The comprehensive effects of occupational exposure to biomass smoke in wildland firefighters is currently not well understood. The inhalation of biomass smoke may cause adverse cardiopulmonary health effects. However, wildland firefighters are often exposed to high concentrations of biomass smoke without respiratory protection. In order for future studies to determine the need and develop effective respiratory protective apparatuses, the comprehensive exposure and health effect must first be characterized. This project utilized the strengths of in situ exposure monitoring and pulmonary health assessments to determine the effects of biomass smoke’s particulate matter (PM) on acute lung function impairment in wildland firefighters. This research assessed the personal concentrations of biomass smoke utilizing lightweighnt monitors along with portable, non-invasive methods of assessing respiratory health of wildland firefighters during active burn events. We utilized BGI-H-FPM Personal samplers and continuous particle counting monitors to determine personal exposures to PM. Changes in lung function were measured by cross-shift spirometry forced expiratory volume in one-second (FEV1), forced vital capacity (FVC), and peak expiratory flow (PEF). Cross-shift changes in inflammation biomarkers were analyzed via nuclear magnetic resonance (NMR) of exhaled breath condensate (EBC) collected pre- and post-burn. During this study, firefighters were exposed to PM ranging from 0.7 to 8.3 mg/m^3 over periods of 3 to 8 hours. We found cross-shift decreases in lung function and increases in inflammation bio-markers indicating acute lung function impairment after biomass smoke inhalation.

INTRODUCTION AND OBJECTIVES

- Firefighters comprise the largest group of public safety employees with more than 1,000,000 career and volunteer firefighters in the United States[5]. Among firefighters, smoke inhalation is the primary risk factor for work-related cardiopulmonary disease incidence, and mortality[2].
- During active fires, firefighters often work within the smoke plume to continuously manipulate the fire front. Exposures can last several days to weeks during peak season. Respiratory protection is rarely practiced due to the weight, limited air capacity, and breathing restriction of most respirators[3].
- As a result of their proximity to active fires and lack of respiratory protection, wildland firefighters are exposed to elevated levels of biomass smoke containing hazardous pollutants such as aerosolized carcinogenic chemicals and particulate matter (PM) that often exceed the occupational limits[4]. In 2010, firefighter exposures were classified as possibly carcinogenic to humans (Group 2B)[5].
- Inhaled smoke particles may trigger systemic inflammation and oxidative stress through formation of reactive oxygen species (ROS). ROS may also induce endothelial dysfunction in arteries, leading to physiological function deterioration[6].
- The comprehensive impacts of smoke exposure and the component(s) responsible for disease outcomes are not well understood[7].
- The characterization of smoke exposures and biological (or clinical) monitoring is limited due to the inherent hazards of interfering with firefighting tasks in an active wildfire environment[8]. Thus, there is a need to develop personal monitoring methods for active wildland firefighting activities.

The objectives of the study are to:
- Characterize personal particulate matter exposures concentration and size distribution;
- Measure the pulmonary health effects; and
- Determine exposure related changes in biomarker identities of oxidative stress and inflammation.

METHODS

Figure 1. Dylos 7200 continuous particle counter (L/E): Burn-site (middle), R/T (right).

- BGI-H-FPM Personal samplers and portable laser particle counting monitors were attached near the breathing zone to the shoulder-pads of line (backpack) of each participant and worn throughout the work shift to determine personal exposures to PM concentration and size distribution.
- Changes in lung function were measured by cross-shift spirometry forced expiratory volume in one-second (FEV1), forced vital capacity (FVC), and peak expiratory flow (PEF).
- Exhaled breath condensate (EBC) was collected by R-Tube pre- and post-shift. EBC is a non-invasive matrix to access the lung airways living fluid and identify biochemical and inflammatory molecules.
- Changes in inflammation and oxidative stress biomarkers were analyzed via nuclear magnetic resonance (NMR) spectroscopy. NMR-based metabolomics of EBC can uniquely recognize biomarkers that differentiate airways inflammation from associated diseases (e.g. asthma, COPD) and environmental stimuli (e.g. smoking, particulate pollution)[10].

RESULTS AND DISCUSSION

- This study determined that the biomass smoke particles are of relevant occupational health concern due to the concentration, composition, and respirable size range.
- We determined personal exposures to smoke suspended particles and the related lung function effect in firefighters during prescribed burn events.
- The post-shift FEV1, FVC, and PEF declined compared to pre-shift measures, indicating acute effects of smoke inhalation.
- Exhaled breath condensate, analyzed by NMR, can provide an effective and relatively less invasive exposure monitoring of the respiratory tract than traditional techniques.

EXPOSURE ASSESSMENT

<table>
<thead>
<tr>
<th>Exposure Variable</th>
<th>Mass, mg/m³</th>
<th>Mean ± SE</th>
<th>Cross-shift, part/cm³ Mean ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine + Coarse particle (PM 2.5)</td>
<td>1.8 ± 0.2</td>
<td>70,922 ± 49,404</td>
<td></td>
</tr>
<tr>
<td>Fine particle (PM 0.5-2.5)</td>
<td>1.5 ± 0.1</td>
<td>33,149 ± 41,545</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Particulate Matter Exposure: Particle mass and number concentration distribution

- Suspended particles larger than 0.5 µm had concentrations ranging from 0.7 to 8.3 mg/m³ over periods of 3 to 8 hours with mean exposures mass of 1.8 mg/m³. The fine + coarse particle counts ranged from 3 to 185,560 part/cm³ with an average of 39,522 part/cm³.
- The composition of particle size distribution showed to be strongly skewed to the fine size range. Fine size particles constituted the majority of the PM mass (1.5 mg/m³) and count (31,145 part/cm³) in comparison to coarse particle mass (0.3 mg/m³) and count (6,491 part/cm³).

Respiratory Function Assessment

- Lower lung function values were measured (FEV1, FVC, PEF) in participants post-shift in comparison to pre-shift.
- Average FEV1, FVC, and PEF decreased by 121 ± 5 mL and 100 ± 5 mL respectively post-shift exposure.
- Average PEF decreased 5.3 ± 10 mL post-shift exposure.

CONCLUSIONS

- This information will guide future studies on acute and chronic respiratory effects of smoke inhalation as well as provide the information needed to develop personal protective methods that effectively reduce physiological impairment due to biomass smoke occupational exposures. Future research includes:
- Examination of the cumulative effects of repeated exposure to determine the effect of recovery time and anti-oxidant regulation over time.
- Cross-evaluation of cardiovascular measures to determine acute cardiopulmonary effects.
- Further evaluate changes within specific biomarkers of oxidative stress and inflammation is still needed.

REFERENCES


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