# Evidence Search Service Results of your search request

## What impact does PPE (mainly FFP3 masks) have on our CO2 levels and cognitive performance

**ID of request:** 23030  
**Date of request:** 4th May, 2020  
**Date of completion:** 15th May, 2020

If you would like to request any articles or any further help, please contact:  Tom Roper at [tom.roper@nhs.net](mailto:tom.roper@nhs.net)

Please acknowledge this work in any resulting paper or presentation as: Evidence search: What impact does PPE (mainly FFP3 masks) have on our CO2 levels and cognitive performance. Tom Roper. (15th May, 2020). BRIGHTON, UK: Brighton and Sussex Library and Knowledge Service.

**Sources searched**  
EMBASE (4)  
Google Scholar (1)  
MEDLINE (28)

**Date range used** (5 years, 10 years): No restrictions   
**Limits used** (gender, article/study type, etc.): English language   
**Search terms and notes** (full search strategy for database searches below):

Relevant natural language and controlled vocabulary terms were selected and combined. Thesaurus terms were adapted for different databases. Final result sets were de-duplicated and reviewed for relevance by the searcher, irrelevant results being discarded.

For more information about the resources please go to: <https://www.bsuh.nhs.uk/library/>.

## Summary of Results

Given the number of results retrieved by a first version of the strategy looking for all forms of PPE, I restricted this to masks only.

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## A. Original Research

1. **Barriers and facilitators to healthcare workers' adherence with infection prevention and control (IPC) guidelines for respiratory infectious diseases: a rapid qualitative evidence synthesis.**  
   Houghton Catherine The Cochrane database of systematic reviews 2020;4:CD013582.

BACKGROUNDThis review is one of a series of rapid reviews that Cochrane contributors have prepared to inform the 2020 COVID-19 pandemic. When new respiratory infectious diseases become widespread, such as during the COVID-19 pandemic, healthcare workers' adherence to infection prevention and control (IPC) guidelines becomes even more important. Strategies in these guidelines include the use of personal protective equipment (PPE) such as masks, face shields, gloves and gowns; the separation of patients with respiratory infections from others; and stricter cleaning routines. These strategies can be difficult and time-consuming to adhere to in practice. Authorities and healthcare facilities therefore need to consider how best to support healthcare workers to implement them.OBJECTIVESTo identify barriers and facilitators to healthcare workers' adherence to IPC guidelines for respiratory infectious diseases.SEARCH METHODSWe searched OVID MEDLINE on 26 March 2020. As we searched only one database due to time constraints, we also undertook a rigorous and comprehensive scoping exercise and search of the reference lists of key papers. We did not apply any date limit or language limits.SELECTION CRITERIAWe included qualitative and mixed-methods studies (with a distinct qualitative component) that focused on the experiences and perceptions of healthcare workers towards factors that impact on their ability to adhere to IPC guidelines for respiratory infectious diseases. We included studies of any type of healthcare worker with responsibility for patient care. We included studies that focused on IPC guidelines (local, national or international) for respiratory infectious diseases in any healthcare setting. These selection criteria were framed by an understanding of the needs of health workers during the COVID-19 pandemic.DATA COLLECTION AND ANALYSISFour review authors independently assessed the titles, abstracts and full texts identified by our search. We used a prespecified sampling frame to sample from the eligible studies, aiming to capture a range of respiratory infectious disease types, geographical spread and data-rich studies. We extracted data using a data extraction form designed for this synthesis. We assessed methodological limitations using an adapted version of the Critical Skills Appraisal Programme (CASP) tool. We used a 'best fit framework approach' to analyse and synthesise the evidence. This provided upfront analytical categories, with scope for further thematic analysis. We used the GRADE-CERQual (Confidence in the Evidence from Reviews of Qualitative research) approach to assess our confidence in each finding. We examined each review finding to identify factors that may influence intervention implementation and developed implications for practice.MAIN RESULTSWe found 36 relevant studies and sampled 20 of these studies for our analysis. Ten of these studies were from Asia, four from Africa, four from Central and North America and two from Australia. The studies explored the views and experiences of nurses, doctors and other healthcare workers when dealing with severe acute respiratory syndrome (SARS), H1N1, MERS (Middle East respiratory syndrome), tuberculosis (TB), or seasonal influenza. Most of these healthcare workers worked in hospitals; others worked in primary and community care settings. Our review points to several barriers and facilitators that influenced healthcare workers' ability to adhere to IPC guidelines. The following factors are based on findings assessed as of moderate to high confidence. Healthcare workers felt unsure as to how to adhere to local guidelines when they were long and ambiguous or did not reflect national or international guidelines. They could feel overwhelmed because local guidelines were constantly changing. They also described how IPC strategies led to increased workloads and fatigue, for instance because they had to use PPE and take on additional cleaning. Healthcare workers described how their responses to IPC guidelines were influenced by the level of support they felt that they received from their management team. Clear communication about IPC guidelines was seen as vital. But healthcare workers pointed to a lack of training about the infection itself and about how to use PPE. They also thought it was a problem when training was not mandatory. Sufficient space to isolate patients was also seen as vital. A lack of isolation rooms, anterooms and shower facilities was a problem. Other important practical measures described by healthcare workers included minimising overcrowding, fast-tracking infected patients, restricting visitors, and providing easy access to handwashing facilities. A lack of PPE, and equipment that was of poor quality, was a serious concern for healthcare workers and managers. They also pointed to the need to adjust the volume of supplies as infection outbreaks continued. Healthcare workers believed that they followed IPC guidance more closely when they saw the value of it. Some healthcare workers felt motivated to follow the guidance because of fear of infecting themselves or their families, or because they felt responsible for their patients. Some healthcare workers found it difficult to use masks and other equipment when it made patients feel isolated, frightened or stigmatised. Healthcare workers also found masks and other equipment uncomfortable to use. The workplace culture could also influence whether healthcare workers followed IPC guidelines or not. Across many of the findings, healthcare workers pointed to the importance of including all staff, including cleaning staff, porters, kitchen staff and other support staff when implementing IPC guidelines.AUTHORS' CONCLUSIONSHealthcare workers point to several factors that influence their ability and willingness to follow IPC guidelines when managing respiratory infectious diseases. These include factors tied to the guideline itself and how it is communicated, support from managers, workplace culture, training, physical space, access to and trust in personal protective equipment, and a desire to deliver good patient care. The review also highlights the importance of including all facility staff, including support staff, when implementing IPC guidelines.

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1. **Consensus of Chinese experts on protection of skin and mucous membrane barrier for health-care workers fighting against coronavirus disease 2019**  
   Yan Y. Dermatologic Therapy 2020;:No page numbers.

Health professions preventing and controlling Coronavirus Disease 2019 are prone to skin and mucous membrane injury, which may cause acute and chronic dermatitis, secondary infection and aggravation of underlying skin diseases. This is a consensus of Chinese experts on protective measures and advice on hand-cleaning- and medical-glove-related hand protection, mask- and goggles-related face protection, UV-related protection, eye protection, nasal and oral mucosa protection, outer ear, and hair protection. It is necessary to strictly follow standards of wearing protective equipment and specification of sterilizing and cleaning. Insufficient and excessive protection will have adverse effects on the skin and mucous membrane barrier. At the same time, using moisturizing products is highly recommended to achieve better protection.<br/>Copyright &#xa9; 2020 Wiley Periodicals, Inc.

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1. **Headaches Associated With Personal Protective Equipment - A Cross-Sectional Study Among Frontline Healthcare Workers During COVID-19.**  
   Ong Jonathan J. Y Headache 2020;60(5):864-877.

BACKGROUNDCoronavirus disease 2019 (COVID-19) is an emerging infectious disease of pandemic proportions. Healthcare workers in Singapore working in high-risk areas were mandated to wear personal protective equipment (PPE) such as N95 face mask and protective eyewear while attending to patients.OBJECTIVESWe sought to determine the risk factors associated with the development of de novo PPE-associated headaches as well as the perceived impact of these headaches on their personal health and work performance. The impact of COVID-19 on pre-existing headache disorders was also investigated.METHODSThis is a cross-sectional study among healthcare workers at our tertiary institution who were working in high-risk hospital areas during COVID-19. All respondents completed a self-administered questionnaire.RESULTSA total of 158 healthcare workers participated in the study. Majority [126/158 (77.8%)] were aged 21-35 years. Participants included nurses [102/158 (64.6%)], doctors [51/158 (32.3%)], and paramedical staff [5/158 (3.2%)]. Pre-existing primary headache diagnosis was present in about a third [46/158 (29.1%)] of respondents. Those based at the emergency department had higher average daily duration of combined PPE exposure compared to those working in isolation wards [7.0 (SD 2.2) vs 5.2 (SD 2.4) hours, P < .0001] or medical ICU [7.0 (SD 2.2) vs 2.2 (SD 0.41) hours, P < .0001]. Out of 158 respondents, 128 (81.0%) respondents developed de novo PPE-associated headaches. A pre-existing primary headache diagnosis (OR = 4.20, 95% CI 1.48-15.40; P = .030) and combined PPE usage for >4 hours per day (OR 3.91, 95% CI 1.35-11.31; P = .012) were independently associated with de novo PPE-associated headaches. Since COVID-19 outbreak, 42/46 (91.3%) of respondents with pre-existing headache diagnosis either "agreed" or "strongly agreed" that the increased PPE usage had affected the control of their background headaches, which affected their level of work performance.CONCLUSIONMost healthcare workers develop de novo PPE-associated headaches or exacerbation of their pre-existing headache disorders.

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1. **Impact of Personal Protective Equipment on the Performance of Emergency Pediatric Tasks.**  
   Adler Mark D. Pediatric emergency care 2020;:No page numbers.

OBJECTIVESPersonal protective equipment (PPE) is worn by health care providers (HCPs) to protect against hazardous exposures. Studies of HCPs performing critical resuscitation tasks in PPE have yielded mixed results and have not evaluated performance in care of children. We evaluated the impacts of PPE on timeliness or success of emergency procedures performed by pediatric HCPs.METHODSThis prospective study was conducted at 2 tertiary children's hospitals. For session 1, HCPs (medical doctors and registered nurses) wore normal attire; for session 2, they wore full-shroud PPE garb with 2 glove types: Ebola level or chemical. During each session, they performed clinical tasks on a patient simulator: intubation, bag-valve mask ventilation, venous catheter (IV) placement, push-pull fluid bolus, and defibrillation. Differences in completion time per task were compared.RESULTSThere were no significant differences in medical doctor completion time across sessions. For registered nurses, there was a significant difference between baseline and PPE sessions for both defibrillation and IV placement tasks. Registered nurses were faster to defibrillate in Ebola PPE and slower when wearing chemical PPE (median difference, -3.5 vs 2 seconds, respectively; P < 0.01). Registered nurse IV placement took longer in Ebola and chemical PPE (5.5 vs 42 seconds, respectively; P < 0.01). After the PPE session, participants were significantly less likely to indicate that full-body PPE interfered with procedures, was claustrophobic, or slowed them down.CONCLUSIONSPersonal protective equipment did not affect procedure timeliness or success on a simulated child, with the exception of IV placement. Further study is needed to investigate PPE's impact on procedures performed in a clinical care context.

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1. **Limiting factors for wearing personal protective equipment (PPE) in a health care environment evaluated in a randomised study.**  
   Loibner Martina PloS one 2019;14(1):e0210775.

Pandemics and re-emerging diseases put pressure on the health care system to prepare for patient care and sample logistics requiring enhanced personnel protective equipment (PPE) for health care workers. We generated quantifiable data on ergonomics of PPE applicable in a health care setting by defining error rates and physically limiting factors due to PPE-induced restrictions. Nineteen study volunteers tested randomly allocated head- or full body-ventilated PPE suits equipped with powered-air-purifying-respirators and performed four different tasks (two laboratory tutorials, a timed test of selective attention and a test investigating reaction time, mobility, speed and physical exercise) during 6 working hours at 22°C on one day and 4 working hours at 28°C on another day. Error rates and physical parameters (fluid loss, body temperature, heart rate) were determined and ergonomic-related parameters were assessed hourly using assessment sheets. Depending on the PPE system the most restrictive factors, which however had no negative impact on performance (speed and error rate), were: reduced dexterity due to multiple glove layers, impaired visibility by flexible face shields and back pain related to the respirator of the fully ventilated suit. Heat stress and liquid loss were perceived as restrictive at a working temperature of 28°C but not 22°C.

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1. **Healthcare workers' perception towards the systematic use of mask during a seasonal influenza outbreak in a French University Hospital: A descriptive study**  
   Beuvelet M. Antimicrobial Resistance and Infection Control 2017;6:No page numbers.

Introduction: Systematic use of mask was recommended for healthcare workers (HCWs) of our institution during the 2016/2017 influenza outbreak to prevent respiratory virus transmission and nosocomial influenza. <br/>Objective(s): To evaluate HCWs' perception towards the systematic use of mask in a French University hospital. <br/>Method(s): Voluntary HCWs (physician, nurse, nursing assistant, physiotherapist and others) of 16 emergency, internal medicine, infectious diseases, geriatric, pediatric and gynecology units were included in the perception survey; one investigator collected data by using a pre-tested questionnaire of 11 items. An infection control nurse observed compliance with use of mask for all HCWs of the same units. <br/>Result(s): Between January and February 2017, 177 HCWs were included (mean of 11 HCWs/units); 102 (58%) were not used to wear a mask more than once per month. Overall, 169 (96%) reported to comply with use of mask during the influenza outbreak. Between December and March 2017, observed compliance with use of mask was 82% (2008/2461). Regarding daily care of patients, 43 (25%) and 26 (14%) declared that use of mask changed their practices and decreased quality, respectively. Comfort was decreased for 142 (80%) and 123 (70%) had trouble communicating with patients. Wearing a mask was an effective mean to protect patients for 158 (89%), themselves for 142 (80%), their coworkers for 133 (75%) and their family for 107 (61%). A total of 33 (19%) considered not to be enough informed about the interest of wearing a mask and 155 (88%) were convinced by the usefulness of this measure. <br/>Conclusion(s): A majority of HCWs is convinced by the interest of wearing a mask during influenza outbreak to prevent influenza transmission and follows this practice. However, wearing a mask is often uncomfortable and modifies daily care of patients for one-quarter of HCWs. Following this survey, we plan several sessions of information for the next influenza outbreak.

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1. **Investigation of the flow-field in the upper respiratory system when wearing N95 filtering facepiece respirator.**  
   Zhang Xiaotie Journal of occupational and environmental hygiene 2016;13(5):372-382.

This article presents a reverse modeling of the headform when wearing a filtering facepiece respirator (FFR) and a computational fluid dynamics (CFD) simulation based on the modeling. The whole model containing the upper respiratory airway, headform, and FFR was directly recorded by computed tomography (CT) scanning, and a medical contrast medium was used to make the FFR "visible." The FFR was normally worn by the subject during CT scanning so that the actual deformation of both the FFR and the face muscles during contact can be objectively conserved. The reverse modeling approach was introduced to rebuild the geometric model and convert it into a CFD solvable model. In this model, we conducted a transient numerical simulation of air flow containing carbon dioxide, thermal dynamics, and pressure and wall shear stress distribution in the respiratory system taking into consideration an individual wearing a FFR. The breathing cycle was described as a time-dependent profile of the air velocity through the respiratory airway. The result shows that wearing the N95 FFR results in CO2 accumulation, an increase in temperature and pressure elevation inside the FFR cavity. The volume fraction of CO2 reaches 1.2% after 7 breathing cycles and then is maintained at 3.04% on average. The wearers re-inhale excessive CO2 in every breathing cycle from the FFR cavity. The air temperature in the FFR cavity increases rapidly at first and then stays close to the exhaled temperature. Compared to not wearing an FFR, wearers have to increase approximately 90 Pa more pressure to keep the same breathing flow rate of 30.54 L/min after wearing an FFR. The nasal vestibule bears more wall shear stress than any other area in the airway.

1. **Respirator masks protect health but impact performance: a review.**  
   Johnson Arthur T. Journal of biological engineering 2016;10:4.

Respiratory protective masks are used whenever it is too costly or impractical to remove airborne contamination from the atmosphere. Respirators are used in a wide range of occupations, form the military to medicine. Respirators have been found to interfere with many physiological and psychological aspects of task performance at levels from resting to maximum exertion. Many of these limitations have been investigated in order to determine quantitatively how much performance decrement can be expected from different levels of respirator properties. The entire system, including respirator and wearer interactions, must be considered when evaluating wearer performances. This information can help respirator designers to determine trade-offs or managers to plan to compensate for reduced productivity of wearers.

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1. **Speech intelligibility assessment of protective facemasks and air-purifying respirators**  
   Palmiero A.J. Journal of occupational and environmental hygiene 2016;13(12):960-968.

Speech Intelligibility (SI) is the perceived quality of sound transmission. In healthcare settings, the ability to communicate clearly with coworkers, patients, etc., is crucial to quality patient care and safety. The objectives of this study were to: (1) assess the suitability of the Speech Transmission Index (STI) methods for testing reusable and disposable facial and respiratory personal protective equipment (protective facemasks [PF], N95 filtering facepiece respirators [N95 FFR], and elastomeric half-mask air-purifying respirators [EAPR]) commonly worn by healthcare workers; (2) quantify STI levels of these devices; and (3) contribute to the scientific body of knowledge in the area of SI. SI was assessed using the STI under two experimental conditions: (1) a modified version of the National Fire Protection Association 1981 Supplementary Voice Communications System Performance Test at a Signal to Noise Ratio (SNR) of -15 (66 dBA) and (2) STI measurements utilizing a range of modified pink noise levels (52.5 dBA (-2 SNR) - 72.5 dBA (+7 SNR)) in 5.0 dBA increments. The PF models (Kimberly Clark 49214 and 3 M 1818) had the least effect on SI interference, typically deviating from the STI baseline (no-mask condition) by 3% and 4% STI, respectively. The N95FFR (3 M 1870, 3 M 1860) had more effect on SI interference, typically differing from baseline by 13% and 17%, respectively, for models tested. The EAPR models (Scott Xcel and North 5500) had the most significant impact on SI, differing from baseline by 42% for models tested. This data offers insight into the performance of these apparatus with respect to STI and may serve as a reference point for future respirator design considerations, standards development, testing and certification activities.

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1. **Respiratory consequences of N95-type Mask usage in pregnant healthcare workers-a controlled clinical study.**  
   Tong Pearl Shuang Ye Antimicrobial resistance and infection control 2015;4:48.

BACKGROUNDOutbreaks of emerging infectious diseases have led to guidelines recommending the routine use of N95 respirators for healthcare workers, many of whom are women of childbearing age. The respiratory effects of prolonged respirator use on pregnant women are unclear although there has been no definite evidence of harm from past use.METHODSWe conducted a two-phase controlled clinical study on healthy pregnant women between 27 to 32 weeks gestation. In phase I, energy expenditure corresponding to the workload of routine nursing tasks was determined. In phase II, pulmonary function of 20 subjects was measured whilst at rest and exercising to the predetermined workload while breathing ambient air first, then breathing through N95-mask materials.RESULTSExercising at 3 MET while breathing through N95-mask materials reduced mean tidal volume (TV) by 23.0 % (95 % CI -33.5 % to -10.5 %, p < 0.001) and lowered minute ventilation (VE) by 25.8 % (95 % CI -34.2 % to -15.8 %, p < 0.001), with no significant change in breathing frequency compared to breathing ambient air. Volumes of oxygen consumption (VO2) and carbon dioxide expired (VCO2) were also significantly reduced; VO2 by 13.8 % (95 % CI -24.2 % to -3 %, p = 0.013) and VCO2 by 17.7 %, (95 % CI -28.1 % to -8.6 %, p = 0.001). Although no changes in the inspired oxygen and carbon dioxide concentrations were demonstrated, breathing through N95-mask materials during low intensity work (3 MET) reduced expired oxygen concentration by 3.2 % (95 % CI: -4.1 % to -2.2 %, p < 0.001), and increased expired carbon dioxide by 8.9 % (95 % CI: 6.9 % to 13.1 %; p <0.001) suggesting an increase in metabolism. There were however no changes in the maternal and fetal heart rates, finger-tip capillary lactate levels and oxygen saturation and rating of perceived exertion at the work intensity investigated.CONCLUSIONSBreathing through N95 mask materials have been shown to impede gaseous exchange and impose an additional workload on the metabolic system of pregnant healthcare workers, and this needs to be taken into consideration in guidelines for respirator use. The benefits of using N95 mask to prevent serious emerging infectious diseases should be weighed against potential respiratory consequences associated with extended N95 respirator usage.TRIAL REGISTRATIONThe study was registered at clinicaltrials.gov, identifier NCT00265926.

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1. **Carbon dioxide rebreathing in respiratory protective devices: influence of speech and work rate in full-face masks.**  
   Smith Carmen L. Ergonomics 2013;56(5):781-790.

UNLABELLEDCarbon dioxide (CO2) rebreathing has been recognised as a concern regarding respirator use and is related to symptoms of discomfort, fatigue, dizziness, headache, muscular weakness and drowsiness. Previous investigations are limited by small sample size and have not evaluated the relationship between CO2 inhalation and phonic respiration (breathing during speech) in respiratory protective devices (RPDs). A total of 40 workers trained in the use of RPDs performed a graded exercise test on a cycle ergonometer that increased in workload every 5 min. During the third minute of each stage, participants read aloud a prepared text. Measures of mixed expired CO2 (PECO2), mixed inspired CO2 (PICO2) and respiration were monitored. The results showed that phonic respiration and low work rates contributed to significantly higher levels of CO2 rebreathing. Aiming to reduce CO2 exposure may result in improved wear time of RPDs. It is recommended that these findings be incorporated in technical specifications regarding human factors for RPDs.PRACTITIONER SUMMARYCarbon dioxide (CO2) rebreathing in respiratory protective devices (RPDs) has been highlighted as a key concern regarding respirator use. However, the problem is relatively under researched. This paper presents novel findings on the impact of phonic respiration (breathing during speech) and CO2 concentrations in RPDs.

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1. **Evaluation of N95 respirator use with a surgical mask cover: effects on breathing resistance and inhaled carbon dioxide.**  
   Sinkule Edward James The Annals of occupational hygiene 2013;57(3):384-398.

OBJECTIVEFor pandemic influenza outbreaks, the Institute of Medicine has recommended using a surgical mask cover (SM) over N95 filtering facepiece respirators (FFRs) among healthcare workers as one strategy to avoid surface contamination of the FFR which would extend its efficacy and reduce the threat of exhausting FFR supplies. The objective of this investigation was to measure breathing air quality and breathing resistance when using FFRs with US Food and Drug Administration-cleared SM and without SM.METHODSThirty National Institute for Occupational Safety and Health (NIOSH)-approved FFR models with and without SM were evaluated using the NIOSH Automated Breathing and Metabolic Simulator (ABMS) through six incremental work rates.RESULTSGenerally, concentrations of average inhaled CO(2) decreased and average inhaled O(2) increased with increasing O(2) consumption for FFR+SM and FFR-only. For most work rates, peak inhalation and exhalation pressures were statistically higher in FFR+SM as compared with FFR-only. The type of FFR and the presence of exhalation valves (EVs) had significant effects on average inhaled CO(2), average inhaled O(2), and breathing pressures. The evidence suggests that placement of an SM on one type of FFR improved inhaled breathing gas concentrations over the FFR without SM; the placement of an SM over an FFR+EV probably will prevent the EV from opening, regardless of activity intensity; and, at lower levels of energy expenditure, EVs in FFR do not open either with or without an SM.CONCLUSIONSThe differences in inhaled gas concentrations in FFR+SM and FFR-only were significant, especially at lower levels of energy expenditure. The orientation of the SM on the FFR may have a significant effect on the inhaled breathing quality and breathing resistance, although the measurable inhalation and exhalation pressures caused by SM over FFR for healthcare users probably will be imperceptible at lower activity levels.

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1. **Physiologic and other effects and compliance with long-term respirator use among medical intensive care unit nurses.**  
   Rebmann Terri American journal of infection control 2013;41(12):1218-1223.

BACKGROUNDLong-term use of respiratory protection may be necessary, but compliance may be low, and physiologic effects have not been well evaluated.METHODSTen nurses participated; physiologic effects, subjective symptoms, and compliance with wearing an N95 alone or with a surgical mask overlay were assessed. Longitudinal analysis based on multivariate linear regression models assessed changes in outcome variables (CO2, O2, heart rate, perceived comfort items, compliance measures, and others). Analyses compared changes over time, and compared wearing only an N95 to wearing an N95 with a surgical mask overlay.RESULTSMost nurses (90%, n = 9) tolerated wearing respiratory protection for two 12-hour shifts. CO(2) levels increased significantly compared with baseline measures, especially when comparing an N95 with a surgical mask to only an N95, but changes were not clinically relevant. Perceived exertion; perceived shortness of air; and complaints of headache, lightheadedness, and difficulty communicating also increased over time. Almost one-quarter (22%) of respirator removals were due to reported discomfort. N95 adjustments increased over time, but other compliance measures did not vary by time. Compliance increased on day 2, except for adjustments, touching under the N95, and eye touches.CONCLUSIONLong-term use of respiratory protection did not result in any clinically relevant physiologic burden for health care personnel, although many subjective symptoms were reported. N95 compliance was fairly high.

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1. **Pulmonary and heart rate responses to wearing N95 filtering facepiece respirators.**  
   Kim Jung-Hyun American journal of infection control 2013;41(1):24-27.

BACKGROUNDFiltering facepiece respirators are the most common respirator worn by US health care and industrial workers, yet little is known on the physiologic impact of wearing this protective equipment.METHODSTwenty young, healthy subjects exercised on a treadmill at a low-moderate (5.6 km/h) work rate while wearing 4 different models of N95 filtering facepiece respirators for 1 hour each, 2 models of which were equipped with exhalation valves, while being monitored for physiologic variables.RESULTSCompared with controls, respirator use was associated with mean 1 hour increases in heart rate (range, 5.7-10.6 beats per minute, P < .001), respiratory rate (range, 1.4-2.4 breaths per minute, P < .05), and transcutaneous carbon dioxide (range, 1.7-3.0 mm Hg, P < .001). No significant differences in oxygen saturation between controls and respirators were noted (P > .05).CONCLUSIONThe pulmonary and heart rate responses to wearing a filtering facepiece respirator for 1 hour at a low-moderate work rate are relatively small and should generally be well tolerated by healthy persons.

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1. **The effects of wearing respirators on human fine motor, visual, and cognitive performance.**  
   AlGhamri Anas A. Ergonomics 2013;56(5):791-802.

UNLABELLEDWhen selecting a respirator, it is important to understand how employees' motor, visual and cognitive abilities are impacted by the personal protective equipment. This study compares dust, powered-air-purifying and full-face, negative-pressure respirators. Thirty participants performed three varied tasks. Each participant performed each task without a respirator and while wearing the three respirator types. The tasks included a hand tool dexterity test, the Motor-Free Visual Perception Test and the Serial Sevens Test to evaluate fine motor, visual and cognitive performance, respectively. The time required for task completion and the errors made were measured. Analysis showed no significant effect due to respirator use on the task completion time. A significant increase was found in the error rate when participants performed the cognitive test wearing the full-face, negative-pressure respirator. Participants had varying respirator preferences. They indicated a potential for full-face, negative-pressure respirators to negatively affect jobs demanding high cognitive skills such as problem solving and decision-making.PRACTITIONER SUMMARYwhile respirators are life-saving personal protective equipment (PPE), they can unintentionally reduce human performance, especially if job characteristics are not considered during PPE selection. An experiment was conducted to compare three respirators (dust respirator, powered-air-purifying respirators and full-face respirator) for varying task types. The full-face respirator was found to affect human cognitive performance negatively.

1. **Absence of consequential changes in physiological, thermal and subjective responses from wearing a surgical mask.**  
   Roberge Raymond J. Respiratory physiology & neurobiology 2012;181(1):29-35.

Twenty subjects treadmill exercised at 5.6 km/h for 1h with and without wearing a surgical mask while being monitored for heart rate, respiratory rate, oxygen saturation, transcutaneous CO2, SpO2, core and skin temperatures, mask deadspace heat and relative humidity, and skin temperature under the mask. Rating scales were utilized for exertion and heat perceptions. Surgical mask use resulted in increases in heart rate (9.5 beats/min; p<0.001), respiratory rate (1.6 breaths/min; p=0.02), and transcutaneous carbon dioxide (2.17 mmHg; p=0.0006), and decreased temperature of uncovered facial skin (0.40 °C; p=0.03). The 1.76 °C increase in temperature of the skin covered by the mask was associated with a mask deadspace apparent heat index of 52.9 °C. Perceptions of heat were neutral to slightly hot, and for exertion ranged from very, very light to fairly light. Surgical mask use for 1h at a low-moderate work rate is not associated with clinically significant physiological impact or significant subjective perceptions of exertion or heat.

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1. **Are exhalation valves on N95 filtering facepiece respirators beneficial at low-moderate work rates: an overview.**  
   Roberge Raymond J. Journal of occupational and environmental hygiene 2012;9(11):617-623.

Exhalation valves (EVs) are touted as useful in dissipating humidity, heat, and carbon dioxide from the dead space of N95 filtering facepiece respirators and decreasing exhalation resistance, thereby making the respirator more comfortable and less physiologically demanding. Despite decades of use, there is limited research on the psychophysiological impact of EVs on the wearer at the current, low-moderate work rates of many workers. The available literature indicates that past and current EVs on the market decrease exhalation resistance to a variable degree and may improve dead space heat dissipation and, consequently, the temperature of the skin covered by the respirator. EVs have little substantial effect on dead space humidity, respiratory rate, heart rate, core temperature, speech intelligibility, or dead space oxygen and carbon dioxide levels at the aforementioned work rates. The studies also indicate that EVs may impact comfort and tolerance when N95 filtering facepiece respirators are worn for extended periods or at high work rates. Because comfort and tolerance impact respirator use compliance and, by extension, protection, more research into the psychophysiological impact of EVs on wearers and the development of new EVs tailored for low-moderate work rates are warranted.

1. **Discomfort and exertion associated with prolonged wear of respiratory protection in a health care setting.**  
   Shenal Brian V. Journal of occupational and environmental hygiene 2012;9(1):59-64.

The nature of discomfort and level of exertion associated with wearing respiratory protection in the health care workplace are not well understood. Although a few studies have assessed these topics in a laboratory setting, little is known about the magnitude of discomfort and the level of exertion experienced by workers while they deliver health care to patients for prolonged periods. The purpose of this study was to determine the magnitude of discomfort and level of exertion experienced by health care workers while wearing respiratory protection for periods up to 8 hr when performing their typical occupational duties. This project was a multiple cross-over field trial of 27 health care workers, aged 24-65, performing their typical, hospital-based occupational duties. Each participant served as his/her own control and wore one of seven respirators or a medical mask for 8 hr (or as long as tolerable) with interposed doffing periods every 2 hr. Self-perceived discomfort and exertion were quantified before each doffing: self-perceived level of discomfort using a visual analog scale, and self-perceived level of exertion using a Borg scale. Overall, and as would be expected, discomfort increased over time with continual respirator use over an 8-hr period. Interestingly, exertion increased only marginally over the same time period. The relatively low level of exertion associated with eight respiratory protective devices, including models commonly used in the U.S. health care workplace, is not likely to substantially influence workers' tolerability or occupational productivity. However, the magnitude of discomfort does appear to increase significantly over time with prolonged wear. These results suggest that respirator-related discomfort, but not exertion, negatively influences respirator tolerance over prolonged periods. Discomfort may also interfere with the occupational duties of workers.

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1. **N95 filtering facepiece respirator deadspace temperature and humidity.**  
   Roberge Raymond J. Journal of occupational and environmental hygiene 2012;9(3):166-171.

The objective of this study was to determine the levels of heat and humidity that develop within the deadspace of N95 filtering facepiece respirators (N95 FFR). Seventeen subjects wore two models each of N95 FFR and N95 FFR with an exhalation valve (N95 FFR/EV) while exercising on a treadmill at a low-moderate work rate for 1 and 2 hr in a temperate ambient environment. FFR deadspace temperature and relative humidity were monitored by a wireless sensor housed within the FFR. Each FFR was weighed pre- and post-testing to determine moisture retention. After 1 hr, FFR deadspace temperature and humidity were markedly elevated above ambient levels, and the FFR deadspace mean apparent heat index was 54°C. N95 FFR/EV use resulted in significantly lower deadspace temperatures than N95 FFR (p = 0.01), but FFR deadspace humidity levels were not significantly different (p = 0.32). Compared with the first hour of use, no significant increase in FFR deadspace heat and humidity occurred over the second hour. FFR mean moisture retention was < 0.3 grams over 2 hr. N95 FFR/EV offer a significant advantage in deadspace heat dissipation over N95 FFR at a low-moderate work rate over 1 hr of continuous use but offered no additional benefit in humidity amelioration. Moisture retention in N95 FFR and N95 FFR/EV is minimal after 2 hr of use. [Supplementary materials are available for this article. Go to the publisher's online edition of Journal of Occupational and Environmental Hygiene for the following free supplemental resource: a file containing N95 filtering facepiece respirator deadspace mean RH and temperature recordings for 17 subjects treadmill exercising at 5.6 Km/H over 1 hour.].

1. **Protective facemask impact on human thermoregulation: an overview.**  
   Roberge Raymond J. The Annals of occupational hygiene 2012;56(1):102-112.

The use of protective facemasks (PFMs) negatively impacts respiratory and dermal mechanisms of human thermoregulation through impairment of convection, evaporation, and radiation processes. The relatively minor reported increases in core temperature directly attributable to the wearing of PFMs suggest that associated perceptions of increased body temperature may have a significant psychological component or that regional or global brain temperature changes are involved. Modifications in PFM structure, components, and materials might allow for improved heat dissipation and enhanced compliance with use.

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1. **The effects of personal protective respirators on human motor, visual, and cognitive skills**  
   AlGhamri Doctoral dissertation, Engineering Management and Systems Engineering, University of Missouri 2012;:2295.

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1. **Does wearing a surgical facemask or N95-respirator impair radio communication?**  
   Thomas Frank Air medical journal 2011;30(2):97-102.

PURPOSEThis study evaluated the impact wearing a surgical facemask or N95 air purifying respirator (N95) has on radio reception.METHODSWe compared the ability of a flight crewmember and a layperson sitting in a Bell 407 crew compartment and a dispatcher sitting in a communication center to accurately record 20 randomized aviation terms transmitted over the radio by a helicopter emergency medical services (HEMS) pilot wearing a surgical facemask and six different N95s with and without the aircraft engine operating.RESULTSWith the aircraft engine off, all terms (100% accuracy) were correctly identified, regardless of the absence or presence of the surgical facemask or N95 studied. With the aircraft engine on, the surgical facemask (3M-1826) and two N95 respirators (3M-1860, Safe Life Corp-150) maintained 100% accuracy. Remaining N95 accuracy was as follows: 3M-8511 and Kimberly-Clark PFR95 (98%), Inoyel-3212 (97%), and 3M-1870 (93%).CONCLUSIONSIn general, despite wearing a facemask, radio reception accuracy is high (>90%). However, aircraft engine noise and N95 type do appear to adversely affect the accuracy of radio reception. All HEMS pilots and crewmembers should be aware of these radio reception findings when using an N95 respirator during transport. A brief review of the surgical facemask and N95 effectiveness to prevent viral respiratory infections is provided.

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1. **Respirator impact on work task performance.**  
   Harber Philip Journal of occupational and environmental medicine 2011;53(1):22-26.

OBJECTIVERespirators are used to maintain work performance and protect against inhaled toxins. The study compared the effects of two commonly used respirator classes--dual cartridge half face mask (HFM) and filtering face piece (N95)--upon work productivity.METHODS107 volunteers performed eight simulated work tasks when using the HFM and N95 respirators. Tasks included several body positions, exertion levels, and concentration requirements. Objective measures of accuracy and speed were developed for each task. Scores for each task were based on the subject's rank among all subjects.RESULTSAll subjects were capable of performing the tasks. There were no statistically significant differences between respirator types in either task performance metric.CONCLUSIONSProductivity impact can be measured effectively and should be considered as part of respirator design testing and when selecting the optimal respirator for a worker.

1. **Physiological impact of the N95 filtering facepiece respirator on healthcare workers.**  
   Roberge Raymond J. Respiratory care 2010;55(5):569-577.

OBJECTIVETo assess the physiological impact of the N95 filtering facepiece respirator (FFR) on healthcare workers.METHODSTen healthcare workers each conducted multiple 1-hour treadmill walking sessions, at 1.7 miles/h, and at 2.5 miles/h, while wearing FFR with exhalation valve, FFR without exhalation valve, and without FFR (control session). We monitored heart rate, respiratory rate, tidal volume, minute volume, blood oxygen saturation, and transcutaneously measured P(CO2). We also measured user comfort and exertion, FFR moisture retention, and the carbon dioxide and oxygen concentrations in the FFR's dead space.RESULTSThere were no significant differences between FFR and control in the physiological variables, exertion scores, or comfort scores. There was no significant difference in moisture retention between FFR with and without exhalation valve. Two subjects had peak P(CO2) > or = 50 mm Hg. The FFR with exhalation valve offered no benefit in physiological burden over the FFR without valve. The FFR dead-space oxygen and carbon dioxide levels did not meet the Occupational Safety and Health Administration's ambient workplace standards.CONCLUSIONSIn healthy healthcare workers, FFR did not impose any important physiological burden during 1 hour of use, at realistic clinical work rates, but the FFR dead-space carbon dioxide and oxygen levels were significantly above and below, respectively, the ambient workplace standards, and elevated P(CO2) is a possibility. Exhalation valve did not significantly ameliorate the FFR's P(CO2) impact.

1. **Reusable elastomeric air-purifying respirators: physiologic impact on health care workers.**  
   Roberge Raymond J. American journal of infection control 2010;38(5):381-386.

BACKGROUNDElastomeric air-purifying respirators offer the benefit of reusability, but their physiological impact on health care workers is unknown.METHODSTen health care workers exercised at 2 health care-associated work rates wearing an elastomeric air-purifying respirator. Mixed inhalation/exhalation respirator dead space gases (oxygen, carbon dioxide) were sampled, and physiological parameters were monitored (heart rate, breathing rate, tidal volume, minute volume, oxygen saturation, transcutaneous carbon dioxide). Numerical rating scales were used to evaluate comfort and exertion.RESULTSCompared with controls (no respirator), significant decreases in the breathing rate at both work rates (P < .05) and increases in tidal volume at the lower work rate (P < .01) were noted with respirator use. Approximately half the subjects had transcutaneous carbon dioxide levels above the upper limit of normal after 1 hour of use. Although well tolerated, comfort was negatively impacted by elastomeric air-purifying respirators wear.CONCLUSIONReusable elastomeric air-purifying respirators impose little additional physiological burden over the course of 1 hour at usual health care work rates. However, the potential for carbon dioxide retention in a significant proportion of users exists and requires further investigation.

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1. **Surgical mask placement over N95 filtering facepiece respirators: physiological effects on healthcare workers.**  
   Roberge Raymond J. Respirology (Carlton, Vic.) 2010;15(3):516-521.

BACKGROUND AND OBJECTIVEFiltering facepiece respirators ('N95 Masks') may be in short supply during large-scale infectious outbreaks. Suggestions have been made to extend their useful life by using a surgical mask as an outer barrier, but the physiological impact of this added barrier upon the wearer has not been studied.METHODSA surgical mask was worn over an N95 filtering facepiece respirator by 10 healthcare workers for 1 h at each of two work rates. Heart rate, respiratory rate, tidal volume, minute volume, oxygen saturation, transcutaneous carbon dioxide levels and respirator dead space gases were monitored and compared with controls (N95 filtering facepiece respirator without a surgical mask). Subjective perceptions of exertion and comfort were assessed by numerical rating scales.RESULTSThere were no significant differences in physiological variables between those who used surgical masks and controls. Surgical masks decreased dead space oxygen concentrations of the filtering facepiece respirators at the lesser work rate (P = 0.03) and for filtering facepiece respirators with an exhalation valve at the higher work rate (P = 0.003). Respirator dead space oxygen and carbon dioxide levels were not harmonious with Occupational Safety and Health Administration workplace ambient atmosphere standards. Exertion and comfort scores were not significantly impacted by the surgical mask.CONCLUSIONSUse of a surgical mask as an outer barrier over N95 filtering facepiece respirators does not significantly impact the physiological burden or perceptions of comfort and exertion by the wearer over that experienced without use of a surgical mask.

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1. **Diminished speech intelligibility associated with certain types of respirators worn by healthcare workers**  
   Radonovich Jr. L.J. Journal of Occupational and Environmental Hygiene 2009;7(1):63-70.

This study sought to determine the level of communication interference associated with commonly used disposable and reusable respirators and surgical masks worn by healthcare workers. Speech intelligibility was assessed using the modified rhyme test in an intensive care unit environment. Respirators decreased speech intelligibility by a range of 1% to 17%, although not all were statistically significant. Differences in speech intelligibility associated with surgical masks and disposable filtering facepiece respirators (without exhalation valves) were not statistically significant compared with controls. Wearing half-face elastomeric respirators with voice augmentation equipment was associated with higher speech intelligibility than models without this equipment (OR = 2.81). Hearing clarity while wearing a powered air-purifying respirator (PAPR) was 79% compared with 90% with no PAPR (OR = 0.40). While some respirators appear to have little or no effect on speech intelligibility, interference with speech intelligibility associated with certain types of respirators commonly worn by U.S. healthcare workers may be substantial.

1. **Physiological burden associated with the use of filtering facepiece respirators (N95 masks) during pregnancy.**  
   Roberge Raymond Joseph Journal of women's health (2002) 2009;18(6):819-826.

OBJECTIVEThe purpose of this study was to review the available literature regarding the physiological burden imposed on pregnant women by their wearing filtering facepiece respirators.METHODSA medical literature search was conducted using MEDLINE (1996-2008) for English language articles, bibliographies of retrieved articles, electronic references from medical and governmental agency sources, and selected textbook articles.RESULTSTwo hundred thirty-four articles from the medical literature and 267 electronic references were retrieved, of which 51 articles from the medical literature, 25 electronic references, and 2 textbook articles were selected for data acquisition.CONCLUSIONSVery little rigorous scientific data exist on the physiological burden associated with the use of filtering facepiece respirators by pregnant women, and no definitive conclusions can be reached at this time. Although studies are warranted, they may be difficult to undertake because of health concerns and potential liability associated with the use of pregnant women in medical research. Computer modeling that incorporates features of pulmonary function in pregnancy might offer an alternative to human studies. Filtering facepiece respirators developed to meet the respiratory limitations of pregnant wearers might offer a universal design that would improve the comfort and tolerability for all users. Alternative strategies that limit the pregnant woman's contact with potentially infectious agents (e.g., job reassignment, working from home) may have to be employed in certain circumstances.

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1. **Speech understanding using surgical masks: a problem in health care?**  
   Mendel Lisa Lucks Journal of the American Academy of Audiology 2008;19(9):686-695.

BACKGROUNDSuccessful communication is necessary in health-care environments. Yet the presence of noise in hospitals, operating rooms, and dental offices may have a deleterious effect on health-care personnel and patients understanding messages accurately. The presence of a surgical mask and hearing loss may further affect speech perception.PURPOSETo evaluate whether a surgical mask had an effect on speech understanding for listeners with normal hearing and hearing impairment when speech stimuli were administered in the presence or absence of dental office noise.RESEARCH DESIGNParticipants were assigned to one of two groups based on hearing sensitivity in this quasi-experimental, cross-sectional study.STUDY SAMPLEA total of 31 adults participated in this study (1 talker, 15 listeners with normal hearing, and 15 with hearing impairment). The normal hearing group had thresholds of 25 dB HL or better at the octave frequencies from 250 through 8000 Hz while the hearing loss group had varying degrees and configurations of hearing loss with thresholds equal to or poorer than 25 dB HL for the same octave frequencies.DATA COLLECTION AND ANALYSISSelected lists from the Connected Speech Test (CST) were digitally recorded with and without a surgical mask present and then presented to the listeners in four conditions: without a mask in quiet, without a mask in noise, with a mask in quiet, and with a mask in noise.RESULTSA significant difference was found in the spectral analyses of the speech stimuli with and without the mask. The presence of a surgical mask, however, did not have a detrimental effect on speech understanding in either the normal-hearing or hearing-impaired groups. The dental office noise did have a significant effect on speech understanding for both groups.CONCLUSIONSThese findings suggest that the presence of a surgical mask did not negatively affect speech understanding. However, the presence of noise did have a deleterious effect on speech perception and warrants further attention in health-care environments.

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1. **Emergency department staff can effectively resuscitate in level C personal protective equipment.**  
   Udayasiri Ruwangi Emergency medicine Australasia : EMA 2007;19(2):113-121.

OBJECTIVEED staff are expected to perform resuscitation of trauma victims of chemical, biological and radiation incidents while wearing level C personal protective equipment (PPE). The present project assessed the subjective discomfort, physiological impact and performance of staff wearing PPE.METHODSA paired intervention study of ED staff in a resuscitation scenario comparing task performance wearing gown and gloves with PPE. Data were collected using a structured self-administered questionnaire and by objective and subjective measurements.RESULTSSeven ED doctors and 11 ED nurses were enrolled. Nine had previous PPE training although only one had used PPE clinically. Overall, ED staff felt that PPE did not affect their ability to perform trauma resuscitation. For individual tasks, staff felt that PPE impaired assessment of pulse, i.v. cannulation, i.v. line attachment, use of a mini-jet, bag and mask ventilation, and communication. However, the only objective difference in task performance was time to control haemorrhage (increase from 38 to 47 s, P = 0.02). PPE was well tolerated, with minimal physiological or psychological impact. Staff wore PPE for a median of 37 min (interquartile range: 33-38) and estimated that PPE could be worn for a further 30 min if required.CONCLUSIONSED staff are able to perform resuscitation procedures in PPE without adverse physiological effects or impact on performance. Subjective concerns regarding task performance were not reflected in objective measurements. This might indicate that appropriate training and feedback could reduce the negative impression associated with activities undertaken while wearing PPE.

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1. **Effect of firefighter masks on monocular and binocular peripheral vision.**  
   Samo Daniel G. Journal of occupational and environmental medicine 2003;45(4):428-432.

Peripheral vision can impact essential job functions of firefighters and other workers who use Self-Contained Breathing Apparatus and other full face masks. It is important for physicians to know how these masks alter peripheral vision. Also, one must understand the effect of monocular vision on peripheral vision. Using the Goldman Perimeter Machine we measured peripheral vision in the monocular and binocular state, with and without two different types of masks. The results show that monocularity causes an average loss of 23 degrees in the nasal meridian. The use of the masks did not affect this difference. Also, the masks caused an average loss of 28 degrees of peripheral vision in the inferior meridian. How these losses affect the ability of the users of the masks to perform their essential job functions still needs to be researched.

1. **An evaluation of factors affecting hazardous waste workers' use of respiratory protective equipment.**  
   Salazar M. K AIHAJ : a journal for the science of occupational and environmental health and safety 2001;62(2):236-245.

The purpose of this study was to describe the perceptions of a group of hazardous waste workers about their workplace hazards and to understand their beliefs and attitudes about the use of respiratory protective equipment (RPE). There were two phases of data collection: (1) interviews to identify factors that influence respirator use and (2) a written survey to evaluate the importance of these factors. This article describes the findings from the written survey completed by 255 eligible respondents (return rate = 46.5%, 255/548). Subjects used a weighting system to score 18 identified factors that influence the use of RPE. Scores were compared according to type of respirator, frequency of use, and associated health symptoms. The factors that had the most positive influence on respirator use were concern about work exposure, fit-testing, and training. The most negative influences were communication, personal comfort, effect on vision, structural environment, and fatigue. More frequent users (once per month or more) were significantly more likely to view fit-testing, health effects, and effects on vision negatively than were less frequent users. Persons who reported health symptoms associated with respirator use had more negative scores than persons without health symptoms. Workers categorized as laborers were more likely to be frequent respirator users and to wear supplied-air respirators, and were significantly more likely to view vulnerability to disease negatively, than were other worker groups. The findings from this study indicate that respiratory protection programs must extend beyond training and education; to be maximally effective, health professionals must be responsive to the specific concerns of the workers.

1. **Surgical helmet systems.**  
   Anon. Health devices 1996;25(4):116-145.

A surgical helmet system (SHS) is either a loose-fitting hood or a hood combined with an integral gown (called a toga system). SHSs are used during orthopedic procedures to decrease the patient's risk of deep wound infection by keeping skin and other particles from the surgeon's face from falling into the open surgical site. They are also used to protect surgical staff from infectious blood splashes and potentially infectious aerosols generated by power tools during orthopedic procedures - and it is this aspect of SHS use that has attracted particular attention, given the intensified interest in healthcare worker (HCW) protection (e.g., against human immunodeficiency virus [HIV], tuberculosis [TB], and hepatitis C virus [HCV]) in hospitals today. Ironically, the very factors that have led to SHSs' recent popularity may limit the need for their use, inasmuch as facilities have instituted so many other effective infection control methods against bloodborne and airborne pathogens. Although SHSs do provide splash protection against bloodborne pathogens, institutions may already by adequately protecting their staff against this hazard. In addition, they may be using SHSs to provide other types of patient and HCW protection that are already being provided by existing infection control measures. SHSs are available in a wide variety of configurations. We evaluated a total of six SHSs: one hood and one toga system each from three manufacturers. The units we tested were among each manufacturer's bestselling systems. We examined how well they would protect patients against deep wound infections and HCWs against splashes and aerosolized particles. We also evaluated their comfort and ease of use for wearers. We found that all of the SHSs provided sufficient patient protection against particles shed by the surgeon. We also found that the hood-only units and the hood components of the toga units provided sufficient HCW splash protection. (The gown portion of the toga systems failed our fluid-resistance criterion. However, we did not test the separate surgical gowns that are used with the hood-only units, and we do not know if they provide any greater level of protection than the toga fabric does). We rated all hood-only units Acceptable. We rated all toga units Acceptable-Not Recommended because the level of patient and HCW protection provided by the toga systems did not justify their significantly higher cost. We did find differences in the level of HCW respiratory protection these systems provided against aerosols. However, we do not believe that this should be a significant selection consideration because there is no established need for respiratory protection during orthopedic procedures. (Respiratory protection is needed against TB aerosols, but hip and knee arthroplasty procedures are usually elective and would be delayed on any active or suspected TB patient until the patient is noninfectious). To establish the context for this study, we first present a Guidance Section, "Do You Need Surgical Helmet Systems for Orthopedic Procedures?" In this section, we discuss the infection risks present during orthopedic procedures. We also outline the protective measures that institutions may already have in place to reduce these risks. We then discuss how SHSs fit into the infection control picture. Supplementary material in this section includes a discussion of the respiratory protection needed against Mycobacterium tuberculosis and a table of factors affecting the choice among SHSs, respirator masks, and surgical masks for patient and HCW protection. Ultimately, the choice to use SHSs may be dictated by the training and preference of the surgical staff. But this Evaluation will help facilities to (1) make this decision and, if appropriate, (2) select the best system for their needs...

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**Word documents**  
Select Edit from the menu, the Find and type in your term in the search box which is presented. The search function will locate the first use of the term in the document. By pressing 'next' you will jump to further references.

## B. Search History

|  | **Source** | **Criteria** | **Results** |
| --- | --- | --- | --- |
| 1. | Medline | exp \*MASKS/ | 6328 |
| 2. | Medline | (FFP3 OR mask OR masks OR "power\* hood\*" OR "air purifying respirator\*" OR PAPR OR "enhanced respiratory and contact precautions" OR ERCP OR "respiratory protection" OR "transparent panel\*" OR "filtering face piece\*" OR "filtering facepiece\*").ti,ab | 45554 |
| 3. | Medline | (1 OR 2) | 46722 |
| 4. | Medline | CARBON DIOXIDE/ae,to | 1323 |
| 5. | Medline | ("carbon dioxide" OR CO2).ti,ab | 124877 |
| 6. | Medline | (rebreathing ADJ9 (FFP3 OR mask OR masks OR "power\* hood\*" OR "air purifying respirator\*" OR PAPR OR "enhanced respiratory and contact precautions" OR ERCP OR "respiratory protection" OR "transparent panel\*" OR "filtering face piece\*" OR "filtering facepiece\*")).ti,ab | 90 |
| 7. | Medline | ("pH" ADJ9 (FFP3 OR mask OR masks OR "power\* hood\*" OR "air purifying respirator\*" OR PAPR OR "enhanced respiratory and contact precautions" OR ERCP OR "respiratory protection" OR "transparent panel\*" OR "filtering face piece\*" OR "filtering facepiece\*")).ti,ab | 73 |
| 8. | Medline | exp \*COGNITION/ OR exp \*PSYCHOMOTOR PERFORMANCE/ OR \*WORK PERFORMANCE/ OR exp \*ATTENTION/ OR exp \*MEMORY/ OR exp \*THINKING/ | 367862 |
| 9. | Medline | ("cognitive performance" OR "mental performance").ti,ab | 18810 |
| 10. | Medline | ((job OR motor OR psychomotor OR work OR task) AND (performance OR ability)).ti,ab | 244582 |
| 11. | Medline | (alertness OR concentration OR attention OR memory OR recall OR reasoning OR judgement).ti,ab | 1836656 |
| 12. | Medline | exp \*FATIGUE/ | 15748 |
| 13. | Medline | (fatigue OR tiredness).ti,ab | 94905 |
| 14. | Medline | (4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13) | 2439874 |
| 15. | Medline | (3 AND 14) | 5343 |
| 16. | Medline | exp \*"HEALTH PERSONNEL"/ | 370604 |
| 17. | Medline | ("health care worker\*" OR "healthcare worker\*" OR "health care personnel" OR "healthcare personnel" OR "health personnel" OR "health provider\*" OR "health care provider\*" OR "medical staff" OR "medical personnel" OR "medical professional\*" OR "medical worker\*").ti,ab | 91762 |
| 18. | Medline | (nurse OR nurses OR nursing OR midwife OR midwives).ti,ab | 444118 |
| 19. | Medline | (anaesthetist\* OR anesthetist\* OR anesthesiologist\* OR surgeon\* OR physician\* OR doctor\* OR medic OR medics OR nurse\* OR midwife OR midwives OR ODP\* OR practitioner\*).ti,ab | 1030781 |
| 20. | Medline | ((health\* OR medical) ADJ2 (profession\* OR personnel OR staff OR worker\* OR manpower OR workforce)).ti,ab | 205755 |
| 21. | Medline | (16 OR 17 OR 18 OR 19 OR 20) | 1530752 |
| 22. | Medline | (15 AND 21) | 480 |
| 23. | Medline | (15 AND 21) [Languages English] | 425 |
| 24. | EMBASE | exp \*MASK/ | 7991 |
| 25. | EMBASE | (FFP3 OR mask OR masks OR "power\* hood\*" OR "air purifying respirator\*" OR PAPR OR "enhanced respiratory and contact precautions" OR ERCP OR "respiratory protection" OR "transparent panel\*" OR "filtering face piece\*" OR "filtering facepiece\*").ti,ab | 66299 |
| 26. | EMBASE | (24 OR 25) | 68167 |
| 27. | EMBASE | \*"CARBON DIOXIDE"/to,ae,am | 460 |
| 28. | EMBASE | ("carbon dioxide" OR CO2).ti,ab | 156249 |
| 29. | EMBASE | (rebreathing ADJ9 (FFP3 OR mask OR masks OR "power\* hood\*" OR "air purifying respirator\*" OR PAPR OR "enhanced respiratory and contact precautions" OR ERCP OR "respiratory protection" OR "transparent panel\*" OR "filtering face piece\*" OR "filtering facepiece\*")).ti,ab | 164 |
| 30. | EMBASE | ("pH" ADJ9 (FFP3 OR mask OR masks OR "power\* hood\*" OR "air purifying respirator\*" OR PAPR OR "enhanced respiratory and contact precautions" OR ERCP OR "respiratory protection" OR "transparent panel\*" OR "filtering face piece\*" OR "filtering facepiece\*")).ti,ab | 98 |
| 31. | EMBASE | exp \*COGNITION/ OR \*"PSYCHOMOTOR PERFORMANCE"/ OR \*"JOB PERFORMANCE"/ OR \*"TASK PERFORMANCE"/ OR exp \*ATTENTION/ | 762633 |
| 32. | EMBASE | ("cognitive performance" OR "mental performance").ti,ab | 27136 |
| 33. | EMBASE | ((job OR motor OR psychomotor OR work OR task) AND (performance OR ability)).ti,ab | 315179 |
| 34. | EMBASE | (alertness OR concentration OR attention OR memory OR recall OR reasoning OR judgement).ti | 234599 |
| 35. | EMBASE | exp \*FATIGUE/ | 35883 |
| 36. | EMBASE | (fatigue OR tiredness).ti,ab | 154407 |
| 37. | EMBASE | (27 OR 28 OR 29 OR 30 OR 31 OR 32 OR 33 OR 34 OR 35 OR 36) | 1460993 |
| 38. | EMBASE | (26 AND 37) | 5540 |
| 39. | EMBASE | exp \*"HEALTH CARE PERSONNEL"/ | 503886 |
| 40. | EMBASE | ("health care worker\*" OR "healthcare worker\*" OR "health care personnel" OR "healthcare personnel" OR "health personnel" OR "health provider\*" OR "health care provider\*" OR "medical staff" OR "medical personnel" OR "medical professional\*" OR "medical worker\*").ti,ab | 121743 |
| 41. | EMBASE | (nurse OR nurses OR nursing OR midwife OR midwives).ti,ab | 504854 |
| 42. | EMBASE | (anaesthetist\* OR anesthetist\* OR anesthesiologist\* OR surgeon\* OR physician\* OR doctor\* OR medic OR medics OR nurse\* OR midwife OR midwives OR ODP\* OR practitioner\*).ti | 320113 |
| 43. | EMBASE | ((health\* OR medical) ADJ2 (profession\* OR personnel OR staff OR worker\* OR manpower OR workforce)).ti,ab | 255631 |
| 44. | EMBASE | (39 OR 40 OR 41 OR 42 OR 43) | 1236219 |
| 45. | EMBASE | (38 AND 44) | 297 |
| 46. | EMBASE | 38 AND 44 [English language] | 278 |

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