

RESPIRATORY PROTECTIVE DEVICES (RPDs) - PHYSIOLOGICAL CONSIDERATIONS FOR THE CIVILIAN NON-ACTIVE POPULATION

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During the Persian Gulf conflict (1991), respiratory protective devices (RPDs) were distributed to the entire population in Israel; they have been used for several hours by civilians of all age groups, healthy people and disabled. The lessons learnt by us during the crisis and the accumulated experience enabled us to implement improvements in the physiological aspects of the protective devices distributed to the civilian population (1). The following describes our experience.

Respiratory protection is of crucial importance in chemical warfare medicine. Wearing a respirator may compromise the sense of well-being and performance capability. Among the associated limitations are higher resistance to breathing, greater respiratory dead space, increased heat load in the head area, visual restriction, speech limitation, strip pressure, inability to eat, limited fluid intake, psychological reactions, and claustrophobia (2).

Excessive resistance to breathing is the major factor determining the subjective tolerance to wearing the mask. Whereas the normal airways' resistance of an adult is 0.8 cm H₂O/l/sec, the mask's canister imposes an additional inspiratory resistance which is 4-5 times the norm. Expiratory resistance is usually much lower, -1 cm H₂O/l/sec, due to the unidirectional outflow valves. Respiratory compensatory changes in strained breathing are characterized by prolonged inspiratory time and decreased peak inspiratory flow rates. During exercise, inspiratory time appears to be conserved at the expense of the expiration. Intolerable shortening of expiration at respiratory rates >30 breaths/min was reported .

Physical performance of healthy subjects wearing a gas mask is undisturbed at rest and at moderate effort (VO₂ 1.7-1.8 Vmin), but may be associated with hyperventilation, hypercapnia, excessive heart rate elevation, and reduced exercise endurance during submaximal or maximal effort. Shortness of breath would not be experienced by most healthy people if the peak-to-peak pressure swing within the mask (as a measure of respiratory effort) would not exceed 17 cm E O .

When a gas mask is worn, its internal volume, usually 300-500 ml, becomes the external dead space, which adds to the physiological dead space of -150 ml. Consequently, the concentration of CO₂ in inspiratory air increases and ventilation has to be adjusted in order to maintain normal arterial pCO₂. Noteworthy is the considerable inter-subject variability in the respiratory compensatory response to increased dead space due to variability in brain-stem sensitivity to elevated pCO₂. Compensatory increase in tidal volume is not a limiting factor, considering the large respiratory reserve of a healthy individual. However, it may become a burden while breathing through increased resistance, and especially in patients with pulmonary disease. Modern RPDs decrease the effective dead space by employing an internal nose-piece and a low resistance system of valves for expired air.

To overcome the difficulties inherent in the mask filtered air may be driven to the mask at a constant flow (-40 Vmin) by a miniature electric blower. The slight positive-pressure created inside the mask eliminates the danger of the inward leakage and the necessity to tight-fit the

mask. Qualitatively, the air supply has to correspond with the user's ventilatory requirements. Insufficient air flow will result in the creation of a negative pressure during inspiration. In loose-fitting systems, such as hoods, where the protection is dependent on constant positive internal pressure, such a condition will instantly result in an inward leakage. In tightfitting systems (masks) peak-flow restriction will result in "air-hunger" during work. The minimal air flow requirement for loose-fitting systems, as stipulated by the U.S. National Institute of Occupational Safety and Hygiene (NIOSH), is at least 170 l/min. However, for civilians who are at rest a lower air flow would be enough.

The active air supply diminishes the respiratory effort and helps to normalize the physiological response to exercise with an RPD. At rest, the pressure within the mask's nosepiece is in general positive throughout the respiratory cycle. This may prove helpful to those who have difficulties sealing the mask: children and adults with small facial dimensions, individuals with beards, congenital or postoperative cranial defects, etc. CO₂-rich air in the nosepiece is diluted, thereby reducing FiCO₂ and elevating FiO₂ when compared to a mask without a blower. The respiratory effort at rest is significantly lower, as reflected by a lower respiratory rate and peak respiratory pressure. Considering these data, the blower may alleviate the intolerance to breathing with the mask experienced by people with disease, especially those with chronic lung disease (3).

Special protective hoods designed for babies and children are also equipped with a mini blower that supplies 40-45 l/min and provides adequate protection during the whole respiratory cycle. In children inspiratory CO₂ levels were found to be negligible (<0.1%) at rest and did not exceed 1.6% during exercise (4,5).

In summary, proficient use of gas masks is of vital importance in a chemical warfare scenario. However, it seems that the common mask has some inherent physiological limitations which might be intolerable for part of the population. Pre-training was found to be particularly effective in improving the compliance with RPDs. People should be encouraged to undergo training, and appropriate incentives should be used in the pediatric age-group. Modern devices which are designed according to advanced human engineering concepts and are equipped with a powered air supply may be helpful for those individuals who remain unfit for respirator wear.

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