FIREWELL

Measuring, Analyzing and Retraining Movement using Occupationally Valid Evaluations (M.O.V.E.)

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KEY FINDINGS

- *Monitoring physiologic responses that identify fitness and system stress is possible with applied technologies designed to meet the rigours of firefighting.*
- *Technology-enabled evaluation of occupational tasks have the potential to identify injury risk during field and simulated firefighting tasks.*

BACKGROUND

- Firefighters (FF) incur high rates of cardiovascular and musculoskeletal stress during training and fire suppression tasks.
- It is challenging to understand these risks in a contextually valid manner that includes full equipment and actual job tasks.

OBJECTIVES

- Test whether a wearable technology (Zephyr BioHarness) can monitor FF physiologic changes and fitness levels.
- Identify relevance and validity of a musculoskeletal risk assessment tool (OWAS) and video analysis software (Dartfish) in assessing firefighting tasks.

PHASE 1 (PHYSIOLOGIC MONITORING): METHODS

Our development work established that the Zephyr BioHarness is a reliable and valid device in the general population.[1,2]

Part 1 – Fitness Testing[3]

- Participants: n = 49 Hamilton FF (46M, 3F; Mean age = 33.7 (SD = 9.0)); n = 40 healthy controls (20M, 20F; Mean age = 39.0 (SD = 11.0)).
- The Zephyr BioHarness device monitored heart rate and respiratory rate and quantified aerobic capacity ($\dot{V}O_2$ max) levels during a submaximal fitness test.
- Data analyses: Wilcoxon rank sum tests (differences between groups). Standardized response mean (SRM; magnitude of difference between groups). Regression analyses (age and gender effects on aerobic capacity).

Part 2 – Simulated Firefighting Tasks[4]

- The Zephyr BioHarness monitored the same cohort of FF physiological responses during a simulated hose drag and stair climb with a high-rise pack.
- Data analyses: Pearson correlation coefficients (fitness parameters vs. task completion times). Regression Models (factors predicting task completion times).

PHASE 1: RESULTS

- The $\dot{V}O_2$ max levels among FF and the general population did not vary significantly (median difference = 4.20; SRM = 0.48).
- Age had a statistically significant impact on FF $\dot{V}O_2$ max levels ($p < 0.001$).
- No gender effect was detected in the FF ($p = 0.300$).
- Near maximal heart rates of ≥ 88% of heart-rate maximum were recorded during the two tasks (See Table 1).
- Higher aerobic capacity levels were associated with faster task completions times with correlation coefficients of ≤ -0.30.
- Age, sex, resting heart rate and upper body/lower body strength levels have similar and moderate predictive values in task completion times (Model r^2 = 0.24-0.25; SE = 13.10-13.55).

PHASE 1 : CONCLUSION

- Zephyr is a wearable device designed specifically to meet the demands of firefighter tasks. It could take reliable and responsive measurement of fitness while assessing submaximal fitness in firefighters.[1-3]

Variable	N	MEAN	SD	MAX	MIN
Heart rate at rest (bpm)	49	73.94	10.66	95.52	61.45
Heart rate at hose drag (bpm)	49	163.00	16.00	195.00	125.00
Respiratory rate at hose drag (brpm)	49	27.00	4.00	40.00	23.00
HR-max % at hose drag (HR-max %)	49	88.00	8.00	106.00	64.00
Rating of perceived exertion hose drag (0-10)	49	1.78	1.10	5.00	1.00
Time elapsed to complete hose drag (seconds)	49	59.00	15.00	100.00	33.00
Heart rate at Stair Climb (bpm)	49	166.00	13.00	197.00	137.00
Respiratory rate at Stair Climb (brpm)	49	31.00	4.00	41.00	25.00
HR-max % at Stair Climb (%)	49	89.00	7.00	102.00	69.00
Rating of perceived exertion Stair Climb (0-10)	49	2.70	1.40	6.00	1.00
Time elapsed to complete Stair Climb (seconds)	49	59.00	14.50	93.00	30.00

Table 1: FF Physiologic Responses & Task Completion Times

PHASE 2 (ERGONOMIC ASSESSMENT): METHODS

- Physiotherapists and a kinesiologist assessed videos of firefighting tasks (n=20) using the Ovako Working Postures Assessment System (OWAS).
- Data analyses: Reliability statistics (Cohen's kappa with quadratic weighting).

PHASE 2: RESULTS

- Simple, static posture (Fig. 1) showed very good OWAS inter-rater reliability (Fig. 2).
- Complex, dynamic postures (Fig. 1) had poor to moderate OWAS inter-rater reliability (Fig. 2).

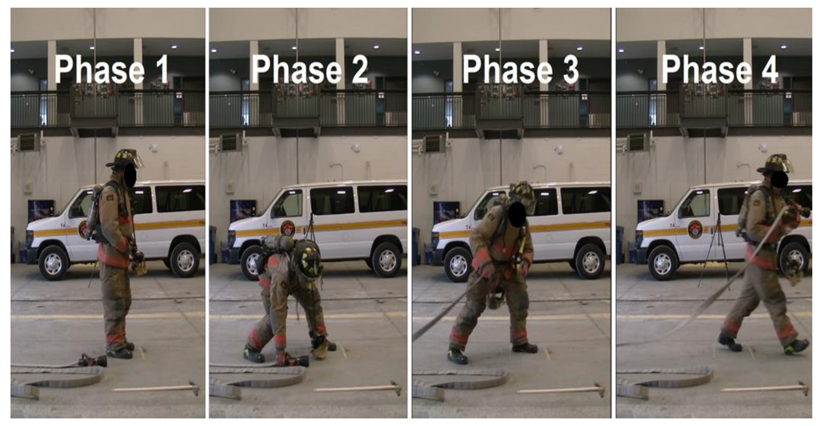

Figure 1: Phases of the Hose Drag Task

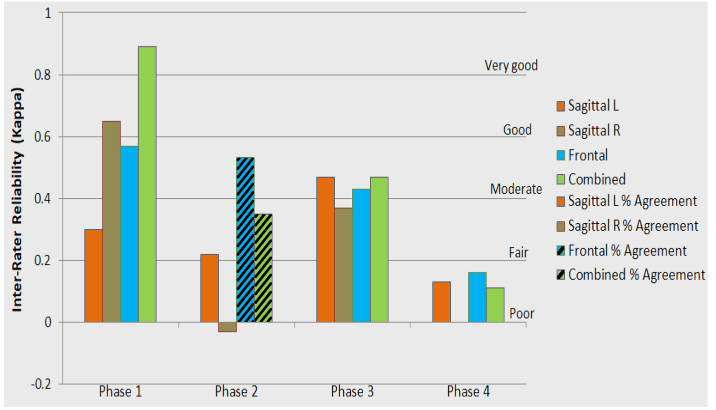

Figure 2: Inter-Rater Reliability between Camera Views

PHASE 2: CONCLUSION

- OWAS measured gross movements related to anatomical regions which may have limited the specificity of the assessment particular during complex movements.
- Combining video from multiple planes (i.e., sagittal and frontal) was associated with higher reliability, however, this may not always be feasible in applied contexts.
- Training on assessment of firefighter tasks analysis will be needed to improve reliability.
- Video analysis may be a way to improve reliability and precision for MOVE analyses.

PHASE 3 (KINEMATIC ANALYSIS): METHODS

- Dartfish movement analysis software was adapted to measure firefighters' movements and postures from video-based inputs.
- Technology-Enabled Analysis of Movement and Feedback (TEAM-Feedback) integrates ergonomic principles with annotation features of Dartfish.
- Kinematic analysis includes measuring angles during dynamic and static postures, as well as horizontal and vertical displacement of anatomical segments.

PHASE 3: RESULTS

- TEAM-Feedback can be refined and disseminated using features of Dartfish including Dartfish TV and / or the Dartfish App.
- This information can be used to identify group level or individual risks and to re-train task performance.
- TEAM-Feedback Examples (Fig. 3 & 4):

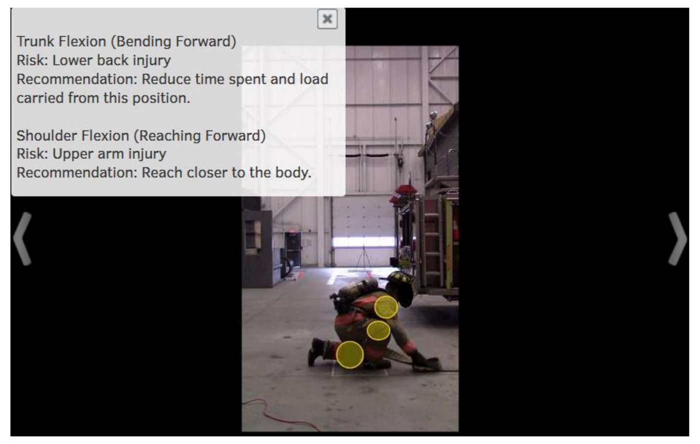

Figure 3: TEAM-Feedback for Hose Pull

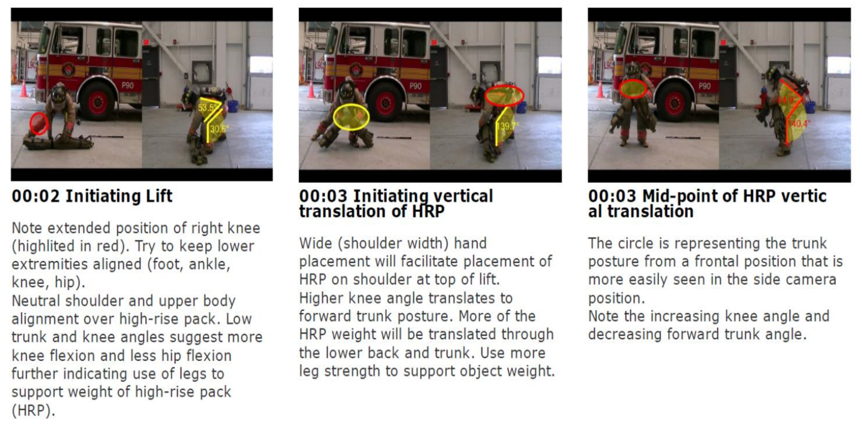

Figure 4: TEAM-Feedback for High-Rise Pack Lift

PHASE 4: NEXT STEPS

Next Research Steps

- Using monitoring during tasks and shift changes to determine physiologic burdens.
- Developing web-based educational tools towards reducing injury risk.

Capacity Building and Collaboration

- Developed with support from CIHR-SSHRC a national FIREWELL partnership engaging 15 new collaborators/partners across Canada to address firefighter research.
- Five graduate trainees have worked with firefighter researchers in the Hamilton Fire Service.
- Firefighters are taking a lead role in research on their health.

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