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Original Research Article

The Effects of Face Mask Use during Self-Paced Running

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ABSTRACT

Introduction: Amid the historic coronavirus (SARS-CoV-2) global pandemic (i.e., COVID -19), public health authorities have recommended the use of facial coverings in order to mitigate the spread of this highly contagious pathogen. While coaches, self-training athletes, and the general public seek to continue their exercise programs in a safe and modified format, there is currently limited research available on the perceptual and physiological effects of facemask usage. This study was conducted to understand the physiological and perceptual effects produced during self-paced running while wearing a face mask. **Methods:** Eleven healthy college students performed three randomly sequenced 3200-meter self-paced running trials, each with a different masked condition (no-mask, surgical mask, and an N95 mask). Heart rate, Rating of Perceived Exertion (RPE), Rating of Perceived Dyspnea (RPD), pace, and completion time were measured for each trial. Prior to testing, subjects completed a PAR-Q+, a COVID-19 screening questionnaire, and a subjective running history questionnaire that was used to document prior running experience. Collectively, the participants reported an average weekly running frequency of 2.9 ± 1.2 days/week and an average running distance of 3.3 ± 1.8 miles/workout. Alpha was set at $p < .05$ to achieve statistical significance. **Results:** No significant difference was found between masked conditions. Wearing a mask did not have a significant effect on pace, completion time, or heart rate. Session RPE was significantly higher in the N95 condition (14.6 ± 2.21) compared to the control (12.8 ± 1.99) condition. Both the surgical (2.4 ± 1.12) and N95 conditions (3.2 ± 1.29) had significantly higher perceived dyspnea scores compared to the control (1.4 ± 1.07) group. **Conclusions:** During self-paced running, healthy young college students tend to maintain their normal running pace and total completion time while compensating with higher RPE and dyspnea scores.

Key words: College Students, Masks, Performance Measures, Self-Paced Running.

Introduction

During the historic coronavirus (SARS-CoV-2) global pandemic (i.e., COVID -19), coaches, self-training athletes, and the general public have found themselves in an unexpected predicament between conflicting health practice recommendations and the continuation of their training programs. COVID-19's primary mode of transmission is thought to be through airborne respiratory droplets[1]. Facemasks effectively block a high

percentage of exhaled respiratory droplets into the surrounding air. Accordingly, public health agencies including the Centers for Disease Control and Prevention (CDC) have recommended that face coverings should be worn in public spaces to mitigate the spread of COVID-19[2]. Nonetheless, as of March 2021, the World Health Organization (WHO) recommended that individuals not wear masks while exercising as it may limit the ability to breathe[3]. Many fitness centers across the U.S. remain open but require facemasks. During exercise, breathing frequency and tidal volume increase which causes more respiratory droplets to be dispersed into the surrounding area which ultimately can increase the likelihood that nearby persons will be exposed to the exerciser's "fume". The "fume", which may extend about 2-meters at rest, may increase to several meters behind a person who is walking, running or cycling[4]. The use of a facemask could significantly reduce the projection of respiratory droplets, thus limiting the spread of viral particles and the risk of transmitting the contagion.

The comfort and acceptability of wearing a mask are important factors which directly impact exercise tolerance and performance. The perceived effects of face covering use with exercise is greatly affected by environmental conditions (temperature and humidity)[5], tightness of the mask fit, breathing resistance[6], the intensity and duration of exercise[7,8], and particularly inspiratory resistance and the magnitude of CO_2 trapping[7]. While exercising, the body is continually adjusting to the workload imposed during a training session. Heart rate (HR), blood pressure (BP), and respiratory rate (RR) all progressively increase during incremental exercise[9]. Epstein et al. found that medical masks have a minimal effect on HR, RR, BP, and oxygen saturation (SpO_2sat) during incremental exercise to exhaustion. However, wearing any type of mask (especially N95 masks) increases end tidal CO_2 ($EtCO_2$), which could increase the sense of dyspnea[22]. A recent review by Shaw et al. found that surgical or N95 masks do not impact exercise performance but do increase ratings of perceived exertion and dyspnea[10]. The study also found that wearing either surgical or N95 facemasks during exercise slightly increased HR and RR, however the effects were minimal and had no impact on exercise performance. The authors found no observed differences in tidal volume, blood lactate, muscle oxygenation, cardiac output, or stroke volume. Rudi et al. observed that masked exercise did not alter the lactate threshold (LT), but that it did increase RPE at the LT. In addition, the authors observed a decrease in maximal performance in the masked groups compared to the unmasked group[11].

The pacing pattern during a timed or competitive bout of exercise has been thought to follow a self-regulated pace according to the anticipatory-feedback model proposed by Tucker [12]. Specific variations of the pacing strategy used are dependent on the anticipated duration of

the event[12,13], the protocol used, experience with the task[14], and the ability to maximize performance while minimizing large homeostatic changes[15,16]. Despite the obvious potential for mask use to modify the feedback received during exercise tasks, to our knowledge there is no research regarding pacing patterns with facemask use in healthy individuals, particularly during the non-incremental exercise pattern that is more common during training. Given the substantial increase in mask usage during and after the COVID-19 pandemic, the purpose of this study was to determine the effect of wearing a surgical and an N95 mask on spontaneous exercise training intensity (e.g., pacing) in young, relatively fit individuals during their normal exercise routines.

Methods

Participants

Eleven healthy college-aged students (4 males and 7 females) between 18-25 years of age volunteered for this study. The subjects used running as part of their normal exercise routine, although none were serious competitive runners. A subjective running history questionnaire was used to document prior running experience. Collectively, the participants reported an average weekly running frequency of 2.9 ± 1.2 days/week and an average running distance of 3.3 ± 1.8 miles/workout. Eligibility of participants was further assessed using the PAR-Q to screen for cardiovascular and orthopedic conditions that would exclude them from participating in this study. Eligible subjects provided written informed consent before undergoing any testing procedures. The study protocol (45CFR46) was approved (August 28, 2020) by the Institutional Review Board at the University of Wisconsin-La Crosse for the Protection of Human Subjects. Descriptive statistics of the subjects who completed the study are presented in Table 1.

Table 1. Descriptive characteristics of the subjects (N = 11).

	Males	Females
Age (years)	23.3 ± 1.26	23.1 ± 1.07
Height (cm)	183.5 ± 3.84	165.5 ± 6.46
Weight (kg)	84.2 ± 12.45	68.4 ± 10.26
HRmax (bpm)	180.8 ± 7.93	188.3 ± 7.70
VO_2@VT ($mL^{-1}·kg^{-1}·min^{-1}$)	43.6 ± 9.54	36.5 ± 3.77
VO_2max ($mL^{-1}·kg^{-1}·min^{-1}$)	52.5 ± 10.40	45.7 ± 6.74

Procedures

Each subject performed a graded exercise treadmill test (Bruce protocol) to determine maximal oxygen consumption (VO_2max), maximal heart rate (HRmax), and ventilatory threshold (VT). Ventilatory

threshold was determined to be the point at which ventilation increased disproportionately relative to VO_2. The study was performed as a randomly ordered, multiple cross-over, self-controlled trial, with each subject serving as their own control. Subjects performed a non-masked familiarization training session in order to ensure task habituation[14] and then three randomly assigned training sessions: (1) no facemask (control); (2) surgical mask; and (3) N95 mask. The minimal time interval between tests was 24 hours and participants were advised to not participate in strenuous exercise during the rest period or exercise the day of a trial.

All trials consisted of a 3200-m self-paced training run performed on an indoor 200-m track. The subjects were told to run at their "normal workout pace" for each trial. Every 400-m, HR, RPE, and lap time were recorded. The HR and lap times were not provided to the subject. Following the training run, the subject walked 400-m as a cool-down. For the purposes of COVID-19 safety, both participants and researchers remained masked during the recovery period. During the unmasked trial, subjects wore a mask until the trial began and put the mask back on immediately after the trial concluded until the cool-down was completed. After the training session, subjects provided their session Rating of Perceived Exertion (sRPE)[17] using the 6-20 modified Borg scale[18], rating of perceived dyspnea (RPD)[19], and the severity of their dyspnea symptoms.

Statistical analyses

Standard descriptive statistics were used to quantify data between conditions. One-way ANOVA with repeated measures were used to test for differences in completion time, average running pace, HR, RPE, and RPD between mask conditions. Bonferroni comparisons were used to evaluate pairwise differences when justified by ANOVA. Alpha was set a 0.05 to achieve statistical significance. All data are presented as mean ± standard deviation. Data was analyzed with SPSS for Windows (IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp) was used for statistical analysis.

Results

Time to complete each trial is presented in Figure 1. There was no significant difference in run time in relation to mask usage. The average completion times were 16.4 ± 2.16 min (control), 16.5 ± 2.07 min (surgical), and 16.5 ± 2.17 min (N95), respectively.

The average pace for each trial run is presented in Figure 2. The individual pattern of running pace was highly consistent across subjects and mirrored the average running pace for the group. There was no significant difference in average pace between any of the conditions.

Average heart rate for each trial is presented in Figure 3. There was no significant difference between the conditions, with HR averaging 176.9 ± 8.89 bpm, 174.9 ± 9.31 bpm, and 176.3 ± 8.65

bpm for the control, surgical mask and N95 mask conditions, respectively. The pattern of HR response over the course of each trial is presented in Figure 3. For all three trials, HR drifted upwards throughout the run with no differences between conditions.

Continuous heart rate average for each trial is presented in Figure 4. There was no significant difference between the conditions. The %HRmax at the halfway point (1600-m) of each training run was 98.7 ± 0.07% (control), 96.0 ± 0.03% (surgical mask) and 98.0 ± 0.07% (N95 mask).

RPE, measured every 400-m during each trial is presented in Figure 5. Terminal RPE for the N95 condition was significantly greater than during the control run. There was quite a large difference in the individual pattern of RPE growth across distance, but the differences appeared to be individually determined, rather than determined by mask condition.

Session RPE for each trial is presented in Figure 6. Session RPE was significantly higher in the N95 mask condition compared to the control condition. The average session RPE was 12.8 ± 1.99 (control), 13.6 ± 1.96 (surgical mask), and 14.6 ± 2.21 (N95 mask), respectively.

RPD for each trial is presented in Figure 7. RPD for both the surgical mask and the N95 mask trials were significantly higher than the control trial. Average RPD was 1.4 ± 1.07 for the control, 2.4 ± 1.12 for the surgical mask, and 3.2 ± 1.29 for the N95 mask conditions, respectively.

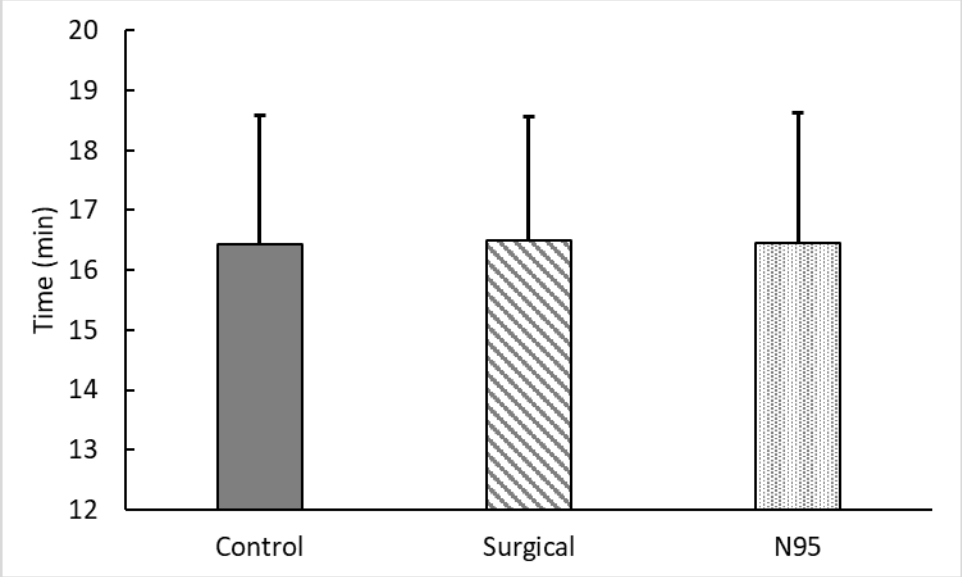

Figure 1. Average 3200-m completion time for each condition.

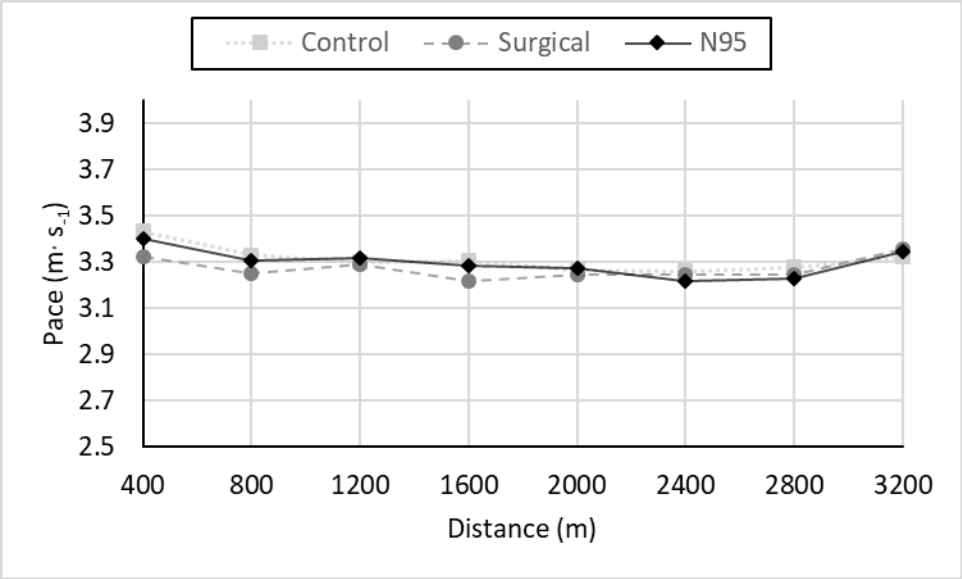

Figure 2. Average running pace for each trial condition every 400 meters.

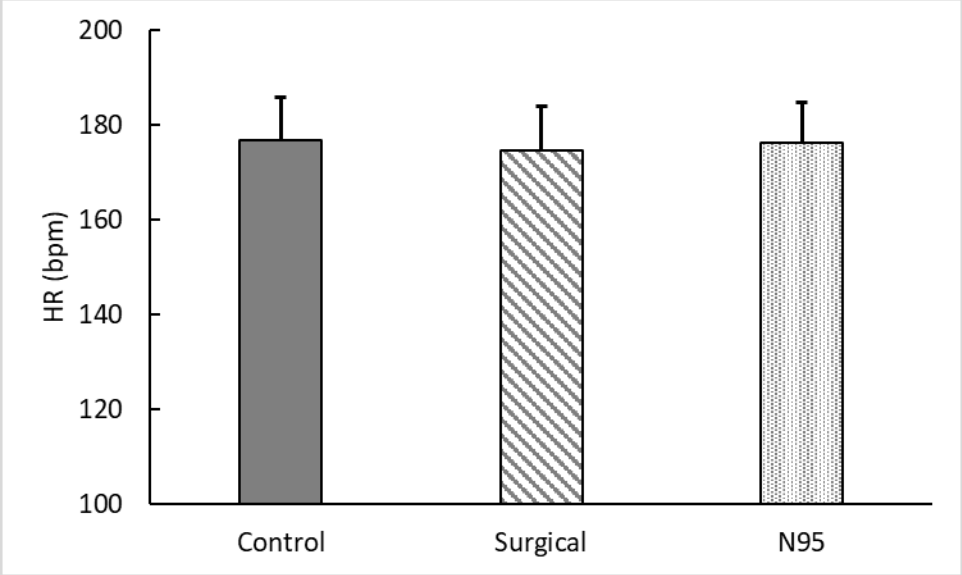

Figure 3. Average running heart rate for each trial condition.

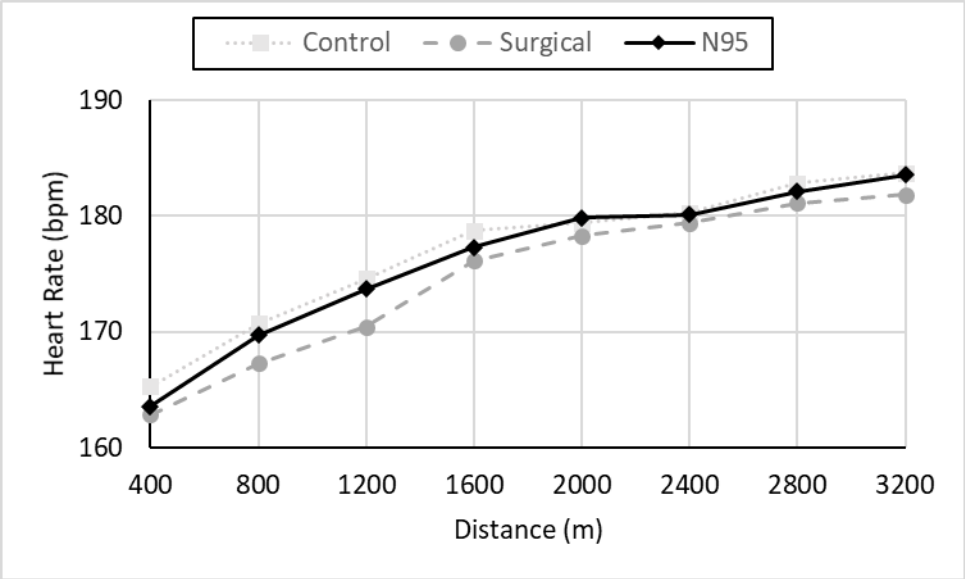

Figure 4. Continuous heart rate averages for each trial conditions every 400 meters during each run.

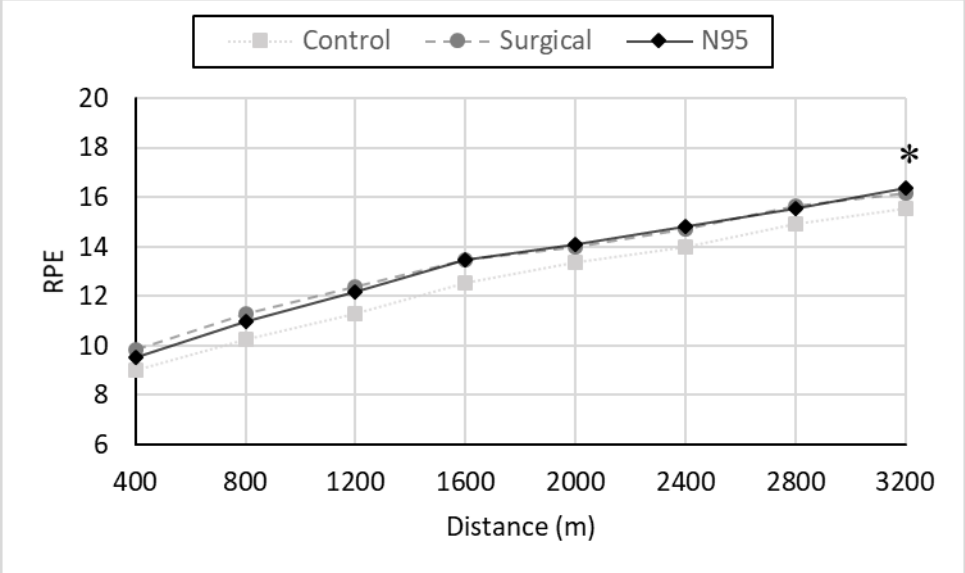

Figure 5. RPE averages for each trial condition every 400 meters.
*N95 condition was significantly greater than the control condition ($p < 0.05$)

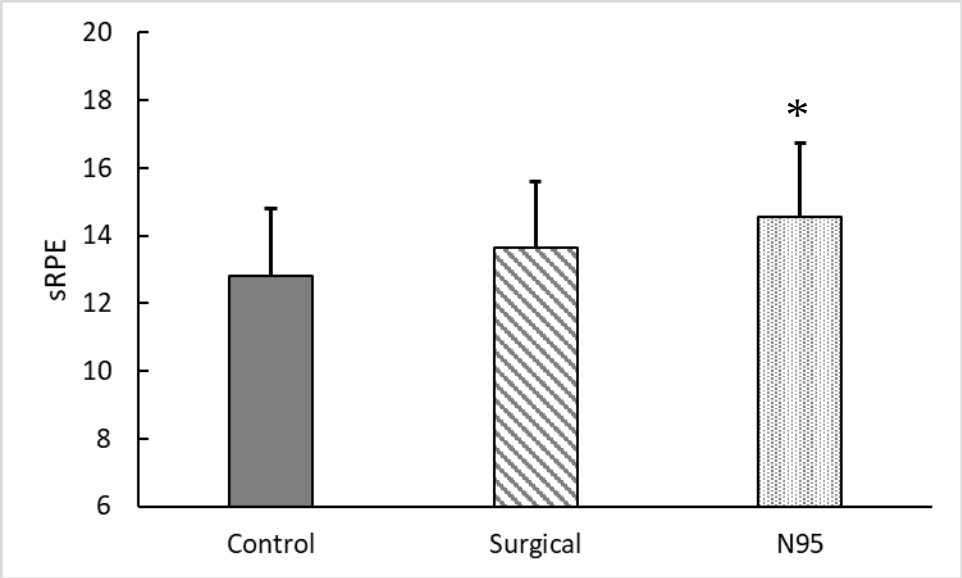

Figure 6. Average sRPE for each mask condition.
*Significantly greater than the control condition ($p < 0.05$)

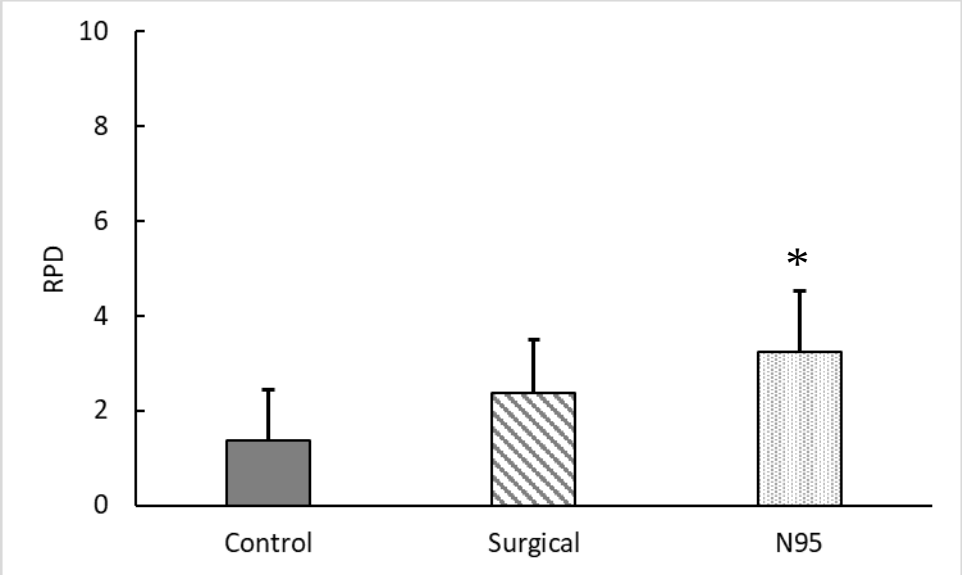

Figure 7. Average RPD score for each condition.
*Significantly greater than control ($p < 0.05$)

Discussion

This study found that self-paced aerobic exercise performance with either a surgical or an N95 mask was not impacted by mask condition. There was no significant difference between conditions for total completion time, average running pace, or exercise heart rate. It was found that both sRPE and terminal RPE were significantly higher in the N95 condition compared to the

control. Wearing either surgical and N95 masks resulted in significantly higher RPD scores compared to the control condition.

During self-paced exercise, the work rate achieved is primarily regulated by feedback from the sensory motor systems based on the presence of a pre-exercise template[14] for that activity and by feedback from the periphery[12]. It is presently thought that the Rating of Perceived Exertion (RPE) is a summation of afferent signals during exercise, and that it, along with central and peripheral fatigue, serve as the "language" of exercise intensity regulation[20]. With self-paced, masked exercise, we expected to see either an increase in trial completion time (i.e., decreased pace) or an increase in RPE. The results showed that with masked aerobic exercise at usual training intensities, there was no significant compromise in running time or pace, but rather the subjects accepted a higher RPE and sRPE to maintain the "template" for training performance.

This study is one of the first to investigate pacing strategies while running with face coverings. Kais (2019) reported that faster, more experienced distance runners keep a more constant running pace throughout the runs compared to less-experienced runners[21]. The subjects in this study showed a relatively constant pace across the different masked conditions, suggesting that mask usage did not alter pacing strategies compared to the subjects self-selected exercise intensity.

Several studies found that prolonged usage of an N95 mask was associated with an increase of CO_2 levels in the blood (estimated by end-tidal CO_2)[22,23,24]. The buildup of CO_2 leads to more acidic blood and an increase in respiratory drive[23,11]. Rudi et al. observed that face mask use during exercise altered both capillary pCO_2 and pO_2 levels within the physiologic range, this further supports the idea that masked exercise induces a type of CO_2 trapping[11]. Though our study did not directly evaluate end-tidal CO_2 levels, an increased end-tidal CO_2 may explain the increased perceived dyspnea found in the current study. The increased perceived breathlessness may also be explained by the findings from Li et al.[25]. In their study, participants perceived the N95 mask to be significantly more uncomfortable than the surgical mask due to the increased breathing resistance, itchiness experienced while wearing the mask, and humidity within the mask. Fikenzer et al. also found that the N95 mask was perceived as extremely uncomfortable compared to the no mask and surgical mask conditions[6]. Factors reported to explain this overall feeling of discomfort included increased breathing resistance, the tight seal of the N95 mask, and increased heat build-up within the mask.

Most previous literature highlights respiratory discomfort (e.g., dyspnea) as a primary side-effect of masked exercise. According to the Mayo Clinic mild to severe symptoms of exercise-related dyspnea with mask usage may include fatigue, dizziness,

headache, significant shortness of breath, muscular weakness, and drowsiness[26]. After completion of each individual trial, subjects were asked if they experienced any symptoms of light headedness, dizziness, nausea, or headaches. In the control condition, there were no symptoms experienced. In the surgical mask condition, 1 subject experienced mild dizziness. In the N95 condition, 1 subject reported having a severe headache immediately following the trial completion, 2 subjects had slight dizziness, and 1 subject had experienced light headedness during the exercise bout. While wearing the N95 masks, most subjects noted that their perceived breathing effort became noticeably harder by 1600-m. This suggests that had the training run been longer, such as routinely performed by recreational competitors, there may have been a down-regulation of running pace. Nevertheless, our findings demonstrate that, at least up to a distance of 3200-m, self-paced aerobic exercise can safely be performed by healthy young adults with either a surgical mask or an N95 mask with little reduction in pace or changes in overall performance, and only moderate symptoms.

When combined with the existing literature, the findings of this study demonstrate that using a mask during self-paced aerobic exercise has minimal effects on HR. Epstein et al.[22] showed that during a graded exercise test on a cycle ergometer, mask use had no significant effect on HR, BP, RR or SpO_2. Similar observations for HR, RR, RPE, and SpO_2 were made in older adults performing the Six-Minute-Walk Test[27]. This study utilized submaximal exercise intensities and showed no cardiopulmonary alterations while exercising with a facemask. Typically, HR can be used as a relatively accurate measure of exercise intensity in normal, unmasked settings. However, this study showed that when running with a mask, HR remains relatively constant while RPE increases suggesting that using HR to gage exercise intensity while running with a mask may not reflect other physiological factors altered by mask usage.

Conclusion

In summary, wearing face masks during exercise has minimal effects on HR and pacing strategies, but it does increase the runner's sense of dyspnea and perceived exertion. Our findings are further supported by existing literature which has shown that exercising with a facemask has very little impact on physiological variables and exercise performance, but it does increase perceived exertion and dyspnea[10]. Further studies should investigate the physiological and perceived responses of masked running in populations that already experience breathing difficulties at lower intensity activities such as COPD or post-COVID conditions. As a precaution, individuals with obstructive lung disease should proceed with caution before attempting any type of physical activity while wearing a mask.

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References

1. Jayaweera M, Perera H, Gunawardana B, Manatunge J. Transmission of COVID-19 virus by droplets and aerosols: A critical review on the unresolved dichotomy. *Environmental Research*. 2020;188:109819.
2. Esposito S, Principi N, Leung CC, Migliori GB. Universal use of face masks for success against COVID-19: evidence and implications for prevention policies. *The European Respiratory Journal.* 2020;55(6):2001260.
3. World Health Organization (2020). https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/myth-busters
4. Blocken B, Malizia F, & Van Druenen T. Towards aerodynamically equivalent COVID-19 1.5 m social distancing for walking and running. 2020. Advanced online publication. doi:http://www.urbanphysics.net/COVID19.html
5. Nielsen, R., Gwosdow, A., Berglund, L., & Dubois, A. The effect of temperature and humidity levels in a protective mask on user acceptability during exercise. *American Industrial Hygiene Association Journal*, 1987;48(7),639-645.
6. Fikenzer S, Uhe T, Lavall D, et al. Effects of surgical and FFP2/N95 face masks on cardiopulmonary exercise capacity. *Clinical Research in Cardiology.* 2020;109(12):1522-1530.
7. Porcari JP, Probst L, Forrester K, et al. Effect of wearing the elevation rraining mask on aerobic capacity, lung function, and hematological variables. *Journal of Sports Science & Medicine*. 2016;15(2):379-386.
8. Wilson JR, Raven PB, Zinkgraf SA, Morgan WP, Jackson AW. Alterations in physiological and perceptual variables during exhaustive endurance work while wearing a pressure-demand respirator. *American Industrial Hygiene Association Journal*. 1989;50(3):139-146.
9. Patel, P. N., & Zwibel., H. (2018). *Physiology, exercise*. StatPearls [Internet]. https://www.ncbi.nlm.nih.gov/books/NBK482280/
10. Shaw KA, Zello GA, Butcher SJ, Ko JB, Bertrand L, Chilibeck PD. The impact of face masks on performance and physiological outcomes during exercise: a systematic review and meta-analysis. *Applied Physiology, Nutrition, and Metabolism.* 2021;46(7):693-703.
11. Rudi WS, Maier F, Schüttler D, et al. Impact of face masks on exercise capacity and lactate thresholds in healthy young adults. *International Journal of Sports Physiology and Performance*. 2021;1-4.
12. Tucker R. The anticipatory regulation of performance: the physiological basis for pacing strategies and the development of a perception-based model for exercise performance. *British Journal of Sports Medicine*. 2009;43:392-400.
13. Ulmer HV. Concept of an extracellular regulation of muscular metabolic rate during heavy exercise in humans by psychophysiological feedback. *Experientia*. 1996;52(5):416-420.
14. Foster C, Hendrickson KJ, Peyer K, Reiner B, deKoning JJ, Lucia A, Battista R A, Hettinga F J, Porcari JP, & Wright G. Pattern of developing the performance template. *British Journal of Sports Medicine*. 2009;43(10),765–769.
15. Foster C, Schrager M, Snyder AC, & Thompson NN. Pacing strategy and athletic performance. *Sports Medicine*. 1994;17(2),77–85.
16. Foster C, de Koning JJ, Bischel S, Casolino E, Malterer K, O'Brien K, Rodriguez-Marroyo J, Splinter A, Thiel C, & van Tunen J. Pacing strategies for endurance performance. *Endurance Performance: Science and Practice.* 2012;89-98.
17. Foster C, Boullosa D, McGuigan M, Fusco A, Cortis C, Arney BE, Orton B, Dodge C, Jaime S, Radtke K, van Erp T, de Koning JJ, Bok D, Rodriguez-Marroyo JA, & Porcari JP. 25 Years of session rating of perceived exertion: historical perspective and development. *International Journal of Sports Physiology and Performance*. 2021;16(5),612-621.
18. Borg GAV. Borg's perceived exertion and pain scales. *Human Kinetics*. 1998.
19. Hareendran A, Leidy NK, Monz BU, Winnette R, Becker K, Mahler DA. Proposing a standardized method for evaluating patient report of the intensity of dyspnea during exercise testing in COPD. *International Journal of Chronic Obstructive Pulmonary Disease*. 2012;(7):345-355.
20. Azevedo RA, Silva-Cavalcante MD, Lima-Silva AE, Bertuzzi R. Fatigue development and perceived response during self-paced endurance exercise: state-of-the-art review. *European Journal of Applied Physiology.* 2021;121(3):687-696.

21. Kais, Ü., Pind, R., Pehme, A., Kaasik, P., & Mooses, M. Pacing strategy of the finishers of the world marathon majors series. *Kinesiology*, 2019;51(1):22–27.
22. Epstein D, Korytny A, Isenberg Y, Marcusohn E, Zukermann R, Bishop B, Minha S, Raz A, & Miller A. 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(1):70-75.
23. Sinkule EJ, Powell JB, Goss FL. Evaluation of N95 respirator use with a surgical mask cover: effects on breathing resistance and inhaled carbon dioxide. *The Annals of Occupational Hygiene*. 2013;57(3):384-398.
24. Smith CL, Whitelaw JL, Davies B. Carbon dioxide rebreathing in respiratory protective devices: influence of speech and work rate in full-face masks. *Ergonomics*. 2013;56(5):781-790.
25. Li Y, Tokura H, Guo YP, et al. Effects of wearing N95 and surgical facemasks on heart rate, thermal stress and subjective sensations. *International Archives of Occupational and Environmental Health*. 2005;78(6):501-509.
26. Mayo Clinic (2020). https://www.mayoclinichealthsystem.org/hometown-health/speaking-of-health/wearing-a-mask-while-exercising-faq
27. Radtke K, Porcari J, Carl F, Michael M, & Alec Helget. Evaluation of Six-Minute Walk Test (6MWT) Performance with and without a Facemask. *International Journal of Research in Exercise Physiology*. 2021;16(2):67-80.