PAPR-Like Protection using Mask Facepiece-Embedded Fans

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Introduction

Advancements for next generation military respirators continue to support the development of scaled protection systems with various air management concepts. One technology with high interest is a dual cavity respirator, which isolates the positive and negative pressure swings during a breathing cycle within the respirator nose cup while supplying positive pressure to the outer eye region. Lessons learned from previous designs led to fabrication of a fourth generation (GEN4) system. Briefly, this GEN4 test bed included a fan dedicated to over-pressurization of the facepiece eye cavity and a separate nose cup fan, incorporated a control system to independently adjust fan speeds, and added a feature to control fan speed based on a pressure feedback controller, which permitted the fans to respond dynamically to in-mask pressures. This study evaluated protective performance of the GEN4 test bed system compared to a commercially available powered air-purifying respirator (PAPR).

Methods

The GEN4 test bed was built using an Avon Protection C50 facepiece with the following modifications: a center module to house a pressure sensor and provide a pass-through for powering fans, two fan housings with impellors/motors, a quarter-mask nose cup, and a new exhalation valve housing (Fig. 1). A body-mounted control box was fabricated for the battery and associated electronics to power/control the mask-embedded fans. The GEN4 operational modes assessed in this investigation are listed in Table 1. Simulated workplace protection factors (SWPF) were measured using 7 volunteers aged 33 ± 5 yrs (mean ± SD) who completed five tasks that ranged from light to heavy intensity workloads (Fig. 2). In-mask particle counts over the course of each 14 min trial were measured within the nose cup using a PortaCount®Plus Respirator Fit Tester mounted to a load bearing vest and carried on the subject's back. These data were transmitted via a wireless serial server and recorded on-line. A second PortaCount® collected particle counts from the eye region when possible and a third particle counter monitored ambient particle concentrations. Minute-by-minute SWPFs were calculated by dividing synchronized ambient and in-mask particle counts. Data regarding eye cavity pressures and subjective feedback on user comfort and facial thermal sensation were also obtained.

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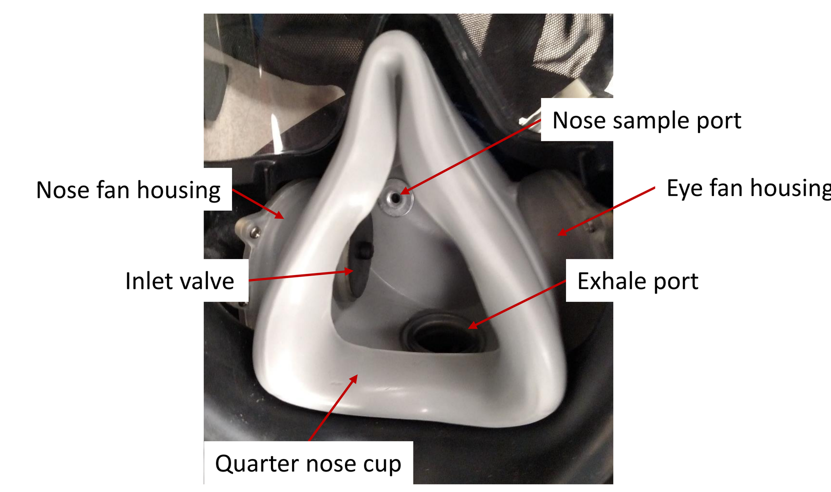


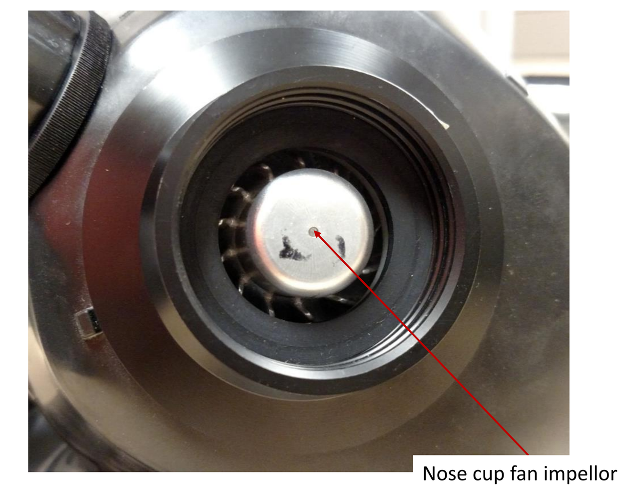
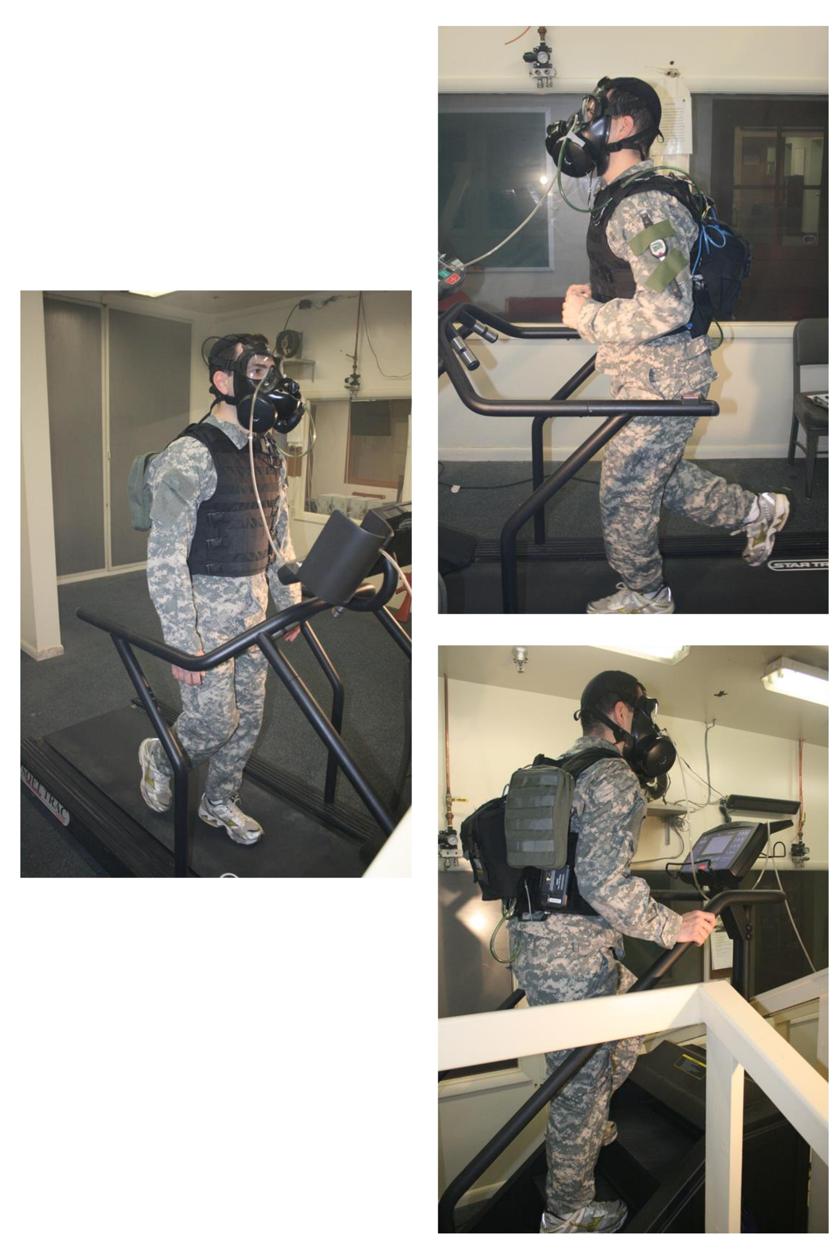


Fig. 1. GEN4 test bed, quarter nose cup design, and embedded nose cup air supply fan.

Table 1. Experimental Mask Wear Conditions.

Mask Test Bed	Eye Fan Mode	Nose Fan Mode
C420	On	N/A
GEN4	Medium	Off
GEN4	Dynamic Response	Off
GEN4	Medium	Medium
GEN4	Dynamic Response	Medium



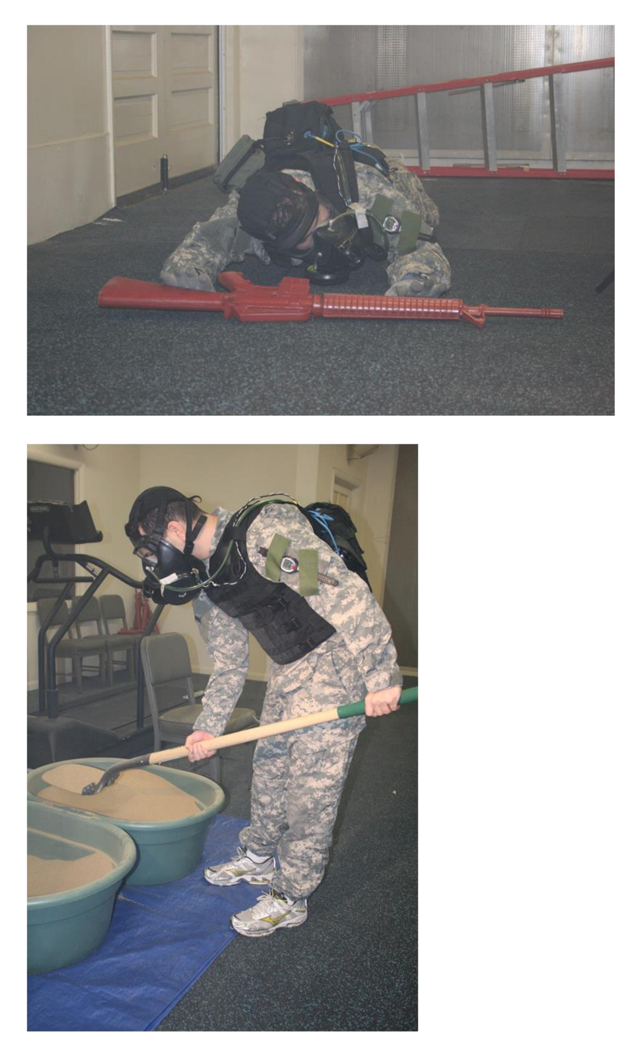


Fig. 2. SWPF Tasks.

Results

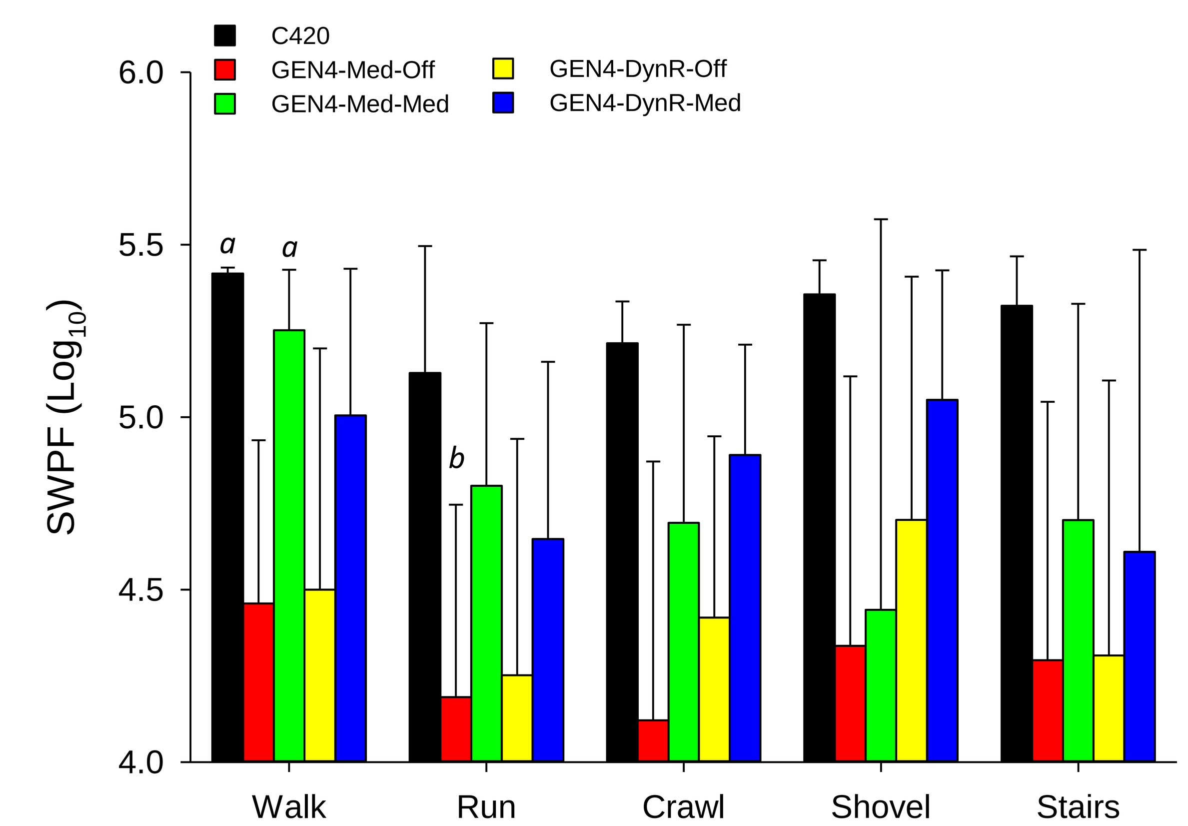


Fig. 3. Average (± SD) $SWPF_{NOSE}$ by activity for all test conditions. a = significantly different vs. GEN4 Med-Off, GEN4 DynR-Off and GEN4 DynR-Med; b = significantly different from C420 PAPR.

Table 2. Average (±SD) $SWPF_{EYE}$ (Log_{10}) by Activity.

Mask Test Bed	Walk	Run	Stairs
C420	5.42 ± 0.06	5.08 ± 0.52	5.33 ± 0.25
GEN4 Med-Off	4.97 ± 0.54	4.97 ± 0.32	5.05 ± 0.31
GEN4 DynR-Off	5.39 ± 0.05	5.21 ± 0.17	5.27 ± 0.22
GEN4 Med-Med	5.35 ± 0.19	5.31 ± 0.25	5.21 ± 0.30
GEN4 DynR-Med	5.08 ± 0.35	4.92 ± 0.35	5.00 ± 0.53

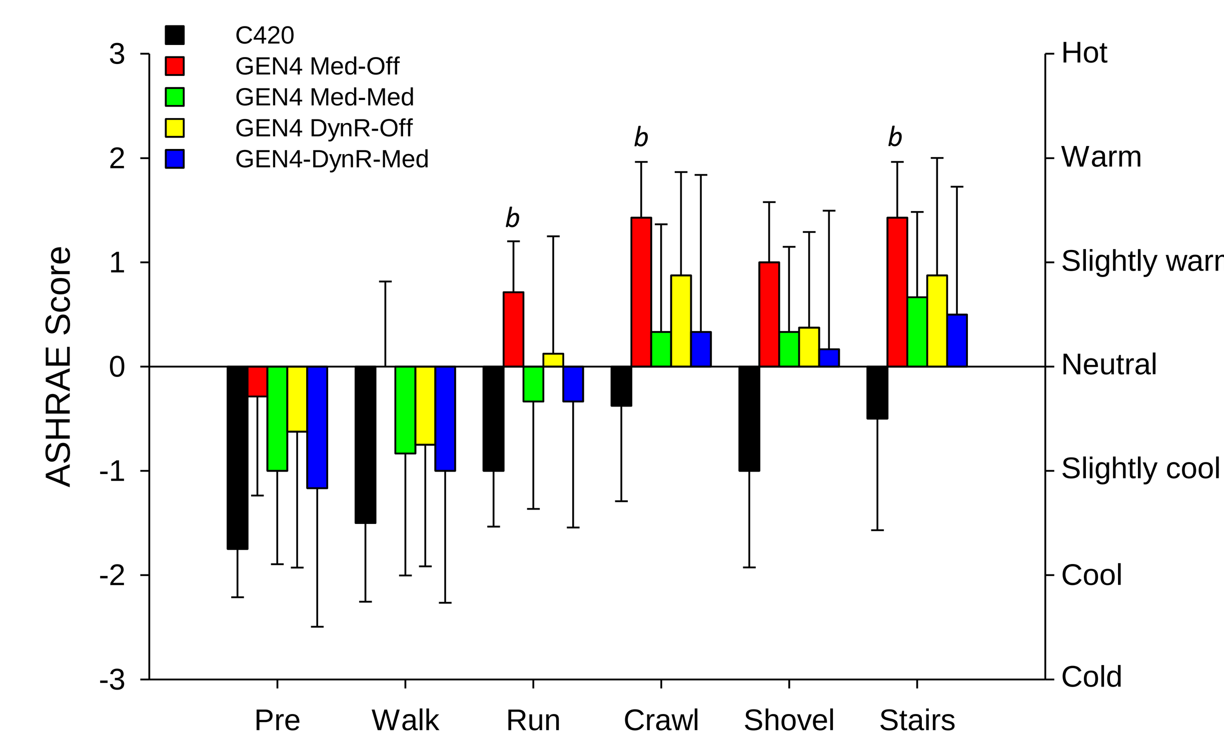


Fig. 4. Average (± SD) thermal sensation ratings. *b* = significantly different from C420 PAPR.

Conclusions

These findings suggest that low-flow facepiece-embedded fans can provide respiratory protection levels comparable to a traditional PAPR system without compromising the comfort and thermal sensation advantages associated with PAPRs.

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