

REMOTE MONITORING AND WEARABLE TECHNOLOGIES

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UNIVERSITY

FIREFIGHTING AND INJURY / ILLNESS BURDEN

- Firefighting: unique occupational context to study determinants of occupational health
- Physically demanding, non-cyclical demands
- High injury rates: musculoskeletal disorders represent 1/3 of all injuries
- Mental Health (PTSD); Cardiovascular Health; Heat Stress

THUNDER BAY FIRE RESCUE (TBFR)

- Medium-sized, professional fire service
 - Largest and busiest professional fire service per-capita in Ontario
- Thunder Bay population: approx. 110,000 people
- 4 platoons; 8 fire stations ($n = 190$)
- Urban and rural emergencies
- 5 year research partnership
 - Successful completion of a series of projects



CRITICAL INCIDENT EXPOSURE

- Work-related trauma exposure
- Causes:
 - Emotional, psychological, &/or physical distress/impacts
 - Inability to properly cope
 - Inability to properly perform job
- 85-91% experienced within last 2 months
- 92% will experience within career
- ↑ risk for developing mental health disorders
 - Posttraumatic stress disorder

Calls with excessive media attention

Injury/death of children

Personal loss/injury

Mission failure

Human error

Natural disasters

Pandemics

POST TRAUMATIC STRESS DISORDER

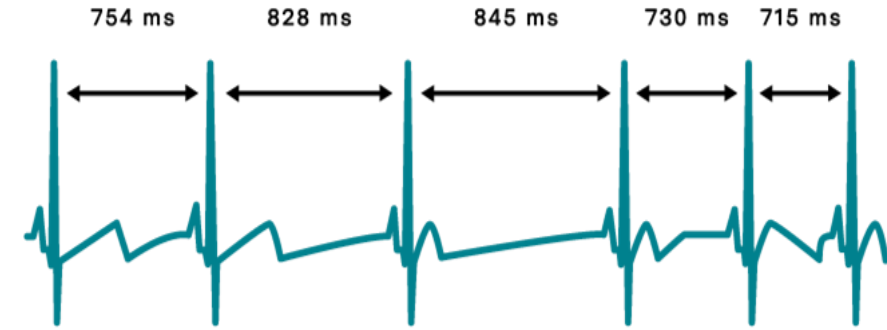
- Mental health disorder
- Often experienced following traumatic exposures (i.e., CIs)
 - 44.5% firefighters experienced mental health disorders
 - 23.2% diagnosed with PTSD
 - 35% firefighters will develop PTSD symptoms
- Top 5 causes of lost-time and workplace disability claims among Canadian firefighters
- ↑ stigma = underreporting



HEART RATE VARIABILITY (HRV)

- Heart Rate (HR) = # of heartbeats
- HRV = time (ms) between consecutive heartbeats
- Cardiac autonomic modulation (biofeedback)
- Autonomic (ANS) regulation between sympathetic (SNS) and parasympathetic nervous system (PNS)
 - Sympathovagal balance/imbalance
 - Psychophysiological factors (i.e., stress, gender, age)

$$\text{Stress} = \uparrow \text{HR} (\uparrow \text{SNS} + \downarrow \text{PNS}) = \downarrow \text{HRV}$$




HEART RATE VARIABILITY AND MENTAL HEALTH

- Indirect measure of the ANS providing insight into adverse mental health measure
- Firefighters with PTSD = \uparrow HR = \downarrow HRV
- CI exposure = \uparrow Stress = \uparrow PTSD risk
 - \uparrow HR = \downarrow HRV
- Identifying HRV to assess the sympathovagal balance/imbalance




METHODOLOGICAL APPROACH

- HRV influenced by multiple physiological and confounding factors
- Review of literature identified that confounding variables influencing HRV are often not controlled
- Consider type of device specific to application (i.e., intrinsically safe device for firefighters)




A Guide to Using Heart Rate Variability to Identify Mental Health Risk




HRV IS ASSOCIATED WITH WORSENERD MENTAL HEALTH IN PUBLIC SAFETY PERSONNEL IN THE MAJORITY OF STUDIES

84% (n=16)

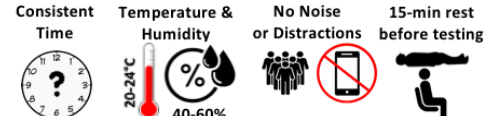


STEP 1: BASELINE TESTING STANDARDIZATION


Account for HRV Confounds



Account for Testing Environment




STEP 2: STUDY DESIGN

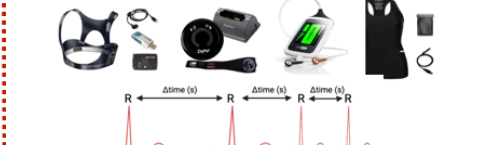


STEP 3: CHOOSE DEVICE TO MATCH MEASUREMENT & ANALYSIS NEEDS

A. WATCHES, RINGS & BANDS: Measure pulse via Photoplethysmography (PPG)



B. HOLLERS & SHIRTS: Measure pulse more accurately via electrocardiogram (ECG)



ANALYSIS TYPE	Measurable with devices described above:	A	B
Time Domain: average variability of PPG or ECG heart rate overtime. <ul style="list-style-type: none"> Less precise, but more practical. Use when monitoring daily activity. 	Standard Deviation of NN Intervals (SDNN): 24 hours Root Mean Square of Successive Differences (RMSSD): 5 min – 24 hours		✓
Frequency Domain: ECG variation in bands. <ul style="list-style-type: none"> High precision, but less practical. Use for lab testing. 	High Frequency (HF) .15hz - .4hz: 1 min Low Frequency (LF) .04hz - .15hz: 2 min LF:HF Ratio: 24 hours	✓	✓

STEP 4: COMPARE HRV DURING INTERVENTION TO BASELINE

Risk for worsened mental health is identified by changes that represent higher sympathetic nervous system activity (higher stress):

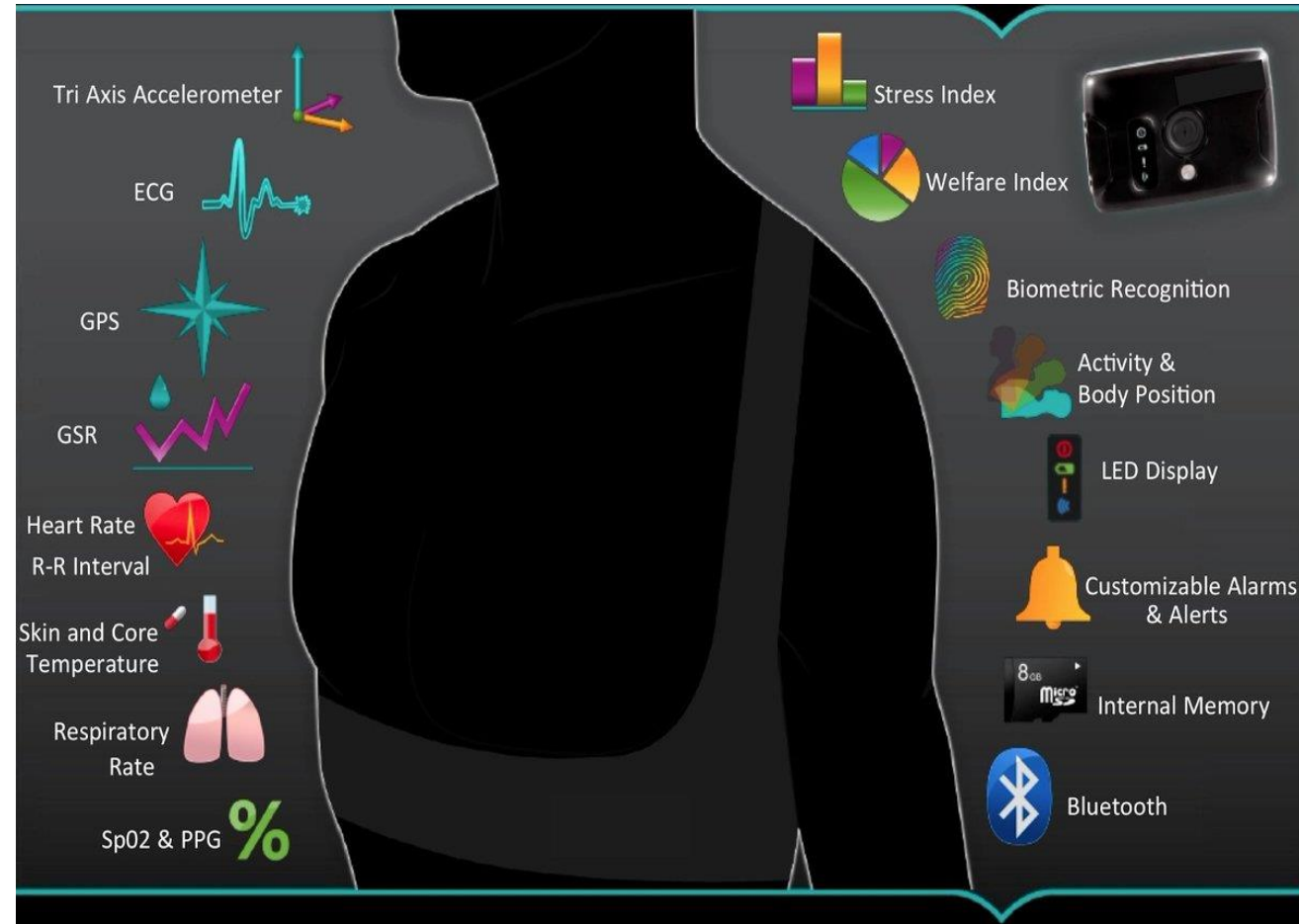
↓ SDNN
↓ RMSSD
↓ HF
↑ LF
High LF:HF ratio

METHODOLOGICAL APPROACH

Posttraumatic Stress Disorder
Checklist for the DSM-5

Self-Report Activity Diary

Wearable Technology
(Zephyr Bioharness / Equivital© EX eq02+
LifeMonitor)



METHODOLOGICAL APPROACH

Equivital© EX eq02+ LifeMonitor



Belt Size	Chest Circumference Measurement User Physique: Narrow build	Chest Circumference Measurement User Physique: Broad build
Size 1	74 - 79 cm	74 - 76 cm
Size 2	79 - 84 cm	76 - 81 cm
Size 3	84 - 89 cm	81 - 86 cm
Size 4	89 - 94 cm	86 - 91 cm
Size 5	94 - 99 cm	91 - 96 cm
Size 6	99 - 104 cm	96 - 101 cm
Size 7	104 - 109 cm	101 - 106 cm
Size 8	109 - 114 cm	106 - 111 cm
Size 9	114 - 119 cm	111 - 119 cm

Date: / / ID Code:
dd mm yyyy

Participant Diary Form

Start Date: End Date:

Resting HR (Radial/10s):

Time	Activity
7:30 - 8:30	
8:30 - 9:30	
9:30 - 10:30	
10:30 - 11:30	
11:30 - 12:30	
12:30 - 13:30	
13:30 - 14:30	
14:30 - 15:30	
15:30 - 16:30	
16:30 - 17:30	
17:30 - 18:30	

1/2 A pilot study to identify the impacts of firefighting on firefighter work health
Version 2 (July 3, 2018)

Date: / / ID Code:
dd mm yyyy

18:30 - 19:30	
19:30 - 20:30	
20:30 - 21:30	
21:30 - 22:30	
22:30 - 23:30	
23:30 - 00:30	
00:30 - 1:30	
1:30 - 2:30	
2:30 - 3:30	
3:30 - 4:30	
4:30 - 5:30	
5:30 - 6:30	
6:30 - 7:30	

2/2 A pilot study to identify the impacts of firefighting on firefighter work health
Version 2 (July 3, 2018)

- Baseline testing
 - Control for behavioural and environmental confounds
- Control for behavioural confounds
 - HRV Confound Diary
- Time-domain frequency
- Medical-grade ECG
 - Valid & reliable measuring occupational multiparameter physiological status
 - HR and interbeat intervals (IBI) of the N-N intervals (bpm)
- Normalization & analysis:
 - Equivital© Manager & Microsoft© Excel
 - Standard deviation of the N-N interval (SDNN)

METHODOLOGICAL APPROACH

Equivital© EX eq02+ LifeMonitor

- Pilot study
- Volunteers from participants ($n=10$)
- Long-term indices
 - 2x 24 hrs/day
 - 1 day on shift; 1 day off shift
 - 4 platoons
 - 2 new recruits
- Completion of the HRV Confound Diary for each day
 - Determine areas of interest

Collection Conditions	Areas of Interest
Prior to shift	Exercise
On shift	Rest
After a shift	Major event

- Absence/presence of psychophysiological stressors
 - Identify sources that can potentially impact HRV

DATA PROCESSING

Wearable Technology

- Download data files
- Export key metrics per participant (HR, HRV, BR)

Task Classification / Confounding variables

- Review HRV confound diaries
- Identify common tasks / confounding variables

Data Merge

- Link diary with physiological data
- Exported per task / per participant

DATA PROCESSING

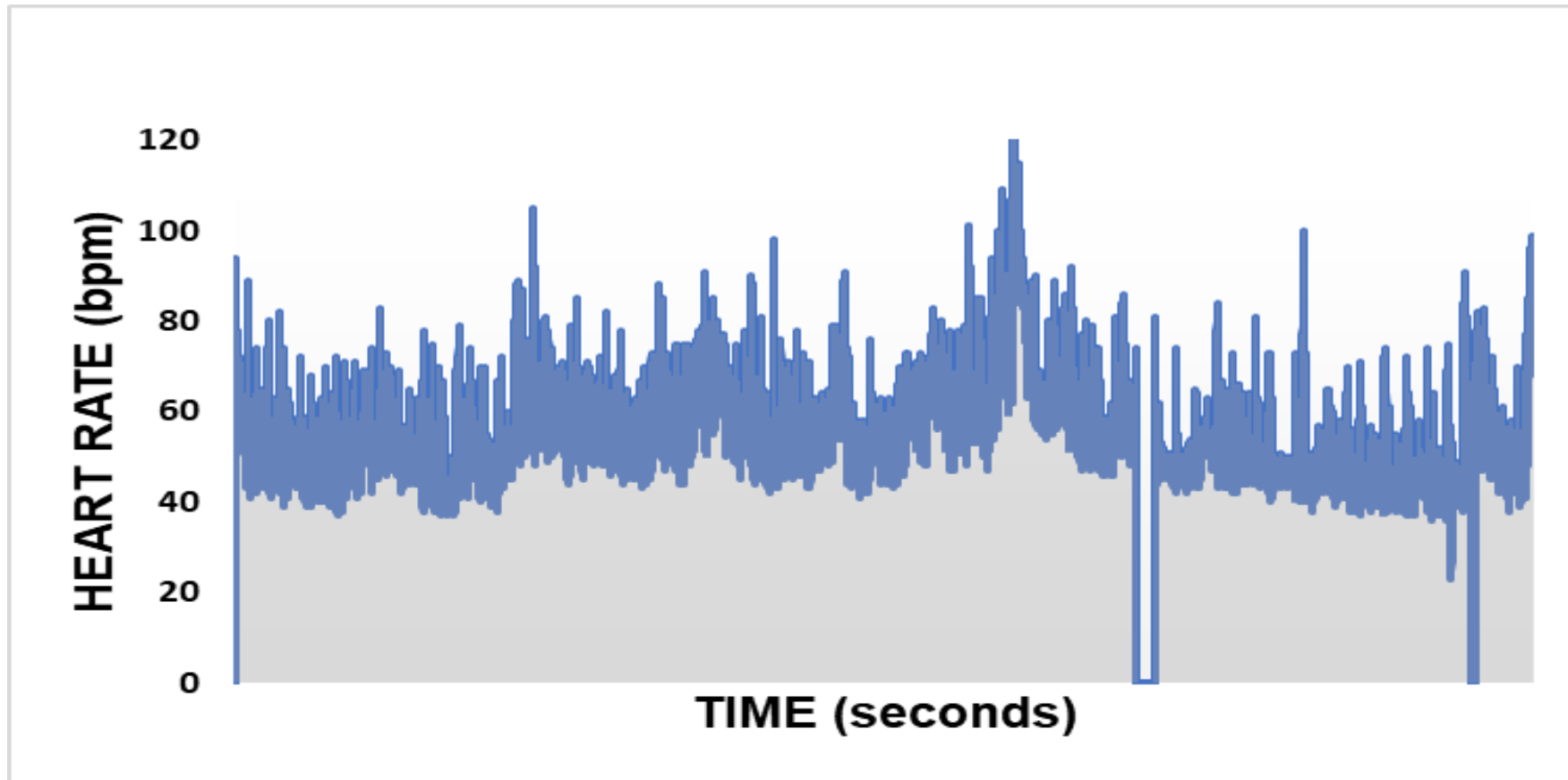


Figure 1: Participant heart rate data (raw) – 1 x 24 hour shift

STATISTICAL ANALYSIS

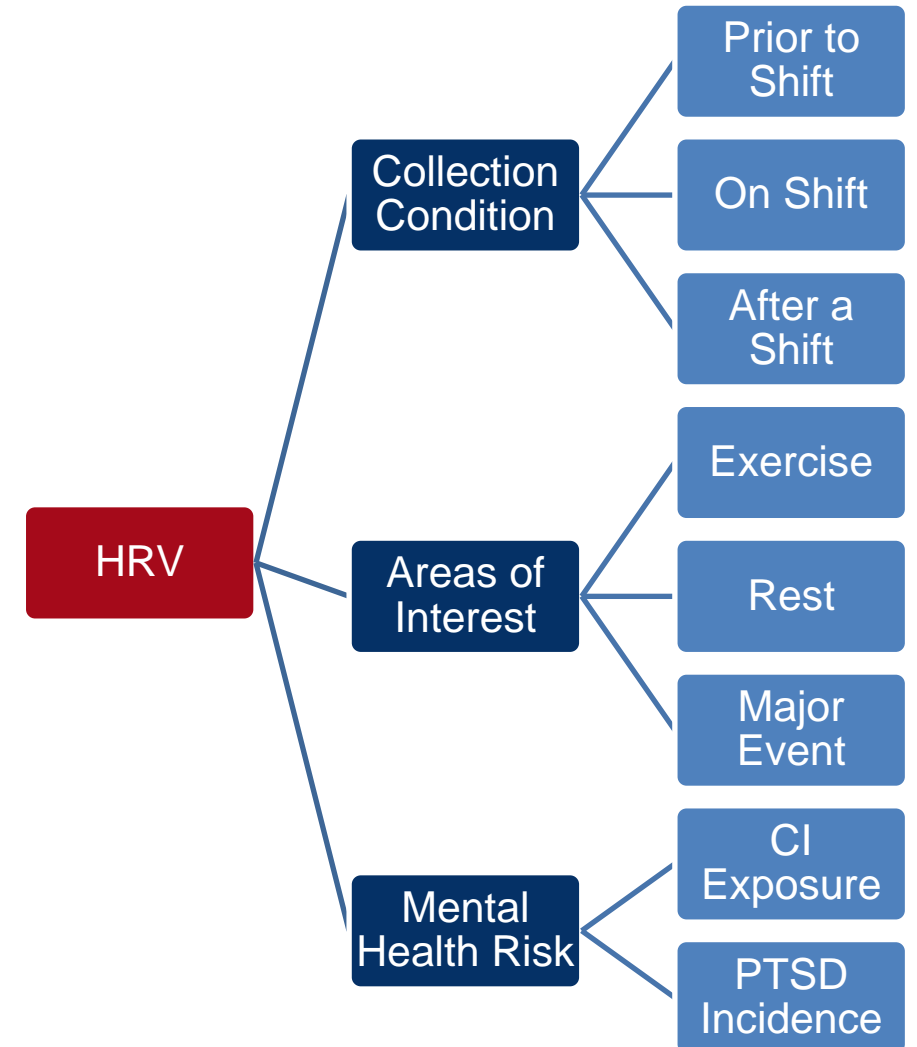
Per Participant

- Descriptive statistics (Mean, SD Min, Max) for each metric (HR, BR, HRV) and for each task



Per Task

- Descriptive statistics (Mean, SD Min, Max) for each task / confounding variable



DATA PROCESSING

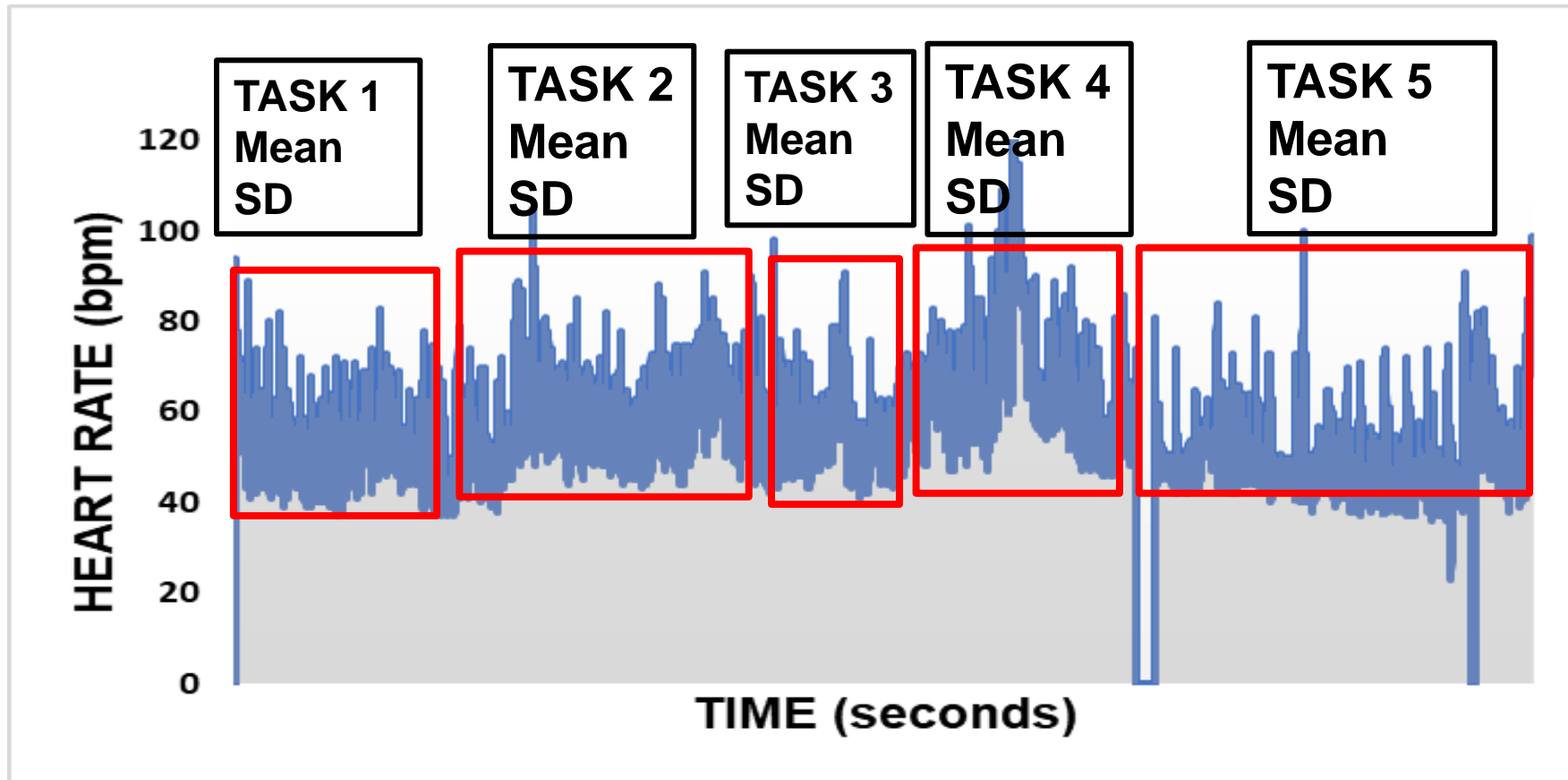


Figure 2: Partitioning Participant HR Data per Task

RESULTS

	Number of Participants (%)
Station Duties	10 (100%)
Fire Response	3 (30%)
Fire Response – False Alarm	6 (60%)
Rescue / Medical Call	4 (40%)
Public Relations	3 (30%)

Table 2: Firefighting **Task Categories** (number of participants who reported performing task at least once in one 24-hour shift)

RESULTS

DUTIES	Mean +/- (SD)	Max.	Min.
Station Duties	69.7 (9.1)	107.3	47
Fire Response	96.7 (14.9)	153.7	56.7
Fire Response (False Alarm)	68.9 (10.1)	103.8	49.5
Rescue / Medical Call	77.3 (15.1)	132.4	49.6
Public Relations	69.3 (9.1)	105	47.5

Table 3: Physiological Response (**Heart Rate (bpm)**) stratified per task; during 1x24 hour shift

RESULTS

DUTIES	Mean +/- (SD)	Max.	Min.
Station Duties	72.2 (22.0)	146.2	37
Fire Response	64.4 (39.4)	207.7	8.7
Fire Response (False Alarm)	90.1 (23.1)	161	53
Rescue / Medical Call	100.1 (41.8)	228.5	38.5
Public Relations	95.0 (17.8)	140.3	59.3

Table 5: Physiological Response (**Heart Rate Variability (SD in ms)**) stratified per task; during 1x24 hour shift

RESULTS

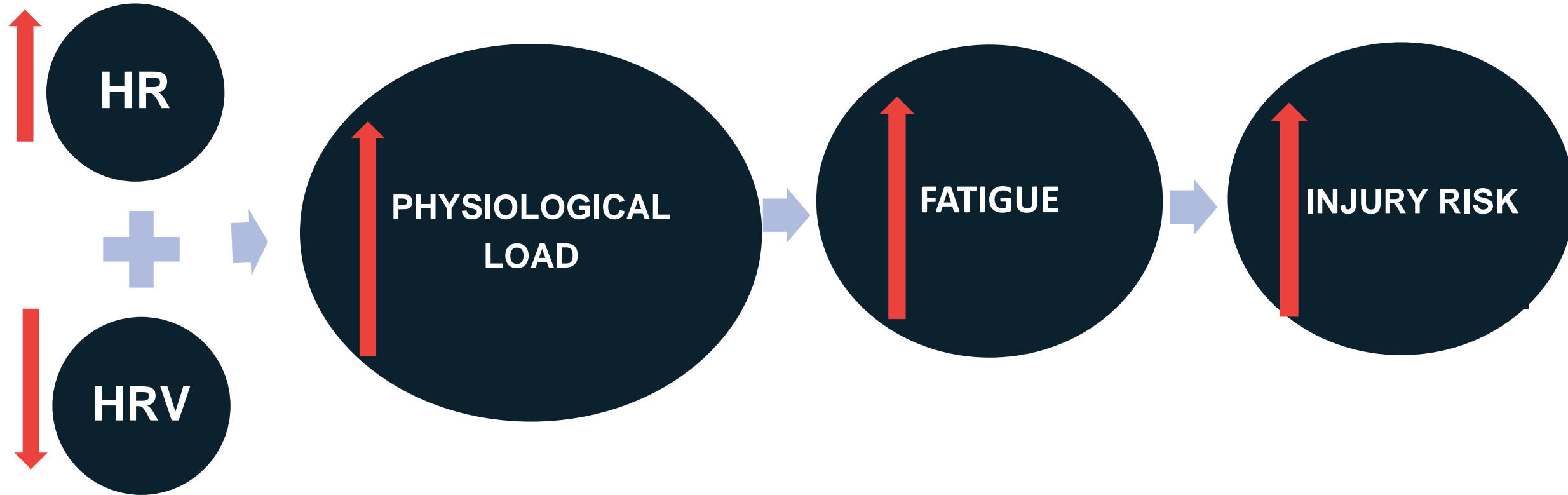
Physiological Metric	Mean +/- (SD)	Max.	Min.
Heart Rate (bpm)	96.7 (14.9)	153.7	56.7
Breath Rate (breaths/min)	21.9 (7.0)	39.6	6.3
HRV (SD – ms)	64.4 (39.4)	207.7	8.7

Table 6: Physiological Response during **Fire Response**

Physiological Metric	Mean +/- (SD)	Max.	Min.
Heart Rate (bpm)	69.7 (9.1)	107.3	47
Breath Rate (breaths/min)	16.2 (4.8)	33.8	4.9
HRV (SD – ms)	72.2 (22.0)	146.2	37

Table 7: Physiological Response during **Station Duties**

STUDY IMPLICATIONS



OVERALL IMPLICATIONS

Key Findings

- Higher physiological load associated with fire response tasks vs. other “less” physically demanding tasks
- Data collection requires logistical support (operationally)
- Data analysis (extraction and processing) is time intensive

Policy to Practice

- Establishing processes for securing biological / physiological data particularly when identifying potential injury / illness risk
- Implications for broader implication across PSP contexts
- Potential to influence both prevention and intervention strategies designed to improve mental health

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