



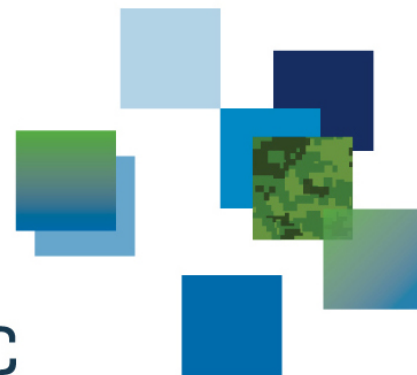
# Impact of Repeated Exposure to Low-level Blast on Health and Performance in Military Personnel: A Holistic Approach

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DRDC | RDDC

# Overview

- History and early aims of DRDC's blast research program,
- Review two sets of completed CAF studies,
  1. CANSOFCOM breachers (2011-2015),
  2. CFSME breachers (2015-2018).
- Current ongoing research with CSOR (2018-present),
  - Cross-sectional comparison of breachers *and* snipers vs. controls,
  - **Longitudinal health monitoring study.**
- Overall conclusions and future directions.

**CAF** = Canadian Armed Forces

**CANSOFCOM** = Canadian Special Operations Forces Command

**CSOR** = Canadian Special Operations Regiment








**CFSME** = Canadian Forces School of Military Engineering

**DRDC** = Defence Research and Development Canada

# History and early aims of DRDC's blast research program

- In 2011 DRDC researchers were asked to investigate the impact of repeated exposure to low-level blast among CANSOFCOM breachers.
- **Mature** CANSOFCOM breachers were exhibiting symptoms consistent with reports of blast-induced mild TBI:
  - Memory impairments,
  - Sleep disturbance,
  - Irritability and impairments in mood,
  - Headache.
- Research aim: Establish a set of measures that exhibit sensitivity to the effects of repeated exposure to low-level blast among CANSOFCOM breachers in the context of annual breaching training exercises (i.e., 4 years).
  - Control group: Non-breacher sex- and age-matched CAF controls.

# CANSOFCOM breachers (2011-2015): Study design

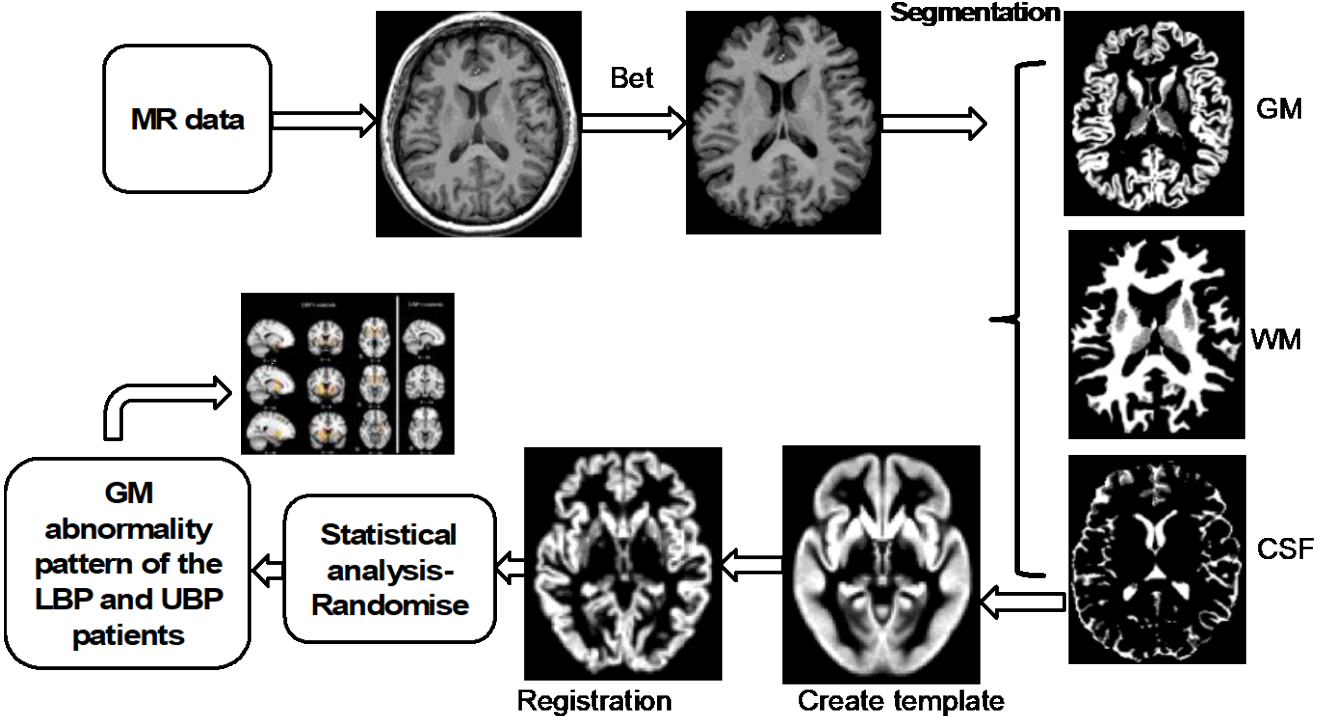
Baseline	Training exercise (4 consecutive days)	Post-training
<ul style="list-style-type: none"> <li>- Background health</li> <li>- MRI</li> </ul>  	<ul style="list-style-type: none"> <li>- Neurocognitive testing</li> <li>- Balance + ataxia</li> <li>- Postural tremor</li> </ul>    	<ul style="list-style-type: none"> <li>- MRI</li> </ul> 

n (16 [Year 1], 20 [Year 2], 20 [Year 3], 14 [Year 4])

# CANSOFCOM breachers (2011-2015): Neuropsychological results

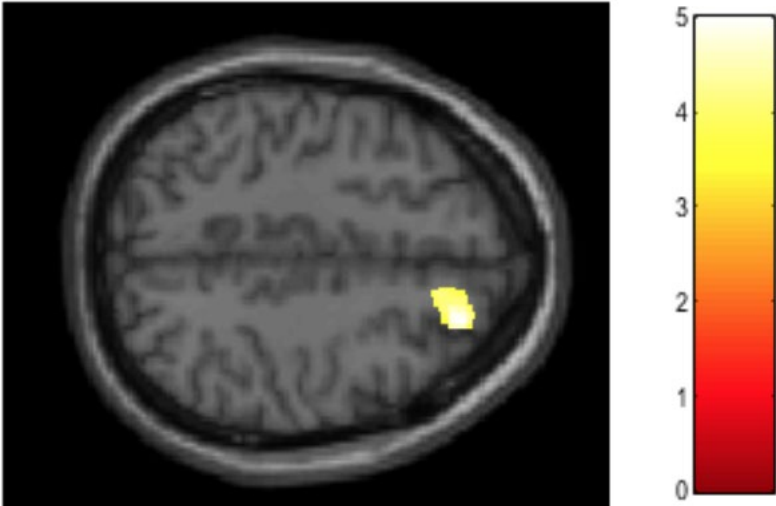
- Rivermead Post Concussion Symptoms Questionnaire:
  1. RPQ3 (early symptoms: headache, dizziness, nausea/vomiting),
  2. RPQ13 (late symptoms: sleep disturbance, fatigue, restlessness),
  3. Cognitive symptoms,
  4. Emotional symptoms.
- RAND SF-36:
  1. Physical functioning,
  2. Role limitation due to physical health,
  3. Social functioning,
  4. Energy/fatigue,
  5. General health.
- Short Musculoskeletal Function Questionnaire
  1. Dysfunction Index: Perceptions of functional musculoskeletal performance.

# CANSOFCOM breachers (2011-2015): MRI VBM analysis



# CANSOFCOM breachers (2011-2015): MRI VBM results

Superior frontal gyrus  
Brodmann Area (BA) 8



Vartanian et al. (2021)

# CANSOFCOM breachers (2011-2015): Conclusions

- Chronic (long-term) exposure to blast is associated with alterations in:
  - Neuropsychological functioning,
  - Brain structure (grey matter volume).
- No changes were detected on any measure as a function of acute exposure to blast—either pre-post training or in the field.



## CFSME breachers (2015-2018)

- In 2015 DRDC researchers were asked to investigate the impact of repeated exposure to low-level blast among CFSME breachers.
- As was the case with mature CANSOFCOM operators, **mature** CFSME breachers were exhibiting symptoms consistent with reports of blast-induced mild TBI:
  - Memory impairments,
  - Sleep disturbance,
  - Irritability and impairments in mood,
  - Headache.
- The emphasis was on the effects of chronic (long-term) exposure to blast.

## CFSME breaching environment (2015-2018)



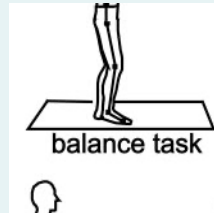
A naturalistic study using B3 gauges demonstrated that approximately 12% of blast events exceeded the 3 psi safety threshold in the CAF *Tactical Breaching Manual* (Vartanian et al., 2015).

# CFSME breachers (2015-2018): Study design

Breachers and range staff ( $n = 19$ )

Sex- and age-matched CAF controls ( $n = 19$ )

- Background health
- Neurocognitive testing
- Balance + ataxia
- Postural tremor
- **Hearing**
- **Blood**
- **Visuomotor integration**



Nakashima et al. (2021), Vartanian et al. (2020)

# CFSME breachers (2015-2018): Prior head injury

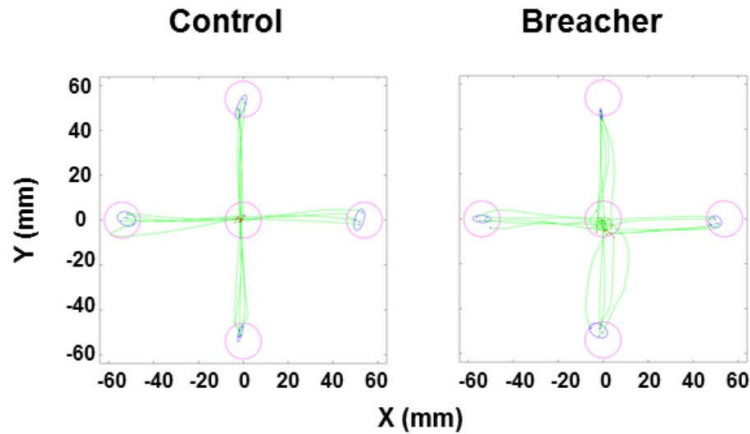
Variables	Breachers/range staff (n = 19)	CAF controls (n = 19)	Mean difference (95% CI)	Bootstrap ratio	P
Concussion	8 (44.4)	5 (26.3)	21 (-5.3-47.4)	1.5	0.088
Physical impact to head	9 (47.4)	11 (57.9)	-10.4 (-36.8-15.8)	0.7	0.402
MVA	14 (73.7)	9 (47.4)	2.6 (-5.3-52.6)	1.7	0.066
Fallen as child	8 (42.1)	6 (31.6)	10.4 (-10.5-31.6)	1	0.206
Physical fight	13 (68.4)	15 (78.9)	-10.6 (-31.6-15.8)	0.9	0.258
Blast exposure	19 (100)	2 (10.5)	89.2 (73.7-100)	12.5	<b>&lt;0.001</b>

# CFSME breachers (2015-2018): Neuropsychological results

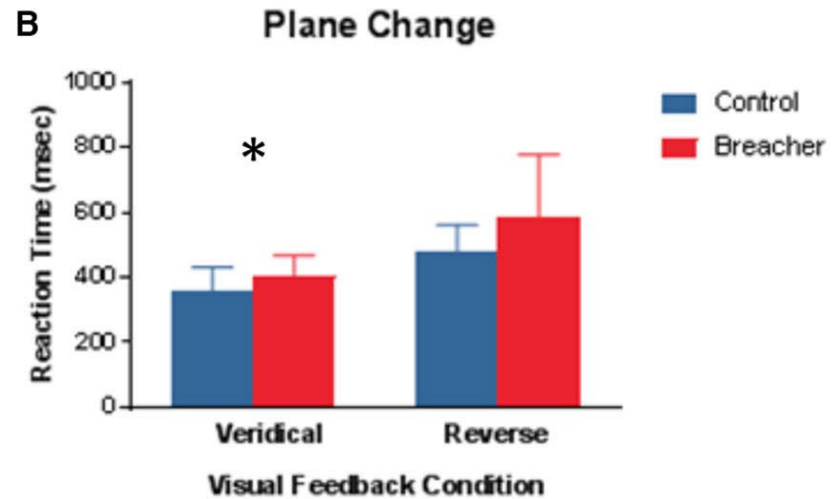
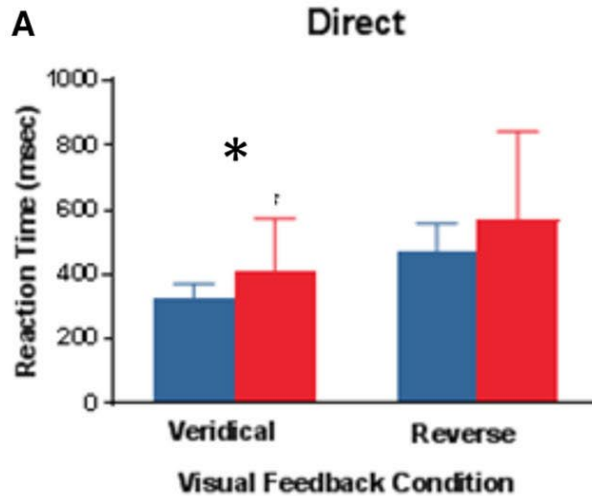
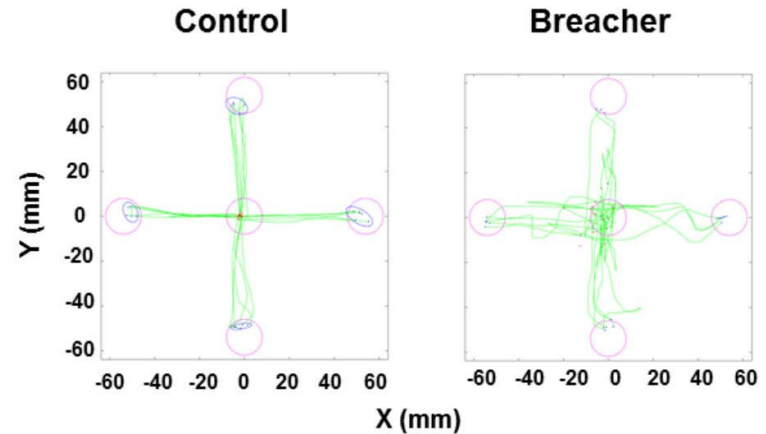
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  4. Emotional symptoms,
  5. Somatic symptoms.
- RAND SF-36:
  1. Energy/fatigue.
- Short Musculoskeletal Function Questionnaire
  1. Dysfunction Index: Perceptions of functional musculoskeletal performance.

# CFSME breachers (2015-2018): Visuomotor integration

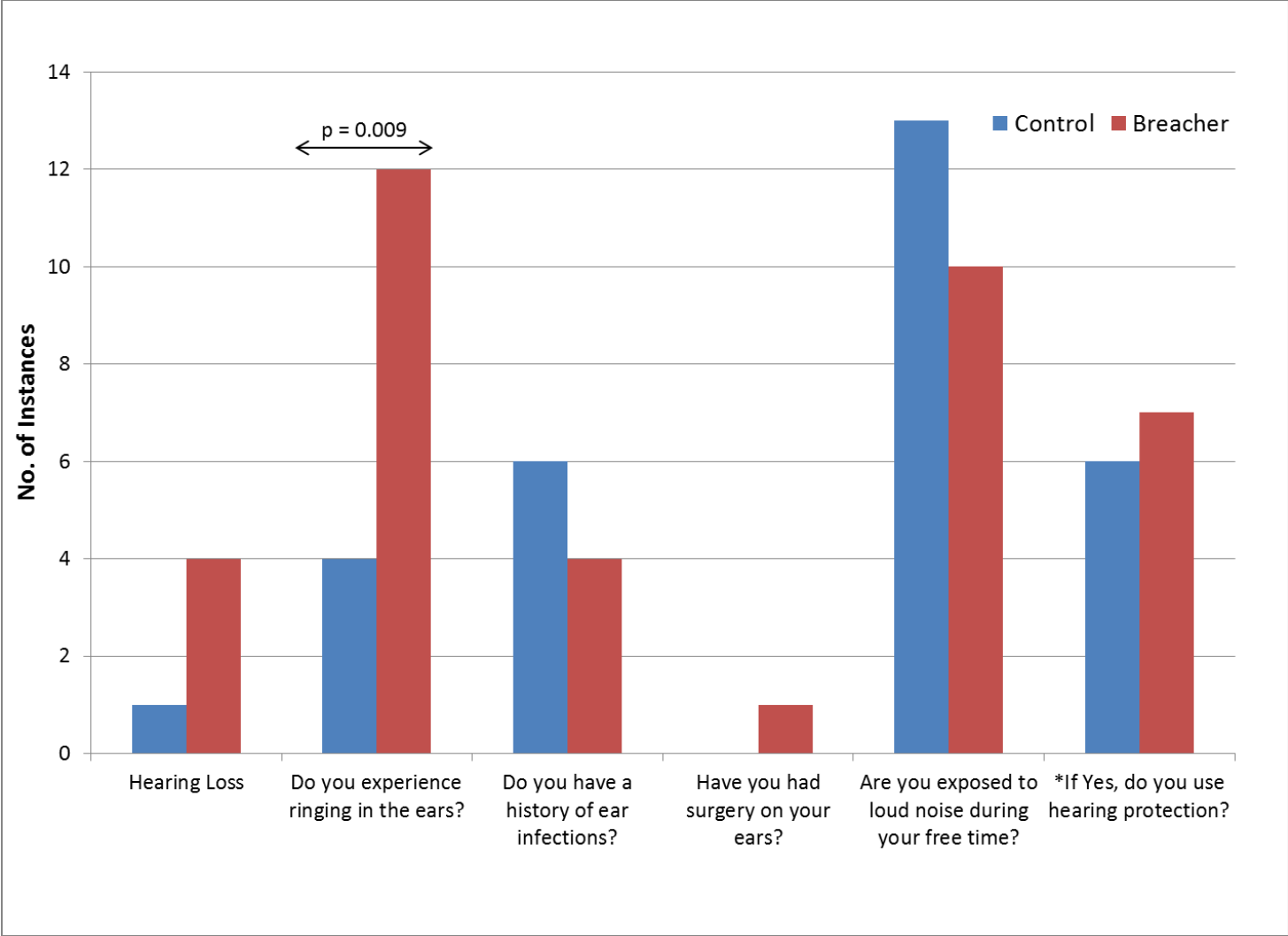
## Direct, veridical visual feedback



## Plane change, feedback reversal

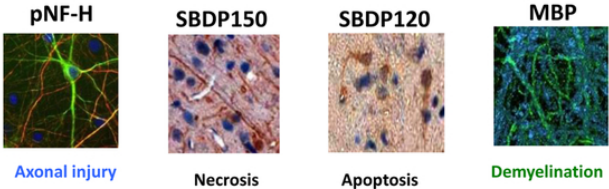
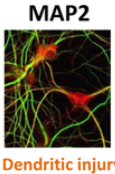
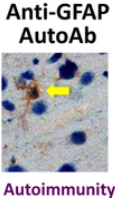
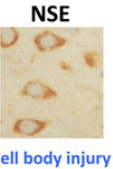
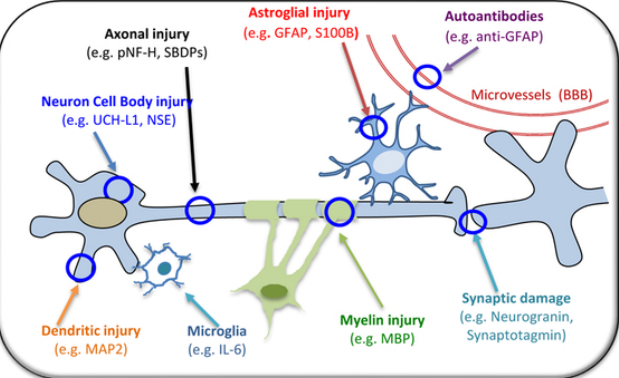
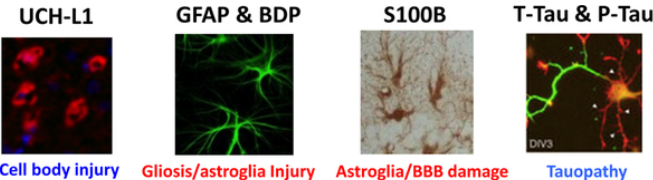


# CFSME breachers (2015-2018): Hearing loss and tinnitus

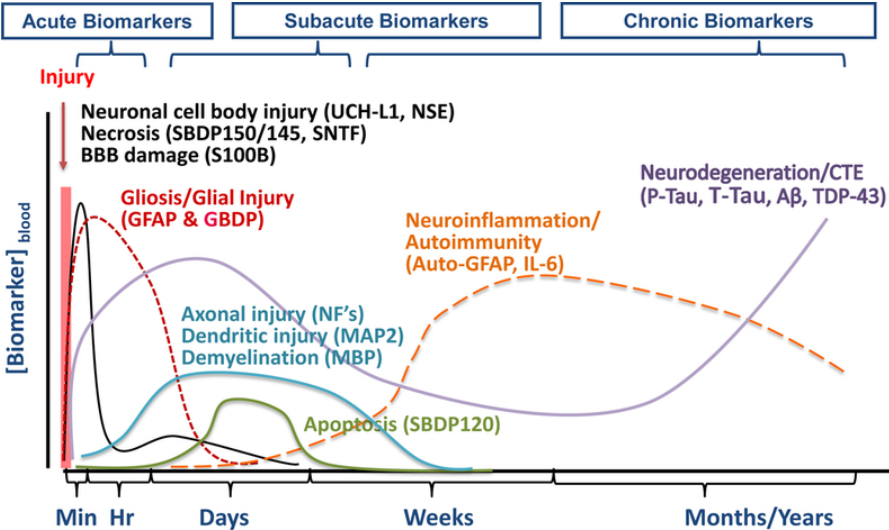


# CFSME breachers (2015-2018): Neuroproteomic Biomarkers

## Major brain biomarkers linked to different pathophysiologic processes in TBI.



## A continuum of protein biomarkers in tracking different phases of TBI.

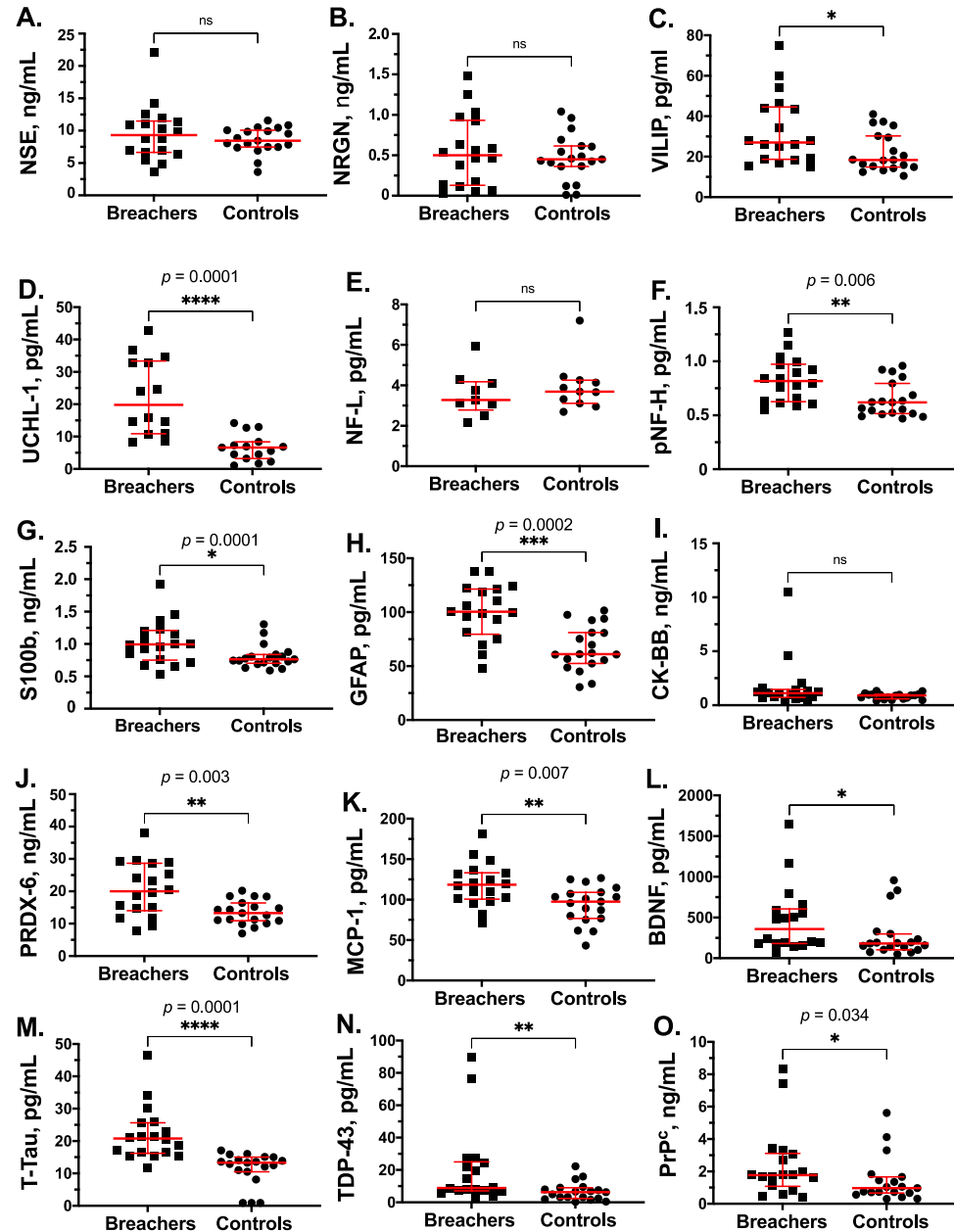
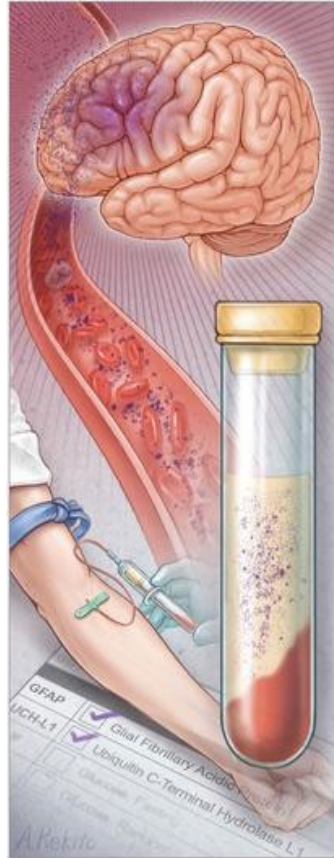


Wang, K.K. et al. *Expert Rev Mol Diagn* 18, 165-180; 2018.





# CFSME breachers (2015-2018): Neurological Biomarker Profiles

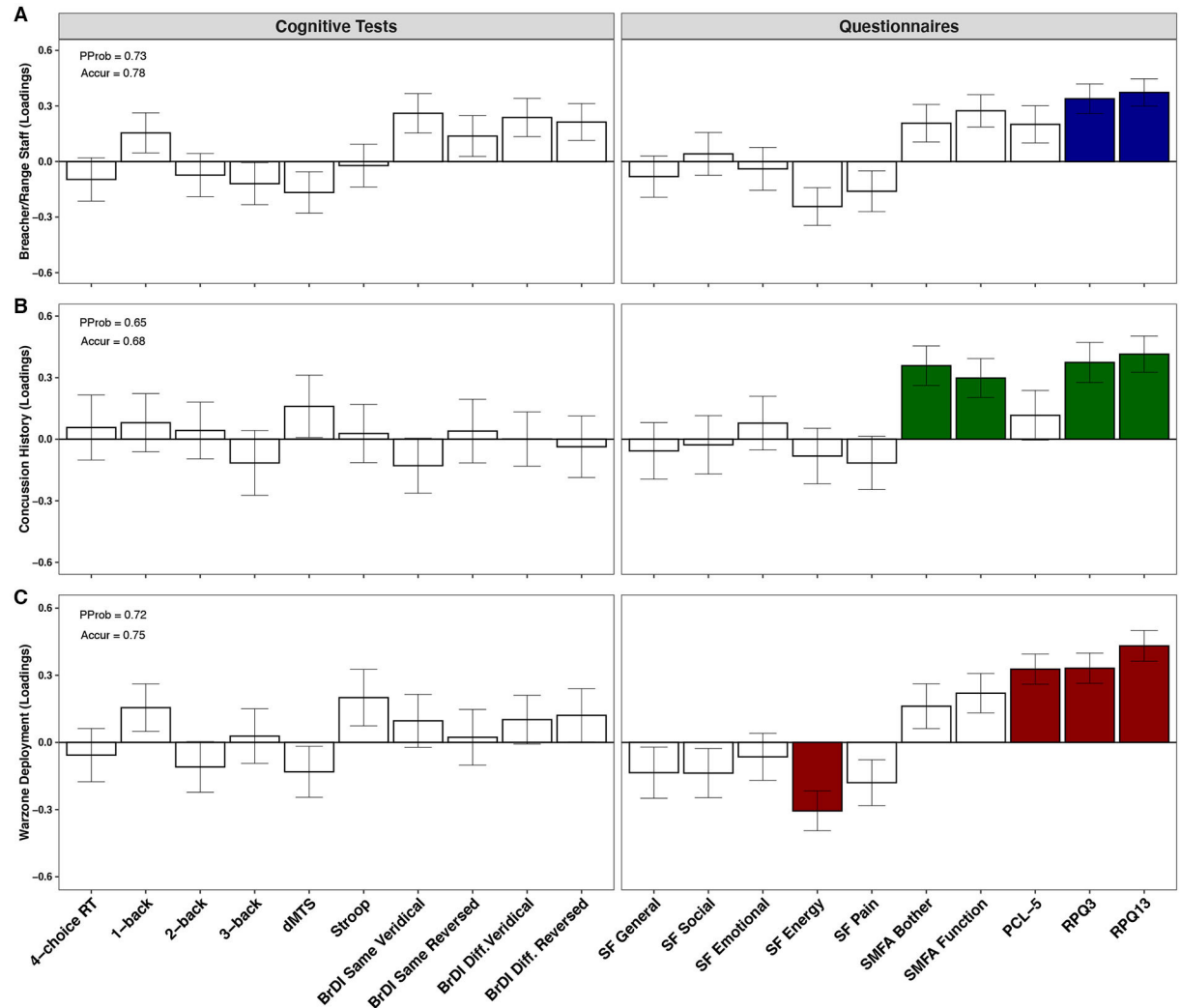


# CFSME breachers (2015-2018): Multivariate analysis (PLSDA)

Breaching

Concussion

Warzone deployment



# CFSME breachers (2015-2018): Conclusions

- Exposure to blast is associated with alterations in:
  - Neuropsychological functioning,
  - Visuomotor integration,
  - Hearing,
  - blood biomarkers
- Measurements of blast overpressure collected during courses demonstrated that up to 10% of blast events for range staff and up to 32% of blast events for instructors exceeded 3 psi:
  - Research needed to substantiate current training guidelines.
- The larger context matters:
  - Breaching,
  - Concussion,
  - Warzone deployment.

# CFSME breachers (2015-2018): Major outstanding questions

1. How can exposure to blast be quantified accurately, and related to clinical outcome measures of interest?
2. Are there reliable and valid measures that exhibit sensitivity and specificity to blast effects?
3. Is it possible to establish a feasible longitudinal health monitoring program for CAF operators?
  1. Canadian Special Operations Regiment (CSOR).

# Research with CSOR (2018-present): Research aims

1. Develop an empirical framework for a longitudinal health monitoring program for CANSOFCOM operators—from selection onwards.
2. Develop a scientifically valid algorithm for determining when an operator is at an elevated risk of exhibiting blast-induced mild TBI.
3. Inform training-related exposure recommendations for operators.



## Research with CSOR (2018-present): Two arms

- **Cross-sectional study:** Assess the effects of blast and/or recoil before and after participation in sniper and breacher training exercises. Data are compared with sex- and age-matched CAF controls with no/minimal exposure.
- **Longitudinal health monitoring study:** Baseline health and performance testing of SFC (Special Forces Course) candidates at selection, with annual follow-up of successful candidates.



# Research with CSOR (2018-present): Measures

## 1. Self-report health measures:

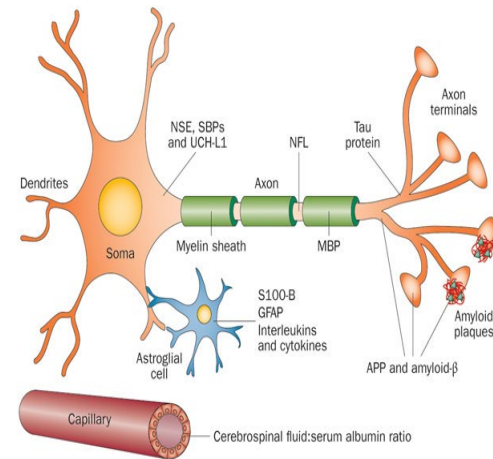
- Exposure history,
- Background health,
- Musculoskeletal function,
- Mental health,
- Sleep.



## 2. Neurocognitive testing:

- Choice reaction time,
- Short-term memory,
- Working memory,
- Executive functions.

## 3. Blood and **saliva** sampling.



# Research with CSOR (2018-present): Measures (cont.)

## 4. Hearing:

- Audiometry and hearing in noise (digits test),
- Self-reported tinnitus, hearing difficulties.



## 5. Balance and ataxia:

- Sharpened Romberg
- Walking-on-floors-eyes-closed.



## 6. MRI brain imaging:

- Structural,
- Resting state,
- Task-based (n-back task).





# Research with CSOR (2018-present): field exposure levels

## ■ Log sheets:

- Number of rounds/blasts, outdoor/indoor,
- Weather conditions,
- Felt recoil,
- Multidimensional fatigue index.

For that **specific** weapon, describe and rate the recoil on the subscales below:

Semantic Differential Rating Subscale – Select the level on each of the following scales that describes the recoil:											
Weak	1	2	3	4	5	6	Strong				
Quiet	1	2	3	4	5	6	Loud				
Short	1	2	3	4	5	6	Long				
Smooth	1	2	3	4	5	6	Jerky				
Soft	1	2	3	4	5	6	Hard				
Likert Intensity Rating Subscale – Rate the recoil on the following scales:											
	Slight			Moderate				Extreme			NA
Forceful	1	2	3	4	5	6	7	8	9	10	<input type="checkbox"/>
Noise	1	2	3	4	5	6	7	8	9	10	<input type="checkbox"/>
Crush	1	2	3	4	5	6	7	8	9	10	<input type="checkbox"/>
Painful	1	2	3	4	5	6	7	8	9	10	<input type="checkbox"/>
Duration	1	2	3	4	5	6	7	8	9	10	<input type="checkbox"/>
Displacement	1	2	3	4	5	6	7	8	9	10	<input type="checkbox"/>
Surprise	1	2	3	4	5	6	7	8	9	10	<input type="checkbox"/>

### DRDC mTBI Study – Breacher Course Daily Log

ZAP \_\_\_\_\_ Date \_\_\_\_\_

**INSTRUCTIONS:** Please list all types of shooting and/or breaching that you completed today, or at the end of each run.

#### 1. Shooting Range Log

Weapon/Calibre	Number of Rounds	Location (exterior/interior)

#### 2. Breaching Log

Calibre/Charge weight	Number of Rounds/Blasts	Location (exterior/interior)	Structure (Door, Window, etc)	Stack Position or Distance From Stack

3. Other blast exposures (distraction device, etc) and how many: \_\_\_\_\_

# Research with CSOR (2018-present): Blast and recoil measures



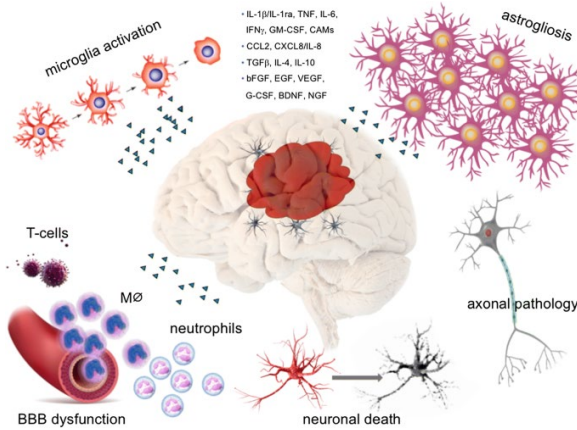
## Research with CSOR (2018-present): Interviews with operators

- Select operator interview prompts:
  - Is your occupation physically and mentally demanding? Explain.
  - What health effects have you noticed?
  - What is the impact on your day-to-day life?
  - What training modifications have you made?
  - What do you think will help?
  - What advice would you give to new operators?

## Research with CSOR (2018-present): Current status

- A power analysis determined that the cross-sectional arm of the study requires 50 operators and 50 sex- and age-matched CAF controls:
  - 32 snipers
  - 15 breachers
  - 23 copntrols
- The longitudinal study (SFC students)
  - **2018**: 39 recruits
  - **2019**: 33 recruits
- We expect data collection to be complete by 2022.

# Biological Aspects of Repetitive Exposure to Low-Level Military Occupational Blast Overpressure



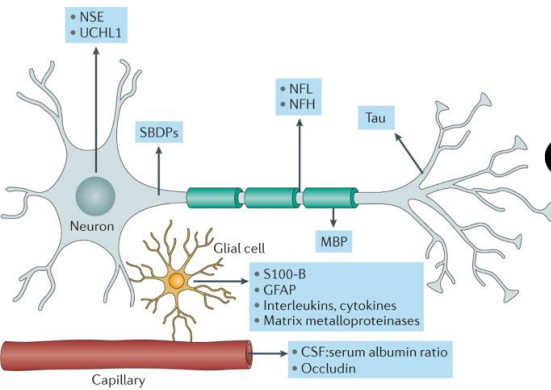
## Identify Molecular Biomarkers

- **NeuroProteomic Discovery Panel** – ~100 blood-based Neuro-inflammatory proteins tested on new Ella system.
- **TruGenomics Targeted Sequencing** – RNAseq + DNA Methylation + mi RNA



## Assess Neuroinjury Biomarkers

- **MSD and SiMO Brain Injury Panel** – S100b, NSE, UCH-L1, GFAP, NF-L/H, PRDX-6, BDNF, T-tau, pTau-u181, A-beta



Nature Reviews | Neurology

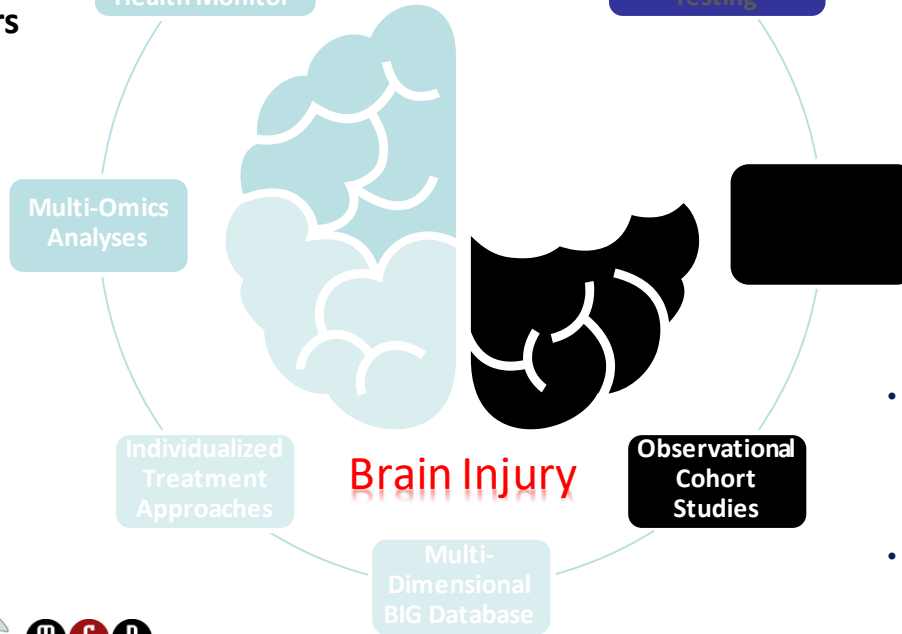


Impact of LL-MOB on Brain

Cross-Sectional/Longitudinal Health Monitor

Acute Exposure Studies/Range Testing

Brain Health

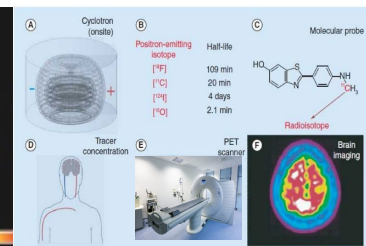
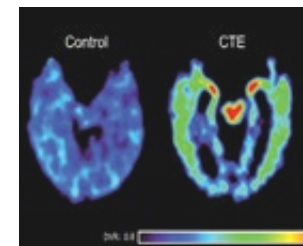


## Optimization of Health & Performance

- Pharmacological/non-pharmacological, treatments (e.g., Omega-3 FA, antioxidants, micro/macronutrients).
- Supplementation Study – RCT v. naturalistic.

## PET-Tau Imaging Study

- Clinical investigation in career CANSOFCOM members at CAMH using novel in vivo PET imaging tracers - [18F]-T807 - **Flortaucipir** to track potential neurodegeneration;
- Examine possible Tau-related pathologies or CTE, as disease mediator and/or treatment target.



# Overall conclusions and future directions

- There are some psychological and physiological measures that exhibit sensitivity to the effects of repeated exposure to low-level blast in the context of breaching.
  - Potential to develop a machine-learning algorithm for risk assessment.
- Valid and reliable quantification of blast effects is necessary for linking exposure to clinical outcomes.
- Breaching appears to be related to post-concussive symptoms but not mental health outcomes (PCL-5, BSI).
- It is necessary to relate variations in clinical outcome measures to job-specific functional targets.
- Overall, we advocate for a holistic approach that takes into account the larger occupational and operational environment within which blast is experienced for longitudinal health monitoring programs of operators.

**Thank you.**

**Questions?**



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