

Physical Fitness Related to Self-Selected Work Rate of Type One (Hotshot) Crew Members during an arduous 9-Day Fire

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General Summary:

During the Kelly Creek Fire on the Salmon River near Riggins, ID, Summer 2002, 10 members of a Hotshot crew agreed to participate in a study sponsored by the USFS Missoula Technology Development Center (MTDC). The 10 Hotshot crew members were first tested in the lab at the University of Montana, and then had their work output evaluated during nine days of line digging and other fire suppression activity in the rugged terrain surrounding the Salmon River by wearing activity monitors. All subjects were considered quite fit by laboratory measures and were well above the standards required for the arduous pack test. The laboratory measure in this study was '*sustainable aerobic fitness*'. Sustainable aerobic fitness is the maximal intensity of work that an individual can maintain for an extended period of time. In science terms this is called the ventilatory threshold.



Research question:

Is there a relationship between sustainable aerobic fitness and self-selected work output during wildland firefighting?

Results and discussion:

When the data were compared for each of the individual nine days there were moderate relationships between sustainable aerobic fitness and work output with the work output greatly influenced by the job assignment.

When the data were evaluated for the average work done each day over the nine-day period, there was a very strong relationship between sustainable aerobic fitness and self-selected work rate.

The most fit individual did almost 50% more work (adjusted for their body mass) than did the least fit individuals. Interestingly, for each percent gain in fitness, there was about a percent gain in work output again showing the direct impact that aerobic fitness has on work performance.



Practical Considerations:

The least fit member in the study had a fitness level (mid fire season) about 20% higher than necessary to pass the arduous pack test while the most fit individual had a sustainable aerobic fitness level the equivalent to maintaining a running pace of 6.1 mph (or 9:50/mile) for 45-60 minutes.



Sustainable fitness may be improved most by slightly increasing the load on muscles of the arms and legs during longer duration work. For work performed by firefighters, the working environment will improve fitness levels based on the work done by each crewmember. In order to improve sustainable fitness prior to the fire season it is necessary to use muscle specific to how they may be used during the fire season with increasing workload over longer (45 minutes to several hour) duration.

Following, on the next page, is the scientific summary of the research.

Effect of Submaximal VO_2 at the Ventilatory Threshold On Self-Selected Work Rate During Wildland Firefighting.

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ABSTRACT

Wildland firefighters are asked to perform extended work shifts necessary to suppress fire as quickly and efficiently as possible, yet maintain a sustainable work rate to ensure safety to the firefighter. Purpose: The primary purpose of this study was to investigate the relationship between submaximal VO_2 at ventilatory threshold (VO_{2vt}) and self selected work rate. Methods: Subjects (9 males and 1 female), consisted of elite wildland firefighters from a Montana hotshot crew, volunteered to wear CSA activity monitors to determine work rate during the 9-day Kelly Creek fire near the Salmon River in Idaho. Following the fire, subjects performed a midseason VO_{2vt} test. CSA counts over the 9-day fire were averaged for each subject and compared with midseason VO_{2vt} to determine a relationship using a Pearson product correlation. Results: The CSA count mean over the 9-day period was 6,101,731 with a standard deviation of 716,958. The Pearson product correlation for VO_{2vt} and CSA counts over the 9-day period was $r = 0.94$. Correlations between daily CSA count and VO_{2vt} ranged from $r = 0.36$ to $r = 0.80$. Discussion: Over a 9-day period work rate is highly related to VO_{2vt} . Daily work rate relation to VO_{2vt} is lower since individual assignments may alter from day to day. Conclusion: Aerobic fitness level of wildland firefighters is firmly related to total work rate during wildland firefighting.

INTRODUCTION

Wildland firefighters are exposed to long and grueling work hours. Total energy expenditure during these work shifts can reach magnitudes greater than 6000 kcal/day (Ruby et. al, MSSE 304(6):1048-54, 2002). With this increased energy demand, high fitness levels are advantageous to maintain a high work output. Firefighters are expected to maintain a relatively high level of fitness during the off-season. In addition, crewmembers must pass a job qualifying fitness standard (the pack test - 4.83 km walk carrying a 20.5 kg pack in less than 45 min). The metabolic demand of this test is approximately $VO_2 = 23-25 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. In addition to doubly labeled water, the total work output in wildland firefighters has been estimated with the CSA activity monitors using an algorithm developed by Heil (Ergonomics 33(5):405-413, 2002).

The purpose of this study was to examine the relationship between sustainable fitness (VO_{2vt}) and total self-selected work over a 9-day period.

METHODOLOGY

Subjects:

(N=10) wildland firefighters (Hotshots). Subject data are shown in Table 1.

Procedures:

CSA (Model 7164; Computer Science and Applications, Inc., Shalimar, FL) activity monitors were initialized and distributed to volunteers within the Hotshot crew. The CSA monitors were mounted to 8x10 cm plastic cards carried in the left shirt pocket. Prior to the fire season (baseline) and just prior to the field data collection (mid), subjects completed a treadmill test to determine VO_{2vt} levels (According to the methods of Gaskill et. al, MSSE, 33:11, 1841-1848, 2001). Field data collection took place during 9 consecutive 12-14 hour days of wildfire suppression on the Kelly Creek fire, in very steep and difficult terrain located along the Salmon River near Riggins, ID. CSA counts during the Kelly Creek fire were correlated to baseline and mid season VO_{2vt} .

RESULTS

Table 2 shows the daily and overall relationship between CSA activity monitor counts and VO_{2vt} . Note that daily relationships are generally strong, but vary from day to day depending on the individual job assignment and overall crew duties. However, the relationship between VO_{2vt} and activity over the 9-day period was $r=0.94$ showing a very strong relationship and suggesting that nearly 90% of the differences in work output could be accounted for by differences in submaximal aerobic fitness (VO_{2vt}).

Table 1: Subject Characteristics.

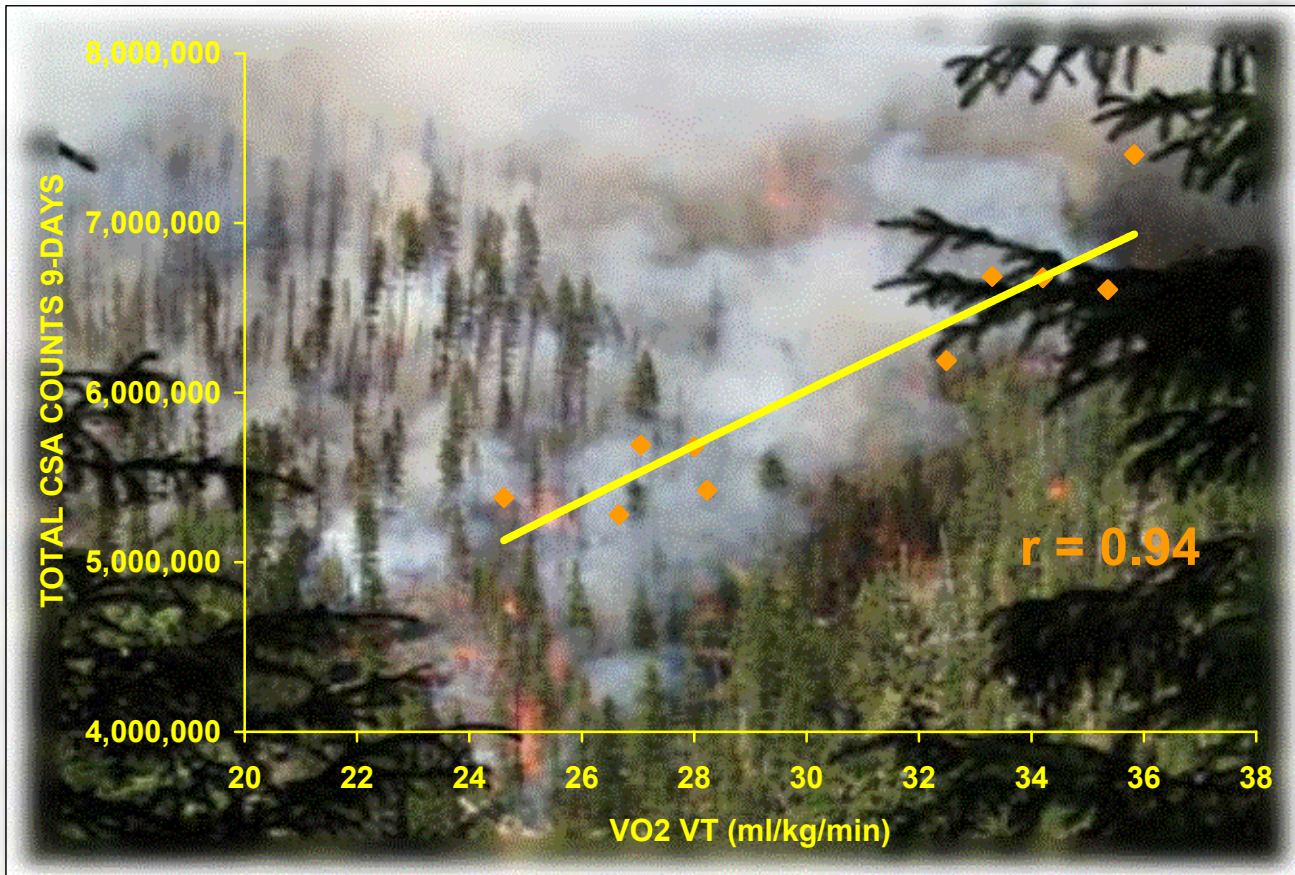
Age	Ht (cm)	baseline VO_{2vt} (ml/kg/min)	Mid VO_{2vt} (ml/kg/min) just prior to Kelly Creek Fire	9 day CSA total counts
26.4 ± 4.2	180.6 ± 6.7	28.3 ± 5.4	30.6 ± 4.1	605949 ± 134301

Table 2: Relationship of VO_{2vt} and VO_{2max} with Activity daily activity and an average of the nine day period monitor counts.

Daily Relationships of Fitness to Work Output		
CSA activity	baseline VO_{2vt}	Mid VO_{2vt}
CSA total-Day 1	$r = -0.18$	$r = 0.55$
CSA total-Day 2	$r = 0.48$	$r = 0.77$
CSA total-Day 3	$r = 0.36$	$r = 0.80$
CSA total-Day 4	$r = 0.22$	$r = 0.37$
CSA total-Day 5	$r = 0.23$	$r = 0.58$
CSA total-Day 6	$r = 0.23$	$r = 0.67$
CSA total-Day 7	$r = 0.11$	$r = 0.66$
CSA total-Day 8	$r = 0.35$	$r = 0.76$
CSA total-Day 9	$r = 0.12$	$r = 0.80$
9 day total	$r = 0.28$	$r = 0.94$

Figure 1 (next page) shows the individual data relating the VO_{2vt} with activity monitor counts. For each 1% increase in VO_{2vt} there was a corresponding 1% increase in CSA counts.

Figure 1: Sustainable aerobic Fitness (VO_{2vt}) related to work rate (Activity Monitor Counts)



DISCUSSION

- Subjects with a higher sustainable fitness accumulated more work (CSA counts).
- On a day-to-day basis the relationship between work and fitness was modest due to variations in the job assignments.
- Overall, there was a strong relationship between self-selected work and sustainable (VO_{2vt}) fitness.
- At this point in the fire season, the fitness levels were within a narrow range (25-36 ml/kg/min), yet there was a large difference in the work output of individual crew members related to the small range in sustainable fitness.
- Prior to the fire season the spread in VO_{2vt} had been quite large (see Gaskill et. al, MSSE 35:5, 2003) and if the current trends for work related to VO_{2vt} were consistent, this would have very serious implications on the work output for the less fit individuals.
- Although the VO_{2vt} of all individuals in this study exceeded that required by the pack test ($VO_2 = 23-25 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), subjects with higher VO_{2vt} were apparently more productive on the fireline.

CONCLUSION

Aerobic fitness level of wildland firefighters is strongly related to total work output during extended wildfire suppression over the duration of a 9-day duty cycle.

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