The Neurodegenerative Effects of Occupational Blasts On Military and Law Enforcement Personnel

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ABSTRACT

This paper gives a thorough analysis of current and past research on the neurodegenerative effects of blast overpressure on military and law enforcement personnel. Chronic neurodegenerative disease has historically been studied among sports such as football and boxing, leading to both pathological and symptomatological findings that have been used as diagnosis tools. The start of war in the Middle East led to a discovery in the same pathological and symptomatological discoveries in military settings. Blast overpressure waves are suspected to be the catalyst attributing to these findings, produced through occupational factors such as weapons. The research analyzed in this paper is used to give a concluding set of general guidelines for prevention practices that can be applied to military and law enforcement training settings. The use of brain proteins as a diagnostic tool for chronic neurodegenerative diseases like CTE is discussed.
INTRODUCTION

Media coverage and medical research on the health of military and law enforcement personnel has primarily focused on the musculoskeletal injuries of soldiers, officers, and tactical operators. The catalyst by which these injuries are attained are commonly documented to be explosive devices and firearms, which usually causes life-changing damage to the body. Research on brain related health issues in this demographic was historically irrelevant, with the only recorded issue being “Shell Shock,” a term used to categorize severe psychological trauma as a result of military combat. Development of this research eventually led to the diagnosis of Post Traumatic Stress Disorder that officially entered the Diagnostic and Statistical Manual of Mental Disorders in 1980. Neurodegenerative damage, however, had not yet been studied in the context of military and law enforcement settings. The only research available on neurodegeneration in humans up until the 21st century was a handful of studies done on boxers. Focusing primarily on veteran professionals, scientists were able to use behavioral and pathological data to diagnose Chronic Traumatic Encephalopathy in people who had nearly always undergone repeated head trauma from boxing.

With the emergence of war in the Middle East during the early 2000s, studies began to take notice of the positive trend of traumatic brain injuries being experienced by soldiers. A traumatic brain injury, or TBI, identifies damage to the brain that affects its normal functions, specifically damage that is caused by an outside variable such as a forceful blow. What made this discovery particularly interesting was that soldiers said to have experienced a high frequency of TBIs were exhibiting symptoms such as memory loss, confusion, and delayed motor function – the same set of symptoms seen in the subjects of previous studies done on CTE. In the 2010s, this trend was also observed in law enforcement personnel, such as SWAT or other tactical
operators. The US Department of Defense held their annual State-of-the-Science meeting in 2018, which centered around the core issue that blasts being experienced by military and law enforcement personnel while carrying out their services may be producing neurodegenerative effects on their brains. A meta analysis conducted as part of this conference brought the first collection of findings, proceedings, and expert recommendations on what was unofficially dubbed “Breacher Syndrome.”

Breacher Syndrome, named after a subgroup of operators who specialize in explosives, categorized the symptomatology of chronic neurodegenerative disease observed in military and law enforcement personnel. Throughout the long and strenuous career of a soldier or officer, this demographic comes into frequent contact with different weapons, like grenades, det cord, C4, or high caliber firearms. The physically aggressive nature of these weapons make them capable of producing fast and forceful explosions every time they are used. With every blast, an incident of overpressure occurs that, when standing close enough to it, can impact your brain via waves of pressure. The damage done to the brain, such as contusions or lacerations, through this catalyst provokes the symptoms seen in neurodegenerative diseases like CTE.

The State-of-the-Sciences meeting conducted in 2018 was also where researchers first began to consider the effects of repeated exposure to low-scale blasts, contrary to prior research that only focused on the detection and tracking of brain injuries in people who underwent a severe incident of TBI. A strong comparison can be drawn to certain full contact sports and their effects on athletes. Football and boxing, as an example, are two sports with the most frequent incidence of concussion and other brain-related injury. In both, an athlete undergoes physical impact to their head that occurs on a repeated basis – with football players being tackled and boxers taking punches. These players are put under a strict safety protocol and required to stay
away from playing when assessed and diagnosed with a concussion by a medical professional, something that may happen on occasions of severe injury. However, the repeated hits and incidents of shock that are mild usually go unevaluated. The same can be observed in military and law enforcement personnel. Protocols are put in place, such as MACE 2, to detect and diagnose severe head injuries. However, there are significantly more minor head impacts taken through low level blast overpressure – and occurring at a higher frequency – which commonly goes unassessed.

While uncomfortable, the impermanence of the symptoms relating to low level blast overpressure usually cause them to be disregarded if not connected to other bodily injuries. However, years or even decades of this exposure to blast overpressure will eventually lead to brain damage that, through discoveries found in the most current sets of research, has pathologically been in line with chronic disease, making Breacher Syndrome a serious health concern for our public servants.

While still being a recent development, there are a number of prevention practices and medical discoveries that can be used to mitigate the effects of blasts on military and law enforcement personnel. With the growing research done on the pathology of blast-related injury, brain proteins can potentially be used as biomarkers to make chronic neurodegenerative disease a diagnosable issue without the need for microscopic data that is only attainable after death. This in turn can not only allow medical professionals to catch the effects early on in military and law enforcement personnel, but provide proper treatment as well. In terms of prevention practices, the key to mitigation lies in reducing exposures to blasts as well as improving the criteria by which people are screened for a traumatic brain injury, particularly in training settings where circumstances are much more easily controlled. Based on the most current sets of research,
factors such as distance from a blast and frequency of exposure are what primarily determine the strength of the overpressure wave. By enforcing policies that keep military and law enforcement personnel at a minimum safe distance from a blast while also limiting the number of times that people are exposed to a blast at all, you greatly reduce the risk of traumatic brain injury incidence. Research done in football settings has shown that coaches who are more well informed of the symptomatology of concussion have been able to greatly reduce occurrence of injury. The same can be applied to training instructors, who can make more frequent detections of abnormal behavior in trainees with more improved and updated criteria.

MEDICAL HISTORY

The first modern instances of association between neurological brain damage and traumatic brain injuries began in the 1920s through preliminary examinations of concussion and head related injury. Beginning with a study carried out in 1927, Osnato & Gilibert reviewed 100 cases of concussion as well as one case of acute traumatic brain injury in which a man involved in an accident died 36 hours post-incident without any sign of musculoskeletal injuries. After doing a posthumous pathological assessment of the subject’s brain, they found signs of hemorrhaging, degeneration around vessels, and an abnormal staining of cells. Their findings led them to one of the first determinations that incidents of acute injury to the head without the presence of other superficial damage may still lead to changes in composition of the brain on par with deterioration. Post-concussive medical factors such as these were then referred to by the term “traumatic encephalitis (Osnato and Gilibert 1927).”

The study of traumatic encephalitis continued a year later with the behavioral observations of Dr. Harrison Martland on professional boxers. Writing a detailed account of his research into the Journal of the American Medical Association, Martland drew attention to the
abnormal way in which certain boxers would move and act in the ring. He pointed out awkward movement, head tilting, leg dragging, slurred speech, slowed reactions, mental confusion, and hand tremors as some of the many different mannerisms and traits that were observed in boxers (Cantu and Bernick 2020). The term used to describe this was “punch drunk,” which was the medical world’s first introduction to behavioral terminology of traumatic encephalitis. Martland also noted that those with the most severe showings of this type of behavior were usually veteran boxers who had participated in several matches throughout their career and who were known for taking increased blows to the head in comparison to others. Deviating now from pathological findings seen with Osnato & Gilibert (1927), Martland directed attention to activities involving repeated acute head injury and abnormal behaviors that were believed to be associated with brain damage. Bowman and Blau’s book, “Psychotic States following Head and Brain Injury in Adults and Children,” touched on the psychiatric assessment of a 28 year old boxer a decade after Osnato and Gilibert, in which signs of depression, paranoia, and short term memory loss were found in this patient. Particularly notable was how he was known for receiving numerous knockouts throughout his career (Cantu and Bernick 2020). Although originally diagnosed with traumatic encephalitis, the persistence of his symptoms over a course of several months after his psychiatric assessment compelled Bowman and Blau to change his diagnosis to “chronic traumatic encephalopathy.” This was both the introduction of CTE as an official medical term and the first acknowledgement of chronic neurological damage in subjects with a history of recurring impacts to the head.

Throughout the mid-late 1900s, boxing continued to be used as a vessel for early CTE research and understanding. A journal published in 1957 further dove into symptomatology of head impact related neurological degeneration by observing 69 different boxers (Cantu and
Bernick 2020). Labeled as “groggy state,” the behavior of boxers involved in this study was compared to someone straddling the line between consciousness and being knocked out. Mental confusion and amnesia were some of the common characteristics of these boxers. The following years of research brought mass reviews of medical literature published up to that point. One of these came from Dr. A.H. Roberts, who wrote a monograph in the United Kingdom tying previous research on the neurodegenerative effects of CTE with studies done on over 200 British boxers (Cantu and Bernick 2020). In this, impaired motor function as well as symptoms comparable with Parkinson’s Disease and Dementia were established as a common observation (Cantu and Bernick 2020). Both Dr. Roberts as well as Friedrich Unterharnscheidt, who published a mass literature review shortly after, warned about the pervasiveness of these traits of chronic brain damage the longer and more frequently a boxer participates in fighting.

With the increasingly strong correlation between repetitive head injury and signs of neurological degeneration, scientists called for more pathological research to analyze the biological composition of athlete demographics (Blonstein and Clarke 1954). Throughout a number of studies beginning in the late 1900s, researchers identified several patterns and similarities in the neuropathological assessment of CTE-affected individuals. Corsellis et al. (1973) gave a detailed posthumous observation of the brains of 15 different retired boxers, including imaging and dissection. Similar to the findings of Osnato & Gilibert (1927), hemorrhaging and loss of pigmentation was noted frequently among the 15 subjects. In addition to that, Corsellis et al. (1973) also recorded neurofibrillary tangles of brain proteins in some areas of the brain as well as enlarged ventricles and septal cavum. Subsequent studies and research conducted after this continued to reaffirm a strong pattern in the spotting of neurofibrillary tangles in brains exposed to repetitive trauma. The development of this type of neurological
degeneration was particularly noted in the frontal lobe beginning with the superficial layers of the brain, and then progressing to other nearby areas as the severity of the CTE case increased (Montenigro, Corp, Stein, Cantu, and Stern 2015). This is something that runs in contrast with pathological assessments of brains affected by similar diseases such as Alzheimer's (Montenigro et al. 2015).

In a similar context, a history of neurodegenerative disease has also been recorded through another popular, high-contact sport: football. Since the early 1900s, football had always been tied to the same symptomatological research as boxing, as it was notorious for its aggressive nature. This began with the New York State Journal of Medicine publishing work claiming that any sport with a high incidence of head injuries would increase the risk of “punch-drunk” symptoms in an athlete (Montenigro et al. 2015). Football players in particular exhibited these symptoms so frequently that a set of behavioral terminology to describe punch-drunkenness in the sport was also developed. In their case, phrases such as “stumble-backs” and “stumble-bums” were created to describe individuals severely affected by the repeated physical impacts of football, clearly reflecting the deterioration in motor function commonly seen in athletes (Cantu and Bernick 2020). Symptom-related research on football players continued even further in 2005 during an assessment of 2,552 professional athletes that were screened using a general health questionnaire. When asked about mental well-being, players who previously endured concussions while playing scored significantly worse than players who had never been diagnosed with a concussion (Montenigro et al. 2015). Pathological studies also identified a higher incidence of neurodegenerative disease among professional players after their death (Montenigro et al. 2015). Case studies involving neurodegenerative brain damage in football players still persist to this day. One of the most famous modern examples of
this was seen in former New England Patriots star Aaron Hernandez, who was convicted of first degree murder in 2015, two years before taking his life. Hernandez was the first person in medical history to be diagnosed with the most severe stage of CTE at his age, being 27 when he passed away.

**MOTIVATION**

Following the initial discovery and scientific assessments of traumatic brain injury, especially through Chronic Traumatic Encephalopathy, it took several years for medical professionals to draw a connection to these findings in a military setting. Researchers were still analyzing boxing as the primary research driver for chronic brain-related injuries during the mid-late 1900s. This was also the time period in which the United States had participated in two of its last three major conflicts: the Korean and Vietnam Wars. Throughout the United States’ earlier days of military operations, the landscape of medical research was much different than what it is today and had a much different focus. War has historically been extremely brutal, and millions of casualties suffered through them have come as a result of lethal weapons combat. Throughout World Wars I and II, numerous accounts have been recorded of horrific musculoskeletal injuries, depicted by lacerations, abrasions, bone fractures, and more. Especially through media tools like movies, we have even been able to see how war has resulted in soldiers returning with missing limbs or organs. Due to a lack of advancement in medical technology, this was the extent of the focus in which America’s medical forces could treat military personnel. As a result of this, there were little developments on the neurological damages a soldier faced as a result of combat.

The earliest of these was known as “shell shock,” which was described as a type of war neurosis seen in military personnel who underwent a traumatic incident on the battlefield(Crocq
Shell shock was characterized by visible fear and emotional disturbance, tied particularly to witnessing extreme violence or facing a situation of great distress. What was also notable about this condition was that medical psychiatric professionals included things like an inability to walk, loss of memory, and muteness as part of the symptomatology used to identify it. With shell shock being such an early assessment of potential brain damage in military personnel, the advancement of neurological research that came in the following years led people to question what shell shock really was. Was it a result of damage to the brain through concussive injury, or an acquired mental disorder like schizophrenia and depression? In the 1980s, a more concrete definition and set of diagnostic markers were established through the addition of Post Traumatic Stress Disorder, better known as PTSD, into the Diagnostic and Statistical Manual of Mental Disorders. It was here that shell shock and its related symptoms were officially considered an acquired mental disorder rather than an outcome of neurological damage (Crocq 2000). The four key components to identify Post Traumatic Stress Disorder were negative changes in mood, emotional numbness, avoidance of stimuli relating to a traumatic incident, and recurring memories or dreams involving a traumatic incident (Crocq 2000). Following PTSD’s integration into the DSM, no other disease or diagnosable sets of symptoms for military personnel were present in medical research leading into the 21st century apart from concussions, which were already widely known and accepted in other contexts.

Modern medical research practices did not intersect with military-related brain injury until the commencement of the War on Terror in the Middle East, which began in 2001. At this point in history, the US Military was making generational strides in technological innovations for weapons and defense systems. Drones, improvised explosive devices (IED), and high caliber semi-automatic weapons were now being integrated into every aspect of the US military, all of
which increased the strength and volume by which a soldier could attain injuries while on the battlefield. As a result of this, throughout the 2000s and early 2010s, a considerable number of veterans were returning from war in the Middle East with a variety of different injuries. With primary concern and focus among medical professionals being musculoskeletal injuries, there was also an alarming increase in the incidence of traumatic brain injuries found in these soldiers. It was reported that between 2010 to 2014, the incidence rate for this injury was 3,265 significant traumatic brain injuries per every 100,000 US soldiers (Agimi, Regasa, and Stout 2010). The incidence rate for non-deployed military personnel was lower but still notable, at 1,705 per 100,000 (Agimi et al. 2019). These statistics were finally being tracked and seen as a trend among military personnel, but it only reflected the number of traumatic brain injuries that have been diagnosed. These diagnoses of severe TBI are not only strongly associated with other injuries, but may also be a cause for these soldiers to be discharged from their service. According to the Department of Defense, the estimated number of soldiers who underwent mild versions of traumatic brain injuries was calculated to be about 230,000 between the years of 2001 and 2014, which excluded early years of war in the Middle East when this statistic wasn’t tracked (Alexander 2015). Two things made this discovery significant. The first was the realization that mild TBI is being experienced at a much higher rate than severe TBI, with data potentially being underreported due to military personnel being able to perform through them. The second was that the symptomatology associated with those involved with mild TBI were things such as headaches, motor function issues, memory issues, and mood changes – all of which presented great similarity to what can be seen in people who have developed neurodegenerative diseases.
The possibility of connecting neurodegenerative disease with activities relating to the military came about through the fact that soldiers experienced high exposures to blasts. A boxer or football player might induce damage to the brain as a result of a physical impact that they undertook during the activities of their sports. For a boxer, this takes the form of punches thrown directly to the head. For football players, this takes the form of a tackle in which their head might make contact with the ground or the body of another player. In both of these situations, the physical impact of an extraneous factor with the person’s head causes violent bumps and jolts to the brain or even concussions, which causes the brain to make direct impact with the skull. In a similar sense, blasts are able to deliver the same effect that physical hits are, with the difference being that the catalyst by which the brain is jolted are instead waves of pressure. In the case of military personnel, things such as the firing of a high caliber firearm, detonating an explosive device, or being in proximity to an explosion all expose soldiers to incidents of overpressure. With either of these activities, waves of pressure are released during the blast, which travel through the air and make impact with the body. Whereas some of these waves are reflected, most are able to travel through the body (Bryden, Tilghman, and Hinds 2019). While it is still unknown exactly how these waves reach the brain, it is hypothesized that they do so via travel through blood vessels as well as facial cavities like the mouth and eyes (Bryden et al 2019). Reaching the interior of the skull, the waves cause a shifting increase in its pressure that can lead to forceful movement of the brain directly, or even decompression of the skull which leads to contact with the brain (Alexander 2015). This, as a result, can potentially cause lacerations, contusions, or shearing of tissue, which constitutes brain trauma (Bryden et al 2019).

With the upticking trends of TBI among soldiers and its potential correlation to blasts experienced from the use of firearms and explosives, the US Department of Defense held their
seventh annual State-of-the-Sciences Meeting in May of 2018, centering around the core issue that blasts being experienced by military and law enforcement personnel while carrying out their services may be producing neurodegenerative effects on their brains. This in turn became the pivotal moment in the research of neurological effects of brain trauma within a military setting, incorporating what was termed “occupational” blast as the primary catalyst that drives TBI incidence. Similar to boxers and football players in the 1900s, a popular unofficial term was developed to categorize the symptomatology of brain damage within this demographic: “Breacher Syndrome.” This came as inspiration from a subgroup of law enforcement tactical operators who received significant exposure to blast due to their specialized work with explosives, used to breach entry points during missions.

Conducted by RAND corporation, a non-profit research and development organization, the primary goal of the conference was to assess the landscape of studies and information relating to “Breacher Syndrome” using current data as well as live discussions from professionals in the medical and military fields. Beginning with an in-depth literature review, RAND found that in 2018 there was hardly any research available that discussed the pathology and implications of blast-related brain trauma, aside from a limited number of animal studies on blast pressure response as well as some human symptomatological screenings. Establishing that Breacher Syndrome was a phenomena that hadn’t been acknowledged, medical and military professionals gave discourse throughout the meeting on the implications of blast-related neurological damage, which allowed RAND to produce the following set of recommendations for policy and research moving forward:

“Recommendation 1. Enforce DoD policies and standards related to low-level MOB exposure.
**Recommendation 2.** Develop a research portfolio of high-quality studies assessing exposure to repeated, low-level occupational blast injury.

**Recommendation 3.** Prepare and plan, in response to recent legislation, for a large-scale population-based longitudinal study of military personnel, with a long follow-up window to assess the prevalence and severity of neurological and general health outcomes after repeated, low-level MOB exposure.

**Recommendation 4.** Continue an animal research portfolio of repeated, low-level blast exposure but emphasize experiments using larger animals, including nonhuman primate models, to facilitate the translation of findings to humans.

**Recommendation 5.** Examine the potential neurologic and general health effects of low level blast exposure indicators, comparing extant military exposure assessment tools and protective practices and devices when feasible and aligned with study objectives, to facilitate incremental improvements in safety and outcomes.

**Recommendation 6.** Catalogue, map, and make available to researchers, safety programs, and military end users unclassified weapon system–specific information and service member–specific load profiles for key military occupations, exposures, and contexts.

**Recommendation 7.** Design policies and increase opportunities for embedded scientists to study repeated MOB exposure in training units and deployed contexts(RAND 2019).”

The next portion of this paper will discuss research findings that were available as part of this study, as well as research that was developed shortly after to address the various recommendations given as part of the State-of-the-Sciences Meeting.

**CURRENT THEORY**
Preliminary Findings

A study done by Ibolja Cernak in 2010 brought some of the first data that showed the theoretical damage that low level blasts could be causing by running tests on animal models. Using a helium-driven shock tube, the biological response of rat subjects was observed using incidents of mild overpressure. While constrained in a supine position, the study tested biological response at full exposure, with head protection, and with torso protection on rat subjects(Cernak 2010). Biological response was measured using in vivo imaging of an enzyme associated with inflammation known as myeloperoxidase(MPO), following the assumption that presence of MPO reflected injury within the organism. The study found that among all subject groups, an increased presence of MPO was detected throughout the entire body in the days following blast exposure. However, subjects that received torso protection not only showed lower levels of MPO, but were even able to reduce it over time(Cernak 2010). At the conclusion of the study, Elder noted that the variation in levels of inflammation among the three groups may be a strong indicator that the type of protective wear used by military and law enforcement personnel may be affecting the interactive pathway between blasts and the body(Cernak 2010).

While analyzing the biological and behavioral response of rat subjects, another study sought to observe how the level of overpressure that subjects were exposed to could affect results(Elder, Stone, and Ahlers 2014). The conclusions of the study found that rats subject to blast exposure over 74.5 kPa lead to behavioral and physiological effects on the subjects’ nervous system(Elder et al 2014). Comparing observations to similarities in comorbid PTSD, control aspects of the study were able to establish causation of effects as a result of blast due to the absence of a psychological stressor.
While animal studies have proven to be useful for preliminary researchers due to their effectiveness at controlling outside variables unrelated to blast overpressure, human observations are still needed to measure symptomatology and pathology in military settings. A pilot study conducted by Charmaine Tate was the first step into doing this, which observed 21 breachers that participated in a two week training course on explosive entry (Tate, Wang, Eonta, Zhang, Carr, Tortella, Hayes, and Kamimori 2013). The study used self-reported symptoms of subjects associated with traumatic brain injury as well as the presence of protein biomarkers in blood serum to measure neurological deterioration as a result of exposure to blast. A strong correlation was found between subjects who had the highest biomarker scores and an increase in the severity of self-reported symptoms (Tate et al 2013).

**Contextual Studies**

Another study conducted in April of 2018 sought to dive deeper into the long term effects of jobs such as breaching that involved high exposure to blast overpressure. Observing a sample of 22 military breachers in New Zealand, blood protein biomarker concentrations, neurocognitive performance, and self-reporting of symptoms were tracked as subjects underwent the normal duties of their job (Kamimori, LaValle, Eonta, Carr, Tate, and Wang 2018). At the half-way point of the study, instructors implemented a safety regulation requiring subjects to stay a distance away from blasts equating to 4 psi or less. At its conclusion, the study found no significant concentration of biomarkers, increase in symptom severity, or deterioration of neurocognitive performance (Kamimori et al 2018). The study suggests that remaining at a minimum safe distance from a blast can help to mitigate the neurodegenerative effects of overpressure waves.
A study done in 2021 by Carlos Leiva-Salinas assessed the long-term effects that blast exposure had specifically on the detection of brain proteins. The study observed changes in Amyloid-\(\beta\) deposits found in the brains of 9 blast subjects compared to 9 control subjects not exposed to blast (Salinas, Singh, Layfield, Flors, and Patrie 2023). Amyloid-\(\beta\), for reference, is a protein commonly associated with neurological damage that is commonly found in the form of plaques in people with Alzheimer’s Disease. Through PET scanning, the study not only found that four regions of the brain consistently had buildup of Amyloid-\(\beta\) after a blast, but that this buildup was still visible in follow-up scans taken five months later. Compared to the blast exposed group, control subjects had no Amyloid-\(\beta\) buildup whatsoever (Salinas 2023). In contrast, a study done in 2019 looked at the changes in Amyloid-\(\beta\) blood serum concentrations as well as tau and Glial Fibrillary Acidic Protein (GFAP) during time frames that immediately followed blasts. 29 US Army personnel that participated in a two week breacher training course were observed, during which they participated in a singular drill that was primarily focused on heavy breaching. Blood samples were taken within 30 minutes of participation, and found that subjects exhibited increases in both Amyloid-\(\beta\) and tau concentration with relation to blood samples taken before blast exposure (Boutte, Thangavelu, LaValle, Nemes, Gilsdorf, Shear, and Kamimori 2019). However, GFAP levels were shown to have decreased after blast exposure. These studies fall in line with a recurring correlation between increased detection of brain proteins in either the blood system or surrounding areas of the brain after exposure to overpressure waves.
DISCUSSION

Given the set of recommendations put out by RAND and the body of research that has accumulated over the years, there are a number of ways that this information can be used to improve the health and safety of military and law enforcement personnel.

Diagnosis and Treatment

With more extensive research being done on the biomarkers being encountered in Breacher Syndrome cases, particularly with reference to brain proteins, medical professionals are making steps toward being able to diagnose CTE and other chronic neurodegenerative diseases before death. While the current standing is that the pathological symptoms of Chronic Traumatic Encephalopathy can only be identified via dissection of the brain, studies conducted over the last six years have detected an overwhelmingly positive correlation between the increase of brain proteins like amyloid-β and tau when military and law enforcement personnel have been exposed to blast overpressure. Contrary to microscopic analyses that have been used to detect neurofibrillary tangles of proteins in the brain for CTE patients in the context of football and boxing, researchers studying neurodegenerative disease in military settings have been able to use blood serum samples and PET scans as the method of detection for proteins. Although only lightly touched on in studies involving military and law enforcement settings, other studies have shown promise that glial fibrillary acidic protein is a reliable biomarker for neurotoxicity, which can occur as a result of traumatic brain injury (O’Callaghan and Sriram 2005). While likely to be limited by costs, building a more concrete body of research surrounding the effectiveness of brain protein detection as an indicator of neurological damage will help to prevent these brain injuries from becoming chronic, opening the door for treatment as a response.
Prevention Practices

When discussing preventative practices in military and law enforcement settings, the current set of research available suggests that the key to maximizing the health of soldiers, officers, and tactical operators is by mitigating the factors concerning exposure to blasts, as well as making improvements to injury screenings given issues with the demographic in question. The best circumstance in which to apply these changes are likely in training settings. Being an integral part of military and law enforcement careers, training usually takes place more frequently than any other activity. Soldiers and officers might run drills multiple times a week throughout the entire year, making it an environment in which it is easy to receive high exposures to blasts. Given that training sessions are environments of low risk where lives and stakes are not on the line, more factors can be controlled in comparison to real operations, which would potentially aid in safeguarding the health of military and law enforcement personnel.

As it stands today, the diagnostic criteria for a traumatic brain injury among military and law enforcement is greatly hindered. The leading factor determining this is the recurring issue in which accurate self-reporting of symptoms is lacking (Helmick, Spells, Malik, Davies, Marion and Hinds 2015). The highly disciplined and hardcore training of these groups have been shown to affect attitudes and behaviors towards self-care, especially due to the extremely violent nature of these people’s careers. Soldiers and officers subconsciously learn to suppress pain and emotions, which makes it difficult for them to accept feelings of injury or abnormality, in turn refusing to make efforts toward assessing their neurological health. As a result of these attitudes, soldiers and officers who are being assessed for a brain injury may be reluctant to share the full extent of their injury, which limits their ability to get proper treatment and hinders the effectiveness of established protocols.
A number of early screenings have been implemented to detect brain injuries like concussions, one of which being the Military Acute Concussion Evaluation, or MACE(Helmick et al 2015). However, another flaw that hinders the effectiveness of these prevention tools is the fact that they are only implemented upon a suspicion of brain injury. Paired with the strong-minded attitudes of military and law enforcement that compel them to suppress signs of injury, training leaders are likely not able to make accurate concussion detections among all soldiers and officers. This not only results in potentially severe issues going unnoticed, but contributes to the development of chronic neurodegenerative disease if the correct protocols are not followed. As mentioned in previous research, a traumatic brain injury can be depicted by contusions, lacerations, and shearing of brain tissue. In the same way that a limb or another part of your body requires time to heal when injured, your brain also requires a healing time. If impacts continue to repeat after a recent injury, it not only won’t have time to heal, but will also hinder proper function of the brain and promote the development of neurodegenerative disease. Improving the sensitivity criteria for concussion screening done by leaders or training instructors can help to increase detections as a whole. While it is not known what instructors are told to look for when observing signs of concussion, research in other settings like sports have shown that familiarity with relevant literature has helped to improve circumstances for detection. A study looking at 340 football coaches who were exposed to the CDC’s “Heads Up” educational material reported that 63% of coaches began to take concussion screening more seriously, and 72% reported now being able to educate others on concussions(Covassin, Elbin, and Sarmiento 2012).

Previous research conducted on both humans and animals can also point organizations in the right direction when it comes to general safety rules in a training setting. The first and most
critical of these centers around the concept of exposure, specifically concerning how often soldiers and officers are near a blast. In certain drills, it may be the case that groups may need to be trained in a specific scenario or strategy, which could involve the use of explosives or high caliber firearms. Given that the environment of training is primarily low-stakes, instructors and departments should consider limiting the actual use of these tools. Breaching training, for example, involves tactical operators learning how to strategically enter a building after forcible entry. The real life operation will require setting off an explosive to create an entry point, but this does not need to be replicated in training if it is not necessary. Numerous studies have shown that the distance from a blast is an important element when it comes to the force by which overpressure waves impact the brain. Whenever necessary to use blasts in training, the establishment of a minimum safe distance that ensures protection from the effects of the blast can help to greatly reduce the risk of TBI incidence. This minimum safe distance has already been developed and applied on a mass scale through organizations like BAaM 360, who have created things like a “blast mat” to give a visual depiction of blast exposure severity for different weapons. Inventions such as these take a proactive approach not only at simplifying the applicability of general safety rules, but also general knowledge about blast-related brain injuries. Lastly, studies done on animal subjects have shown that protective equipment can play a role in either reducing or increasing the interactive pathway between overpressure waves and the body. In particular, covering of the body has been shown to reduce biological injury response in contrast to head coverings. Military and law enforcement organizations should discuss how to further research on this discovery in relevant settings like training, and incorporate protocols to reflect that. If studies continue to show that protection of the body limits the effects of blasts,
then instructors should require all trainees to wear body armor when participating in a drill that will expose them to it.

**CONCLUDING THOUGHTS**

This paper produced a detailed analysis of the neurological effects of blast overpressure in military and law enforcement personnel. High-contact sports such as football and boxing have been effective references for the study of neurodegenerative diseases as a result of repeated impacts to the head that induce injury. To the same effect, military and law enforcement personnel experience repeated trauma to the brain through the use of explosives and high caliber firearms in their daily jobs. Whereas typical medical research involving this demographic involves musculoskeletal injury, the findings collected in this paper across several studies sheds light on neurological damage that usually goes undetected due to its recent emergence and difficulty to observe in the real world. The continued growth and development of research on neurological damage as a result of blasts can help to not only improve safety protocols within military and law enforcement training settings, but also provide diagnostic tools for the early detection and treatment of chronic neurodegenerative disease.
REFERENCES


