Evolution of a Firefighter Research Program: Integrating Science and Application

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Firefighting and Injury / Illness Burden
Overview

1. **Epidemiology** of firefighter injuries

2. **Developing** collaborative research questions

3. **Results**
   a) Developing a Firefighter Physical Demands Analysis
   b) Female Firefighters and Task Approaches
   c) Injury / Illness Burden Amongst Firefighters

4. Workshop using an app to **enhance postural analysis**

5. **Take-home messages** for developing Applied Ergonomic Programs
Firefighting and Injury / Illness Burden

- Firefighting: unique occupational context to study determinants of occupational health

- Male dominant occupation = impacts on female firefighter work health (Hulett 2008; Sinden et al., 2013)

- Physically demanding, non-cyclical demands (Gentzler et al., 2010; Guidotti and Clough 1992)

- High injury rates: musculoskeletal disorders represent 1/3 of all injuries (Reichard and Jackson 2010; Walton et al., 2003)

- Mental Health (PTSD); Cardiovascular Health; Heat Stress
Context: City of Hamilton Firefighters

- Relationship = 10 years
- Stakeholders = Firefighters, Researchers, Union, Management, Occupational Health and Safety, Return-to-Work, Fire Chief, Deputy Chief
- Problem = Develop and Implement an evidence-based injury management system
- Collaborate using Integrated Knowledge Translation (iKT)
Identifying the Problem

Stakeholder Questions:

1. What are the physical demands associated with firefighter work?

2. Do female firefighters have the same / different needs compared to male firefighters?

Researcher Question:

1. What type of injury and / illnesses do these firefighters experience and how do they impact job performance?
1. Developing a Firefighter Physical Demands Analysis
Project Goals

1. Inform KT Science
   • What are the ‘key ingredients” to operationalizing iKT in an occupational research context?
   • Does the KTA Framework (as a ‘recipe’) identify ‘key ingredients’ of collaboration and knowledge synthesis during PDA development ?

2. Develop an evidence-based Physical Demands Analysis
   • Use evidence-based guidelines (i.e., OHÇOW, IAPA)
   • Develop a PDA that meets identified needs of the firefighter and relative stakeholders
The Knowledge-to-Action Framework

Graham et al., 2006, 2007
Developing the Firefighter PDA

• 4 semi-structured participatory stakeholder meetings

• 7 months

• Meetings 1 and 2 = “Knowledge Creation”
  • Participants reviewed, selected, synthesized existing knowledge sources
    • Existing PDAs, PDA guidelines

• Meetings 3 and 4 = “Action Cycle” – Identifying Barriers and Facilitators; Contextualizing Knowledge
Features of the Firefighter PDA

• Allows end-user to custom “build” with level of content to address application
  • General format vs. task specific

• Task Representation

• Provides review of potential ways to use PDA
2. Qualitative Study on the Experiences of Female Firefighters
• 3% of all firefighters are female (Hulett DM et al. A National Report Card on Women in Firefighting. www.i-women.org/images/pdf-files/35827WSP.pdf.)
  • In our cohort female firefighters = 2.8%

• Female firefighters report 33% more injuries than male firefighters (Liao et al., 2001)
Female Firefighter Work Health Themes

3. Injury / Illness amongst the Hamilton Professional Firefighters
Developing FIREWELL

- **FIREWELL = The Firefighter Injury Reduction Enterprise – Wellness Enabled Life and Livelihood**
- **Dr. Joy MacDermid (Western University)**
- **Rob D’Amico – Hamilton Professional Firefighters Association**
- **Stakeholders:** Firefighters, Union, Management, Occupational Health and Safety, Return-to-Work, Fire Chief, Deputy Chief
- **Research Collaborators and Partners**
  - Academic Researchers; Rehabilitation Professionals
- **Primary Objective:** Identify indicators associated with work health and task performance amongst Hamilton firefighters.
FIRE-Well – Protocol Overview

N = 300

Musculoskeletal Screen
- History
- Motion/Posture Scan
- Musculoskeletal Screening Survey

Functional Performance Screen (n=150)
- Hose drag
- Stair climb
- Grip strength
- Floor lift

Pain Body Diagram (IPAT)
If Applicable:
- NDI
- QuickDASH
- LEFS
- RMDQ

Surveys
- Comorbidity
- Critical Incident Inventory (CII)
- Organizational Policies and Practices (OPP)
- Work Limitations Questionnaire (WLQ)
Musculoskeletal Screen

- High rates of MSD
  - Neck (20%), back (33%), upper limb (44%), and lower limb symptoms (45%)
- Rate of MSD is high in firefighters and severity is elevated with age and tenure implicating impacts of cumulative exposures

Negm, MacDermid, Sinden, MacIntyre
(Under Review – Occ Environ Medicine)
Functional Screen - Purpose

• To identify firefighters’ physiological response and impact on task performance time.

• Implications: To develop targeted, individualized modules positioned towards injury prevention.
Data Collection: Hose Drag Task

- Firefighters performed tasks in full bunker gear (23 kg./ 50 lbs) + SCBA (18 kg. / 40 lbs)
- Pull hose to first hose coupling.
- Drag hose (18m) to second marker (12 m)
- Assume initial attack position.
- Return to start / finish.
Data Collection: High Rise Pack

- Lift high rise pack (18.1 kg / 40 lbs.) to shoulder level
- Climb all stairs as possible (10 flights; 5 up and 5 down)
Measures

• Individual Attributes
  • Age, sex, height, weight, hand dominance and tenure

• Cardiovascular Parameters
  • Heart rate, blood pressure (pre/post task)

• Strength
  • Grip strength (Bilateral)
  • NIOSH static lift

• Task performance time (DV)
  • Total time (seconds) to Hose Drag task completion
## Results: Demographic Characteristics

<table>
<thead>
<tr>
<th></th>
<th>n (%)</th>
<th>Age (years)</th>
<th>Height (inches)</th>
<th>Weight (lbs)</th>
<th>Tenure (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>143 (96.6)</td>
<td>42.1 (9.6)</td>
<td>71.0 (2.7)</td>
<td>204.5 (26.8)</td>
<td>14.0 (9.9)</td>
</tr>
<tr>
<td>Female</td>
<td>5 (3.4)</td>
<td>34.2 (6.9)</td>
<td>65.8 (1.8)</td>
<td>144.5 (17.3)</td>
<td>5.1 (3.5)</td>
</tr>
<tr>
<td>Total</td>
<td>148 (100)</td>
<td>41.9 (9.6)</td>
<td>70.9 (2.9)</td>
<td>202.5 (28.6)</td>
<td>13.7 (9.9)</td>
</tr>
</tbody>
</table>

Sinden, MacDermid and D’Amico, 2013
## Results: Physiological Response

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Completion Time (sec.)</td>
<td>76.7 (37.2)</td>
<td>146 (98)</td>
</tr>
<tr>
<td><strong>Cardiovascular Parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Pressure – Pre (mmHg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>139.1 (15.1)</td>
<td>148 (100)</td>
</tr>
<tr>
<td>Diastolic</td>
<td>86.2 (10.3)</td>
<td>148 (100)</td>
</tr>
<tr>
<td>Blood Pressure – Post (mmHg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>166.8 (21.3)</td>
<td>147 (99.3)</td>
</tr>
<tr>
<td>Diastolic</td>
<td>91.0 (14.2)</td>
<td>147 (99.3)</td>
</tr>
<tr>
<td>Heart Rate (bpm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-</td>
<td>68.1 (12.2)</td>
<td>148 (100)</td>
</tr>
<tr>
<td>Post-</td>
<td>99.4 (18.4)</td>
<td>147 (99.3)</td>
</tr>
<tr>
<td><strong>Strength Parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grip Strength (kg.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>51.5 (11.4)</td>
<td>147 (99.3)</td>
</tr>
<tr>
<td>Left</td>
<td>49.6 (10.8)</td>
<td>147 (99.3)</td>
</tr>
<tr>
<td>NIOSH Lift (kg.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 1</td>
<td>97.9 (24.0)</td>
<td>71 (48.0)</td>
</tr>
<tr>
<td>Time 2</td>
<td>92.7 (24.0)</td>
<td>71 (48.0)</td>
</tr>
<tr>
<td>High Mean</td>
<td>101.2 (23.5)</td>
<td>71 (48.0)</td>
</tr>
<tr>
<td>Maximum</td>
<td>121.3 (27.2)</td>
<td>71 (48.0)</td>
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</table>
## Results: Gender Stratified Analysis

<table>
<thead>
<tr>
<th></th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Tenure (years)</th>
<th>Grip strength (right) (kg)</th>
<th>% increase (Systolic Blood Pressure) (mmHG)</th>
<th>% increase (Diastolic Blood Pressure) (mmHG)</th>
<th>% increase in Heart Rate (bpm)</th>
<th>Hose Drag Time (sec)</th>
<th>Stair Climb Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Female</strong></td>
<td>34.2 (6.9)</td>
<td>167.1 (4.6)</td>
<td>65.5 (7.8)</td>
<td>5.1 (3.5)</td>
<td>39.2 (4.1)</td>
<td>13.7</td>
<td>2.0</td>
<td>35</td>
<td>42.5 (8.3)</td>
<td>72.1 (12.4)</td>
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<tr>
<td>(n=5)</td>
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<td></td>
</tr>
<tr>
<td><strong>Male</strong></td>
<td>42.3 (9.5)</td>
<td>180.1 (6.3)</td>
<td>92.3 (11.0)</td>
<td>14.0 (9.8)</td>
<td>54.1 (11.2)</td>
<td>22.0</td>
<td>5.3</td>
<td>46.9</td>
<td>50.0 (13.8)</td>
<td>64.5 (14.0)</td>
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<tr>
<td>(n=104)</td>
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*Female firefighters seem to tolerate physiological demands better than male counterparts*
Next Steps!

• Stratified gender analysis supports continued focus on training (cardiovascular and strength training)
  • Differential gendered approach may be warranted

• Improved understanding of firefighter task performance determinants
  • Height, elevated pre-task systolic blood pressure, NIOSH-Max floor lift associated with improved task performance time

• Firefighting training programs focused on improving strength may improve firefighter task performance
Using Dartfish and Video inputs

Journal of Ergonomics

Research


Kathryn E. Sinden1, Joy C. MacDermid1,2, Thomas R. Jenkyn1,2, Sandra Moll1 and Robert D’Amico3

1McMaster University, School of Rehabilitation Science, 1400 Main Street West, MS-103, Hamilton, Ontario, Canada

Results: Fire-fighters demonstrated 150° ± 12° of left knee flexion, 150° ± 13° of right knee flexion and 98° ± 17° of trunk flexion when lifting a high-rise pack from floor to shoulder level. Hip vertical displacement was 19% ± 8% when normalized to the individual’s height. Absolute reliability results indicated that fire-fighter knee postures could be assessed within 5° and trunk postures within 9° when using Dartfish.

Conclusion: Although measurement reliability of trunk and knee angles was comparable to previous studies, accuracy limitations and methodological challenges were identified. Protocol recommendations to optimize reliability and interpretability include focusing on using positional coordinates to identify hip displacement; further research to validate this approach is suggested. Implications include measuring impacts of ergonomic interventions designed to modify fire-fighter task performance strategies in response to known injury risk factors.
Development of Individualized Injury Prevention Strategies Mediated by Age and Gender

What we did:

• Used Dartfish to analyze movement patterns based on height/weight, age or gender

• Measured physiological response using Zephyr BioHarness

• Surveyed firefighters about gender, critical exposures and work limitations
00:02 Initiating Lift

Note extended position of right knee (highlighted in red). Try to keep lower extremities aligned (foot, ankle, knee, hip). Neutral shoulder and upper body alignment over high-rise pack. Low trunk and knee angles suggest more knee flexion and less hip flexion further indicating use of legs to support weight of high-rise pack (HRP).

00:03 Initiating vertical translation of HRP

Wide (shoulder width) hand placement will facilitate placement of HRP on shoulder at top of lift. Higher knee angle translates to forward trunk posture. More of the HRP weight will be translated through the lower back and trunk. Use more leg strength to support object weight.

00:03 Mid-point of HRP vertical translation

The circle is representing the trunk posture from a frontal position that is more easily seen in the side camera position. Note the increasing knee angle and decreasing forward trunk angle.
Current Work

00:01 Initiating Lift
Establishing lower body position to initiate lift.

00:02 Stance and hand placement
Note high knee angle and low hip angle increasing risk of injury to low back and upper extremities. Note narrow stance and hand placement (highlighted in yellow circle).

00:03 Trunk position during lift
Note stooped back and high knee flexion. At this point in the lift lower knee flexion angles (around 90 degrees) and neutral trunk posture would reduce risk of strain/sprain injuries to the low back and shoulders.
Workshop: Using the Dartfish App

Step 1: Click the “+”

Step 2: Click “Video”

Step 3: Click “Arrow”
Workshop: Using the Dartfish App

Step 4: Choose Format

Step 5: Edit Placement of angles
- Take a “picture”
1. Identify 4 “participants” and 4 “recorders”.

2. Record each participant demonstrating one of each of the following exercises.

3. Identify opportunities to improve posture / mechanics.

4. Provide the feedback on the app.

5. Communicate the feedback to your “client”.

6. Ask your “client” to perform the exercise a second time after receiving the feedback.

7. Record the video and compare the “Pre” and “Post” mechanics.
Workshop: Using the Dartfish App

Questions:

1. What did you find beneficial about using the App as a way to give feedback?

2. What did you find challenging?

3. How might you incorporate using a method like this into your clinical practice?
Current Work

• Developing a website as a community of practice for firefighters
I. Take Time to Build Relationships

- Collaborative research requires trust between researchers and employers
- Trust develops over time
- Start small and build to bigger projects

Sinden and MacDermid, 2014
II. Keep the Working Groups Small and Meet Often

- Maintain a regular meeting cycle
- A smaller group (4-5 participants) facilitates communication and maintains group focus on the project goal
- Logistics of conducting a meeting with multiple stakeholders can often complicate progress
- Challenging when stakeholders are represented at different meetings to retain transparency

Sinden and MacDermid, 2014
Take-Home Messages: Working with Stakeholders in Applied Ergonomics

III. Allow Design of Protocol to be Collaborative

• Ensures outcomes are relevant to the stakeholders and knowledge users
• Allow collaborators to “drive” research agenda
• Strength of both firefighter and paramedic research

Sinden and MacDermid, 2014
Take-Home Messages: Working with Stakeholders in Applied Ergonomics

IV. Engage intermediaries in research

- Multiple stakeholders with very strong union presence
- Contentious issue with significant implications for workers and management
- A Neutral Facilitator to mediate meetings / discussions may be helpful to facilitate objectivity in tool development agenda
Current Work

Healthy and Productive Work (HPW) Joint Initiative
Acknowledgements

• Rob D’Amico – Hamilton Professional Firefighter Association
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