What Happens When We Wear a Mask While Exercising?

By: Liam Mongeon

One of the most visible adjustments to our lives during the Covid-19 pandemic is the required use of face masks in public spaces. Initially the idea of wearing a mask during exercise was controversial, as the mask was perceived as a hindrance. Having acknowledged that, is it harmful to wear a mask during exercise? Not all masks are created equal, but the research generally suggests that exercising while masked is not detrimental to the athlete's health. Here we examine the arguments of seven academic works tackling the topic of masked athletic activity, each of which selected a different set of metrics to address the same question. Two studies described below had participants exercise with either no mask, a surgical mask, or an N95 respirator using maximal stress testing (led by Epstein) and incremental exertion testing (led by Fikenzer) respectively. The participants of another inquiry (led by Otsuka) completed a cardiopulmonary stress test both with a surgical mask and with no mask. One more study (led by Shaw) documents volunteers completing a progressive cycle ergometer exercise test wearing no mask, a cloth mask, and a surgical mask. The fifth investigation monitored volunteers of varying degrees of fitness who walked on a slightly inclined treadmill to simulate hiking (led by Wong). Here participants wore either a surgical mask or no mask. The sixth piece (written by Davis and Tsen), drawing on data gathered by other authors, specifically tackles the use of N95 respirators during exercise. The seventh and final work (led by Samannan) focused more narrowly on patients with chronic obstructive pulmonary disease, having the levels of oxygen in their blood tested before and after six minutes of walking. Looking at these articles together, we gain a fairly comprehensive understanding of how the use of masks affects athletic training.

Four of the investigations reviewed here checked for the effects of wearing a mask on the participant's heart rate. The study led by Epstein found no significant differences in heart rate due to the presence or absence of a mask.[1] Similarly, Shaw's research team saw similar results for heart rate at the end of exercise across conditions.[2] Furthermore, they observed no heart rate differences at any level of power output.[3] The authors of the study led by Fikenzer note that heart rate recovery appears unaffected by masks, in spite of their overall argument that masks do affect physiological parameters.[4] The one study here that observed an effect on heart rate by the use of masks was by Wong's and her co-authors.[5] Their conclusion, however, is not to avoid exercise while masked, but rather to "rest when heart rate exceeds 150 beats/min or 70% of expected maximum (based on age) and scaling activities to individual ability."[6] In the interests of keeping exercise intensity on the low-to-moderate side, we concur with the recommendation to rest when one's heart rate becomes too intense. Moreover, scaling activities to individual ability is good advice anytime, pandemic aside.

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[1] See figure 1 in appendix

[2] 179bpm ± 16 (no mask) 179bpm ± 19 (surgical mask) 182bpm ± 12 (cloth mask). Keely Shaw, Scotty Butcher, Jongbum Ko, Gordon A. Zello, Philip D. Chilibeck, "Wearing of Cloth or Disposable Surgical Face Masks has no Effect on Vigorous Exercise Performance in Healthy Individuals," *International Journal of Environmental Research and Public Health* 17, no. 21 (November 2020): 4.

[3] See figure 4 in appendix

[4] −39.7bpm ±15.9 (no mask) −38.1bpm ±9.2 (surgical mask) −39.9bpm ±11.2 (FFPM). Sven Fikenzer, T. Uhe, D. Lavall, U. Rudolph, R. Falz, M. Busse, P. Hepp, U. Laufs, "Effects of surgical and FFP2/N95 face masks on cardiopulmonary exercise capacity," *Clinical Research in Cardiology*, 109, no. 12 (July 2020): 1526.

[5] 124.4bpm ± 12.8* (unmasked)128.4bpm ± 13.2* (masked) at the 6-minute mark. Ashley Ying-Ying Wong, Samuel Ka-Kin Ling, Lobo Hung-Tak Louie, George Ying-Kan Law, Raymond Chi-Hung So, Daniel Chi-Wo Lee, Forrest Chung-Fai Yau, Patrick Shu-Hang Yung, "Impact of the COVID-19 pandemic on sports and exercise," *Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology* 22 (October 2020): 42.

[6] Wong, Ling, Louie, Law, So, Lee, Yau, and Yung, "Impact," 41.

Looking at some other cardiac metrics, masks continue to show a minimal effect if any. Epstein's group observed only minor differences in systolic blood pressure after exercising,[7] while Fikenzer's team notes that stroke volume (the amount of blood exiting the ventricles during a contraction) did not significantly change in response to condition.[8] These two parameters together are used to calculate stroke work. One would therefore expect cardiac work to be unaffected by mask use, being the product of stroke work and heart rate. Observations made by Fikenzer regarding cardiac work are consistent with this expectation; no significant effects were reported there.[9]

Shifting toward oxygen consumption and distribution throughout the body, there is further cause for optimism. In Shaw's study, masks did not show an effect on muscle tissue oxygenation.[10] Furthermore, both Shaw's[11] and Samannan's[12] teams failed to observe an impact of mask use on arterial oxygen saturation, while Epstein's[13] inquiry noted no difference in oxygen saturation at all. The Fikenzer study did observe differences in blood oxygenation levels at maximum load, but only when participants wore an FFPM (N95-style) mask.[14] Looking at oxygen consumption, Otsuka's team concluded masks had no effect[15]. This runs contrary to the findings of Fikenzer's team, which found mask use, especially FFPM, reduced oxygen consumption.[16] Having said that, Shaw's paper points out that the use of a spirometry mask over the surgical mask in the Fikenzer study likely has its own effect on inhalation, calling into question how well Fikenzer's findings represent masked exercise outside of a laboratory setting.[17] Furthermore, Fikenzer's team noted that cardiac output was not significantly affected.[18] Cardiac output is calculated using oxygen consumption and saturation, so the effect on oxygen consumption cannot be too pronounced. Davis and Tsen, looking only at the use of N95 masks, noted that inspired oxygen was reduced and cardiac output was increased in other works.[19] Their argument, however, points to differences in proportions of gases inhaled as an exercise benefit, a topic to be revisited in greater detail below.

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[7] 143 ± 14 mm Hg (unmasked), 143±16mmHg (surgical mask), and 147±16mmHg (N95). Danny Epstein, Alexander Korytny, Yoni Isenberg, Erez Marcusohn, Robert Zukermann, Boaz Bishop, Sa'ar Minha, Aeyal Raz, Asaf Miller, "Return to training in the COVID-19 era: The physiological effects of face masks during exercise," *Scandinavian Journal of Medicine & Science in Sports* 2021 31, no. 1 (January 2021): 72.

[8] 151ml±26.4 (unmasked), 165ml±35.0 (surgical mask), 164ml±20.4 (FFPM). Fikenzer, Uhe, Lavall, Rudolph, Falz, Busse, Hepp, and Laufs, "Effects of surgical and FFP2/N95 face masks," 1526.

[9] Fikenzer, Uhe, Lavall, Rudolph, Falz, Busse, Hepp, and Laufs, "Effects of surgical and FFP2/N95 face masks," 1526.

[10] Decrease in tissue oxygenation index of 20 ± 16% (unmasked), 20 ± 16% (surgical mask), and 20 ± 14% (cloth mask). Shaw, Butcher, Ko, Zello, and Chilibeck, "Wearing of Cloth or Disposable Surgical Face Masks," 5.

[11] See figure 4 in appendix

[12] Rajesh Samannan, Gregory Holt, Rafael Calderon-Candelario, Mehdi Mirsaeidi, Michael Campos, "Effect of Face Masks on Gas Exchange in Healthy Persons and Patients with Chronic Obstructive Pulmonary Disease," *Annals of the American Thoracic Society* 18, no. 3 (March 2021): 540.

[13] See figure 1 in appendix

[14] Percentage difference in arteriovenous oxygen content ($avDO_2$): 12.8±2.8 (unmasked), 11.5±2.2 (surgical mask), 10.5±2.0 (FFPM). Fikenzer, Uhe, Lavall, Rudolph, Falz, Busse, Hepp, and Laufs, "Effects of surgical and FFP2/N95 face masks," 1526.

[15] Atsuya Otsuka, Junya Komagata, Yuta Sakamoto, "Wearing a surgical mask does not affect the anaerobic threshold during pedaling exercise," *Journal of Human Sport and Exercise* 17, no. 1 (January 2020): 4.

[16] Volume of oxygen consumed (VO_2max/kg) 39.7±5.8 (ml/min)/kg (unmasked) 37.9±6.0 (ml/min)/kg (surgical mask) 34.5±5.3 (ml/min)/kg (FFPM). Fikenzer, Uhe, Lavall, Rudolph, Falz, Busse, Hepp, and Laufs, "Effects of surgical and FFP2/N95 face masks," 1526.

[17] Shaw, Butcher, Ko, Zello, and Chilibeck, "Wearing of Cloth or Disposable Surgical Face Masks," 6.

[18] 25.8±4.2 l/min (unmasked), 27.3±5.6 l/min (surgical mask), 27.0±3.8 l/min (FFPM). Fikenzer, Uhe, Lavall, Rudolph, Falz, Busse, Hepp, and Laufs, "Effects of surgical and FFP2/N95 face masks," 1526.

[19] Sinkule et al, cited by Bryan A. Davis and Lawrence C. Tsen, "Wearing an N95 Respiratory Mask: An Unintended Exercise Benefit?" *Anesthesiology* 133, no .3 (September 2020): 684.

On the question of masks and respiration during exercise, the results are mixed. Starting with respiratory rate, the number of breaths taken per minute, Epstein's team observed no difference between conditions.[20] Fikenzer's study did notice a reduction in breathing frequency, though only with the use of an FFPM.[21] Looking more specifically at gas exchange during breathing, Otsuka's group did not observe a significant difference in the amount of gas taken into the lungs in a minute (minute ventilation).[22] Fikenzer's team did observe a difference[23] on this point; however, the spirometry mask used in this study likely had its own effect on respiration, as noted above. Davis and Tsen also discussed minute ventilation, noting an increase rather than a decrease.[24] This they attributed to an increase in end-tidal carbon dioxide and subsequent increase in the amount of CO_2 inhaled. This is consistent with Epstein's findings, in which end-tidal carbon dioxide was only influenced by N95 masks or prolonged exercise.[25] Furthermore, Davis and Tsen point out that a slight increase in the amount of CO_2 inhaled can confer some benefits. They acknowledge the increased work of breathing, noting that the resulting rise improves respiratory muscle strength and endurance when done often while making respiration and oxygen delivery more efficient.[26] Breathing frequency therefore appears unaffected, while minute ventilation only sees significant effects where N95 masks are concerned, and these effects are not necessarily harmful.

In spite of the potential increase in the work of respiration, power output seems to be affected minimally if at all. Otsuka's findings did not indicate any difference in power output between masked conditions[27], while Shaw's group observed no differences across conditions for peak power.[28] The only study to note a drop in maximum power was Fikenzer's,[29] which, as previously noted, is of questionable generalizability. Even if this is true, under the current circumstances in which we all try to keep our breathing levels moderate, achieving maximum power output should not be a priority. Other measures related to maximum output were not compromised by mask use. Anaerobic threshold time was unchanged by condition,[30] as was time to exhaustion, according to both Shaw[31] and Epstein.[32]

One effect of masks widely acknowledged is the apparent increase in perceived exertion and discomfort. Here the findings are somewhat surprising; the authors of the studies do not unequivocally find support for increased perceived exertion. Wong's[33] and Otsuka's[34] studies do, but Epstein's[35] and Shaw's[36] do not.

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[20] See figure 1 in appendix

[21] 40.9±5.1 breaths per minute (unmasked), 39.3±6.2 brpm (surgical mask), 36.8±5.9 brpm (FFPM). Fikenzer, Uhe, Lavall, Rudolph, Falz, Busse, Hepp, and Laufs, "Effects of surgical and FFP2/N95 face masks," 1526.

[22] 34.1 ± 7.2 l/min (surgical mask) 32.2 ± 5.9 l/min (unmasked). Otsuka, Komagata, and Sakamoto "Wearing a surgical mask," 4.

[23] See figure 5 in appendix

[24] . Sinkule, Powell, and Goss, cited by Davis and Tsen "Wearing and N95 Respiratory Mask," 684.

[25] See figure 2 in appendix

[26] Álvarez-Herms, Julià-Sánchez, Corbi, Odriozola Martínez, and Burtscher, cited by Davis and Tsen "Wearing and N95 Respiratory Mask," 684.

[27] Otsuka, Komagata, and Sakamoto "Wearing a surgical mask," 4.

[28] Peak power was 234 ± 56W (unmasked), 241 ± 57W (surgical mask), and 241 ± 51W (cloth mask). Shaw, Butcher, Ko, Zello, and Chilibeck, "Wearing of Cloth or Disposable Surgical Face Masks," 6.

[29] See figure 5 in appendix

[30] 12.5 ± 1.2 min (masked) 11.9 ± 1.5 min (unmasked). Otsuka, Komagata, and Sakamoto "Wearing a surgical mask," 4.

[31] See figure 3 in appendix

[32] 18.9 ± 3.7 minutes (unmasked), 18.3 ± 3.7 minutes (surgical mask), and 18.5 ± 3.6minutes (N95). Epstein, Korytny, Isenberg, Marcusohn, Zukermann, Bishop, Minha, Raz, and Miller, "Return to training," 72.

[33] Rate of perceived exertion on 6-20 scale: 10.8 ± 2.2* (unmasked) and 12.7 ± 2.1* (masked). Wong, Ling, Louie, Law, So, Lee, Yau, and Yung, "Impact," 42.

[34] Rate of perceived exertion: 6.3 ± 2.2 (masked). 5.0 ± 1.8 (unmasked). Otsuka, Komagata, and Sakamoto "Wearing a surgical mask," 4.

[35] See figure 1 in appendix

[36] See figure 4 in appendix

Perceived discomfort is apparently uncontroversial,[37] but Samannan points out that masks cause adjustments in facial temperature, as well as in the temperature of inspired air which, along with an uptick in perceived breathing difficulty, lead to discomfort.[38] While wearing a mask during exercise is perhaps uncomfortable, surely this sacrifice pales in comparison to the discomfort that would result from transmission of the novel coronavirus!

Overall, the research suggests that exercising while masked is safe, and perhaps less different from maskless exercise than one might expect. Even the Fikenzer study, which takes the most critical stance on masked exercise, concedes that FFP2 (N95) masks are far more of a hindrance than surgical masks. Most of the facts, taken together, suggest a conclusion in line with Shaw's team, who argues that "For healthy, active people, wearing a face mask during vigorous exercise has minimal effect on arterial or muscle oxygen levels and no effects on exercise performance."[39]

[37] See figure 5 in Appendix
[38] Samannan, Holt, Calderon-Candelario, Mirsaeidi, and Campos, "Effect of Face Masks," 540.
[39] Shaw, Butcher, Ko, Zello, and Chilibeck, "Wearing of Cloth or Disposable Surgical Face Masks," 7.

APPENDIX

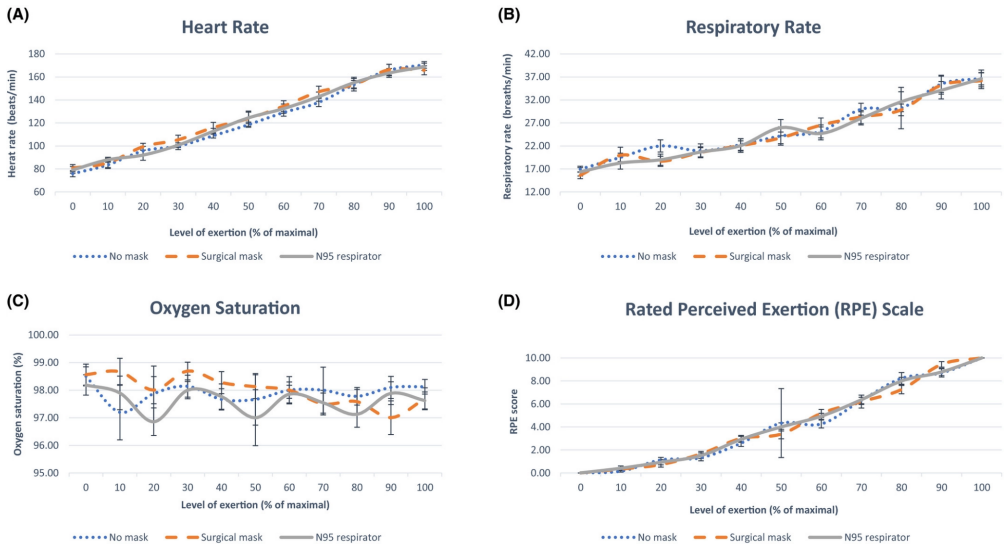
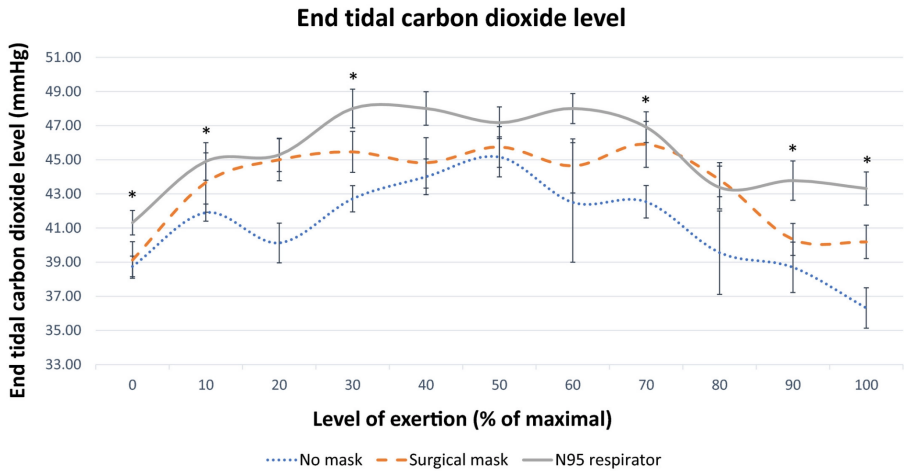


Figure 1: "Mean changes in physiological parameters throughout the exercise test performed by 16 subjects without a mask, with a surgical mask, and with N95 respirator. A, Heart rate (beats/min). B, Respiratory rate (breaths/min). C, Oxygen saturation (%). D, Rated Perceived Exertion (RPE) Scale (score). Error bars represent 95% confidence interval."[40]



[40] Epstein, Korytny, Isenberg, Marcusohn, Zukermann, Bishop, Minha, Raz, and Miller, "Return to training," 72.

Figure 2: “Mean changes in end-tidal carbon dioxide throughout the exercise test performed by 16 subjects without a mask, with a surgical mask, and with N95 respirator. Error bars represent 95%confidence interval. *indicate significant differences (P<.05)”[41]

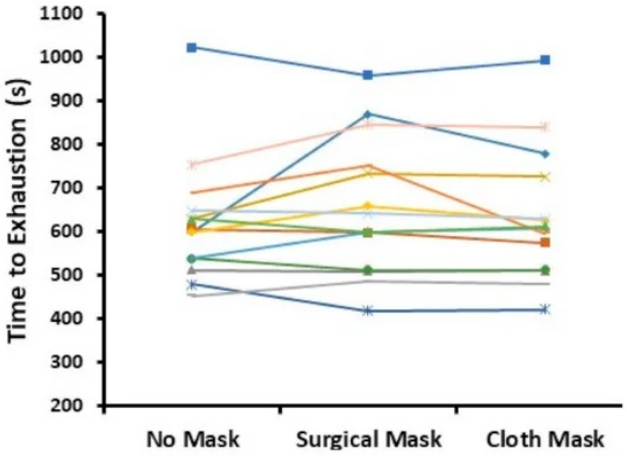
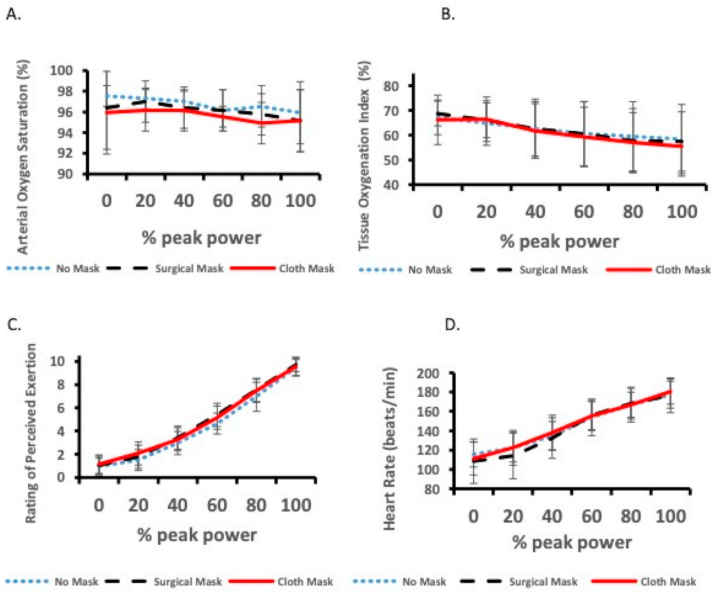


Figure 3: “Time to exhaustion during the exercise test for individual participants across conditions. There were no statistical differences between conditions (p = 0.20).”[42]



[41] Epstein, Korytny, Isenberg, Marcusohn, Zukermann, Bishop, Minha, Raz, and Miller, “Return to training,” 73.
[42] Shaw, Butcher, Ko, Zello, and Chilibeck, “Wearing of Cloth or Disposable Surgical Face Masks,” 4.

Figure 4: "(A) Arterial oxygen saturation, (B)muscle tissue oxygenation index, (C) rating of perceived exertion, and (D) heart rate expressed as percentage of peak power during the exercise test. All values are mean ± SD."[43]

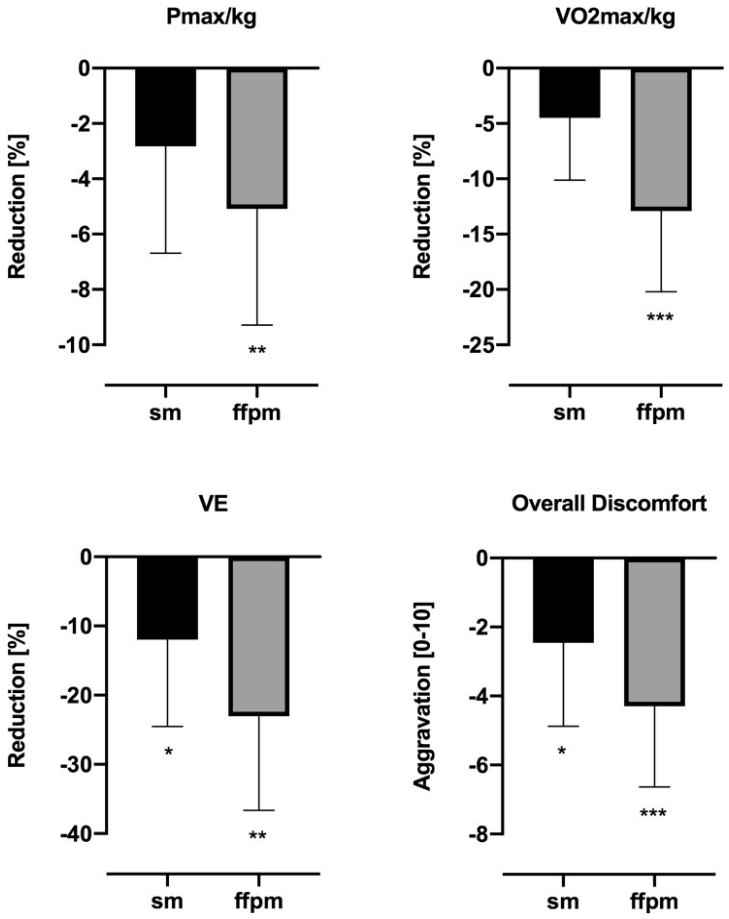


Figure 5: "Effects of wearing a surgical mask (sm) and a FFP2/ N95 mask (fpm) compared to no mask on maximal power (Pmax), maximal oxygen uptake (VO2max), ventilation (VE) and overall discomfort.

*p<0.05; **p<0.01; ***p<0.001"[44]

[43] Shaw, Butcher, Ko, Zello, and Chilibeck, "Wearing of Cloth or Disposable Surgical Face Masks," 5.
[44] Fikenzer, Uhe, Lavall, Rudolph, Falz, Busse, Hepp, and Laufs, "Effects of surgical and FFP2/N95 face masks," 1527.

BIBLIOGRAPHY

Davis, Bryan A., Lawrence C. Tsen, “Wearing an N95 Respiratory Mask: An Unintended Exercise Benefit?” *Anesthesiology* 133, no .3 (September 2020): 684-686.

Epstein, Danny, Alexander Korytny, Yoni Isenberg, Erez Marcusohn, Robert Zukermann, Boaz Bishop, Sa’ar Minha, Aeyal Raz, Asaf Miller, “Return to training in the COVID-19 era: The physiological effects of face masks during exercise.” *Scandinavian Journal of Medicine & Science in Sports* 2021 31, no. 1 (January 2021): 70-75.

Fikenzer, Sven, T. Uhe, D. Lavall, U. Rudolph, R. Falz, M. Busse, P. Hepp, U. Laufs, “Effects of surgical and FFP2/N95 face masks on cardiopulmonary exercise capacity.” *Clinical Research in Cardiology*, 109, no. 12 (July 2020): 1522-1530.

Otsuka, Atsuya, Junya Komagata, Yuta Sakamoto, “Wearing a surgical mask does not affect the anaerobic threshold during pedaling exercise.” *Journal of Human Sport and Exercise* 17, no. 1 (January 2020).

Samannan, Rajesh, Gregory Holt, Rafael Calderon-Candelario, Mehdi Mirsaeidi, Michael Campos, “Effect of Face Masks on Gas Exchange in Healthy Persons and Patients with Chronic Obstructive Pulmonary Disease.” *Annals of the American Thoracic Society* 18, no. 3 (March 2021): 541-544.

Shaw, Keely, Scotty Butcher, Jongbum Ko, Gordon A. Zello, Philip D. Chilibeck, “Wearing of Cloth or Disposable Surgical Face Masks has no Effect on Vigorous Exercise Performance in Healthy Individuals.” *International Journal of Environmental Research and Public Health* 17, no. 21 (November 2020): 8110.

Wong, Ashley Ying-Ying, Samuel Ka-Kin Ling, Lobo Hung-Tak Louie, George Ying-Kan Law, Raymond Chi-Hung So, Daniel Chi-Wo Lee, Forrest Chung-Fai Yau, Patrick Shu-Hang Yung, “Impact of the COVID-19 pandemic on sports and exercise.” *Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology* 22 (October 2020): 39-44.