LUPINE PUBLISHERS

Research and Reviews on Healthcare: Open Access Journal

DOI: 10.32474/RRHOAJ.2022.07.000266

ISSN: 2637-6679

Review Article

Efficiency and Burdens of Wearing Masks for Protection Against Sars-Cov-2: A Narrative Review Focused on the Current Situation at Workplaces

Jürgen Bünger*, Eike Maximilian Marek, Vera van Kampen and Thomas Brüning

Institute for Prevention and Occupational Medicine of the German Social Accident Insurance - Institute of the Ruhr-University Bochum (IPA), Bochum, Germany

***Corresponding author:** Jürgen Bünger, Institute for Prevention and Occupational Medicine of the German Social Accident Insurance - Institute of the Ruhr-University Bochum (IPA), Bürkle-de-la-Camp-Platz 1, 44789 Bochum, Germany

Received: March 11, 2022 **Published:** March 18, 2022

Abstract

At workplaces, many additional conditions and influences must be considered when choosing adequate personal protection equipment, including masks to protect from SARS-CoV-2 infection and transmission to other workmates. Conditions like type, proximity and duration of contact with colleagues, duration of mask wear, virus load, heat, humidity must be included for the risk analysis and decision if a mask is needed and if yes, what kind of mask is the best choice. A good scientific knowledge on the efficiency and burden of protection against SARS-CoV-2 by wearing masks is useful as an additional fundamental prerequisite for this decision. Depending on the type of mask, respiratory masks can be effective for both self-protection and protection of others (Asadi et al. [1], Chu et al. [2], Leung et al. [3], Liang et al. [4]). Jefferson and colleagues presented the state of knowledge on the effectiveness of masks in preventing the transmission of respiratory viruses until 2020 in a comprehensive literature review. The knowledge gained in the meantime (01.01.2022) will be briefly supplemented here. However, the main concern of this overview is the evaluation of the current scientific data on possible objective and subjective strains and stresses caused by wearing masks at rest and under different working (exercising) conditions.

Efficiency of protective masks

At workplaces, many additional conditions and influences must be considered when choosing adequate personal protection equipment, including masks to protect from SARS-CoV-2 infection and transmission to other workmates. Conditions like type, proximity and duration of contact with colleagues, duration of mask wear, virus load, heat, humidity must be included for the risk analysis and decision if a mask is needed and if yes, what kind of mask is the best choice. A good scientific knowledge on the efficiency and burden of protection against SARS-CoV-2 by wearing masks is useful as an additional fundamental prerequisite for this decision. Depending on the type of mask, respiratory masks can be effective for both self-protection and protection of others (Asadi et al. [1], Chu et al. [2], Leung et al. [3], Liang et al. [4]). Jefferson and colleagues presented the state of knowledge on the effectiveness of masks in preventing the transmission of respiratory viruses until 2020 in a comprehensive literature review. The knowledge gained in the meantime (01.01.2022) will be briefly supplemented here. However, the main concern of this overview is the evaluation of the current scientific data on possible objective and subjective strains and stresses caused by wearing masks at rest and under different working (exercising) conditions.

Efficiency of protective masks

In a Cochrane review that was updated several times (2007 - 2020), the effectiveness of protective masks in reducing the transmission of viruses was still classified as uncertain. The pooled results of randomized clinical trials (RCTs) showed no clear reduction in respiratory viral infections (mainly influenza) with the use of medical/surgical masks or FFP2/N95 masks (Jefferson et al. [5]). However, no studies on protection against SARS-CoV-2 were included in this research. In the meantime, numerous other experimental, clinical, and population-based studies have been published that show good efficiency, especially of FFP2/N95 masks, but also of surgical masks (SM) and to a lesser extent of community masks

(CM) in protecting against SARS-CoV-2. The good effectiveness of masks against the transmission of SARS-CoV-2 or COVID-19 was already evident at the beginning of the pandemic through lower infection rates of healthcare workers despite the much higher exposure to SARS-CoV-2 compared to the infection rates of the population in New York and Long Island (Jeremias et al. [6]). After the introduction of the mask requirement in German cities and communities, the number of cases fell rapidly. For example, the 7-day incidence fell to zero within 2 weeks in the city of Jena (Mitze et al. [7]). A study in 15 states of the USA and Washington, DC (Lyu et al. [8]) and a nationwide study in Canada (Karaivanov et al. [9]) showed comparable results. The reduction of SARS-CoV-2 transmission by wearing masks has also been convincingly demonstrated in airplanes (Freedman & Wilder-Smith [10], Doung Ngern et al. [11]). In a comprehensive review with meta-analyses, Chu and co-authors (2020) concluded that face mask use could lead to a significant reduction in the risk of infection. The effectiveness of FFP2/N95 masks was rated higher than that of SM or CM (Chu et al. [2]). In the meantime, other reviews (Ju et al. [12], Li et al. 2021, Tran et al. [13], Zhang et al. [14]) have also been published that support the protection against COVID-19 infection by wearing masks. Ju et al. [15] conclude that while definitive evidence is still lacking for the superiority of N95 masks compared to SM for protection against COVID-19, experimental laboratory tests are conclusive and consistent in establishing the superior performance of FFP2/N95 versus SM.

In these experimental studies, the protection afforded by wearing masks was examined and was convincingly demonstrated, especially for FFP2 and SM (Bagheri et al. [16], Cheng et al. [17], Sickbert Bennett et al. [18], Ueki et al. [19]). Results for CM were less convincing (Maurer et al. [20]). Bagheri and colleagues (2021) used a comprehensive database with information on particle size distribution in the airways, the physics of the exhalation flow, mask leakage, and further parameters for the multimodal calculation of the risk of exposure and infection when wearing face masks under various environmental conditions. For a typical SARS-CoV-2 viral load, these authors calculated a transmission probability of less than 30% for 2 people both wearing SM at a distance of 1.5 m after 1 hour. If both wear a well-fitting FFP2, the risk is only 0.4%. The authors conclude that wearing appropriate masks provides excellent protection for others and oneself (Bagheri et al. [16]). In a similarly designed study (Cheng et al. [17]), the authors conclude that SM can effectively prevented the spread of SARS-CoV-2 in the case of contact under conditions of low virus density. In potentially virus-rich indoor environments, including medical institutions and hospitals, FFP2 or FFP3 masks and other protective equipment are required. Sickbert Bennett et al. [18] evaluated 29 different N95 masks and found that compliant products offer very good protection and that re-sterilized N95 respirators can also be used. Ueki et al. [19] found that CM, SM, and N95 have a protective effect in relation to the transmission of infectious droplets and aerosols of SARS-CoV-2. The protection provided by SM and N95 masks is better than by CM. However, all 3 types of masks could not completely prevent the transmission of virus droplets or aerosols, even with a good fit. Maurer et al. [20] investigated reusable CM and measured a filtration efficiency ranging from 34.9% ± 1.25% to 88.7% ± 1.18%. The respiratory resistance ranged from 4.3 ± 0.06 Pa/cm2to 122.4 ± 0.12 Pa/cm2. A high correlation was found between filtration efficiency and breathing resistance (R^2 = 0.88). In a study by Dreller et al. [21], various SM and FFP were examined based on the EN 149 standard. With an air flow rate of 95 L/min, the breathing resistance fell into the range of 10 - 280 Pa (corresponding to 0.1 - 2.8 mbar), which is in the range of the masks used in current mask studies. These Data were confirmed by Marek and cowork**ers in 2022 [22].**

Objective and subjective physical loads and strains

Reviews

Hopkins et al. [23] reviewed the literature on the effects of different face masks and respirators on the airways during physical activity. Overall, according to the authors, the available data suggest that the effects on work of breathing, blood gases and other physiological parameters during physical activity are small. There is currently no evidence of gender or age-related differences in physiological responses to training while wearing a mask. A systematic review and meta-analysis were carried out by Shaw and co-authors [24] on the effects of wearing masks (CM, SM, FFP2/N95) during physical exertion (training). Twenty-two studies with 1,573 participants (620 women, 953 men) were included. SM or N95 had no effect on exercise performance (SMD 0.05 [0.16, 0.07] and SMD 0.16 [0.54, 0.22], respectively). However, there was an increased subjectively perceived exertion for SM (SMD 0.33 [0.09, 0.58]) and FFP2/N95 (SMD 0.61 [0.23, 0.99]) and for dyspnea (SMD 0.6 [0.3, 0.9]) for all masks. End-tidal CO_2 was slightly increased for SM (MD 3.3 mmHg [1.0, 5.6]) and for FFP2/ N95 (MD 3.7 mmHg [3.0, 4.4]), as well as heart rate (HR) in FFP2/N95 (SMD 2.01 [0.13, 3.89] beats/min). According to the authors, face masks can be used during physical exertion without affecting performance and with minimal impact on physiological variables (Shaw et al. [24]). Engeroff et al. [25] included 14 RCTs with 246 study participants for their review and found general changes when wearing masks. Mask wearing lead to a decrease in oxygen saturation (SO_2) during intensive training (SMD −0.40 [95% CI:−0.70, −0.09]), mostly attributed to FFP2/N95.

Wearing a mask at rest

Engeroff et.al [25] found the following changes when wearing infection protection masks at rest: The use of masks changes the breathing rate and depth of breathing. FFP2 or N95 respirator masks and SM tended to lead to an increase in SO_2 at rest. Compared to SM, FFP2 and N95 had a stronger impact on gas exchange (Engeroff et al. [25]). Lässing et al. [26] examined the changes in lung function when wearing a SM at rest. Respiratory resistance was almost twice as high with SM than without mask (MNS: 0.58 ±

0.16 kPa/L; control: 0.32 ± 0.08 kPa/L; $p < 0.01$). Mapelli et al. [27] showed a reduction in static and dynamic lung function parameters (FVC/FEV1) when wearing SM or N95.

Wearing a mask under physical stress

Short term maximum physical stress

The changes in lung function and gas exchange associated with using masks at rest differ from the effects of wearing masks during physical activity. Mask use during strenuous activities shows the greatest impact on oxygen uptake (Engeroff et al. [25]). Cardiopulmonary stress from wearing masks has been observed in numerous studies in which the strain on the subjects was stepwise increased up to the maximum load [28-44]. In summary, a measurable but non-health-relevant drop in oxygen partial pressure (PO2) was observed in these studies. Slight increases in the carbon dioxide partial pressure (PCO2) were also measured in addition but were assessed as not relevant to health. It should be noted that the sometimes very high loads of up to 280 watts carried out in the studies do not represent the typical conditions at workplaces. In addition, the measurements were predominantly carried out on young, well-trained people (thereof relatively few women). For these reasons, the mentioned studies were not further analysed in the context of this evaluation.

Typical workplace load/continuous load

Typical workplace stresses were more likely to be identified in the study by Georgi et al. [45] investigating 24 hospital employees (age 44.7 ± 11.7 years; 46 % male; BMI 25.4 ± 4.3 kg/m2; 26.9% smokers; 19.2 % hypertensive). These subjects were examined by means of ergometry at typical workplace loads (50/75/100 watts, for three minutes each in direct succession) without a mask and wearing CM, SM, or FFP2. In particular, less trained people (strong increase in HR) reported symptoms such as dyspnoea, headaches, feeling hot or dizzy with all mask types, but especially with FFP2, even at low levels of exertion. Overall, the authors found a "a measurable but clinically irrelevant effect on blood gases and vital parameters in people of working age with no known underlying cardiopulmonary disease". Lässing et al. [26] investigated the physiological effects of SM at constant loads over 30 min on 14 healthy men (age 25.7 ± 3.5 years). Although the subjects exercised only at 66 % of the individual maximum load, this corresponded to a power of 200 watts, indicating a very welltrained test group. The loads with masks over 30 min resulted in significantly different respiratory minute volumes (SM: 77.1 ± 9.3L/min; control: 82.4 ± 10.7 L/min; $p < 0.01$), oxygen uptake (SM: 33.1 ± 5 mL/min/kg; control 34.5 ± 6 mL/min/kg; $p = 0.04$) and heart rates (SM: 160.1 ± 11.2 beats/min; control: 154.5 ± 11.4 bpm; $p<0.01$) compared to those without masks (controls). The authors conclude that SM increases respiratory resistance and heart rate during constant exercise in healthy volunteers. Perceived exertion and endurance performance did not differ significantly. Doherty et al. [46] determined the influence of wearing CM and SM on the cardiopulmonary functions of 12 persons (5 women) during moderately intensive ergometer training (70% of the maximum heart rate, or 74 - 107 watts) over a period of 5 minutes. There were no differences in breathing rate, heart rate, or SO2. The authors conclude that wearing a mask (CM/SM) during short-term exercise with moderate-intensity results in minimal effects on cardiopulmonary stress in young, healthy individuals and may subjectively increase feelings of dyspnoea Doherty et al. [46].

Cabanillas Barea et al. [47] investigated in 50 healthy volunteers whether the use of masks (FFP2/N95, SM) compared to the situation without a mask causes effects in the 6-minute walk test (6MWT). Significant differences were observed between the three situations in terms of subjectively perceived dyspnoea (FFP2/N95 SM > no mask). No significant differences were found regarding the walking distances covered in the 6MWT, the heart rate, blood gases, and respiratory muscle tone (Cabanillas Barea et al. [46]). Shein et al. [48] investigated PCO2 and SO2 at the end of six 10-minute periods of sitting quietly and walking briskly without a mask, wearing CM or SM, respectively. There were no episodes of hypoxemia or hypercapnia among the 50 adult volunteers studied (mean age 33 years; 32 % with comorbidities). There were no statistically significant differences in PCO2 or SO2 between measurements without a mask and those while wearing either mask type, either at rest or after 10 minutes of brisk walking. The authors conclude that the risk of pathological gas exchange disorders in the general adult population when using cloth and surgical masks is close to zero (Shein et al. [48]). Reychler et al. [49] investigated the influence of CM and SM using a relatively rarely used stress test (standing up and sitting down on a chair for 1 min, corresponding to submaximal stress) on 20 young persons (9 women, 11 men, age 22±2 years) The authors conclude that in healthy adults, both CM and SM have minimal to no effect on dyspnoea, cardiorespiratory parameters, and exercise performance during a brief submaximal exercise test, with the observed effects being slightly more pronounced in CM.

Wearing masks for a longer period at work

In this literature search, 5 interventional or observational studies were identified in which the mask was worn for a period of 30 minutes or longer with simultaneous measurement of physiological parameters and survey of subjective stress. In the study by Butz [50], the accumulation of carbon dioxide (CO2) behind SM was examined over a period of 30 minutes. The accumulation led to increased rebreathing of CO2 and this in turn led to a significant increase in pCO2 in the tested subjects. The accumulation of CO2 under surgical masks in normally breathing people is caused by the impaired permeability of the mask (Butz [50]). In a study by Roberge et al. [51], 20 people (13 men, 7 women, all non-smokers) walked on a treadmill for 1 hour with and without SM at a walking speed of 5.6 km/h monitoring heart rate, respiratory rate, so2, transcutaneous CO2 as well as relative humidity and skin temperature under the mask. Rating scales were used for perceptions of exertion and warmth. Use of the SM resulted in increases in heart rate

(9.5 bpm; p<0.001), respiratory rate (1.6 breaths/min; p=0.02), and transcutaneous carbon dioxide (2.17 mm Hg; p= 0.0006). The temperature rise of the skin covered by the mask was 1.76°C. The subjective perception of warmth was neutral to slightly hot. Perceived exposure ranged from very light to fairly light. Overall, the authors conclude that the use of the SM for 1 hour during light to moderate work is not associated with clinically significant physiological effects or a significant subjective perception of exertion or heat (Roberge et al. [51]). The study by Nwosu et al. [52] included 76 healthcare workers who wore different types of masks (CM, SM, N95) over a period of 68-480 minutes. The authors concluded that N95 may cause greater subjective discomfort than SM. Neither mask affected arterial oxygen saturation. Similar effects were shown in the earlier work by Shenal et al. [53] and Rebmann et al. [54], in which subjective complaints increased with increasing wearing time (8-12 hours), but the masks did not lead to any clinically relevant physiological stress on the nursing staff. In a review article, Gupta [54] defined the microclimate behind the mask primarily in terms of increased heat and moisture accumulation. He states that removing the face mask immediately neutralizes the increased temperature and relative humidity behind the mask. Therefore, taking off the mask for a short time under safe precautions at home/workplace/in a facility provides for a temporary "mask vacation".

Cognitive function

Spang and Pieper [56] investigated the effects of wearing an N95 mask on demanding cognitive tasks for 15 minutes in 44 people (24 women, ages 18-65, academics, students). Parameters related to physiology (SO2, HR), behaviour (performance parameters in the tasks), and subjectively perceived mental stress were measured. All endpoints examined showed statistical equivalence within the specified limits. No parameters showed a significant difference between wearing the mask compared to the situation without mask. The authors interpret the data that there are no statistical differences between the two groups (Spang et al. [56]). Slimani et al. [57] studied the effect of a physical warm-up program with MNB/CM and no mask wearing on cognitive function in 17 healthy non-smoking sports students (8 females, age = 17.6 years). The warm-up improved cognitive skills. Results showed significant differences (p<0.001) between MNB/CM and control for concentration (186.06±15.47 vs. 178.12±13.66), total number of errors (23.47±14, 50 vs. 29.06±13.74) and subjective effort (6.0±1.37 vs. 4.7±0.85). Wearing MNB/CM had overall positive effects on cognitive abilities.

Conclusion

Self-protection against viral infections by wearing masks is very efficient according to experimental studies. Masks prevent transmission of viruses like SARS-CoV-2. Protection by FFP2/N95 is better than by SM. CM can protect to a lesser extent depending on the making of the masks (fit and material). It is difficult to show the effectiveness of wearing masks in clinical controlled trials due to extremely varying environmental and occupational conditions such as virus load, humidity, temperature, and so on. Wearing masks at workplaces is mandatory when secure social distancing is not possible and may last 8 hours and more . However, the increased breathing resistance of the mask materials leads to enhanced breathwork and wearing the mask causes additional physical strain and subjective discomfort depending on workload, climatic conditions, and duration. Therefore, risk assessment should be performed for each occupational task, if periods without wearing the mask are necessary. Short-term removing of the mask is adequate when the physical load is low and only the higher temperature and humidity must be considered. Breaks should be extended under higher physical workloads and unusual climatic conditions.

References

1. Asadi S, Cappa CD, Barreda S, Wexler AS, Bouvier NM, Ristenpart WD (2020) Efficacy of masks and face coverings in controlling outward aerosol particle emission from expiratory activities. Sci Rep 10: 15665.
2. Chu DK, Akl EA, Duda S, Solo K, Yaacoub S, et al. (2020) Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV- 2 and COVID-19: a systematic review and meta-analysis. Lancet 395(10242):1973-1987.
3. Leung NH, Chu DKW, Shiu EYC, Chan KH, McDevitt JJ, et al. (2020) Respiratory virus shedding in exhaled breath and efficacy of face masks. Nature medicine 26: 676–680.
4. Liang M, Gao L, Cheng C, Zhou Q, Uy JP, et al. (2020) Efficacy of face mask in preventing respiratory virus transmission: a systematic review and meta-analysis. Travel Med Infect Dis 36: pp.101751.
5. Jefferson T, Del Mar CB, Dooley L, Ferroni E, Al Ansary LA, et al. (2020) Physical interventions to interrupt or reduce the spread of respiratory viruses. Cochrane Database Syst Rev CD006207.
6. Jeremias A, Nguyen J, Levine J, Pollack S, Engellenner W, Thakore A, Lucore C (2020) Prevalence of SARS-CoV-2 Infection Among Health Care Workers in a Tertiary Community Hospital. JAMA Intern Med 180: 1707-1709.
7. Mitze T, Kosfeld R, Rode J, Wälde K (2020) Face masks considerably reduce COVID-19 cases in Germany. Proc Natl Acad Sci USA 117: 32293-32301.
8. Lyu W, Wehby GL (2020) Community use of face masks and COVID-19: evidence from a natural experiment of state mandates in the US. Health Aff 39: 1419–25.
9. Karaivanov A, Lu SE, Shigeoka H, Chen C, Pamplona S(2020) Face masks, public policies and slowing the spread of COVID-19: Evidence from Canada. National Bureau of Economic Research Working Paper Series pp.27891.
10. Freedman DO, Wilder Smith A (2020) In-flight transmission of SARS-CoV-2: a review of the attack rates and available data on the efficacy of face masks. J Travel Med 27 (8) taaa178.
11. Doung Ngern P, Suphanchaimat R, Panjangampatthana A, Janekrongtham C, Ruampoom D, et al. (2020) Case-control study of use of personal protective measures and risk for SARS-CoV 2 infection, Thailand. Emerg Infect Dis 26: 2607–2616.
12. Ju JTJ, Boisvert LN, Zuo YY (2021) Face masks against COVID-19: Standards, efficacy, testing and decontamination methods. Adv Colloid Interface Sci 292: 102435.
13. Li Y, Wei Z, Zhang J, Li R, Li H, et al. (2021) Wearing masks to reduce the spread of respiratory viruses: a systematic evidence mapping. Ann Transl Med 9: pp. 811.

14. Zhang M, Emery AR, Tannyhill RJ 3rd, Zheng H, Wang J (2020) Masks or N95 Respirators During COVID-19 Pandemic-Which One Should I Wear? J Oral Maxillofac Surg 78: 2114-2127.
15. Just IA, Schoenrath F, Passinger P, Stein J, Kemper D, Knosalla C, Falk V, Knierim J (2021) Validity of the 6-Minute Walk Test in Patients with End-Stage Lung Diseases Wearing an Oronasal Surgical Mask in Times of the COVID-19 Pandemic. Respiration 100: 594-599.
16. Bagheri G, Thiede B, Hejazi B, Schlenczek O, Bodenschatz E (2021) An upper bound on one-to-one exposure to infectious human respiratory particles. Proc Natl Acad Sci USA 118 :e2110117118.
17. Cheng Y, Ma N, Witt C, Rapp S, Wild PS, Andreae MO, Pöschl U, Su H (2021) Face masks effectively limit the probability of SARS-CoV-2 transmission. Science 372, 1439–1443.
18. Sickbert Bennett EE, Samet JM, Clapp PW, Chen H, Berntsen J, Zeman KL, Tong H, Weber DJ, Bennett WD (2020) Filtration Efficiency of Hospital Face Mask Alternatives Available for Use During the COVID-19 Pandemic. JAMA Intern Med. 180:1607-1612.
19. Ueki H, Furusawa Y, Iwatsuki-Horimoto K, Imai M, Kabata H, Nishimura H, Kawaoka Y (2020) Effectiveness of Face Masks in Preventing Airborne Transmission of SARS-CoV-2. mSphere 5: e00637-20.
20. Maurer L, Peris D, Kerl J, Günther F, Köhler D, Dellweg D (2021) Community Masks During the SARS-CoV-2 Pandemic: Filtration Efficacy and Air Resistance. J Aerosol Med Pulm Drug Deliv 34: 11-19.
21. Dreller S, Jatzwauk L, Nassauer A, Paszkiewicz P, Tobys HU, Rüden H (2006) Zur Frage des geeigneten Atemschutzes vor luftübertragenen Infektionserregern. Gefahrstoffe, Reinhaltung der Luft 66:14-24.
22. Marek E, van Kampen V, Jettkant B, Thelen C, Brüning T, Bünger J (2021a) Vergleich von verschiedenen Masken zum Schutz vor SARS-CoV-2 im Hinblick auf die entsprechenden Prüfverfahren und die ermittelten Atemwiderstände. Internes Arbeitspapier 2021:12-28.
23. Hopkins SR, Dominelli PB, Davis CK, Guenette JA, Luks AM, et al. (2021) Face Masks and the Cardiorespiratory Response to Physical Activity in Health and Disease. Ann Am Thorac Soc 18: 399-407.
24. Shaw KA, Zello GA, Butcher SJ, Ko JB, Bertrand L, Chilibeck PD (2021a) The impact of face masks on performance and physiological outcomes during exercise: a systematic review and meta-analysis. Appl Physiol Nutr Metab 46: 693-703.
25. Engeroff T, Groneberg DA, Niederer D (2021) The Impact of Ubiquitous Face Masks and Filtering Face Piece Application During Rest, Work and Exercise on Gas Exchange, Pulmonary Function and Physical Performance: A Systematic Review with Meta-analysis. Sports Med Open 7: p.92.
26. Lässing J, Falz R, Pökel C, Fikenzer S, Laufs U, Schulze A, Hölldobler N, Rüdrich P, Busse M (2020) Effects of surgical face masks on cardiopulmonary parameters during steady state exercise. Sci Rep 10: 22363.
27. Mapelli M, Salvioni E, De Martino F, Mattavelli I, Gugliandolo P, et al. (2021) "You can leave your mask on": effects on cardiopulmonary parameters of different airway protective masks at rest and during maximal exercise. Eur Respir J 58: 2004473.
28. Ade CJ, Turpin VG, Parr SK, Hammond ST, White Z, et al. (2021) Does wearing a facemask decrease arterial blood oxygenation and impair exercise tolerance? Respir Physiol Neurobiol. 294: ppp.103765.
29. Ahmadian M, Ghasemi M, Nasrollahi Borujeni N, Afshan S, et al. (2021) Does wearing a mask while exercising amid COVID-19 pandemic affect hemodynamic and hematologic function among healthy individuals? Implications of mask modality, sex, and exercise intensity. Phys Sportsmed 10:1-12.
30. Alkan B, Ozalevli S, Akkoyun Sert O (2021) Maximal exercise outcomes with a face mask: the effects of gender and age differences on cardiorespiratory responses. Ir J Med Sci 26:1-7.
31. Barbeito Caamaño C, Bouzas Mosquera A, Peteiro J, López Vázquez D, Quintas Guzmán M, et al. (2021) Exercise testing in COVID-19 era: Clinical profile, results and feasibility wearing a facemask. Eur J Clin Invest. 51: e13509.
32. Driver S, Reynolds M, Brown K, Vingren JL, Hill DW, Bennett M, Gilliland T, McShan E, Callender L, Reynolds E, Borunda N, Mosolf J, Cates C, Jones A (2021) Effects of wearing a cloth face mask on performance, physiological and perceptual responses during a graded treadmill running exercise test. Br J Sports Med 56(2):107-113.
33. Egger F, Blumenauer D, Fischer P, Venhorst A, Kulenthiran S, et al. (2021) Effects of face masks on performance and cardiorespiratory response in well-trained athletes. Clin Res Cardiol 6:1-8.
34. Epstein D, Korytny A, Isenberg Y, Marcusohn E, Zukermann R, Bishop B, Minha S, Raz A, Miller A (2020) Return to training in the COVID-19 era: The physiological effects of face masks during exercise. Scand J Med Sci Sports 31: 70-75.
35. Fikenzer S, Uhe T, Lavall D, Rudolph U, Falz R, Busse M, Hepp P, Laufs U (2020) Effects of surgical and FFP2/N95 face masks on cardiopulmonary exercise capacity. Clin Res Cardiol 109:1522-1530.
36. Fukushi I, Nakamura M, Kuwana SI (2021) Effects of wearing facemasks on the sensation of exertional dyspnea and exercise capacity in healthy subjects. PLoS One 16(9): e0258104.
37. Kampert M, Singh T, Sahoo D, Han X, Van Iterson EH (2021) Effects of Wearing an N95 Respirator or Cloth Mask Among Adults at Peak Exercise: A Randomized Crossover Trial. JAMA Netw Open. 4: e2115219.
38. Jesus JP, Gomes M, Dias-Gonçalves A, Correia JM, Pezarat-Correia P, Mendonca GV (2021) Effects of surgical masks on the responses to constant work-rate cycling performed at different intensity domains. Clin Physiol Funct Imaging 42(1):43-52.
39. Modena R, Fornasiero A, Callovini A, Savoldelli A, Pellegrini B, Schena F, Bortolan L (2021) Exercising at the time of the COVID-19 pandemic: acute physiological, perceptual and performance responses of wearing face masks during sports activity. J Sports Med Phys Fitness 2021 Dec 16.
40. Rojo Tirado MA, Benítez Muñoz JA, Alcocer Ayuga M, Alfaro Magallanes VM, Romero Parra N, et al. (2021) Effect of Different Types of Face Masks on the Ventilatory and Cardiovascular Response to Maximal-Intensity Exercise. Biology (Basel) 10: 969.
41. Rudi WS, Maier F, Schüttler D, Kellnar A, Strüven AK, Hamm W, Brunner S (2021) Impact of Face Masks on Exercise Capacity and Lactate Thresholds in Healthy Young Adults. Int J Sports Physiol Perform 25: 1-4.
42. Shaw K, Butcher S, Ko J, Zello GA, Chilibeck PD (2020) Wearing of Cloth or Disposable Surgical Face Masks has no Effect on Vigorous Exercise Performance in Healthy Individuals. Int J Environ Res Public Health 17: pp.8110.
43. Shaw KA, Butcher S, Ko JB, Absher A, Gordon J, Tkachuk C, Zello GA, Chilibeck PD (2021b) Wearing a Surgical Face Mask Has Minimal Effect on Performance and Physiological Measures during High-Intensity Exercise in Youth Ice-Hockey Players: A Randomized Cross-Over Trial. Int J Environ Res Public Health 18: pp.10766.
44. Zhang G, Li M, Zheng M, Cai X, Yang J, Zhang S, Yilifate A, Zheng Y, Lin Q, Liang J, Guo L, Ou H (2021) Effect of Surgical Masks on Cardiopulmonary Function in Healthy Young Subjects: A Crossover Study. Front Physiol 12: pp.710573.
45. Georgi C, Haase-Fielitz A, Meretz D, Gäsert L, Butter C (2020) The Impact of Commonly Worn Face Masks on Physiological Parameters and on Discomfort During Standard Work-Related Physical Effort. Dtsch Arztebl Int 117:674-675.

46. Doherty CJ, Mann LM, Angus SA, Chan JS, Molgat Seon Y, Dominelli PB (2021) Impact of wearing a surgical and cloth mask during cycle exercise. Appl Physiol Nutr Metab 46:753-762.
47. Cabanillas Barea S, Rodríguez Sanz J, Carrasco Uribarren A, López de Celis C, González Rueda V, et al. (2021) Effects of Using the Surgical Mask and FFP2 during the 6-Min Walking Test. A Randomized Controlled Trial. Int J Environ Res Public Health. 18:12420.
48. Shein SL, Whitticar S, Mascho KK, Pace E, Speicher R, Deakins K (2021) The effects of wearing facemasks on oxygenation and ventilation at rest and during physical activity. PLoS One 16(2): e0247414.
49. Reychler G, Straeten CV, Schalkwijk A, Poncin W (2021) Effects of surgical and cloth facemasks during a submaximal exercise test in healthy adults. Respir Med186: 106530.
50. Butz U (2005) Rückatmung von Kohlendioxid bei Verwendung von Operationsmasken als hygienischer Mundschutz an medizinischem Fachpersonal (Dissertation, Technische Universität München).
51. Roberge RJ, Kim JH, Benson SM (2012) Absence of consequential changes in physiological, thermal and subjective responses from wearing a surgical mask. Respir Physiol Neurobiol 181:29-35.
52. Nwosu ADG, Ossai EN, Onwuasoigwe O, Ahaotu F (2021) Oxygen saturation and perceived discomfort with face mask types, in the era of COVID-19: a hospital-based cross-sectional study. Pan African Medical Journal 39: pp.203.
53. Shenal BV, Radonovich LJ Jr, Cheng J, Hodgson M, Bender BS (2012) Discomfort and exertion associated with prolonged wear of respiratory protection in a health care setting. J Occup Environ Hyg. 9: 59–64.
54. Rebmann T, Carrico R, Wang J (2013) Physiologic and other effects and compliance with long-term respirator use among medical intensive care unit nurses. Am J Infect 41:1218–1223.
55. Gupta D (2020) Living with in-mask micro-climate. Med Hypotheses 144:110010.
56. Spang RP, Pieper K (2021) The tiny effects of respiratory masks on physiological, subjective, and behavioural measures under mental load in a randomized controlled trial. Sci Rep 11: pp.19601.
57. Slimani M, Miarka B, Znazen H, Moalla W, Hammami A, et al. (2021) Effect of a warm-up protocol with and without facemask-use against COVID-19 on cognitive function: a pilot, randomized counterbalanced, cross-sectional study. Int J Environ Res Public Health 18: 5885.

DOI: 10.32474/RRHOAJ.2022.07.000266