Impact of the COVID-19 pandemic: Effects of High Intensity Exercise on Physiological Indicators of Recovery Period by Wearing Face Masks of Elite Athletes

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Research Article

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Abstract

Background

Athletes need to maintain the necessary physical conditioning for sports performance with wearing face masks to reduce the risk of virus transmission during training and competition during the COVID-19 situation. The quantitative and physiological (i.e., heart rate, PRE, lactate) effects of face masks on exercise capacity needs to be reported. The purpose of this study was to evaluate elite athletes’ sports performance and body composition during the COVID-19 in 2020, and to quantify in detail the effect of KF94 on changes in lactic acid during recovery after high-intensity aerobic exercise.

Methods

The 13 athletes who participated in December 2019 and December 2020 were surveyed and matched by age, gender, and sports categories to evaluate their body composition and sports performance (lower limb strength test, anaerobic power test). In addition, a crossover design was used to examine the effects of using a disposable KF94 face mask during exercise.

Results

The 2020 group (16.29 ± 3.25 kg) was lower in the leg muscle mass than the 2019 group (16.72 ± 3.24 kg). The right knee extensor strength (p = 0.005) and power (p = 0.003) were lower in the 2020 group's isokinetic muscle function than in the 2019 group. In the Wingate anaerobic test, peak power (p = 0.001) and average power (p = 0.006) of the 2020 group were also lower than those of the 2019 group. Resting state blood lactate level were 1.35 ± 0.14mM/L without a mask, 2.50 ± 0.49mM/L with an KF94 mask (p < 0.001). Also, the lactic acid concentration at 20 minutes of recovery after maximum exercise was 5.98 ± 1.53mM/L without a mask, 7.61 ± 1.85mM/L with an KF94 mask (p < 0.001). However, there was no statistical differences in blood lactate concentrations immediately after exercise (p = 0.407), at 5 (p = 0.671) and 10 minutes (p = 0.313) of recovery. The rate of lactic acid removal in the post-exercise recovery period were 53.56 ± 6.77 (%) without a mask, 45.5 ± 9.9 (%) with a KF94 mask (p < 0.001). The maximum laps of shuttle run tests were 101.5 ± 22.5 laps without a mask, 94.2 ± 20.2 laps with a KF94 mask (p < 0.001). However, changes in maximum heart rate and post-exercise recovery heart rate showed no statistical difference regardless of the mask (p = 0.118).

Conclusions

The main results of the study show that anaerobic peak power, average power, and extensor muscles of the lower-limb were significantly lower than before the COVID-19 situation by wearing masks in training
and normal daily living, and the KF94 mask-wearing group had lower performance in high-intensity aerobic exercise and recovery rate than non-mask group.

**Background**

The World Health Organization officially proclaimed COVID-19 to be a pandemic on March 11, 2020 [1]. As of September 2022, the number of cases and affected countries is still rapidly increasing, with over 600 million confirmed cases in 223 countries across the world [2]. Among other activities, many sporting events have been suspended or postponed, affecting the training of athletes.

The primary path of COVID-19 contagion is droplet infection by carriers during speaking, breathing or coughing [3, 4]. Therefore, since the outbreak of the COVID-19 pandemic, many health authorities and governments have strongly recommended and even mandated the use of face covering such as surgical and N95 face mask [5–7]. N95 masks have been shown to be more effective than surgical masks in reducing exposure to viral infections [8, 9]. Exercise situations are no exception. Some studies show that droplets can spread as far as 5m while walking (4km/h) and 10m while running (14.4 km/h) [10]. However, exercising with a face mask can induce an environment of hypercapnic hypoxia [inadequate oxygen (O$_2$) and carbon dioxide (CO$_2$) exchange] [11].

Athletes have faced specific challenges during the recent emergency. They must train constantly to maintain the necessary physical conditioning for activities that can be held at any time. It is recommended that elite athletes wear fabric face masks, unless they are exercising alone, as a strict measure to reduce the risk of virus transmission during training and competition [12]. However, information about the safety and physiological effects of masking during exercise is still lacking and is mainly based on research conducted with medical personnel as the subjects.

Most athletes wear masks for long periods of time and perform high-intensity exercise. However, the quantitative and physiological (i.e., heart rate, PRE, lactate) effects of face masks on exercise capacity have never been systematically reported. In particular, the measurement of lactate among physiological indicators has traditionally been used as an indicator of relative effort during exercise [13]. This is a very useful method as performance influencing parameters since it assesses the rate of lactate released from active muscles during exercising [14].

Although there did not appear to be any difference in blood lactate level during high-intensity exercise (incremental exertion bicycle test) while wearing an N95 face mask and without a mask [15], to date, few studies have examined physiological indicators in the recovery phase after exercise while wearing a mask. Therefore, this study aims 1) to evaluate elite athletes’ sports performance and body composition during the COVID-19 related quarantine policy period in 2020, 2) to quantify in detail the effect of KF94 face masks on changes in lactic acid during recovery after high-intensity aerobic exercise.

**Methods**
Subjects

This study was conducted at the Center for Sport Science in Incheon. Thirteen elite soft tennis athletes (seven male and six female) were recruited. Those with cardiac, pulmonary or inflammatory diseases or other medical contraindications were not included. All athletes have never had a history of COVID-19 infection before. The characteristics of the participants are shown in Table 1. All subjects who agreed to participate in the study described the study to fully understand its purpose and the methods used in the ethical standards of the Declaration of Helsinki. In addition, all subjects signed an informed consent form prior to participation. This study was approved by the Kang-won National University Review Board for Human Subjects (KWNUIRB-2020-03-007-002).

Table 1
The characteristic of the subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n = 7)</th>
<th>Female (n = 6)</th>
<th>Total (n = 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>29.57 ± 3.54</td>
<td>20.50 ± 3.59</td>
<td>25.38 ± 5.76</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>176.8 ± 6.68</td>
<td>164.3 ± 3.32</td>
<td>170.5 ± 8.17</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>74.95 ± 8.70</td>
<td>59.87 ± 4.98</td>
<td>67.41 ± 10.35</td>
</tr>
<tr>
<td>SMM (kg)</td>
<td>34.50 ± 3.58</td>
<td>23.57 ± 2.20</td>
<td>29.03 ± 6.22</td>
</tr>
<tr>
<td>%Body fat (%)</td>
<td>18.95 ± 3.12</td>
<td>28.37 ± 3.84</td>
<td>23.66 ± 5.87</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.97 ± 2.08</td>
<td>22.17 ± 1.44</td>
<td>23.07 ± 2.00</td>
</tr>
<tr>
<td>Career (years)</td>
<td>18.57 ± 3.02</td>
<td>12.50 ± 3.69</td>
<td>15.77 ± 4.51</td>
</tr>
</tbody>
</table>

Abbreviations: BMI; body mass index, SSM; skeletal muscle mass

Procedures

Study design 1

During the COVID-19 quarantine policy, athletes were regularly tested quarterly at the Sports Science Center to evaluate their body composition and sports performance (lower limb strength test, anaerobic power test). The 13 athletes who participated in December 2019 and December 2020 were surveyed and matched by age, gender, and sports categories, and all athletes performed team training in the same team with the same schedule, showing the same level of sports performance (the highest level in the country).

Study design 2

A crossover design was used to examine the effects of using a disposable KF94 face mask (Suavel Protec Plus, Meditrade, Kiefersfelden, South Korea) compared with not masking during exercise. The
participants completed a shuttle run test (SRT) experiment two times during a 3-day period, including 5–10 minutes of dynamic stretching and a warm-up according to their personal preferences. The participants were blinded with regard to their respective test results to avoid anticipation bias. The subjects were advised to consume a defined amount of carbohydrates within 24 h prior to all tests to ensure that glycogen conditions remained stable. Figure 1 presents the timeline of the study. Statistical analysis was performed by an independent and fully blinded researcher who was not involved in conducting the tests.

**Body Composition**

Anthropometric parameters included body weight (BW), body mass index (BMI), lean body mass (LBM), body fat mass, body fat percentage (%FAT), muscle mass, skeletal muscle mass index (SMI), muscle mass of the limbs and trunk, and basal metabolic rate (BMR); these measurements were obtained using the body composition analyzer InBody 770 (InBody Co., Seoul, South Korea) using the simultaneous multi-frequencies impedance measurement method. To increase measurement accuracy, alcohol consumption and strenuous exercises on the day before measurement and any form of drinking or eating 2 hours before measurement were prohibited.

**Knee Isokinetic Muscle Strength**

The knee extension and flexion strength were evaluated with two different angular velocities (60 and 180°/s) using a computer-controlled isokinetic dynamometer (CSMI, USA). After the general warm-up protocol, participants were seated on a dynamometer (their dominant hip locked at 85° and knee rested at 90°) for knee muscle strength. Knee isokinetic muscle strength was measured by adjusting the fixed protocol performed with sequential concentric/concentric contractions at angular velocities of 60°/s (3 repetitions, 15s rest, and 5 retest) and 180°/s (5 repetitions, 15 s rest, and 5 retest).

**Wingate Anaerobic Test**

Muscle power was assessed by a supramaximal cycling test (Wingate) using a cycle ergometer (Monark ergomedic 894 E, Monark Exercise AB; Vansbro, Sweden). After individual adjustment on the cycle ergometer, participants performed 5 minutes of light cycling. At the end of the warm-up, the participant performed approximately five seconds of sprinting. During the Wingate test, the volunteers were instructed to cycle against a predetermined resistance (5 ~ 7.5% body weight) as fast as possible for 30 seconds. Wingate average power (W) was calculated (average of all five-second intervals over the entire 30 s test).

**Incremental Exertion Test (IET)**

IETs were performed via a 20-m shuttle run test (SRT). After dynamic stretching and a warm-up, the modified protocol was initiated at a speed of 8.0 km/h (speed of the 1st preparatory exercise) and increased by 0.5 km/h incrementally. The test was stopped if the subject failed to reach the interior pylon prior to the “beep” on two successive occasions. Otherwise, the test ended when the subject stopped.
because of fatigue. Each subject was encouraged to keep running as long as possible. Heart rate was recorded throughout the test using a Polar telemetry system. This protocol was designed to maintain an exercise duration of at least 15 minutes.

**Blood Lactate and Heart Rate Level**

Each subject evaluated lactic acid for a 20-minutes recovery time with a non-mask and a KF94 facemask after maximum exercise, who blood sample was evaluated for a 20-minutes recovery time with a non-mask and KF94 facemask after maximum exercise. Capillary blood lactate (mmol/L) was drawn from the finger (20 µl) before, immediately after, 5, 10, and 20 minutes after the interruption of exercise to assess the lactate concentration (Biosen C-Line Lactate analyzer, EKF Diagnostics, Cardiff, United Kingdom). The blood lactate removal rate (LArr) was calculated from the resting value (LAm) measured during the test to the lactate concentration of 20 minutes of following exercise (LAm20min) (i.e., LArr = [LAm − LAm20min] / LAm − LArest) × 100). Heart rate (HR) was observed at the first 5 minutes of recovery period.

**Statistical Analyses**

All values are presented as means with standard deviation. GraphPad Prism 8 (GraphPad Sofware Inc., California, USA) was used for the statistical evaluation and preparation of graphs. Data analysis was conducted with the Statistical Package for the Social Sciences, version 23.0 (IBM SPSS Statistics for Windows, vVersion 23.0: IBM Corp), if a normal distribution was evident, statistical comparisons were made using a paired t-test. The level of significance for all the comparisons was set at \( p < 0.05 \).

**Results**

**Study design 1**

As a result of comparing the 2020 group with the 2019 group before the COVID-19 situation, the 2020 group (16.29 ± 3.25 kg) was lower in the leg muscle mass than the 2019 group (16.72 ± 3.24 kg). The mean age of the participants was 25 ± 6 years. The mean height, weight, and BMI were 170 ± 8 cm, 67.4 ± 10.3 kg, and 23.07 ± 2.00 kg/m², respectively. In addition, the right knee extensor strength \( (p = 0.005) \) and power \( (p = 0.003) \) were lower in the 2020 group's isokinetic muscle function than in the 2019 group. In the Wingate anaerobic test, peak power \( (p = 0.001) \) and average power \( (p = 0.006) \) of the 2020 group were also lower than those of the 2019 group (Table 2).
Table 2  
Comparison of the physical fitness data between 2019 group and 2020 group

<table>
<thead>
<tr>
<th>Body type composition</th>
<th>2019</th>
<th>2020</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>68.27 ± 12.5</td>
<td>68.8 ± 11.38</td>
<td>0.513</td>
</tr>
<tr>
<td>%Body fat (%)</td>
<td>21.61 ± 4.42</td>
<td>22.35 ± 5.32</td>
<td>0.504</td>
</tr>
<tr>
<td>SMM (kg)</td>
<td>30.05 ± 6.07</td>
<td>30.22 ± 6.4</td>
<td>0.494</td>
</tr>
<tr>
<td>LLM (kg)</td>
<td>16.72 ± 3.24</td>
<td>16.29 ± 3.25</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Isokinetic muscle strength</th>
<th>2019</th>
<th>2020</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>60° Rt KEM (Nm/kg)</td>
<td>276.4 ± 32.6</td>
<td>246.3 ± 28.4</td>
<td>0.005*</td>
</tr>
<tr>
<td>60° Lt KEM (Nm/kg)</td>
<td>263.2 ± 28.2</td>
<td>250.9 ± 31.5</td>
<td>0.183</td>
</tr>
<tr>
<td>60° Rt KFM (Nm/kg)</td>
<td>143.3 ± 28.9</td>
<td>140.6 ± 31.0</td>
<td>0.55</td>
</tr>
<tr>
<td>60° Lt KFM (Nm/kg)</td>
<td>141.2 ± 30.0</td>
<td>139.4 ± 34.8</td>
<td>0.79</td>
</tr>
<tr>
<td>180° Rt KEM (Nm/kg)</td>
<td>304.1 ± 42.6</td>
<td>280.5 ± 37.2</td>
<td>0.003*</td>
</tr>
<tr>
<td>180° Lt KEM (Nm/kg)</td>
<td>284.5 ± 42.1</td>
<td>281.0 ± 43.1</td>
<td>0.694</td>
</tr>
<tr>
<td>180° Rt KFM (Nm/kg)</td>
<td>194.3 ± 46.7</td>
<td>184.5 ± 45.9</td>
<td>0.05*</td>
</tr>
<tr>
<td>180° Lt KFM (Nm/kg)</td>
<td>192.1 ± 41.8</td>
<td>183.7 ± 43.9</td>
<td>0.332</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anaerobic capacity</th>
<th>2019</th>
<th>2020</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak power (W/kg)</td>
<td>7.18 ± 1.64</td>
<td>6.68 ± 1.59</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Average power (W/kg)</td>
<td>5.52 ± 1.22</td>
<td>5.24 ± 1.18</td>
<td>0.006*</td>
</tr>
<tr>
<td>Fatigue index (%)</td>
<td>36.2 ± 6.10</td>
<td>35.4 ± 8.14</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Each parameter is shown as mean ± standard deviation. * p < 0.05. Abbreviations: SSM; skeletal muscle mass, LLM; Leg lean mass, KEM; Knee extension muscle; KFM; Knee flexion muscle

Study design 2

The change of lactate level and lactate removal rate are shown in Fig. 3. Resting state blood lactate level were 1.35 ± 0.14mM/L without a mask, 2.50 ± 0.49mM/L with an KF94 mask (p < 0.001). Also, the lactic acid concentration at 20 minutes of recovery after maximum exercise was 5.98 ± 1.53mM/L without a mask, 7.61 ± 1.85mM/L with an KF94 mask (p < 0.001). However, there was no statistical differences in blood lactate concentrations immediately after exercise (p = 0.407), at 5 (p = 0.671) and 10 minutes (p = 0.313) of recovery. The rate of lactic acid removal in the post-exercise recovery period were 53.56 ± 6.77 (%) without a mask, 45.5 ± 9.9 (%) with a KF94 mask (p < 0.001). The number of shuttle-runs and heart rate changes are shown in Fig. 2. The maximum laps of shuttle run tests were 101.5 ± 22.5 laps without a mask, 94.2 ± 20.2 laps with a KF94 mask (p < 0.001). However, changes in maximum heart rate and post-exercise recovery heart rate showed no statistical difference regardless of the mask (p = 0.118).
Discussion

This study compared longitudinal changes in exercise performance and body composition before and during COVID-19 with trained athletes, and evaluated high-intensity aerobic exercise ability by wearing KF94 (FFP2) masks and physiological variables that occur in the human body during recovery after exercise. The main results of the study show that anaerobic power, average power, and extensor muscles of the lower-limb were significantly lower than before the pandemic by wearing masks in training and normal daily living, and the KF94 mask-wearing group had lower performance in high-intensity aerobic exercise and removal rate than the non-mask group.

Sports clubs, gyms, and public places where it is difficult to maintain social distancing could be important vulnerabilities in virus transmission, so masks or face cloths are recommended, which is an essential part of physical activity [16]. In previous studies [17, 18], athletes were mostly tested under general exercise conditions from low to moderate intensity while wearing a mask. In particular, athletes who exercise vigorously for a long time while wearing tight masks might be at risk of physiologically serious hypercapnic hypoxia [11], and clear recommendation should be presented for their health and safety.

Since the pandemic, sports scientists have raised new questions about how to counter negative physiological adaptations and effects related to athletic performance, as months of intense lockdown have left athletes unable to train regularly. In a study by Obayashi et al. [19], COVID-19 related inactivity reduced lower-limb muscle strength without changing jump height, upper-limb strength, and flexibility of athletes. Tsoukos and Bogdanis [20] reported that the five month lockdown due to COVID-19 negatively affected participants’ strength, power, flexibility and body mass due to inactivity, especially in male participants. Sunda et al. [21] also suggested that the COVID-19 lockdown had a negative effect on male athletes’ muscular exercise status.

The impact of a decrease in training on the strength of athletes is controversial. Although grip strength could be maintained after four weeks without training [22], it is known that lower-limb muscles weaken after five weeks without training [23]. In our study, the lower-limb muscle mass of both male and female athletes decreased due to changes in body composition during the lockdown period, and the weight and body fat rate of female athletes increased significantly. In addition, peak and average power were reduced in the lower-limb anaerobic power test before COVID-19, and lower-limb muscle strength and power were reduced as a result of the isokinetic muscle test.

These results may have led to a decrease in lower-limb muscle mass because athletes were inactive due to long-term lockdown policies, leading to a decrease in performance. In the 2020 evaluation, due to the government’s quarantine policy, it was essential to wear a mask even if exercising indoors, so the impact of masks could not be ruled out. It is known that wearing a surgical mask reduces anaerobic running ability (50 and 400m running test) [24], wearing a mask negatively affects the number of laps during lower-limb resistance training [25]. Resistance training while wearing a mask produced less cardio-respiratory response than aerobic exercise [26], and in mask-related studies limiting breathing [25], re-
breathing of CO₂ exhaled from the mask could degrade resistance training performance, and a decrease in neuromuscular function may have contributed to participants’ muscle weakness [27].

As the COVID-19 situation continues, wearing masks while training has become a part of life for athletes. Studies of the physiological effects of wearing a mask during exercise are being actively conducted. Epstein et al. [28] compared differences in physiological variables according to the presence or absence of a mask in healthy participants, and there were no significant differences in heart rate, respiratory rate, blood pressure, oxygen saturation, and time to exhaustion depending on exercise intensity. However, the end-tidal carbon dioxide (EtCO₂) level increased significantly in the group wearing N95 masks, indicating that O₂ decreased and CO₂ increased significantly when wearing a mask during aerobic exercise. Fikenzer et al. [15] reported that ventilation and cardiopulmonary exercise capacity were greatly reduced by wearing a mask.

In a review by Chandrasekaran and Fernandes [29], wearing a mask during exercise lowers the partial pressure of oxygen (PaO₂) in the human body and increases the partial pressure of carbon dioxide (PaCO₂), causing hypercarboxonic hypoxia in the human body, renal cell metabolism, and immune cell. In addition, increasing the cardiac load and anaerobic metabolism negatively affected muscle fatigue, lethargy, and susceptibility to infection. These data are very important to consider in recommending wearing a mask during exercise.

The accumulation of lactate during exercise is not simply a waste product related to oxygen deficiency, and it would be reasonable to assume an increase in the contribution of anaerobic energy in the metabolic process in the human body. Lactic acid is also transported to other organs, including the heart and brain, and serves as a substrate for mitochondrial metabolism. In the liver and kidneys, lactic acid is converted to glucose and used as an energy source in other organs, including the working muscles [30].

In the results of this study, there was no statistical difference in the maximum heart rate due to high-intensity exercise performance in the two groups, but the number of STR laps, which is the quantity of exercise performance, was about 7% lower in the group wearing the KF94 mask than in the non-mask group. On the other hand, in the change in lactic acid during recovery after high-intensity exercise, the recovery period of 20 minutes and lactate removal rate after exercise were higher in the non-mask group, especially in the lactic acid concentration at rest. These results suggest that wearing a mask and limiting oxygen availability during exercise and rest can affect the muscles’ ability to balance ATP decomposition and production, thereby limiting lactic acid/H⁺ regulation and cell recovery after exercise [31]. In addition, increased CO₂ partial pressure in the human body can lead to decreased hemoglobin saturation and increased aortic pressure and left ventricular pressure, which can directly affect sports performance [32].

Finally, athletes who are repeatedly exposed to high-intensity exercise and training are encouraged to take off their masks and rest in their personal space when recovering after exercise and to use acid buffers such as bicarbonate or sodium citrate as an ergogenic strategy.
Conclusions

Athletes and coaches should be aware of the effects of masks on sports performance and the safety of athletes during the global pandemic. Our findings provide information to help in developing appropriate training programs while wearing masks in preparation for persistent COVID-19 and other respiratory disease pandemic situations.

Abbreviations

SRT
shuttle run test
BW
body weight
BMI
body mass index
LBM
lean body mass
SMI
skeletal muscle mass index
BMR
basal metabolic rate
IET
Incremental exertion test
LArr
lactate removal rate
HR
heart rate

Declarations

Ethics approval and consent to participate

This study was approved by the Kang-won National University Review Board for Human Subjects (KWNUIRB-2020-03-007-002). All subjects who agreed to participate in the study described the study to fully understand its purpose and the methods used in the ethical standards of the Declaration of Helsinki. In addition, all subjects signed an informed consent form prior to participation.

Availability of Data and Materials

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Acknowledgements
We thank all the study participants and staff for their assistance.

**Authors’ contributions**

HTK, DYK, and DHK were responsible for the conception and design of the study. HTK, DYK, and DHK were involved in the analysis and/or interpretation of data. HTK and DHK were responsible for the first drafts of the manuscript, which was revised critically for important intellectual content. All authors approved the final version of the manuscript for publication.

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**Consent for publication**

Not applicable

**Competing interests**

The authors declare that they have no competing interests.

**Author details**

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Figures
Figure 1
Timeline of the study

<table>
<thead>
<tr>
<th></th>
<th>Rest for 10min</th>
<th>High intensity exercise (Shuttle run test)</th>
<th>Recovery for 20min</th>
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</thead>
<tbody>
<tr>
<td>Non-mask</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>KF94 mask</td>
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</table>

After 48h

<table>
<thead>
<tr>
<th></th>
<th>Rest for 10min</th>
<th>High intensity exercise (Shuttle run test)</th>
<th>Recovery for 20min</th>
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</thead>
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<tr>
<td>Non-mask</td>
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<td></td>
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<tr>
<td>KF94 mask</td>
<td></td>
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</tbody>
</table>

Figure 2
Effects of wearing a KF94-mask compared to no mask on heart rate and Shuttle run test. (A) Heart rate; (B) Shuttle run count. * Indicate significant differences (p < .05)
Figure 3

Maximum post-exercise lactate level change and lactate removal rate. (A) lactate level; (B) lactate removal rate. * Indicate significant differences ($p<.05$)