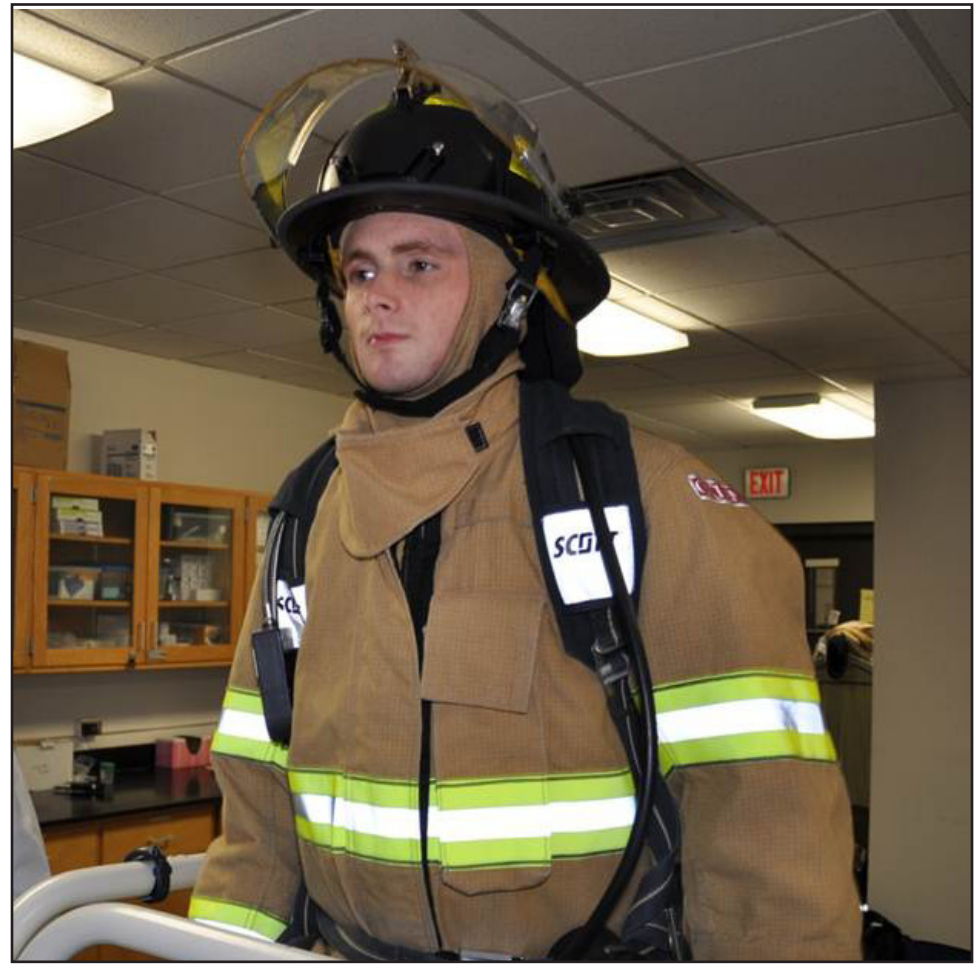




Influence of Clothing Layers Under Firefighting Protective Clothing on Physiological/Perceptual Responses to Intermittent Work

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ABSTRACT

Personal protective clothing protects firefighters from thermal and other occupational hazards; however, it also contributes to the physiological and perceptual strain experienced by the wearer. Although research suggests that the addition of a clothing layer could cause an increase in thermal stress, the influence of additional layers of clothing, such as a station uniform shirt over a t-shirt, has not been well studied. **PURPOSE:** To examine the effect of clothing layers worn under structural firefighting turnout gear (TOG) on physiological and perceptual responses during alternating work/recovery cycles. **METHODS:** Ten men (age, 21 ± 1 yr; height, 174 ± 6 cm; weight, 74.3 ± 7.4 kg; VO_2max , 58.9 ± 6.3 ml·kg⁻¹·min⁻¹) completed a 110-min intermittent walking protocol (three 20-min exercise bouts/10, 20 and 20 min recovery sessions) in a thermo-neutral (21.0°C , 58.7% RH) laboratory while wearing a cotton t-shirt (COT) or COT and a station uniform (SU) shirt under firefighting TOG (COT+TOG and COT+SU+TOG, respectively). Some or all TOG was removed during each recovery session. Changes in heart rate (HR), core temperature (Tco), skin temperature (Tsk), rating of perceived exertion (RPE), and thermal sensations (TS) were compared across exercise and recovery periods using general linear models with repeated measures ANOVA. **RESULTS:** During exercise sessions HR, Tco, Tsk, and RPE reached similar levels for COT+TOG and COT+SU+TOG. During Recovery 1, 2, and 3, chest Tsk decreased by 3.96°C , 6.64°C , and 6.49°C , respectively, for COT+TOG compared to 2.24°C , 3.78°C and 4.09°C for COT+SU+TOG ($P < 0.05$ for each period). Change in TS differed during Exercise 1; however, mean peak TS corresponded to “hot” for both ensembles. **CONCLUSIONS:** The additional layer of clothing in the COT+SU+TOG ensemble imposed no greater level of physiological or perceptual strain during moderate-intensity work bouts compared with the COT+TOG ensemble. However, some modest benefits were experienced during the recovery sessions for the COT+TOG ensemble as evident by a lower chest Tsk. These findings could guide departmental decisions about the use of station shirts.

INTRODUCTION

Personal protective clothing (PPC) is worn by firefighters to shield them from thermal and other occupational hazards; however, it also contributes to physiological and perceptual strain. Clothing plays a central role in thermoregulatory responses as it influences both heat production and heat dissipation. Clothing provides a barrier to heat and vapor transfer between the skin and the environment; the barrier is comprised of the clothing materials and the air they enclose (1). Research suggests that adding an additional layer of clothing with an accompanying air layer would cause an increase in thermal stress due to a decrease in evaporative cooling efficiency and increases in thermal insulation and water vapor resistance (1,2). There is currently no standard practice in the United States as to the number of layers worn under structural firefighting gear. Furthermore, the influence of additional layers of clothing, such as a station uniform shirt (SU) over a t-shirt, has not been well studied.

PURPOSE

To examine the effect of clothing layers worn under structural firefighting turnout gear (TOG) on physiological and perceptual responses during alternating work/recovery cycles.

METHODS

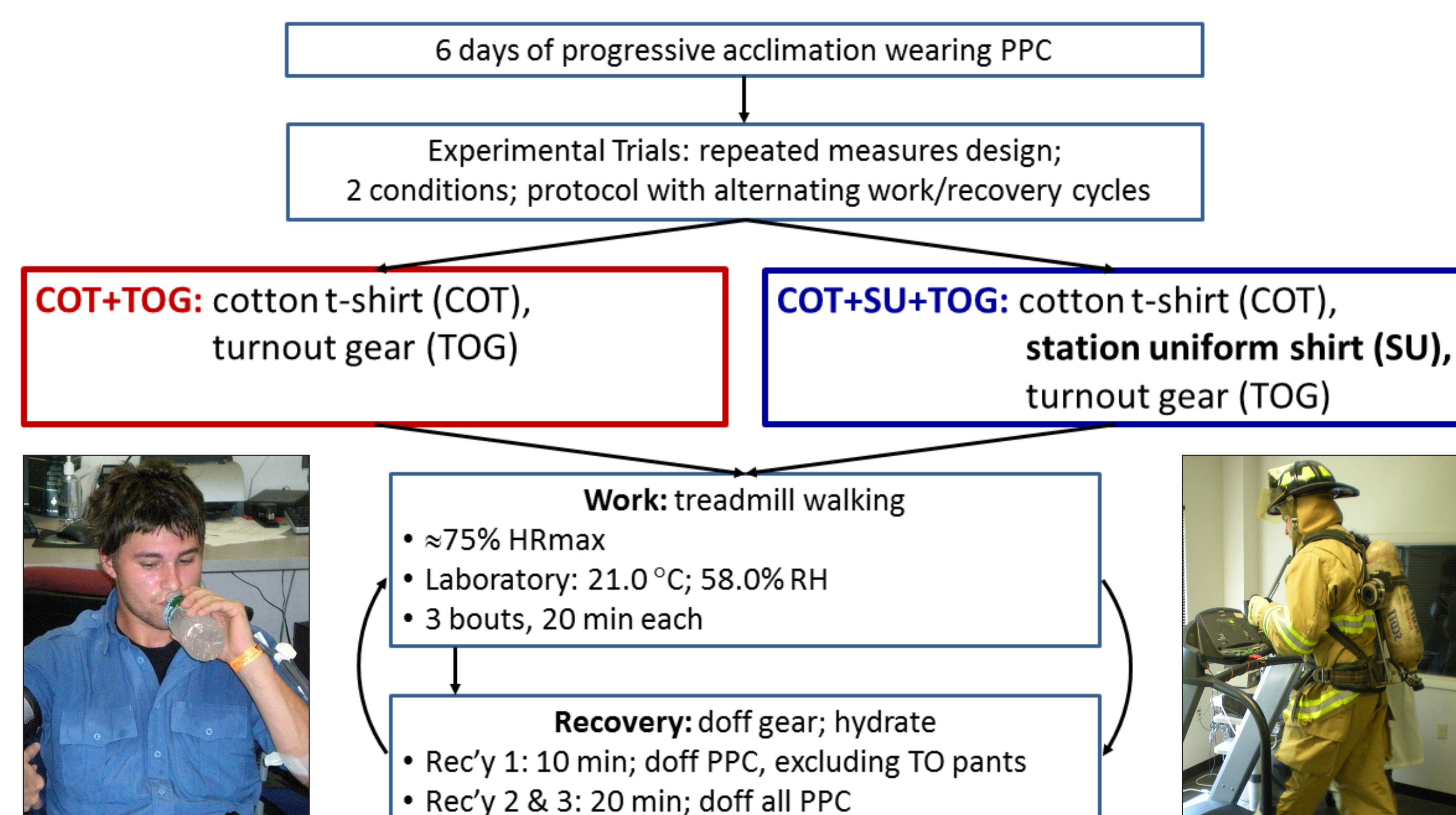


Figure 1. Experimental protocol.

Participants

- Ten healthy, fit men (mean $\pm$ SD: age, 21 ± 1 yr; height, 174 ± 6 cm; weight, 74.3 ± 7.4 kg; VO_2max , 58.9 ± 6.3 ml·kg⁻¹·min⁻¹).

Measurements

- Core temperature (Tco): via gastrointestinal pill (VitalSense, Philips Respironics, Bend, OR).
- Skin temperature (Tsk): at chest and forearm (Measurement Specialties, Inc., Dayton, OH).
- Heart Rate (HR): Polar FS1 heart rate monitor (Polar Electro, Lake Success, NY).
- Rating of perceived exertion (RPE): 0–10 scale.
- Thermal sensations (TS): 0–8 scale (0 = unbearably cold; 8 = unbearably hot).

Statistical Analysis

- Separate repeated measures ANOVA models were constructed for each exercise and recovery period to examine changes in Tco, Tsk, HR, RPE, and TS across the time periods.
- For post-hoc tests, a Bonferroni correction was used to adjust for multiple comparisons. Statistical significance was set at $P < 0.05$. Values are mean $\pm$ SD unless indicated otherwise.

RESULTS

- Core temperature (Figure 2A), Tsk (Figure 2B), HR (Figure 3) and RPE reached similar levels for both conditions at the end of each exercise period.
- During Recovery 1, 2, and 3, chest Tsk dropped more when not wearing the SU ($P < 0.05$). There was a greater increase in chest Tsk when wearing a SU during Exercise 2 and 3 ($P < 0.05$); however, peak Tsk was similar.
- There was a greater increase in HR when wearing the SU during Exercise 2 ($P < 0.05$).
- The only significant difference for perceptual responses was a greater increase in TS during Exercise 1 in the SU trial. Mean peak TS corresponded to “hot” for both ensembles.

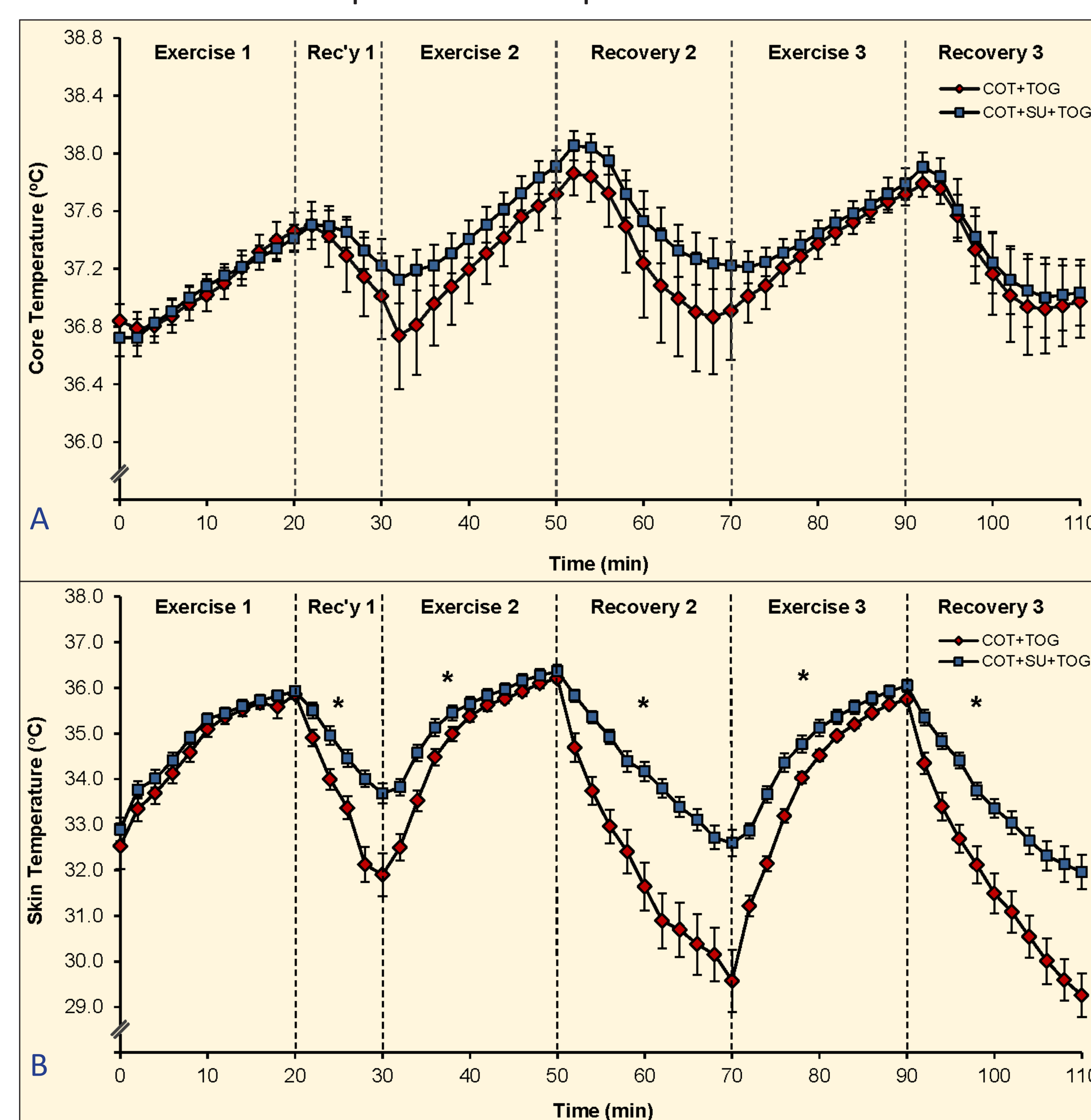


Figure 2. Mean ($\pm$ SE) core temperature (A; $n = 8$) and chest skin temperature (B; $N = 10$) during trials. COT+TOG: cotton t-shirt and turnout gear; COT+SU+TOG: cotton t-shirt, station uniform shirt, turnout gear. * $P < 0.05$ over the period.

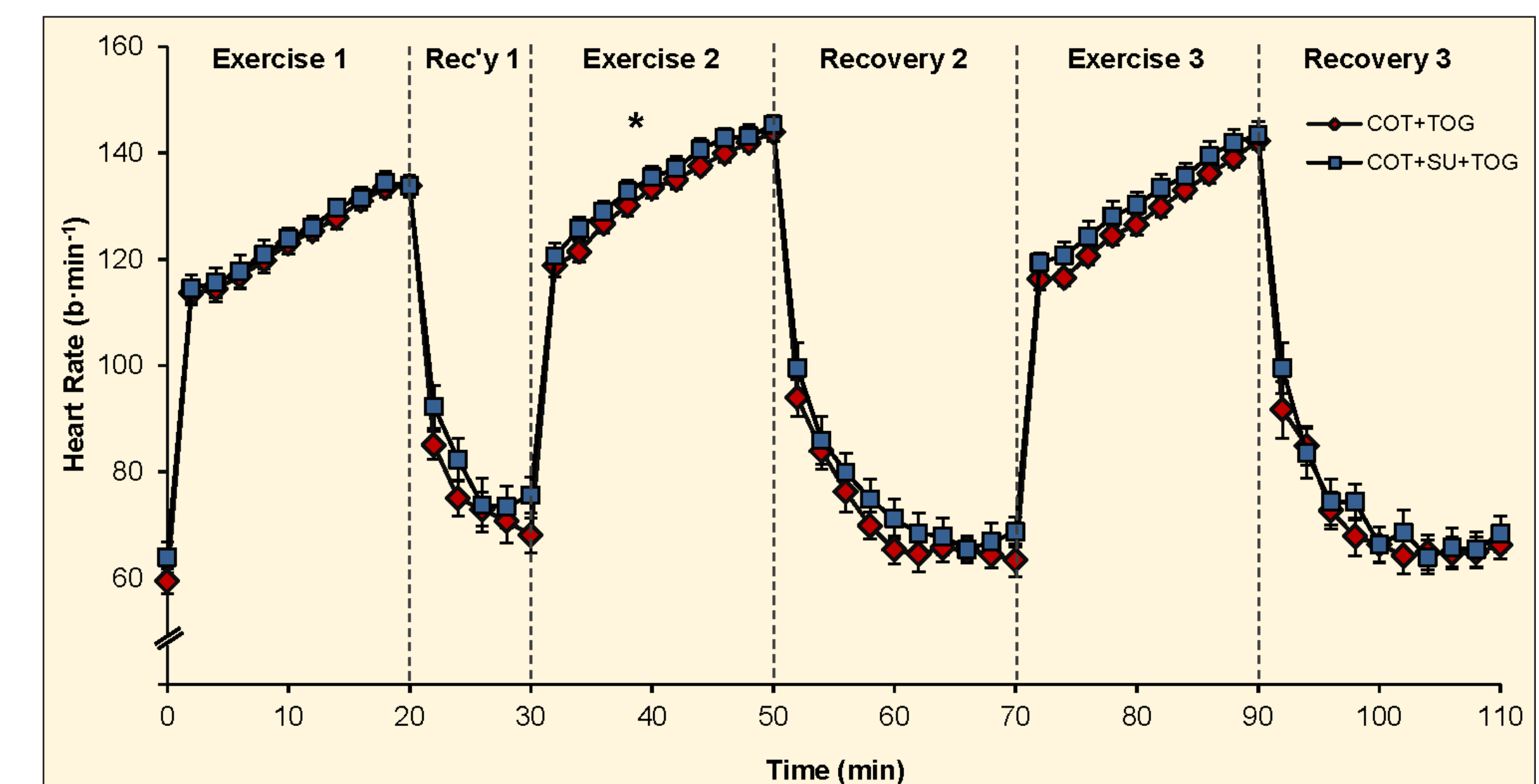


Figure 3. Mean ($\pm$ SE) heart rate during trials ($N = 10$). COT+TOG: cotton t-shirt and turnout gear; COT+SU+TOG: cotton t-shirt, station uniform shirt, turnout gear. * $P < 0.05$ over the period.

DISCUSSION/CONCLUSIONS

- The present study examined the effect of clothing layers (COT+SU) worn under firefighting TOG compared with just a cotton t-shirt under TOG on physiological and perceptual responses during an exercise protocol that simulated work/recovery cycles experienced by a firefighter in the line of duty.
- The additional layer of clothing (SU) imposed no greater level of physiological strain or perceived exertion during work bouts than the cotton t-shirt and TOG ensemble.
- Modest benefits were experienced during the recovery sessions for the COT+TOG ensemble as evident by a larger reduction in chest Tsk when wearing COT compared to COT+SU following removal of the TO coat. The use of a fan during recovery likely influenced water vapor transfer, and the SU shirt restricted water vapor transfer at the torso, causing chest Tsk to be higher when the SU shirt was worn.
- In general, our findings are similar to those of other investigators who examined the addition of an extra clothing layer during moderate or heavy exercise/work (3,4). However, greater thermal stress has been reported when wearing an additional clothing layer under PPC (4,5). Both work intensity and textile properties of the additional layer influence responses.
- The findings of our study could help fire departments make an informed decision as to whether or not to wear a SU over a standard cotton t-shirt.

ACKNOWLEDGMENTS

This study was supported by a research grant from the Department of Homeland Security (EMW-2009-FP-02044). We would like to express our appreciation to the study participants and to the staff members of the First Responder Health and Safety Laboratory who assisted with data collection. We also wish to thank Patricia Bosen, MSN, FNP-C, and Michael W. Dailey, MD, for their assistance with this study.

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