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VENTILATORY DYNAMICS IN FIREFIGHTERS DURING SIMULATED FIREGROUND TASKS PERFORMED AT A STANDARDIZED PACE

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INTRODUCTION

- Firefighters' (FFs) self-contained breathing apparatus (SCBA) contains a finite volume of air that supports the performance of occupational tasks for a duration that is dependent on ventilatory rate.
- Ventilatory economy has been found to be variable during fixed work rate treadmill ambulation in firefighters (1). However, no literature has examined the potential variability in ventilatory responses between firefighters during fixed pace simulated fireground tasks. Evaluation of variability in ventilatory efficiency is important to identify countermeasures to enhance FFs work efficiency and safety.

AIMS

AIM 1 – To investigate the ventilatory dynamics of FFs while completing simulated fireground tasks at a fixed pace.

AIM 2 - To identify ventilatory characteristics associated with greater SCBA air consumption.

METHODS

- Incumbent FFs (N=40) completed two randomized trials of a continuous air consumption drill (ACD) at a predetermined, standardized pace (i.e., 7.8 min) while wearing full turnout gear. FFs were instructed to avoid using breathing techniques that could alter ventilation.
- During one trial, FFs breathed through a self-contained breathing apparatus (ACD_{SCBA}) and the change in air pressure (nearest 1 PSI) was recorded.
- During the other trial (ACD_{VO₂}), FFs wore a portable gas analyzer to measure:
 - Minute ventilation (VE)
 - Oxygen consumption (relative and absolute; VO₂)
 - The ratio of minute ventilation to oxygen consumption (VE/VO₂)
 - Tidal volume (TV)
 - Respiratory frequency (Rf)
- Data from ACD_{VO₂} were compared to air consumption data from ACD_{SCBA} using descriptive statistics, paired-samples t-tests, effect sizes (Cohen's d), and correlations.

AIM 1 - RESULTS

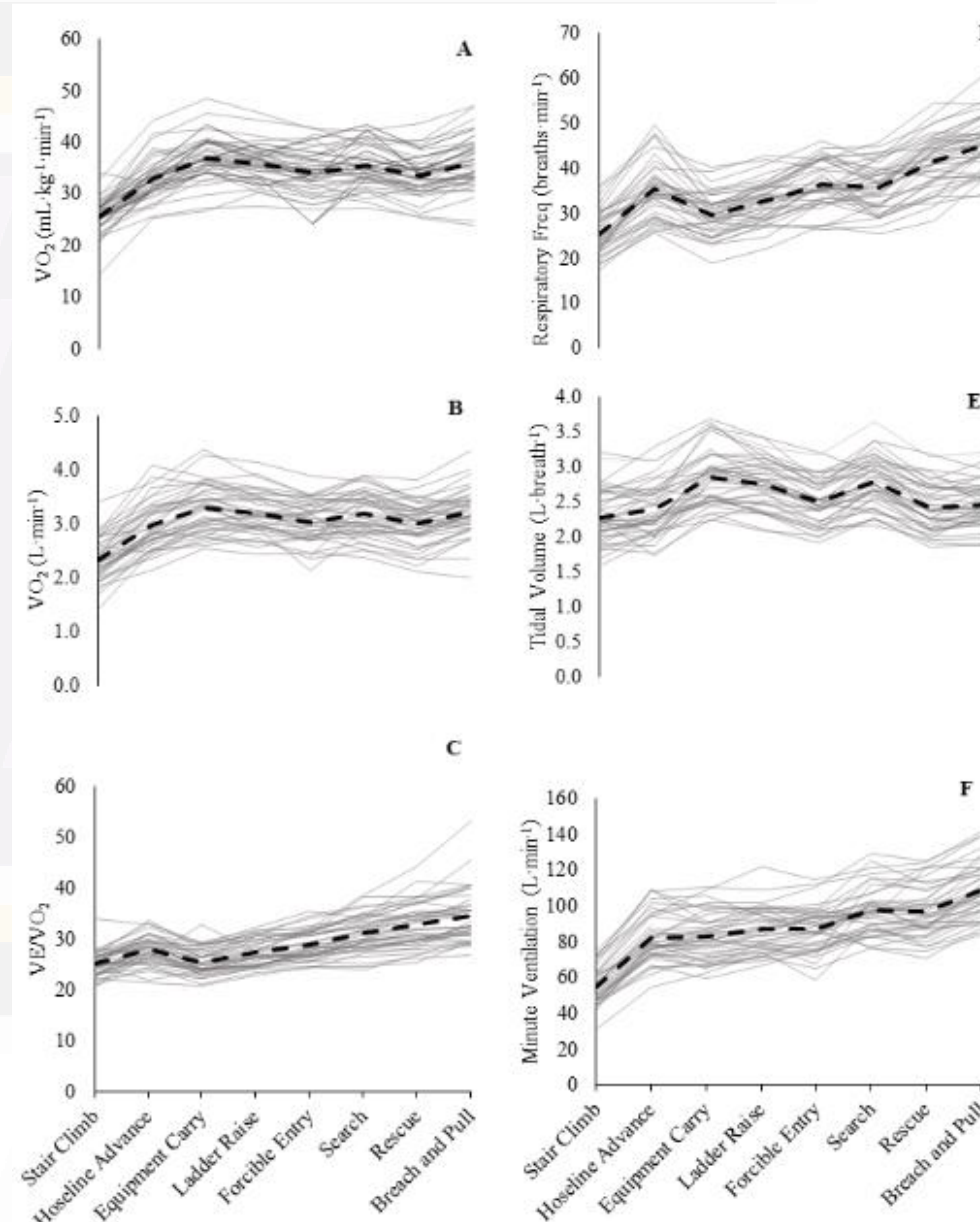


Figure 1. Oxygen consumption (VO₂ (relative: Panel A; absolute: Panel B)), the ratio of minute ventilation to oxygen consumption (VE/VO₂; Panel C), respiratory frequency (Panel D), tidal volume (Panel E), and minute ventilation (Panel F) of firefighters (N=40) completing a fixed pace air consumption drill composed of eight continuous tasks. Group mean values are represented with a dashed line.

AIM 2 - RESULTS

Table 1. Ventilatory and air consumption outcomes of 40 structural firefighters who performed an occupational air consumption drill at a standardized pace. Correlation coefficients and significance values are reported between each variable versus total air consumption.

	Mean ± SD	95% CI				r	p-value
		Min	Max	Lower	Upper		
Δ SCBA pressure (lb·in ⁻²)	1559 ± 217	1048	2016	1490	1629	1	N/A
Relative VO ₂ (mL·kg ⁻¹ ·min ⁻¹)	33.6 ± 3.6	25.7	42.8	32.4	34.7	0.08	0.611
Absolute VO ₂ (L·min ⁻¹)	3.0 ± 0.4	2.3	3.9	2.9	3.12	0.45	0.004
Total VO ₂ (L)	23.3 ± 2.8	18.0	38.8	22.4	24.2	0.44	0.005
Respiratory frequency (breath·min ⁻¹)	35.1 ± 4.6	26.0	44.4	33.6	36.5	0.15	0.349
Tidal volume (L·breath ⁻¹)	2.6 ± 0.3	2.0	3.3	2.5	2.7	0.34	0.032
Minute ventilation (L·min ⁻¹)	87.4 ± 11.4	70.8	112.0	83.7	91.0	0.50	0.001
Total ventilation (L)	678.7 ± 87.8	551.5	870.3	650.6	706.8	0.51	0.001
Average VE/VO ₂	29.4 ± 2.9	24.0	35.3	28.4	30.3	0.14	0.397
Work economy (mL·m ⁻¹)	88.2 ± 11.1	65.8	113.5	84.6	91.8	0.43	0.006

Δ: Change in variable; SCBA: Self-contained breathing apparatus; VO₂: oxygen consumption; VE/VO₂: Ventilatory equivalent for oxygen. Significance set at *p* < 0.05.

- Coefficient of variation for ΔSCBA pressure = 13.7%

CONCLUSIONS

- Despite performing tasks at a fixed pace, there was considerable variability in ventilatory outcomes, likely due to differences in stature and economy.
- As expected, VE was related to total SCBA air consumption. Although VO₂ remained relatively steady throughout the drill, VE exhibited a gradual rise, reflecting decreased efficiency as the drill progressed.
- Further, predominantly anaerobic tasks were characterized by increases in Rf, whereas predominantly aerobic tasks were characterized by increases in TV.
- TV was related to total air consumption, though Rf was not.

PRACTICAL APPLICATIONS

- Ventilatory dynamics appear to be influenced by the duration and types of tasks performed.
- FFs may demonstrate better air management by using breathing techniques to control TV.
- Additionally, future research should investigate how body size and fitness level relate to air management.

REFERENCES

1. Gendron, P., Freiburger, E., Laurencelle, L., Trudeau, F., & Lajoie, C. (2015). Greater physical fitness is associated with better air ventilation efficiency in firefighters. *Applied ergonomics*, 47, 229-235.