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Physiological Workload Analysis on the Use of Face Masks during Physical Activities

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***Abstract*— During the COVID-19 pandemic people are required to limit outside activities and keep following social distancing protocol. However, several studies have reported that indoor exercises have a greater risk toward COVID-19 virus infection. Therefore, wearing a mask during light to moderate intensity of outdoor physical activity is still recommended. We conduct an experiment to analyze physiological ergonomics aspect, whether people wearing different type of masks during physical activities and distraction of music would affect heart rate. Analysis of the average heart rate data was carried out using the calculation of VO2max and Energy Expenditure to determine the workload level of the four scenarios of treatment combination. The result shows a heavy level of physical load on the use of surgical mask with distraction of music and moderate level of physical load on the use of surgical without distraction of music.**

***Keywords*—physiological performance, ergonomics, physical workload, human factors.**

I. INTRODUCTION

The rapid transmission of the COVID-19 virus has made restrictions on human movement around the world. Activities such as work and school are all switching into online. This restriction has consequences, namely changes in lifestyle habits that were originally active into more relaxed or sedentary behavior. During the pandemic, many activities must be limited and people need to adapt to new habits. One of the restricted activities is exercise at the gym or other indoor places. Several studies have reported that indoor sports have a greater risk of contracting COVID-19 virus infection [1]. The closed condition of the room with many people could make the virus transmission process easier.

These circumstances limit us to do various physical activities. However, since we have to maintain our health as a priority, we still need to do exercise regularly. The benefits of exercising regularly include increasing the ability of the heart to work, increasing work ability and muscle strength, increasing HDL cholesterol levels and decreasing triglycerides, both of which result in a reduced risk of heart and blood vessel disease, improving cognitive function, and preventing depression [2]. Regular exercise is also beneficial in improving sleep quality, protecting the body and increase immunity.

Wearing a face mask during physical activity, such as exercising, is an individual choice. Some knowledge related to the need to take care of our personal health, how the environment supports us to do physical activity will affect people's decision whether choosing to wear a face mask [3], [4].

Wearing face masks is recommended for the prevention of contracting or exposing others to cardiorespiratory infections, such as COVID-19, especially for a light to moderate intensity of the activities [5]. As mentioned in [6], the WHO advises the wearing of face masks during vigorous physical activities, since it might affect people to breathe uncomfortably. For instance, cycling during the pandemic must still follow the provisions of the health protocol, such as washing hands, keeping a distance between other cyclists, and wearing masks. The recommended mask to wear for exercising is a comfortable mask, not too tight, but still able to prevent the spread of the virus [7]. However, previous studies have shown that wearing a surgical facemask or even a N95 filtering facepiece during exercising at low-to-moderate work rate has no physiological impact [5], [6], [8]. Thus, an experiment was conducted, in this study, to analyze physiological ergonomics aspect, whether people wearing different type of masks during physical activities and distraction of music would affect heart rate.

II. EXPERIMENT METHODOLOGY

The experiment was conducted to analyze several combinations of treatment toward the average of heart rate, during physical activity, such as running at treadmill with several speed settings, various type of masker, and the existence of music distraction. Analysis of the average heart rate data was carried out using the calculation of VO_2max and Energy Expenditure to determine the workload level of the given four scenarios of treatment combination. Participants of this experiment was students from Department of Industrial Engineering, Faculty of Advanced Technology and Multidiscipline, Universitas Airlangga. Experiments used some tools and equipment like thermometer gun, weight and height

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scale, blood pressure measure, treadmill, and smartwatch to record the heart rate.

Prior the experiment, data (such as weight, height, age, gender, and exercising frequency) from all of the participants was collected. Participants will be wearing a heart rate monitor strap and smartwatch to record the heart rate progress during exercise. There will be 4 treatment combinations such as wearing surgical mask with music (S-M), cloth mask with music (C-M), wearing surgical mask without music (S-NM), cloth mask without music (C-NM). Each of them will be running on the treadmill for total 9 minutes, with different speeds for each treatment scenario. In each treatment, the participants will be running at speed 2 mph for the first minute, then continue to increase speed at 6 mph for 6 minutes, 1 minute at 7 mph, and finished at speed 2 mph for the last minute. Observer will record the heart rate at every minute. Participants were given 5 minutes break to rest, taking blood pressure test and body temperature, before continuing the next treatment scenario. until 4 treatment combinations are all observed successfully. All those procedures were documented as shown in Fig.1

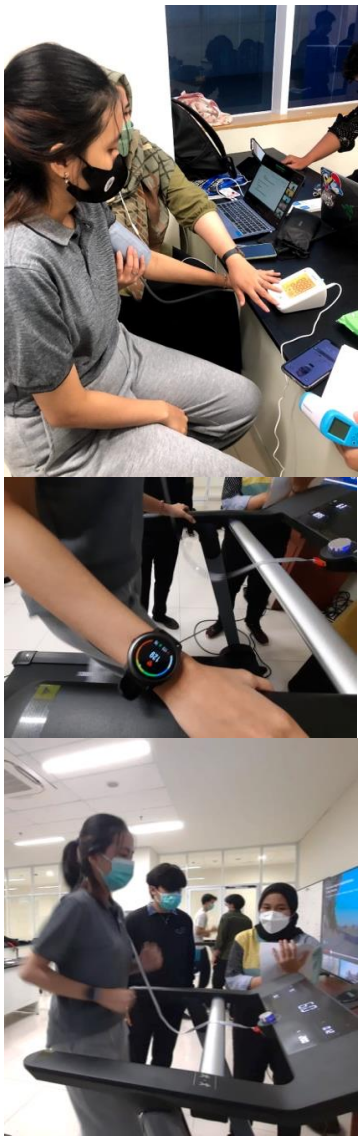

Figure. 1 Experiment Activity

After all the observation data was successfully collected, the quality of maximum oxygen uptake, and energy expenditure will be calculated and analyzed. According to [9], the best way to measure VO_2max is by a treadmill or a cycle ergometer lab test with equipment that analyze the exhaled air composition during exercise until volitional exhaustion [9]. The measurement of VO_2max can be conducted directly or indirectly to measure the quality of maximum oxygen uptake. Direct measurement of VO_2max is an accurate method to determine the maximal aerobic capacity. Meanwhile, the indirect measurement is more applicable because it can be performed in a measured field and with more than one individual [10]. Thus, we will use indirect VO_2max measurement in this study, since it is easier to perform and does not require expensive equipment. All the observation result is presented in Table 1.

Table 1. Experiment Data Collection

Variable			Treatment			
			S-M	C-M	S-NM	C-NM
Measuring Variable (Heart Rate)	Minutes of observation	0	101	103	84	104
		1	128	132	93	94
		2	147	155	72	126
		3	146	158	113	108
		4	148	136	127	118
		5	130	127	150	118
		6	173	159	131	130
		7	163	165	147	141
		8	170	172	132	135
		9	150	164	144	158
		Rest*	105	115	116	117
Body Temperature		Start	36.4	36.4	36.4	36.4
		Finished	36.3	36.3	36.3	36.3
Blood Pressure		Start	93/74	110/78	115/75	99/82
		Finished	110/68	112/69	114/69	114/72

III. Result and Analysis

A. Measurement of Maximum Oxygen Uptake and Energy Expenditure

Maximum oxygen consumption, known as VO_2max, is an indicator to measure how much oxygen the human body can uptake during exercising. It is closely related to the function of the lung system, heart, blood vessel system, and blood flow that are interconnected and mutually support each other in delivering oxygen to the working muscles.

Oxygen is important in the respiratory process. When inhaling oxygen, the lungs will absorb and convert it into

energy called adenosine triphosphate (ATP). ATP provides power or energy to body cells and helps release carbon dioxide (CO_2) during the respiratory process. The greater the VO_2max value, the more oxygen the body can consume and the more effectively the body uses oxygen to produce the maximum amount of ATP energy. VO_2max also refers to the rate of oxygen consumption, thus it can be concluded that VO_2max can be used to measure the capacity or the ability of the body to breathe, transport, circulate, and use oxygen to its full potential.

Oxygen consumption and heart rate are related to Energy Expenditure (EE). It is an energy needed by the body to carry out vital physiological functions, such as breathing, blood circulation, the work of the kidneys, pancreas, and other organs. EE is also needed for cellular metabolic processes and to maintain body temperature. The heavier the physical activity, then the EE will increase, as well as the level of O_2 consumption and heart rate. Therefore, we will calculate and measure VO_2max and Energy Expenditure to determine the level of workload and physiological reactions of the participants based on data collected from the conducted experiment. The complete record of measurements can be seen in Table 2.

Table 2. Data of Average Heart Rate, VO_2max, and EE

Variable		Treatment			
		S-M	C-M	S-NM	C-NM
Average Heart Rate		141.91	144.18	119	122.64
	Level	H	H	M	M
VO_2max		1.82	1.86	1.38	1.45
	Workload Level	H	H	M	M
EE		8.72	8.92	6.63	6.96
	Workload Level	H	H	M	M

Note:
H: Heavy; M: Moderate; L: Low

A.1. Treatment Scenario S-M

According to Table 2, the result of calculating VO2max in sports activities using surgical masks with distraction of music is 1.82 liters/minute, and the EE result is 8.72 kcal/minute. Both results are categorized as Heavy Work Load. Likewise, the average heart rate of this scenario was found to fall at 141.91 bpm, which is considered as Heavy. It can be concluded that activities on a treadmill using a surgical mask with distraction of music is considered as heavy activity. This shows a contrary result mentioned by previous studies in [6], which mostly stated that wearing a surgical facemask or even a N95 filtering facepiece during exercising at low-to-moderate work rate has no physiological impact.

Based on our analysis, this could be happened because music can stimulate and motivate adrenaline which can prime the body for more strenuous activities [11], [12]. When undergoing sports or more strenuous activities, the body requires more energy to carry out vital physiological functions (energy expenditure). Therefore, oxygen consumption (VO_2max) and heart rate also increase along with the increasing need for energy expenditure.

A.2. Treatment Scenario C-M

The result of calculating VO_2max and EE in sports activities using cloth masks with distraction of music (scenario C-M) shows a value of 1.86 liters/minute and 8.92 kcal/minute, respectively. Similar with the result for treatment scenario S-M, both results of C-M scenario are considered as Heavy Workload. Likewise, the average heart rate of 144.18 bpm is included in the Heavy category. It can be concluded that sports activities using cloth masks and accompanied by music are included in the level of heavy workload. Align to our previous analysis that the influence of music which can spur a person to exercise or move with more stamina so that the body requires more energy to carry out vital physiological functions of the body (energy expenditure), followed by the increasing oxygen volume (VO_2max) and heart rate. In addition, it was also found that cloth masks have average heart rate, VO_2max, and energy expenditure results that slightly larger than surgical masks. This could be due to several factors, such as cloth masks generally make us feel more uncomfortable to overcome overheating reaction on the face, it is too airy, and there is a slight possibility of a respiratory constriction process because the material of cloth masks is generally thicker than surgical masks. Hence, it can be concluded that the thicker fabric masks might cause the body to need more oxygen consumption, especially during exercising on a treadmill (in this experiment).

A.3. Treatment Scenario S-NM

The result of calculating VO_2max and EE during sports activities using surgical masks without music distraction is 1.38 liters/minute and 6.63 kcal/minute, respectively. Both results are considered in the Moderate Workload category. The average heart rate value for this treatment scenario is 119.00 bpm which considered in the Moderate category as well. Hence, regarding the workload classification result, we shall see that exercising on a treadmill using a surgical mask without music distraction considered as moderate workload activity level. In contrast with the two previous scenarios, this might be happened because there is no music that can stimulate and motivate adrenaline of the body to trigger movements with more weight and increase heart rate. Thus, the need for energy to carry out vital physiological functions of the body (energy expenditure) is not as much as the activity that accompanied with music. Therefore, oxygen consumption (VO_2max) and heart rate are not too high (moderate) proportional to energy expenditure needs.

A.4. Treatment Scenario C-NM

Similar with the result for treatment scenario S-NM, both results of C-NM scenario are considered as Moderate Workload, with the value of VO_2max and EE results are 1.45 liters/minute and 6.96 kcal/minute, respectively, including the category for average heart rate value in this scenario C-NM. Similar reason with the scenario S-NM might be the cause of no source to stimulate the increasing adrenaline in the C-NM

scenario, as well. Then, it was found that there was a small difference between the results of the average heart rate, VO_2max, and energy expenditure where the results on cloth masks were greater than surgical masks. This is caused by the same factors as described in the analysis of the second treatment or treatment, which might be influenced by the different thickness of the mask. Furthermore, cloth masks are usually made from various types of woven and non-woven fabrics, which have lower filtration standards and breathability requirements. The filtration efficiency of the mask depends on the diameter of the fiber or yarn, the tightness of the weave, and manufacturing process [13].

B. Statistical Analysis

The average heart rate data was analyzed using the Two-Way ANOVA method to determine the comparison of the average heart rate to the different type of masks and the distraction of music as well as the use of both factors simultaneously. According to Fig.2, the statistical result analysis on different type of face masks was found to be insignificant, with significance value at 0.672. It implies that any type of face mask does not bring a significant different effect toward the average heart rate. Furthermore, the factor of using music to accompany us to do physical activities could obtained the significance value of 0.03. It implies that the use of music has an effect with a significant difference on the average heart rate. On the other hand, the use of both factors simultaneously obtained the significance value of 0.922, which implies that the type of mask and the use of music simultaneously give a small or insignificant effect toward the average heart rate.

Tests of Between-Subjects Effects

Dependent Variable: Hasil Heart Rate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5535.705[a]	3	1845.235	3.504	.024
Intercept	765864.205	1	765864.205	1454.143	< ,001
Masker	96.023	1	96.023	.182	.672
Musik	5434.568	1	5434.568	10.319	.003
Masker * Musik	5.114	1	5.114	0.10	.922
Error	21067.091	40	526.677		
Total	792467.000	44			
Corrected Total	26602.795	43			

a. R Squared = .208 (Adjusted R Squared = .149)

Figure. 2 Statistical Analysis Result

IV. CONCLUSION

The workload level is very influential on human physiological aspects. It can be seen from the experimental result that the level of workload for physical activity carried out will be equivalent to the required EE, as well as O_2 consumption and heart rate.

Analysis of the average heart rate data was carried out by calculating the value of VO_2max and EE to determine the workload level of the four treatment scenarios implemented in the experiment. The result shows Heavy level of workload on surgical mask treatment accompanied with music, and Moderate level of workload on surgical mask and cloth treatment without music.

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