Physiological Responses of Firefighters to a Flashover Training

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Introduction.

Firefighting…

- **high physiological strain** (Sothmann et al. 2004)

- **high ambient temperature whilst wearing protection gears**

- **often investigated without the presence of heat** (e.g. Davis, Dotson and Lane 1982; Bilzon et al. 2001; Rhea, Alvar and Gray 2004; Harvey et al. 2008; Perroni et al. 2010)

- **exposure to heat: additional burden for the cardiovascular system** (Barr, Gregson and Reilly 2010)
Flashover Training.

1. close simulation of a real fire scene
2. presence of heat
3. impaired visibility due to smoke
4. typical firefighting tasks such as
   stair/ladder climb
   hose run
   equipment carry etc
5. extinguishing different kind of fires (stair case
   fire, deep fryer fire, room fire)
6. extinguishing two unexpected flashovers
Flashover Training.

Flashover
= different surfaces are exposed to thermal radiation and reach their ignition temperature
  fire rapidly spreads across the enclosed area

Research objective.

Assessment of the physiological strain of a flashover training
Methods.

Subjects.

- 16 professional firefighters from Munich Airport

- Subjects characteristics:
  1. mean age: 38.9 \( \pm \) 8.9 years with a range from 26 to 53 years
  2. height: 1.77 \( \pm \) 0.1m, weight: 82.1 \( \pm \) 8.0 kg, BMI: 26.2 \( \pm \) 2.0 kg/m\(^2\)

- Equipment during Flashover Training (21.5 kg):
  1. full personal protective clothing
  2. self-containing breathing apparatus (SCBA) for air supply

- Equipment during treadmill testing:
  functional sports wear and sports shoes
Methods.

Flashover training.

- heart rate
- blood lactate

Treadmill Testing (Protocol Ellestad)

- determine the maximum of oxygen uptake \( (V_{O2peak}) \) and maximum heart rate \( (HR_{max}) \)

- determine two thresholds:
  1. ventilatory threshold 1 \( (VT1) \) and
  2. respiratory compensation point \( (RCP) \)
Methods.

Flashover training.

- used as a reference how much time subjects spent in three different physiological intensity zones during the flashover training

  (1) Zone 1 (Z1): below ventilatory threshold 1 (VT1)
  (2) Zone 2 (Z2): between ventilatory threshold 1 (VT1) and respiratory compensation point (RCP)
  (3) Zone 3 (Z3): above respiratory compensation point (RCP)
Results.

- $\text{VO}_{2\text{peak}}$: 44.4 ± 5.4 ml/min/kg
  (range 33 to 54)

- Mean completion time:
  15.50 min (± 1.22 min)

- Average HR responses:
  148 ± 13 beats per minute (bpm)
  84 ± 9.2 % of the treadmill-determined maximal HR
Results.

- Recommended minimum threshold:
  42 ml/min/kg (IAFF 2007)

Subjects with a
- $\text{VO}_{2\text{peak}} > 42$ (n= 10): 79 ± 8% of $HR_{\text{max}}$
- $\text{VO}_{2\text{peak}} \leq 42$ (n= 6): 90 ± 7% of $HR_{\text{max}}$
Results.

Similar kinetics of HR (% $HR_{\text{max}}$) during ladder climb

Beginning with the 2$^{\text{nd}}$ minute subjects with a

- $VO_{2\text{peak}} \leq 42$: worked above 80% of $HR_{\text{max}}$
- $VO_{2\text{peak}} > 42$: reached 80% of $HR_{\text{max}}$ not before the 7$^{\text{th}}$ minute

Beginning with the 7$^{\text{th}}$ minute subjects with a

- $VO_{2\text{peak}} > 42$: 86 % $HR_{\text{max}}$
- $VO_{2\text{peak}} \leq 42$: 96 % $HR_{\text{max}}$
Percentage of time spent in 3 physiological intensity zones.

### Results

<table>
<thead>
<tr>
<th>Zone</th>
<th>All 16 subjects</th>
<th>VO2 &gt; 42</th>
<th>VO2 ≤ 42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1 (%)</td>
<td>23 ± 18</td>
<td>30 ± 14</td>
<td>11 ± 10</td>
</tr>
<tr>
<td>Zone 2 (%)</td>
<td>58 ± 14</td>
<td>61 ± 12</td>
<td>52 ± 17</td>
</tr>
<tr>
<td>Zone 3 (%)</td>
<td>19 ± 19</td>
<td>9 ± 9</td>
<td>37 ± 17</td>
</tr>
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</table>
Discussion and Conclusions.

- Literature: physical strain averaged between 80% and 90% of heart rate maximum

Mean heart rate of all 16 subjects (84% of HR\text{max}) corresponded with the values presented in literature

2\textsuperscript{nd} part of training:
- Subjects with a $\text{VO}_{2\text{peak}} > 42 \text{ ml/min/kg}$ still in line with literature
- Subjects with a $\text{VO}_{2\text{peak}} \leq 42 \text{ ml/min/kg}$ averaged higher than values of other studies
Discussion and Conclusions.

- Highest energy contribution during FT: aerobic-anaerobic system (time spent between VT1 and RCP)

- High contribution of the anaerobic system in the second half of the flashover drill (time spent above RCP)

- More work effectiveness: subjects spending more time in Z1 were able to supply a greater percentage of the total energy demand aerobically
Key outcomes of our study.

The physiological strain depended on

1. Firefighter‘s VO$_{2peak}$ - level
2. Firefigther‘s capacity to supply energy aerobically

The physiological strain was significantly lower in subjects
- with a maximum oxygen uptake (relative VO$_{2peak}$) of $\geq$ than 42 ml/min/kg
- with the capacity to spend more time in the lowest physiological strain – zone (zone 1) we have defined
Practical implications.

Results showed the necessity of maintaining a high level of cardiovascular fitness

- Endurance training with a focus on enhancing ventilatory threshold 1 (VT1)
- Firefighters should possess a VO$_{2peak}$ of $>42$ ml/min/kg

Resulting in more effectiveness and less physiological strain for the cardiovascular system
Thank you very much for your attention!
References.


References.


