FIRE FIGHTER SAFETY AND DEPLOYMENT STUDY

Effect of Deployment of Resources on Cardiovascular Strain of Firefighters*

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* This study was undertaken as a discrete study within the larger project titled "FireFighter Safety and Deployment Study" conducted by CPSE, IAFF, IAFC, NIST, WPI, and www.firereporting.org

Report to Department of Homeland Security –

Assistance to Firefighters Grant Office

This report is submitted as an addendum to a report titled “MULTI-PHASE STUDY ON FIREFIGHTER SAFETY AND THE DEPLOYMENT OF RESOURCES (Year 2 Report)” that was submitted by the principle investigators (Jason Averill, Dr. Lori Moore-Merrell, and Dr. Kathy Notarianni) earlier this year. The purpose of this report is to describe the findings of a smaller study that focused on detailing the effect of crew size on the cardiovascular strain experienced by firefighters. This adjunct study was conducted as part of the larger “Deployment Study”.

Introduction

The focus of the parent project "Firefighter Safety and Deployment of Resources Study" was on understanding of the effect of deployment of resources on the time required to achieve critical steps in fire suppression during "low-hazard" residential fires. The time required to achieve critical steps is important for several reasons, notably, as discussed in this report, because it determines how long civilians can survive in a burning structure and the extent of property damage that results from the fire. However, the deployment of resources can also have a direct effect on firefighter safety at the scene of a fire.

The leading cause of line of duty fatalities are overexertion/overstrain (Fahey 2005). Based on United States Fire Administration (USFA) data, 43.9% of all firefighter fatalities from 1990-2000 were due to cardiac events, nearly double the second leading cause of death (trauma) (USFA, 2002). There is strong epidemiological evidence that heavy physical exertion can trigger sudden cardiac events (Mittleman et al. 1993; Albert et al. 2000). Therefore, understanding the effect of crew size on the physiological strain experienced by the firefighter is of great importance.

Purpose

Therefore, the purpose of this study, conducted as part of the parent study, was to quantify the effect of crew size on physical exertion and cardiovascular strain of firefighters working at the scene.

Methods

Participants were firefighters (FF) taking part in the DHS-funded deployment study who were invited to participate in this phase of the study. The study took place in Montgomery County, Maryland at the Montgomery County Fire Rescue Training Academy during the months of January and February 2009. Experiments were not conducted in heavy rain, ice, or snow. Firefighters from Montgomery County (MD) and Fairfax County (VA) participated in the study as part of the larger deployment study. Crews that normally operated together as a company participated in this study as an intact company.

Participants were informed of the goals of the study and provided written informed consent. The study was approved by the Institutional Review Board at Skidmore College. Participants received a briefing on the full study prior to the start of fire suppression activities. They were fitted with a chest strap and watch/receiver (Polar Electro Oy, CE0537, Finland) which they wore while engaged in the fire suppression drills. The heart rate watches recorded the heart rate data (one second intervals) throughout the drills, and were downloaded at the completion of the drill.

As it was not the primary focus of the study and because of restrained resources, we limited our measure of cardiovascular strain to measuring heart rates and to combining this information with the time required to extinguish the fire.

Results

As expected, the time to complete all firefighting tasks differed by crew size. When the apparatus arrived in close temporal proximity to each other (1st Engine = 4 min after notification; Truck = 5 min; 2nd Engine = 5½ min; 3rd Engine = 7 min), it took an average of 20:27 min to complete the drill when 2 FF were deployed per apparatus, 19:26 min when 3 FF were deployed, 15:06 min when 4 FF were deployed, and 14:44 min when 5 FF where deployed. When there was a greater time between the arriving units (1st Engine = 4 min after notification; Truck = 6 min; 2nd Engine = 6½ min; 3rd Engine = 9 min), it took an average of 20:56 min to complete the drill when 2 FF were deployed per apparatus, 20:11 min when 3 FF where deployed, 16:39 min when 4 FF where deployed and 16:16 when 5 FF where deployed (see Figure 39 of Safety and Deployment report).

Thus, when less than 4 fire fighters are deployed per apparatus, it takes longer to perform the tasks necessary to reduce the hazardous environment inside the structure and to extinguish the fire. This has implications for civilian survival and for property damage. It also suggests that each firefighter must do more work and work for longer time periods.

Heart rates were collected throughout the fire suppression drills. Because heart rate is affected by age, heart rate data are presented as a percentage of maximal heart rate. Maximal heart rates were estimated using the formula HRmax = 220 – age (Miller, 1993).

Figure 1 depicts the average peak heart rate for the crews of Engine 1 (first arriving engine) when varying crew sizes were deployed. The average peak heart rates for firefighters on the 1st Engine were above 80% of age-predicted maximum values when only 2 firefighters were deployed. In fact, the driver had an average peak heart rate of nearly 90% of age-predicted maximum when there were only 2 firefighters on the engine. When 3 firefighters were deployed per apparatus the peak heart rate averaged 72% across the three positions, and this value did not vary much when 4 firefighters (average 71%) were deployed.

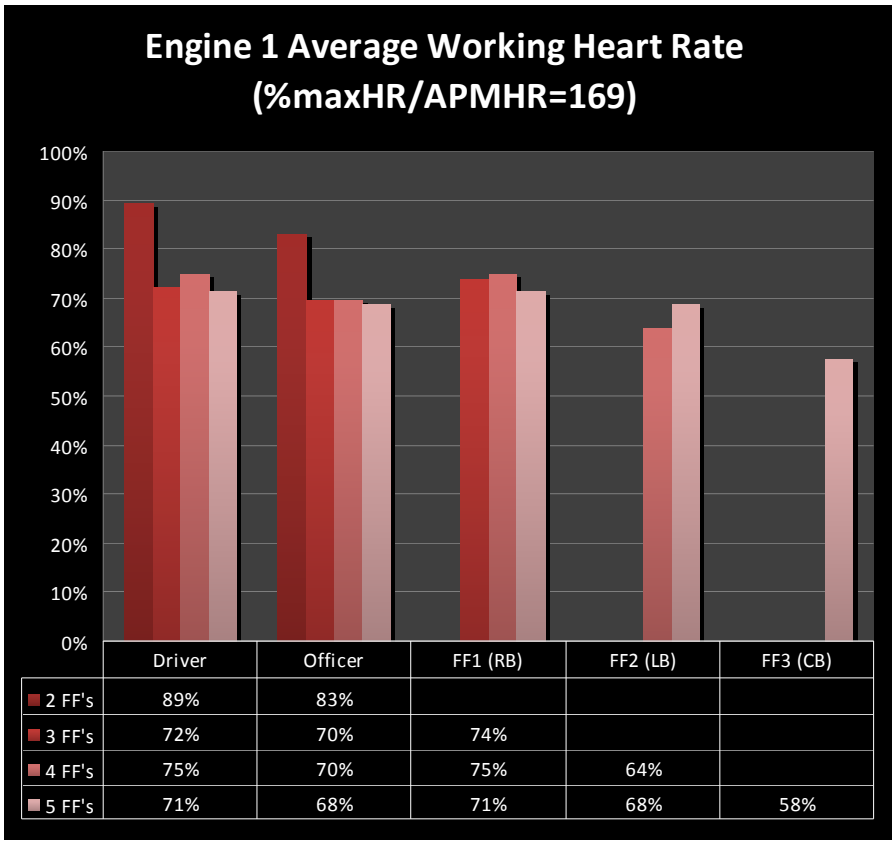
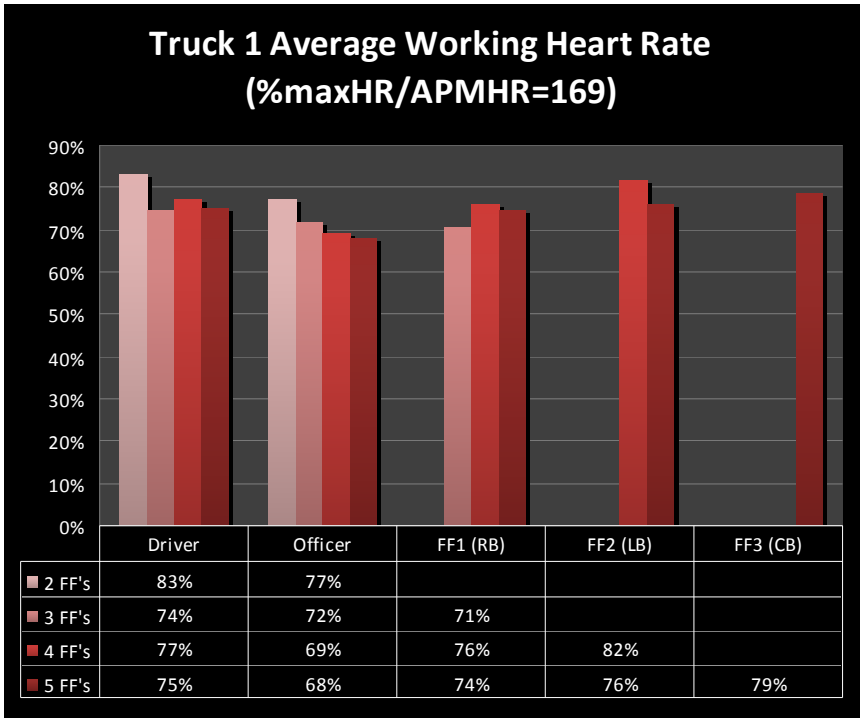


Figure 1. *Average peak heart rate of first engine (E1) with different crew sizes by position. Heart rates are expressed as a percent of maximal age-predicted maximal HR.*

Figure 2 depicts the average peak heart rates for the Truck crew when different numbers of firefighters were deployed. The peak heart rates for firefighters on the Truck averaged 80% of age-predicted maximum values when only 2 firefighters were deployed. When 3 firefighters were deployed per apparatus the peak heart rate of truck crews averaged 72% across the three positions, and this value did not vary much when 4 firefighters (average 76%) or 5 firefighters (average 74%) were deployed.



	Driver	Officer	FF1 (RB)	FF2 (LB)	FF3 (CB)
2 FF's	83%	77%			
3 FF's	74%	72%	71%		
4 FF's	77%	69%	76%	82%	
5 FF's	75%	68%	74%	76%	79%

Figure 2. *Average peak heart rate of truck (T1) with different crew sizes by position. Heart rates are expressed as a percent of maximal age-predicted maximal HR.*

Figure 3 depicts the heart rate response of crew members throughout the fire suppression activities when a crew of two firefighters was deployed and when a crew of five firefighters was deployed. This graph reveals that heart rates remain elevated throughout the firefighting activities. The graph also reinforces the information presented earlier, namely that cardiovascular strain, as reflected by heart rate, was higher when a crew of 2

firefighters was deployed than when a crew of 5 firefighters was deployed. Both peak heart rate and the heart rate that was sustained throughout the fire suppression activity was higher when only 2 crew members were deployed.

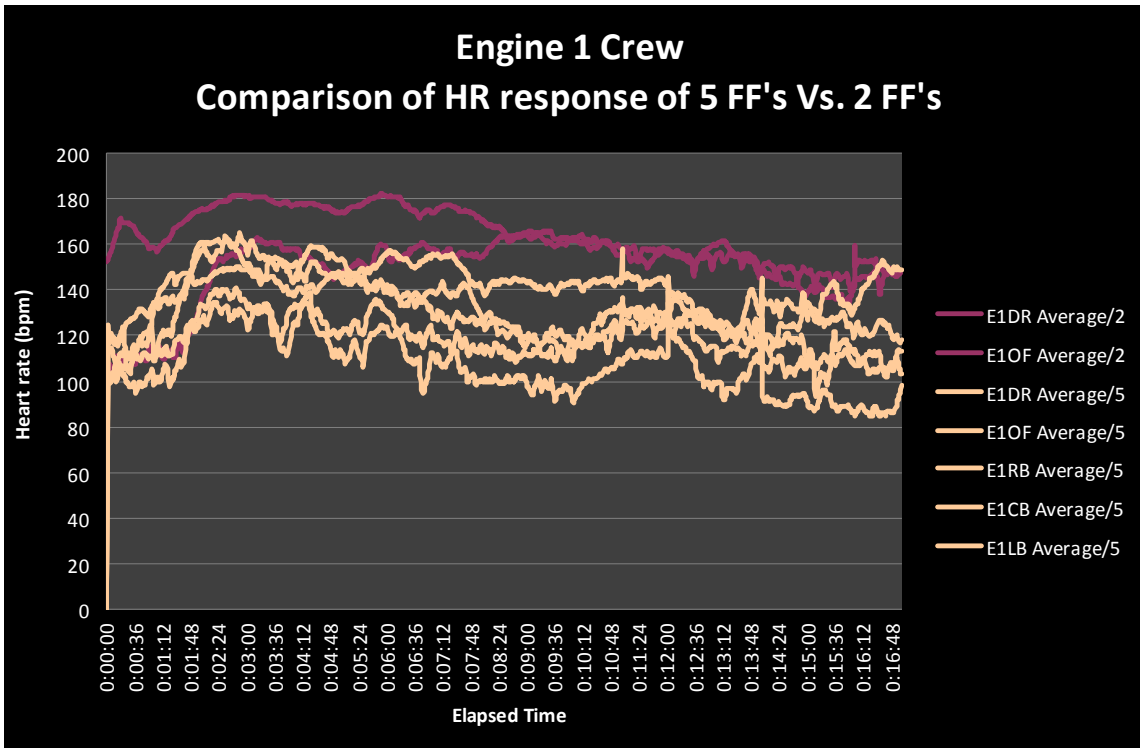


Figure 3. *Heart rate responses of first engine (E1) crew members with different crew sizes.*

The heart rates reported in this study are consistent with previously published research (Romet and Frim, 1987). However, they are lower than values that have been reported during strenuous live fire training (Smith et al, 1995; 2001) and during actual firefighting activities (Barnard and Duncan, 1975). It is generally reported that heart rate responses to firefighting activity vary by position, the type of work performed, and the environment in which it is performed (Manning and Griggs, 1983; Romet and Frim, 1987; Smith et al,

1997). This is the first study to systematically investigate the effect of crew size on heart rate response to a standardized fire suppression drill.

Conclusions

This study investigated the cardiovascular strain experience by firefighters as a function of the crew size that was deployed to suppress a "typical" low-hazard fire. This study was part of a larger study that revealed that it took longer to complete the fire suppression duties including reducing the hazardous atmosphere inside the structure and extinguishing the fire when smaller crews were deployed. The current study also revealed that average peak heart rates were higher when a smaller crew was deployed. The combination of longer work times and higher peak heart rates when two person crews are deployed strongly suggests that two person crews experience considerably more cardiovascular strain than when larger crews are deployed. In this experiment, when only 2 crew members where deployed with a shorter response time between the arriving companies, it took an average of 20:27 min for all fire ground tasks to be completed. When 3 person crews were deployed it took an average of 3:32 to 4:20 min longer for the work to be completed (depending upon the response time stagger in getting all responding apparatus on scene) than when 4 person crews were deployed in the same time parameters. The average peak heart rates of the 3 person crew did not differ greatly from the average peak heart rates when 4 or 5 firefighters were deployed per apparatus. However, it should be noted that when only 3 firefighters were deployed they worked longer than when 4 or 5 member crews were deployed, thus indicating more cumulative cardiovascular strain.

Limitations

This pilot study sought to extend the original study (designed to investigate effect of resources deployed on the time to control the interior conditions created by the fire and the time to extinguish the fire) by investigating heart rate responses of firefighters during standardized fire suppression activity when different crew sizes were deployed to a low hazard residential fire.

This study relied on peak heart rate and time engaged in fire suppression activity as the sole indicators of cardiovascular strain. It would have been advantageous to be able to describe other measures of cardiovascular strain. The study was also limited due to some data loss because of strap displacement or improperly programmed monitors. Additionally, the overall number of monitors available for the experiments was twenty-three resulting in the occasional exchange of monitors throughout the day, attributing to some data loss in the transition. These issues often limited the number of observations per cell. We did not conduct a medical evaluation or screening of our participants therefore we can not assure that medications or medical issues did not affect the heart rate responses shown. However, there is no reason to believe that factors that may affect heart rate were not randomly distributed among firefighters in all crew sizes. Finally, this study only addressed cardiovascular strain as it is known to be related to sudden cardiac events. We also know that overexertion/overstrain plays a role in injuries on the fire ground. In 2006, 83,400 firefighting injuries were reported, with 53% of the injuries occurring on the fireground (Karter & Molis, 2007). Despite the importance of these

events, this study did not address the role of crew deployment size on fireground injury statistics.

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