

Changes in Sustained Aerobic Fitness During a Season of Arduous Wildfire Suppression.

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General Summary:

12 members of a Type 1 Hotshot crew were evaluated for aerobic fitness before, during and after the 2002 wildfire season. All crew members had passed the arduous pack test and completed physical training. Prior to heading out into the field there was a wide range in sustainable aerobic fitness between firefighters. Sustainable aerobic fitness is the maximal work output that an individual can sustain for an extended period of time. In science terms sustainable aerobic fitness is called the ventilatory threshold.

During the first four months of the fire season the sustainable aerobic fitness level of all crew members migrated towards the work output required for the jobs that they were assigned to. The most fit crew members actually detrained and paced themselves at a lower level of work done overall by the crew than they had been doing during the off season. The lower fit crew members improved their sustainable aerobic fitness and by mid season the average sustainable fitness was $31.2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, or about 25% higher than required by the pack test. During the second half of the season sustained aerobic fitness improved slightly in all individuals.



Practical Considerations:

The pack test workload is about 25% lower than what is often required for sustained work output by Type 1 wildland firefighter crews. This does not suggest that the pack test is inadequate, but that it should be viewed as a screening tool and prospective Type I crew members should understand that the demands of the work required by Type 1 crews will often exceed that of the pack test.

Crewmembers should strive to be ready for the field work by being able to sustain a 5.5 to 6 mile/hour or hiking uphill (10% grade) with a 30 lb pack at 3 miles/hour for extended periods to meet the work output requirements of many of the tasks required by Type 1 crews. Additionally, though not evaluated in this study, upper body sustained work need to be included in the training period.

Crewmembers who are initially lower fit than the job demands will, through increased work output, increase their fitness levels to meet the requirements of the job. Activity monitor data, reported in a separate report also showed that the more fit individuals do more work on a daily and duty cycle (and probably seasonal) basis.

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Changes in Maximal and Sustained Aerobic Fitness During a Season of Arduous Wildfire Suppression.

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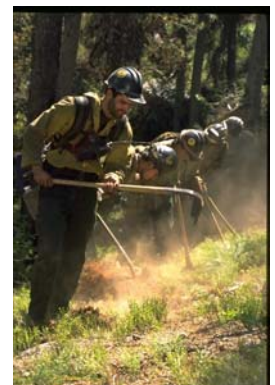
Abstract

Sustainable aerobic fitness is a key component in the determination of work capacity in wildland firefighters (WLFF). PURPOSE: This study evaluated season-long changes in submaximal aerobic fitness in a group of elite WLFF. Additionally, we were interested in the response of submaximal VO_2 at the ventilatory threshold ($\text{VO}_{2\text{vt}}$) as a marker of demands of the aerobic work requirements. $\text{VO}_{2\text{vt}}$ was evaluated as it has been shown to adapt to the requirements of sustained work. METHODS: Wildland firefighters (9 males and 1 female) from an elite hotshot crew were lab tested pre-, mid- and post-fire season (May, July, & Oct.) for $\text{VO}_{2\text{vt}}$. RESULTS: The five most aerobically fit firefighters at baseline (mean $\text{VO}_{2\text{vt}} = 33.8 \pm 3.6 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) decreased ($p < 0.05$) in $\text{VO}_{2\text{vt}}$ to $31.3 \pm 2.6 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ at the mid season and did not change thereafter. The 5 least fit crewmembers pre-season (mean $\text{VO}_{2\text{vt}} = 24.4 \pm 3.8 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) increased ($p < 0.05$) through mid-season to $31.2 \pm 4.1 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and did not change thereafter. At the mid and post-season testing there was no difference between the initially high and lower fit groups. DISCUSSION: Pre-season $\text{VO}_{2\text{vt}}$ changed within two months to meet the wildland firefighting job demands. Subjects who in the pre-season testing were more aerobically fit than required for the demands of the job detrained while those who were less fit than required improved in aerobic fitness. These data suggest that the upper requirement for sustainable aerobic fitness in WLFF is about $31.2 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ (9 METS). Though firefighters may average only 6.5 METS over the course of a day, the value of 9 METS probably better estimates the upper level of sustained work during uphill hiking, line-digging and other arduous tasks. These data suggest that the sustainable aerobic job demands for elite WLFF crews members may be higher than the mean VO_2 of $24.3 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ required by the 'pack-test' used as a screening tool for employment.

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Introduction

Changes in Aerobic Fitness over the course of a wildland firefighter (WLFF) season has been previously documented for aerobic capacity ($\text{VO}_{2\text{max}}$, but not for sustainable fitness (VO_2 at the ventilatory threshold). Sustainable fitness of the WLFF is of high interest as previous work in our laboratory has shown that more fit individuals are likely to be less prone to upper respiratory track infections, perform more work, recover more quickly and potentially be more alert during extended work shifts.



Purpose

To evaluate changes in maximal and sustainable aerobic fitness during a wildland fire season.

Methodology

Lab testing was performed preseason (May), mid season (August) and post season (October) using a calibrated metabolic cart, Parvo Medics, Salt Lake City) to assess oxygen consumption. Ventilatory threshold was evaluated using a combination of three commonly used methods (V-Slope, Ventilatory Equivalents and Excess CO_2). $\text{VO}_{2\text{max}}$ was taken as the point of volitional fatigue when respiratory exchange ratio (RER) > 1.1 , Rating of perceived exertion (RPE) 6-20 Borg Scale > 19 , Heart Rate (HR) $> 95\%$ anticipated max and a lessening in the VO_2 to work slope (plateau) was seen. Body composition was assessed using underwater (hydrostatic weighing) with residual volume using a helium dilution technique. Percent fat, and percent lean body mass were calculated from body density using age adjusted formulas from Lohman.

Subjects

Age = 26.4 ± 4.2 years

N=12

1 female, 11 males



Results

The Pre- to Mid- season period consisted of consistently hard work cycles while the second half of the season was less arduous and ended with over a month in light duty and hotel accommodations. These work assignments are somewhat reflected in the body composition and fitness data.

Figure 1 shows the changes in body mass over the course of the fire season. There was no change from pre- to mid-season, and a significant increase from pre- and mid- to post-season.

Figure 1: Changes in Body mass of 12 hotshot firefighter crewmembers over the course of the 2002 wildland fire season. Error bars represent standard deviation.

Figure 2: Changes in % Fat of 12 hotshot firefighter crewmembers over the course of the 2002 wildland fire season. Error bars represent standard deviation.

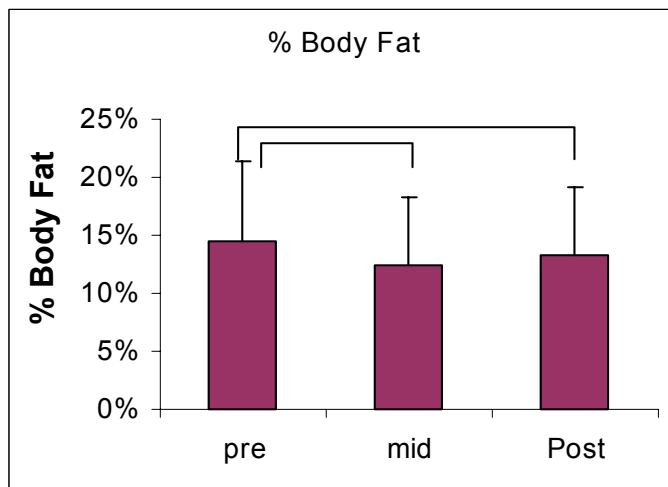
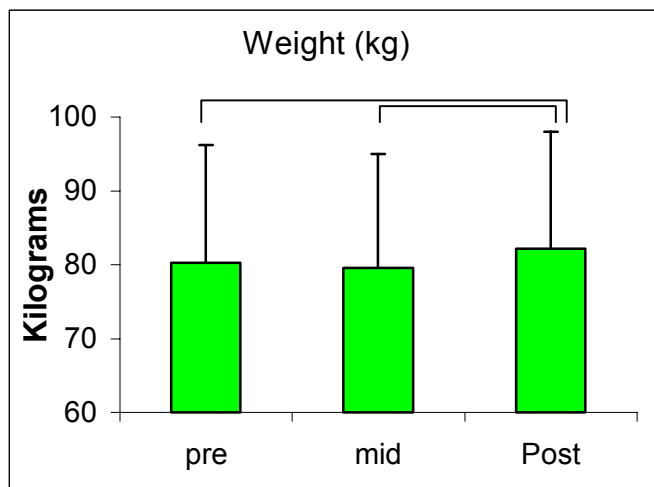


Figure 2 shows that there was a decrease in % body fat from pre- to mid season, but no change from mid- to post-season. All members of the crew remained within guidelines for healthy percent body fat.



Figure 3 shows that there was an increase in lean body mass (primarily muscles) over the course of the fire season from pre- to post-season.

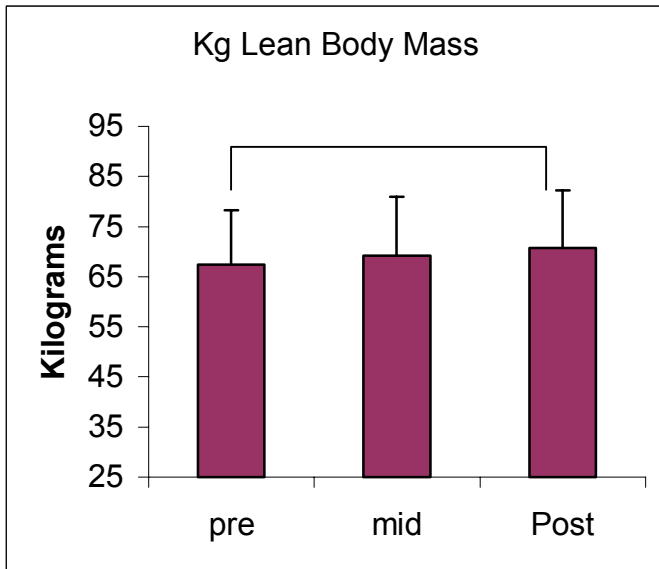


Figure 3: Changes in Lean Body Mass of 12 hotshot firefighter crewmembers over the course of the 2002 wildland fire season. Error bars represent standard deviation.



Figures 4 and 5 show group means for changes in aerobic fitness. Body weight adjusted VO_{2max} increased 13% over the course of the fire season while VO_{2vt} increased 37%, mostly during the first half of the fire season, though there were increases in VO_{2vt} during each period of the fire season.

Figure 4: Changes in body weight adjusted VO_{2max} of 12 hotshot firefighter crewmembers over the course of the 2002 wildland fire season. Bars represent standard deviation.

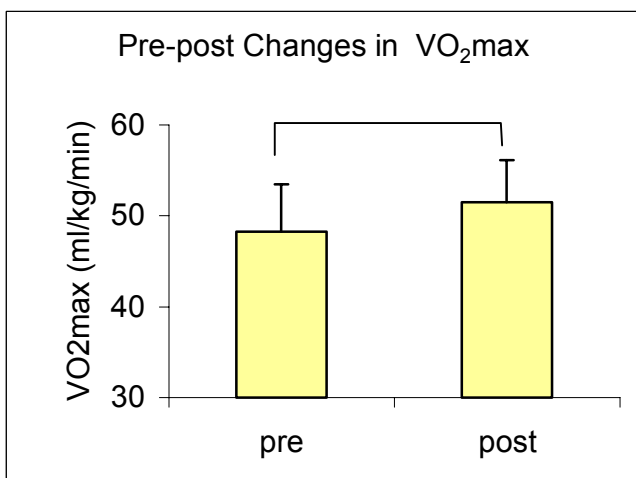


Figure 5: Changes in VO_{2vt} of 12 hotshot firefighter crewmembers over the course of the 2002 wildland fire season. Bars represent standard deviation.

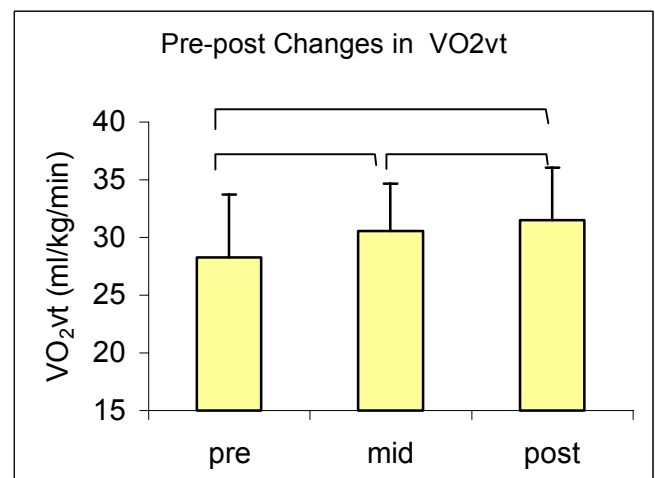


Figure 6 shows the group separated into the half of the group (n=6) with the lowest sustainable fitness ($\text{VO}_2\text{vt ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) compared to the group representing those with the highest sustainable fitness (n=6). During the first half of the fire season the sustainable fitness for the two groups migrated towards a common value of about $31 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. During the second half of the fire season both groups improved somewhat in VO_2vt .

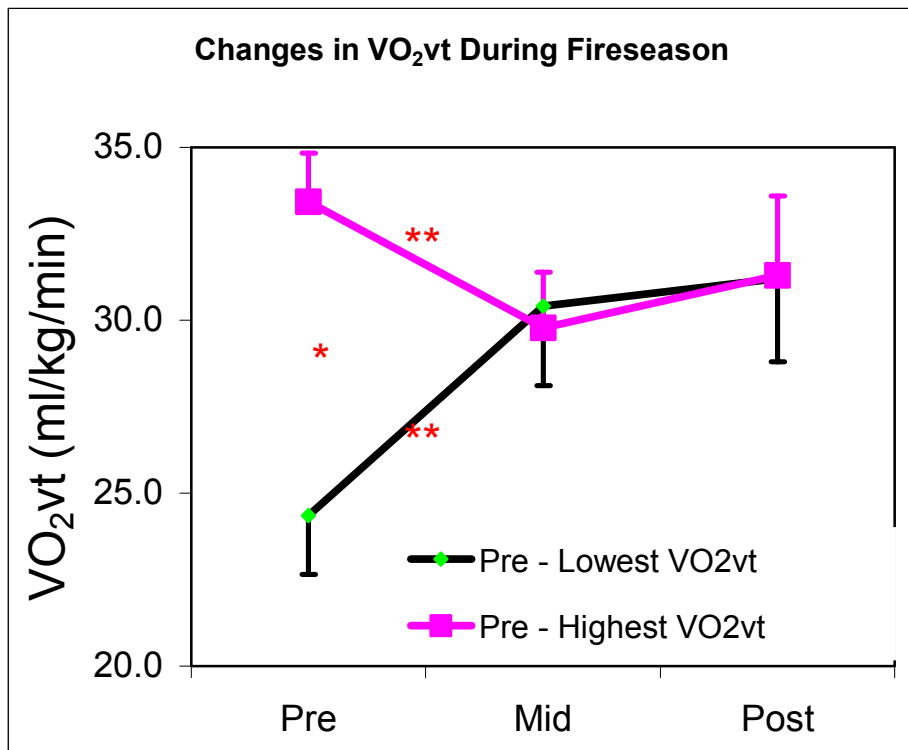


Figure 6: Changes in sustainable aerobic fitness over the course of the 2002 fire season for 12 hotshot crew members. Participants were separated into two groups of high and low baseline sustainable fitness. The single asterisk denotes that there was a significant difference at base line between the two groups. The double asterisks denote a change from pre- to mid-season. At mid and post-season there were no differences between the two groups. Crew members over the course of the 2002 wildland fire season. Bars represent standard deviation.



Discussion

Over the season there was a loss in body fat, a gain in body mass and an increase in lean body mass. The loss in body fat and increase in lean body mass seemed to be most associated with the pre-mid season work which was rated as more arduous by the crew members than the second half of the season.

Both sustainable VO_2vt and VO_2max increased during the fire season. VO_2vt has been previously shown to be a marker of the intensity of sustained work. Since the average VO_2vt increased each period this suggests that the physical work required greater physical activity than was done by crew members during the off season. However, VO_2vt migrates toward the level of sustained activity and since all crew members were required to do similar work (similar sustained VO_2 requirement) each individual's VO_2vt migrated toward a common mean of $30.4 \pm 4.2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. The higher fit individuals decreased in sustainable fitness and the lower fit individuals improved.

The tasks of wildland firefighting for hotshot crewmembers appear to require $30\text{-}32 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. The sustainable fitness levels of all crew members was above that required by the Pack Test required for WLF crew members of $22 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$.

Further research may help to understand the relationship



between work assignments and VO_{2vt} and if the $30-32 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ range found in the current study is true for other hotshot crews and duty assignments. Also, fitness levels during the season may be influenced by pre-season levels and crews with initially high levels of fitness may maintain higher work rates throughout the season while initially less fit crews may self-select lower work rates and never achieve high VO_{2vt} values.

These data suggest:

1. The Pack Test underestimates the necessary aerobic fitness required of Hotshot crewmembers.
2. The sustainable fitness (VO_{2vt}) of WLFF migrates towards the demands of the job of about $31 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ at least under the work conditions of the crew studied for this project.
3. Further research may be necessary to evaluate the effect of pre-season crew fitness and duty assignments on self-selected work rates and sustainable fitness achieved during the season.

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