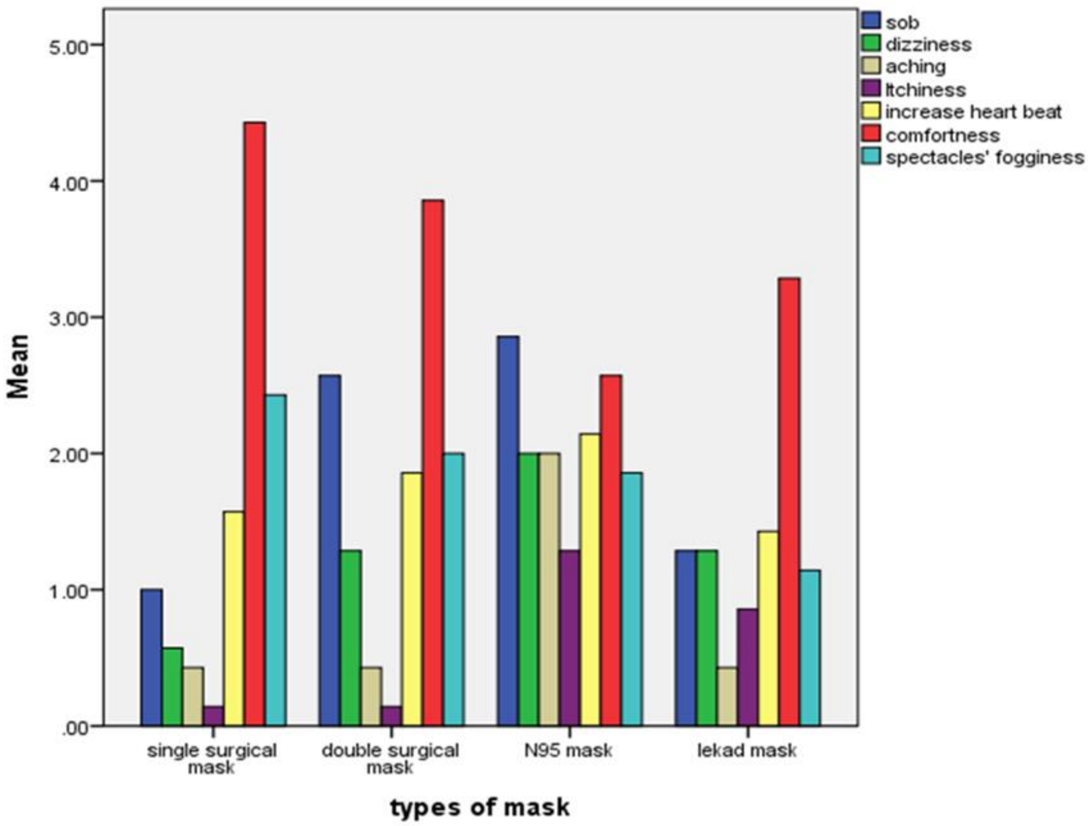
**Table 3: Results of subjective symptoms among wearers after donning different types of masks**

| Subjective feeling | Mean | SE | 95% CI | | $P^a$ |
|---|---|---|---|---|---|
| | | | Lower | Upper | |
| SOB | | | | | |
| +Single surgical mask | 1.300 | 0.423 | 0.343 | 2.257 | 0.084 |
| Double surgical mask | 0.280 | 0.490 | 1.692 | 3.908 | |
| N95 | 2.900 | 0.526 | 1.710 | 4.090 | |
| Stick-on mask Lekad | 1.600 | 0.542 | 0.375 | 2.825 | |
| Dizziness | | | | | |
| Single surgical mask | 0.900 | 0.314 | 0.189 | 1.611 | 0.251 |
| Double surgical mask | 1.900 | 0.504 | 0.759 | 3.041 | |
| N95 | 2.300 | 0.651 | 0.828 | 3.772 | |
| Stick-on mask Lekad | 1.200 | 0.533 | -0.007 | 2.407 | |

| | | | | | |
|---|---|---|---|---|---|
| Aching | | | | | |
| Single surgical mask | 0.400 | 0.306 | -0.291 | 1.091 | |
| Double surgical mask | 0.500 | 0.307 | -0.195 | 1.195 | 0.001** |
| N95 | 2.400 | 0.521 | 1.222 | 3.578 | |
| Stick-on mask Lekad | 0.300 | 0.300 | -0,379 | 0.979 | |
| Itchiness | | | | | |
| Single surgical mask | 0.300 | 0.153 | -0.046 | 0.646 | |
| Double surgical mask | 0.700 | 0.396 | -0.195 | 1.595 | 0.139 |
| N95 | 1.800 | 0.533 | 0.594 | 3.007 | |
| Stick-on mask Lekad | 1.100 | 0.504 | -0.041 | 2.241 | |
| Increased heart beat | | | | | |
| Single surgical mask | 2.000 | 0.650 | 0.530 | 3.470 | |
| Double surgical mask | 2.200 | 0.680 | 0.662 | 3.738 | 0.657 |
| N95 | 2.600 | 0.686 | 1.047 | 4.153 | |
| Stick-on mask Lekad | 1.600 | 0.653 | 0.122 | 3.078 | |
| Comfort | | | | | |
| Single surgical mask | 3.600 | 0.521 | 2.422 | 4.778 | |
| Double surgical mask | 3.200 | 0.512 | 2.042 | 4.358 | 0.375 |
| N95 | 2.500 | 0.438 | 1.531 | 3.469 | |
| Stick-on mask Lekad | 3.100 | 0.482 | 2.010 | 4.190 | |
| Spectacle's fogginess | | | | | |
| Single surgical mask | 1.700 | 0.668 | 0.190 | 3.210 | |
| Double surgical mask | 1.400 | 0.562 | 0.129 | 2.671 | 0.416 |
| N95 | 0.179 | 0.496 | 0.179 | 2.421 | |
| Stick-on mask Lekad | 0.800 | 0.554 | -0.453 | 2.053 | |

Note: SE: Standard error; CI: Confidence interval; SOB: Shortness of breath; a: Kruskal Wallis test; **P<0.01

Summary results from secondary outcomes indicated that N95 mask relatively causing the most SOB, dizziness and itchiness. Single surgical mask and double surgical mask are still the most comfortable one. Surprisingly, participants reported more shortness of breath when they wore N95 mask. While single mask causing the most fogginess. Stick-on mask Lekad found to have the least fogginess and causing the least tachycardia (Figure 3).




Note: SOB: Shortness of breath

**Figure 3: Subjective symptoms experienced by participants donning four (4) different types of masks**

**Discussion**

The results indicated that all four different types of masks show no significant changes in oxygen saturation level but some mild significant changes in pulse rate. Nonetheless, participants wearing N95 masks experienced more dizziness, itchiness, SOB and discomfort compared with other masks. Participants wearing N95 also found to have significantly higher pulse rate compared with participants with other masks. This goes in line with the fact that N95 filtering face piece is found to have dead space between 100 to 190ml depending on model and contour of the faces of the wearers (12). This is about 20 to 40% of tidal volume of normal individual which is 500ml. To overcome the compromised air exchange, breathing need to be deeper and faster which is subjectively reflected in the more giddiness and SOB when the participants were wearing N95. Objectively, the effect of the dead space is reflected in the increase of pulse rate also when the participants were wearing N95. Since the compromise in respiration still within physiological limit, no significant changes in oxygen saturation demonstrated.

Fogginess was found to be maximum with normal surgical mask and minimum with stick-on mask Lekad. This is because the amount of expired air directed to the spectacles mainly contributed by the leakage. These findings go inline with results of other studies which reported normal surgical mask exhibits 35% leakage compared to N95 with 9% leakage (13). In separate smoke lab test showed stick-on mask Lekad was significantly better than N95 and normal surgical mask in terms of leakage (14). In the smoke test, there was no visible smoke leak out from the sites of stick-on mask Lekad, this implied it effectively addressed the problem of leakage of face mask. Even-though there is no leakage in stick-on mask, it was found not associated with the symptom of shortness of breath. This clearly implies the common misconception of the fitness is associated with difficulty in breathing. In actual fact, the main factor for difficulty in breathing is the volume of dead space, which would compromised quantity of exchangeable air. In simple language, the bigger the dead space, the larger the quantity of second-hand air will be inhaled first before one can enjoy fresh air during inspiration.

The results in this study coincided with the study by Epstein et al. (15) on healthy subjects, that short-term moderate physical activity with a mask was associated with only minor changes in physiological parameters especially with mild decrease in SpO2 and moderate increase in pulse rate. Likewise, this study also concurs with reviews conducted by Hopkin et al. (16) that face masks, including N95 and surgical masks have small and often difficult-to-detect effects on physiological parameters during physical activity, even with strenuous or maximal exercise.

There are limitations in this study which include no direct objective measurement of difficulty in breathing which could be done with recording of respiratory rate. Nevertheless, the difficulty in breathing can be monitored with symptoms of SOB and giddiness and objective taking of pulse rate can similarly reflect physiologically the problem of difficulty in breathing. Additional downside is a small sample of study which might affect the generalization of the study, limited range of age for the participants as they were conveniently recruited from young university student population, short duration for participants on mask wearing which might fail to capture the real findings for people on masking for long duration especially for healthcare workers.

## Conclusion

In the nutshell, we have recapitulated two pertinent points. First, the results of this study clearly indicate none of the mask cause significant drop in oxygen saturation level even after 1 hour of planned physical activities regardless of quality of fitting of mask on the face. The study helps to clear doubt on misconception by certain segment of population that wearing mask can cause significant health issue with secondary drop in oxygen saturation. So generally, there is no scientific reason or excuse for us not to comply to wearing mask. Second, quality of the fitting of a mask is not the reason for the cause of difficulty of breathing (17). Thus, demystify the belief that good fitting would augur well with better breathing. This finding can contribute by convincing the public to be more responsible to protect themselves via wearing mask in addition to observing other standard operating procedures as recommended by authority based on WHO guidelines. In addition, remember to give due attention to quality of fitting of the mask they wear in the prevention of transmission of corona virus (18,19). With the current roll out of vaccines in many countries, wearing mask is still important and relevant to maximize the protection in the battle against COVID-19 pandemic.

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