2018

TISSUES AND TRAUMA: PAIN NEUROSCIENCE EDUCATION FOR VETERANS WITH POST-TRAUMATIC STRESS AND LOW BACK PAIN

Timothy Mark Benedict
University of Kentucky, benedict.tim@gmail.com
Author ORCID Identifier:
https://orcid.org/0000-0002-9946-1311
Digital Object Identifier: https://doi.org/10.13023/etd.2018.311

STUDENT AGREEMENT:

I represent that my thesis or dissertation and abstract are my original work. Proper attribution has been given to all outside sources. I understand that I am solely responsible for obtaining any needed copyright permissions. I have obtained needed written permission statement(s) from the owner(s) of each third-party copyrighted matter to be included in my work, allowing electronic distribution (if such use is not permitted by the fair use doctrine) which will be submitted to UKnowledge as Additional File.

I hereby grant to The University of Kentucky and its agents the irrevocable, non-exclusive, and royalty-free license to archive and make accessible my work in whole or in part in all forms of media, now or hereafter known. I agree that the document mentioned above may be made available immediately for worldwide access unless an embargo applies.

I retain all other ownership rights to the copyright of my work. I also retain the right to use in future works (such as articles or books) all or part of my work. I understand that I am free to register the copyright to my work.

REVIEW, APPROVAL AND ACCEPTANCE

The document mentioned above has been reviewed and accepted by the student's advisor, on behalf of the advisory committee, and by the Director of Graduate Studies (DGS), on behalf of the program; we verify that this is the final, approved version of the student's thesis including all changes required by the advisory committee. The undersigned agree to abide by the statements above.

Timothy Mark Benedict, Student

Dr. Arthur J. Nitz, Major Professor

Dr. Esther Dupont-Versteegden, Director of Graduate Studies

TISSUES AND TRAUMA: PAIN NEUROSCIENCE EDUCATION FOR VETERANS WITH POST-TRAUMATIC STRESS AND LOW BACK PAIN

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in the
College of Health Sciences at the University of Kentucky

By
Timothy Mark Benedict

Lexington, Kentucky

Director: Dr. Arthur Nitz, Professor of Physical Therapy

Lexington, Kentucky

2018

ABSTRACT OF DISSERTATION

TISSUES AND TRAUMA: PAIN NEUROSCIENCE EDUCATION FOR VETERANS WITH POST-TRAUMATIC STRESS AND LOW BACK PAIN

Low back pain (LBP) is the top reason for Soldiers to seek medical care and one of the top reasons to be medically discharged. Mental health problems and psychosocial stressors have been increasing in Soldiers and are also top causes for medical discharge. Dysregulated stress has contributed to many Soldiers and Veterans to develop chronic LBP as well as mental health disorders like post-traumatic stress disorder (PTSD). Research suggests that psychosocial characteristics, as opposed to physical factors or tissue health, contribute to chronic pain the most. Focusing entirely on tissues for individuals seeking care for LBP can increase disability and vulnerability. Attributing physical pain to mental health concerns, however, risks stigmatizing patients or making them feel dismissed. The purpose of this dissertation was to develop a pain neuroscience education (PNE) program for Veterans and Soldiers with LBP and stress and determine if PNE is more effective in improving disability, PTSD symptoms, and beliefs about pain compared to traditional education about back pain and stress.

This dissertation demonstrated that Veterans with PTSD can comprehend the neuroscience of pain and PTSD at a comparable level to a highly educated Veteran and medical panel without PTSD when adjusting for education. Since a proportion of participants were concerned that using military examples in PNE might increase PTSD symptoms, however, results from pilot testing suggested that the PNE materials developed for this dissertation should be tested in a clinical trial to ensure they do not increase PTSD symptoms.

A systematic review and meta-analysis demonstrated that Veterans with PTSD have higher depression and pain-catastrophizing beliefs for a large effect size compared to Veterans without PTSD. Furthermore, Veterans with PTSD have significantly lower pain self-efficacy with a large effect size. Compared to Veterans without PTSD, Veterans with PTSD have higher pain and disability. These results, however, were not confirmed in Veterans presenting to a Physical Therapy clinic. In fact, this dissertation revealed that many of the negative outcomes previously attributed to PTSD in the literature may be due to the correlation between PTSD symptoms and pain-catastrophizing beliefs rather than from trauma. Furthermore, Veterans with chronic LBP do not appear to have different sensitivity levels to pressure based on PTSD symptoms.

Finally, the results from a randomized controlled trial provide evidence that PNE greatly improves the confidence of Veterans and Soldiers to increase participation in social, work, and life roles despite the pain as measured by the pain self-efficacy questionnaire. Participants in the experimental group were more likely to achieve a meaningful reduction in disability at the 8-

week follow-up compared to the control group. Furthermore, Veterans and Soldiers with LBP were more satisfied with how PNE explains pain and believed the PNE curriculum connected with their military experiences better than traditional psychosocial education about stress. Participants in the experimental arm were less likely to believe that exercise is harmful compared to traditional education. Finally, PNE improved PTSD symptoms beyond the clinically meaningful threshold in the experimental arm. In conclusion, PNE appears to be an effective treatment for PTSD, disability, and pain-related beliefs in Veterans and Soldiers with chronic LBP. These results should be replicated in a larger sample to ensure generalizability beyond the current study.

KEY WORDS: Low Back Pain, Post-Traumatic Stress Disorder, Stress, Pain Neuroscience Education

Timothy Mark Benedict
Student Signature

June 5, 2018
Date

TISSUES AND TRAUMA: PAIN NEUROSCIENCE EDUCATION FOR VETERANS WITH POST-TRAUMATIC STRESS AND LOW BACK PAIN

By

Timothy Mark Benedict

Arthur J. Nitz, Ph.D., PT, ECS, OCS
Director of Dissertation

Esther Dupont-Versteegden, Ph.D.
Director of Graduate Studies

June 5, 2018
Date

DEDICATION:

To my Grandfather, COL (ret) William Benedict (1926-2015): a true hero who volunteered to serve in the Army during World War II and had combat tours in the Korean and Vietnam Wars. Because of your service, you taught three generations the meaning of sacrifice, honor, and grit. Thank you for leaving a legacy that still lives today. Thank you to my parents for your hard work and example of service as well.

To all the Veterans and families who have served in the Armed Forces: Thank you for your service! My hope is that this work will in some way contribute to the good fight.

ACKNOWLEDGEMENTS

First, I would like to thank my research committee for your support and flexibility throughout this process. I know working with a military PhD student is not the typical way to mentor a doctoral student and many programs and professors are not willing to support such an aggressive timeline. To Dr. Nitz, I am very grateful for all your efforts and leadership among our committee. I greatly admire you as a researcher, professor, and as a person of integrity. Dr. Abt, thank you for sharing your vast experience and resources within military research. Dr. Gold, thank you for taking the time to humor my naïve observations about neuro-imaging and your patient instruction and insight into a fascinating topic. Dr. Noehren, thank you for sharing your lab equipment and for your thoughtful and challenging insights into my research. Dr. Dupont, thank you very much for supporting military students and your generous provision of pilot funding for my project.

Next, my journey to the University of Kentucky. COL (ret) Scott Shaffer, Sir, thank you so much for everything you did for me personally and for Army Physical Therapy. I was facing a challenging time in my career many years ago and your words of encouragement truly inspired me to aim for this program. CPT Shawn Stoute: when we met, you were just a Physical Therapy intern, but you introduced me to Pain Neuroscience Education and I have been fascinated by the implications of neuroplasticity ever since. COL (ret) John Childs, thank you for your insight and for introducing me to Dr. Adriaan Louw. Dr. Louw, thank you so much for all the time you have personally devoted to me and for advancing education to our Armed Forces. Thank you for believing in my project and for encouraging me in my work. Rod, thank you for your art work, it is vital to the education program we developed. Brianne, thank you for designing the education booklets for this research. I would not have known where to start but you generously donated your expertise and time. Thank you!

Dr. Carlson, thank you so much for your insight into post-traumatic stress disorder (PTSD). I really appreciate your mentorship and guidance in refining the education we developed for Veterans with PTSD. Garrett, thank you for your humor and editing attention.

To all the staff at the VA Physical Therapy Clinic, thank you so much! Susan and Dr. Schleenbaker, thank you for letting me be a nomadic researcher in your department. Mike, thank you for supporting our research project and for always being flexible and ready to perform assessments. John, thank you so much for all your time and feedback to make this research work better. Thank you for tirelessly searching for participants. Without your personal efforts, there is no way I could have completed this project. To all the other therapists, thank you so much for supporting our project and for referring participants to me. To Dawn Biddulph, thank you so much for your support. I have now submitted to 5 different IRB offices and by far, you have been the best to work with! Your responsiveness and instructions always went above and beyond to make sure our project was successful. Thank you!

To the Fort Campbell, KY, Physical Therapy Department: thank you for working so hard to establish this research program at an Active Duty site with such short notice. MAJ Lechanski, thank you for taking so much on your shoulders even as you were leaving Fort Campbell. CPT Embry, thank you for your assistance and dedication to Pain Neuroscience Education in the Army. 1LT Harms, thank you for all your efforts. SPC Gonzalez, thank you for all your help, you made a huge impact on this project and I could not have managed the logistics without you. I also want to thank Joe Kardouni for helping me with the cohort study. Without your assistance there is no way I would have been able to even scratch the surface on longitudinal outcomes with the Army database.

I also want to thank all the other PhD students in the RHB program. Taz, thanks for going through pilot testing with me. Kelsey and Caroline, thanks for the RCT envelopes. Kate and Josh, thanks for your flexibility with the algometers. Kirby, thanks for setting up my poster.

Jen, thank you for your editing and input. To everyone else, you consistently gave constructive feedback and were always an inspiration to be a better researcher. Alejandro, thank you for your statistical expertise. Dr. Uhl, thank you so much for taking me under your wings. I learned so much from you and you make an incredibly positive impact to the entire RHB department. Thank you for what you do.

To my wife Melissa, thank you for sticking with me all these years! I still remember our conversation in Verona, Italy, as we discussed our future in the military. I love the military, but I love you way more! I am thankful that you have sacrificed so many of your dreams so that we could be a military family and continue to serve in the Army. You really are the most loyal person that I know! You have fought for our family and for us from the beginning. You are so supportive of me and my research and ideas, almost to a fault. I am so thankful that you work so hard to make our family a priority and encourage me to always keep our priorities straight. Thank you for being a wonderful wife and friend and mother of our four girls. To our girls: you are a blessing beyond words!

"I can do all things through Christ who strengthens me" (Self-efficacy—Philippians 4:13). "Do not be conformed to the pattern of this world, but be transformed by the renewing of your mind" (Neuroplasticity—Romans 12:2). Self-efficacy and neuroplasticity have been a part of behavior change literature dating back to the first century AD. I am so thankful that our nervous system has such an incredible design and capacity for resilience and adaptability.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1: Introduction

Background

Low back pain (LBP) has been called a "Twentieth Century Health Care Enigma."[1] Well in to the 21st Century, LBP continues to be an enigma despite advances in treatments and diagnostic imaging[2]. The global point prevalence of LBP ranges from 11.9-23.2%, incurring substantial societal and individual burden[3]. In the U.S. alone, LBP costs surpass more than $100 billion annually[4]. LBP is the most common pain condition reported by adults in the U.S.[5] and a top reason for an individual to visit a physician[6]. In the U.S. military, LBP matches the general population as the top reason to seek healthcare treatment[7] and is the leading cause of disability in the U.S. Army[8].

Given the demanding nature of the mission of the U.S. Army, it is not surprising that Service Members experience high levels of stress[9], defined as disruptions in neurophysiological homeostasis due to environment or psychosocial situations[10]. Approximately one-third of military members experience high levels of occupational stress[9]. Soldiers who have deployed to a combat location report even higher levels of stress[11]. Although stress is ubiquitous to all individuals[10,12], Veterans with previous military experience display greater stress dysregulation compared to matched civilians without military experience[13]. Higher levels of stress contribute to greater mental health needs within the military[9].

As occupational stressors and combat deployments have increased over the past two decades, mental health disorders have risen as the top reason for a Service Member to be hospitalized[7]. A specific mental health disorder that is particularly problematic for the military is post-traumatic stress disorder (PTSD). PTSD is diagnosed after exposure to a stressful, traumatic event and experiencing the cluster of symptoms of hyper-arousal, re-experiencing traumatic memories, avoidance, and negative cognitions for at least 30 days beyond trauma exposure[14]. Although up to 83% of Americans report lifetime prevalence of trauma exposure,[15] only 7.8% develop persistent PTSD symptoms[16]. Therefore, development of PTSD may indicate an inability

to appropriately regulate stress responses following trauma[12]. Understanding some of the differences between individuals who develop PTSD and those who do not may contribute to developing specific therapies tailored to an individual's ability to regulate stress.

Independently, PTSD and LBP cause significant disability in the U.S. military. Almost one-half of all medical discharges from the U.S. Army can be attributed to PTSD or LBP[8]. The impact of co-morbid PTSD and LBP, however, is not as well reported among Active Duty Soldiers as in Veteran populations[17]. Although at face value PTSD and LBP have different etiologies, these two conditions are highly co-prevalent in Veterans with military service. 66% of Veterans with PTSD have chronic pain[18], with LBP as the most common condition[18,19]. On the other hand, 7-51% of individuals who have chronic LBP have PTSD symptoms[20,21]. In fact, chronic LBP and PTSD share many underlying neurobiological characteristics[22]. Chronic LBP, like PTSD, may be the result of a hypervigilant nervous system[23] and dysregulated stress response[24].

Not only do PTSD and LBP mutually increase the risk for each other[25-27], when PTSD and pain are co-morbid, it amplifies negative symptoms and beliefs which are known to lead to greater disability[28,29]. For example, compared to Veterans with chronic pain only, Veterans who also have co-morbid PTSD have significantly higher pain[19,30-33], pain catastrophizing beliefs[30-32], and disability[19,30,31]. On the other hand, Veterans with PTSD and chronic pain have lower self-efficacy[30-32] and lower function[30,33] compared to Veterans with pain only. Traditional biomedical education about LBP, which focuses on pathology and anatomy, is not only ineffective in Veterans with LBP and PTSD[34], but might even increase disability and catastrophizing by magnifying the threat of their condition[35].

Attributing physical pain to a mental health disorder, on the other hand, may lead patients to feel they are being dismissed[36] and contribute to providers making broad, premature judgments about patients with PTSD and pain[37,38]. Individuals in chronic pain likely desire a biological

explanation for their pain, not just a psychological approach for bodily pain[39]. Many healthcare providers, however, lack confidence examining patients with physical symptoms in the presence of mental health disorders[40]. Many Physical Therapists do not feel equipped to appropriately manage the psychosocial symptoms that contribute to LBP[41]. These reasons could contribute to feelings of stigma in patients with PTSD[42] and LBP[41]. The disconnect between explanations for physical and mental health disorders may help explain why many patients with PTSD have difficulty engaging in cognitive-based or counter-intuitive therapies for their pain[39,43].

Pain neuroscience education (PNE) represents a novel therapy to help both clinicians and patients understand the link between mental health—ultimately driven by the central nervous system—and bodily pain[44]. Instead of focusing on anatomy and injured tissues, which typically heal in 3-6 months[45], PNE helps patients understand that on-going pain is the result of a hypervigilant and sensitive nervous system[44]. PNE uses metaphors and stories to relate complex neurobiological principles about pain[46]. Two systematic reviews have found PNE effective in improving pain, disability, and maladaptive beliefs about pain[47,48]. Since pain represents bodily *danger* as perceived by the central nervous system, as opposed to actual tissue damage[49], PNE is proposed to decrease the threat of on-going pain, resulting in a top-down reduction of the pain experience[50].

Some of the patient populations that have benefited from PNE include fibromyalgia, chronic fatigue syndrome, and chronic LBP. These conditions are noteworthy for both dysregulated stress systems[24,51,52] as well as a hypervigilant nervous system characterized by central sensitization[53]. Central sensitization is defined as upregulation of pro-nociceptive neuronal messages and impaired endogenous inhibition of nociceptive signaling[53]. If an individual believes that on-going pain is the result of damaged tissues that have failed to heal properly, then it makes sense (common sense model[54]) that this individual's nervous system would continue to facilitate sensory information which may communicate danger to the tissues.

According to a modern neuroscience definition of pain[49], this will result in greater pain and avoidance of activities like exercise that could promote tissue health and function[29,55]. Therefore, since PNE has helped decrease the threat of pain in other patient populations with hypervigilance, military Veterans and Soldiers with high levels of stressors and PTSD stand to greatly benefit from PNE.

A key question among healthcare providers is whether patients in chronic pain, however, can comprehend and understand the neuroscience of pain[56]. Research has shown that patients, in fact, are able to comprehend PNE to a greater degree than predicted by medical providers[56]. PNE comprehension has not, however, been tested in Veterans. Furthermore, Veterans with PTSD have neurocognitive deficits[57] which may limit their comprehension of PNE. Therefore, although PNE appears to be a logical intervention that could validate both psychosocial and physical symptoms in Veterans with PTSD, a first step is determining if Veterans can comprehend PNE materials. The purpose of this dissertation is to develop a PNE curriculum for Veterans with pain and PTSD or stress and test its effectiveness compared to traditional education about pain and stress. The following aims support this overall purpose:

Specific Aims

1. Develop a PNE curriculum for Veterans with PTSD and pain and determine if Veterans can comprehend PNE materials (Chapter 3).
2. Determine if co-morbid PTSD and chronic LBP increases disability in Active Duty Soldiers compared to chronic LBP alone (Chapter 4).
3. Determine if Veterans and Soldiers with PTSD and LBP have poorer health outcomes compared to Veterans and Soldiers without PTSD (Chapters 2 and 5).
4. Determine the effectiveness of PNE for Veterans and Soldiers with LBP (Chapter 6).

Operational definitions

Stress: Environmental, psychosocial, and physical disruptions to an individual's homeostasis[10]. Stress can promote adaptive or maladaptive behaviors; stress can be classified as "good", "tolerable", or "toxic"[58]. Throughout this dissertation and when communicating with research participants, maladaptive or negative stress was primarily considered.

Post-traumatic stress (PTS): Following a life-threatening traumatic event, it is normal to experience an acute disruption in an individual's homeostasis. An individual may also experience chronic physiologic adaptations following trauma. The difference between PTS and PTSD, however, is that an individual may continue to experience stressors following trauma but achieve a level of adaptation that prevents psychosocial disability.

Post-traumatic stress disorder (PTSD)**:** Following a life-threatening traumatic event, an individual exhibits the following symptom clusters: hypervigilance, intrusions from traumatic experience, negative cognitions, and avoidance of trauma reminders. These symptoms persist for longer than 30 days following the trauma and interfere with an individual's functioning[14].

Veteran: An individual who previously served in the United States Armed Forces. A combat deployment is not required to obtain Veteran status.

Soldier: A current member of the Armed Forces Army branch.

Active Duty: A uniformed individual employed full-time by the United States Armed Forces.

Service Member (SM)**:** Sometimes used interchangeably for Veterans and Active Duty military personnel, a SM is a member of the Armed Forces to include all five branches of the military: Army, Air Force, Navy, Marines, and Coast Guard.

Service Connection: Upon separation from the U.S. Armed Forces, a SM may receive a rating of service connected disability. The Veteran's Administration uses the service connected rating to administratively classify Veterans and the service connected disability also serves as a compensation for service-related injuries incurred while in the Armed Forces. The compensation

is typically in the amount of a percentage (from 0-100%) of the individual's base pay prior to separation from the military.

Medical Evaluation Board (MEB): If a Soldier's supervisor or medical physician believes the Soldier may not have the medical capability of continuing to serve in the Soldier's current occupation, the Soldier may be evaluated for medical disability retirement.

Assumptions

Chapter 3: Participants fully read all the materials they rated.

Chapter 4: Although the study discussed the implications of a Soldier having a history of both PTSD and chronic LBP independently, co-morbid PTSD and chronic pain is frequently discussed as overlapping during a common time-frame. To continue the discussion with other research, participants in the Chapter 4 cohort study may be assumed to have co-morbid PTSD and chronic LBP, although the study methods were not able to definitively identify the temporal relationship between those with both PTSD and chronic LBP.

Chapter 5: Pain pressure threshold and self-report outcomes accurately represent the baseline and pre-treatment condition of participants.

Chapter 6: Participants will provide accurate self-report information at all time-points.

Limitations:

Chapter 2: The articles in the systematic review have not yet been graded for quality by a secondary assessor. Many studies dichotomized participants into PTSD/no PTSD only by using a cut-off score in PTSD symptomology.

Chapter 3: This study used a convenience sample and the study participants may not reflect the general opinion of Veterans with chronic pain and PTSD.

Chapter 4: This study relied on secondary analysis from a medical database.

Chapter 5**:** This study had a small sample size which potentially limited its ability to detect differences in some of the psychosocial outcomes that have been reported in the literature. This

study did not use a dynamic measure of quantitative sensory testing and did not use a remote, pain-free testing site to assess for characteristics of central sensitization.

Chapter 6: Only a small percentage of participants returned their activity and reading log. For some variables, this study lacked statistical power to confidently conclude the results were not due to chance, likely due to a relatively small sample size. Finally, the study included in this dissertation only has a short-term follow-up period of 4 and 8 weeks and will require 6-month long-term follow-up of healthcare utilization to be calculated and added to the final results.

Delimitations

Chapter 2: Study populations included in the systematic review required at least 30% of participants to have pain. Although this improved study homogeneity, it also excluded many studies that highlight important differences and outcomes in Veterans with PTSD compared to Veterans without PTSD.

Chapter 3: Veterans who reviewed the PNE materials must have previously served in the U.S. Armed Forces.

Chapters 5 and 6: Participants were Veterans or Soldiers ages 18-65.

Participants had chronic LBP.

Participants did not have schizophrenia, bi-polar disorder, or personality disorder.

Participants did not have a substance use disorder in the previous 6 months.

Soldiers were not undergoing Medical Evaluation Board.

Chapter 2: Post-Traumatic Stress Disorder (PTSD) Symptoms Contribute to Worse Pain and Health Outcomes in Veterans with PTSD Compared to those Without: A Systematic Review with Meta-Analysis.

Introduction

The "healthy warrior effect"[59] does not appear to protect Service Members and Veterans from chronic pain. Similar to the high prevalence of pain in the U.S. population[60], chronic pain is the number one reason for a Service Member to seek healthcare[7]. Musculoskeletal pain is also the number one reason for a Service Member to be medically discharged from the military[8]. Veterans from recent conflicts are estimated to cost the nation between $300-$700 billion over the course of their lifetime in medical expenses and disability compensation[61]. Although the modern era Service Member has a greater chance of combat survival than any other period in the history of warfare due to increased body armor[62] and medical evacuation capabilities[63], not all wounds are visible or result in a purely physical injury[64].

One of the "wounds" that often accompanies combat trauma is post-traumatic stress disorder (PTSD), with a prevalence of approximately 10-17%[65,66]. PTSD is diagnosed following exposure to life-threatening trauma and the presence of intrusive symptoms, avoidance, negative cognitions, and hyperarousal. These symptoms persist for at least 1 month following trauma exposure and impairs the individual's function[14]. As the Department of Defense has prioritized identifying PTSD and other neurocognitive disorders within Active Duty and Veteran populations[67], it is evident that PTSD is not an isolated entity[68]. Among one sample of treatment seeking Veterans with PTSD, 66% of them also had chronic pain[18]. The phenomenon of co-morbid pain and PTSD is not unique to the Veteran population, as meta-analysis has indicated PTSD as a significant risk factor for developing chronic, widespread pain[27]. In Afari 2014, individuals with a history of combat PTSD incurred the highest odds of developing chronic, widespread pain with a pooled odds-ratio of 3.06. Furthermore, increased baseline pain predicts the development of PTSD longitudinally[69].

The bi-directional risk for pain and PTSD in the literature appears to support some of the theories offered to explain the co-morbidity of these two conditions. One theory is that individuals possess a shared vulnerability[70]; faced with a traumatic event or injury, some individuals have a higher risk for developing disability compared to a resilient individual. Another explanation involves mutual maintenance[25] in which PTSD and pain reinforce the chronicity of each other whereby hypervigilance in someone with PTSD elevates potential threats and pain serves as an on-going threat which elevates hypervigilance in a continual cycle. Finally, altered central nervous system sensitivity due to PTSD symptoms could increase nociceptive signaling and amplify the subjective pain experience[71]. While the exact mechanism for the relationship between chronic pain and PTSD may be lacking[72], evidence certainly supports many common neurobiological processes and neuroanatomic structures between pain and PTSD[22].

Just as there are several theories that postulate mechanisms for the co-occurrence of chronic pain and PTSD, several narrative reviews have also offered potential treatment strategies for the co-morbid Veteran population[73,74]. Initial treatment programs specifically directed at Veterans with PTSD and pain, however, have yielded nearly 50% drop-out rates[17,75]. As integrated treatment programs have emerged for the Veteran population with chronic pain[55], the high drop-out rate for Veterans with co-morbid PTSD highlights the need to further understand this group. Identifying the profile and impairments of a Veteran with co-morbid pain and PTSD is a first step in developing targeted interventions. The purpose of this study, therefore, was to systematically review the literature and quantify disability, function, and pain-related beliefs and outcomes (O: Outcomes) in Veterans with PTSD (P: Patient) compared to Veterans without PTSD (C: Comparison).

Methods

Article Selection

The primary author (TMB) performed an electronic search of CINAHL, Medline, and PsychINFO according to the strategy in Table 2.1, resulting in 193 articles. During this initial

stage, exact duplicates, books, dissertations, and titles that clearly did not meet inclusion criteria were removed. The author next reviewed abstracts and full-text of 163 publications.

To be included in the systematic review and meta-analysis, the following Inclusion Criteria was applied:

- Articles available in English.
- Participants were U.S. Active Duty Military or Veterans. Since population cohorts indicate pain prevalence of approximately 30-40%[76,77], this study required at least 30% of participants to have pain to maintain study homogeneity.
- The authors examined pain, disability, beliefs, or other health related outcome.
- The authors compared groups with and without PTSD.
- The authors presented group means with standard deviation, Risk/Odds-Ratio with confidence interval, or other descriptive measure between groups with and without PTSD.

Articles were excluded if they did not meet this inclusion criteria, or if the primary study population was traumatic amputee, burn injury, spinal cord injury, inpatient, sexual trauma, or headache pain. The populations in the exclusion criteria would likely add too much variability in patient characteristics and outcomes.

After applying inclusion/exclusion criteria, 18 articles were identified for systematic review and meta-analysis. The primary author also searched the reference list for all included articles for relevant publications, identifying two additional articles which met established inclusion criteria. This resulted in 20 articles which were included in the systematic review and meta-analysis (see Figure 2.1). Next, the primary author reviewed all articles and graded them for methodological quality and risk for bias. Since the majority of articles included in the review were observational, the primary author graded these articles with the Newcastle-Ottawa Quality Assessment Scale for Cohort Studies[78] (NOS). The NOS is the preferred observational quality

assessment tool for observational studies as recommended by the Cochrane group[79]. The NOS assesses potential bias related to selection, comparability, and outcomes (Table 2.2). A maximum of 9 stars or points is possible for each study, representing higher quality. For comparability, studies are awarded up to two stars depending on how they control for potential confounding variables. For this review, depression was selected as one covariate and a study could earn an additional star for controlling for a separate characteristic. For outcome, the follow-up period varied between 3-12 months, depending on the outcome assessed.

Data extraction

The principle aim of this systematic review was to describe pain-related outcomes between Veterans with and without PTSD. The broad categories evaluated in the included studies measured pain, disability, function, cognitive beliefs, and other health outcomes to include sleep, healthcare utilization, medication use, and suicide related behavior. The results among these domains were summarized in tabular form for each article. When possible, the primary author extracted the group means with number of subjects per group and respective standard deviation and entered these values into the Comprehensive Meta-Analysis Software (version 2.2.064; BioStat, Englewood, NJ, USA) for meta-analysis for health outcomes in which more than one study measured a similar outcome. Since many of the studies utilized questionnaires and measures with different psychometric properties, the outcome measure most consistently used or most similar across studies was selected for meta-analysis and computation of the standardized mean difference (SMD). Although all these studies were within Veterans and Service Members, the type of pain condition, population characteristics, and outcome measures varied among studies. Therefore, a random effects model was utilized in CMA except for two studies which used identical patient populations and outcome measures[30,31]. Furthermore, as the majority of these studies were observational, bias was assessed through methodological quality assessment rather than through publication bias or funnel plot assessment.

Results

PTSD Diagnosis

Table 2.3 summarizes outcomes for all studies included in the systematic review. The most common method to assess PTSD exposure was through International Classification of Diseases (ICD-9) classification via electronic chart review[33,76,77,80-86]. Only one study[87] specifically referenced using the Clinician Administered PTSD Scale (CAPS)[88]—considered the gold standard in diagnosing PTSD—to generate the PTSD ICD-9 diagnosis. It was not possible to identify exactly how clinicians diagnosed participants with PTSD, although some studies mentioned clinical interview[80,84] while another the Primary Care PTSD Screen (PC-PTSD)[83]. The next most common tool to assess PTSD symptomology was the PTSD Checklist (PCL). The PCL consists of a military and civilian version. Both tests have good validity, reliability, and excellent internal consistency[89]. Cut-off scores for PTSD vary between 30-60[89]. In this systematic review, 5 studies used a PCL cut-off score of ≥ 50[19,32,90-92] and 2 used a cut-off score of ≥ 41 in combination with the PC-PTSD[30,31]. Other methods of determining PTSD exposure included the Davidson Trauma Scale ≥ 40[93] and the Mini-International Neuropsychiatric Interview (MINI)[94].

Quality Assessment

Quality assessment is summarized in Table 2.2. Many of the studies were population-based[76,77,81-83,85,86], limiting selection bias. Others, however, consisted of Veterans presenting for treatment at interdisciplinary pain specialty clinics[19,30-33,90]. Veterans referred to pain specialty clinics might differ in prognosis and characteristics compared to the average Veteran. Adjusting for confounding factors is also important to limit potential study bias. Although most studies attempted to control for appropriate characteristics, many studies did not control for depression, which could inflate the contribution of PTSD symptoms if the PTSD group had disproportionate rates of depression. Finally, the cross-sectional design of many of the studies prevents

determining the temporal relationship between PTSD symptomology and health outcomes as they were measured at the same time.

Pain and Depression

Of the 7 studies that compared pain between Veterans with and without PTSD symptomology, 5 were included in meta-analysis[19,30-32,92]. Meta-analysis determined that Veterans with PTSD had significantly higher self-reported pain for a pooled standardized mean difference of SMD=0.58 (95%CI .28-.89), indicating a medium effect size.

Most of the studies included in the meta-analysis for pain severity did not control for major depression. One study which did adjust for major depression determined that Veterans with and without PTSD did not statistically differ in pain severity[19]. Another study, however, found significant and independent associations for pain severity between both PTSD and depression even when adjusting for each condition[30]. Three studies[30,31,92] were possible to pool depressive symptoms in meta-analysis and determined that Veterans with PTSD have significantly higher depressive symptoms than Veterans without PTSD (SMD=1.40, 95%CI 1.2-1.6), large effect.

Furthermore, another study determined that Veterans with chronic, widespread pain (defined as pain in all four quadrants of a body pain chart) have 2.54 odds of being diagnosed with PTSD compared to those without chronic, widespread pain (χ^2=17.89, p<.001)[95]. Additionally, Veterans with PTSD were less likely to achieve a clinically meaningful reduction in pain compared to individuals without PTSD in Veterans receiving opiod-agonist treatment[86]. This relationship persisted when adjusting for depression and other characteristics. Finally, Veterans with PTSD were less likely to achieve a reduction in pain severity after completing a multi-disciplinary and integrated healthcare program for pain[33].

Disability and Function

For the studies that analyzed disability, a higher score indicates more disability. Three studies were included for meta-analysis[19,30,31]. Veterans with PTSD and pain had higher disability than Veterans with pain only (SMD=.52, 95% CI .33-.71, Figure 2.2). For function, on the other hand, a higher score indicates greater participation in physical and occupational roles. Two studies[30,33] were analyzed for meta-analysis and found lower function in Veterans with PTSD and pain (SMD=.41, 95% CI .25-.56). Furthermore, one study found that Veterans with PTSD and pain were much more likely to score lower than the median for physical function (χ^2=73.09, p<.001)[95]. Finally, Nunnink 2012[93] reported that Veterans with PTSD scored significantly lower in physical function than Veterans without PTSD; however, this relationship did not maintain significance after adjusting for other covariates.

Cognitive Beliefs

Measures of pain catastrophizing and self-efficacy were included in meta-analysis. Pain catastrophizing measures increased negative appraisals towards pain[96] and was measured by three studies in this review[30-32]. Compared to Veterans without PTSD, Veterans with PTSD report higher pain catastrophizing for a large effect size of .95 (95% CI .69-1.2). On the other hand, two studies[30,31] determined that Veterans with PTSD and pain had lower self-efficacy as measured by the Arthritis Self-Efficacy Scale (ASES) compared to Veterans with pain only. The standardized mean difference between the two groups was SMD=.77 (95% CI .55-.99), reflecting a large effect size. These two studies indicate that Veterans with PTSD and pain have decreased confidence to personally cope with their pain condition compared to Veterans without PTSD.

In Outcalt et al[31], 2014, Veterans with co-morbid PTSD and pain were more likely to rate their pain as central to their identity as measured by the Centrality of Pain Scale[97]. Another study captured a similar higher focus on physical pain despite co-morbid mental health disability[32]; Alschuler 2012 found that Veterans with PTSD and pain were more likely to believe pain is a sign of physical damage as measured by the Survey of Pain Attitudes (SOPA), Harm subscale[98]:

2.41 (±.89) for PTSD versus 2.03(±.90) without PTSD, p=.01. The SOPA[99] is measured on a scale from 0-4 with 0 indicating "very untrue" and 4 "very true." This difference, however, did not remain statistically significant after Bonferroni correction.

Other maladaptive cognitions associated with PTSD symptoms include more negative affect strategies[19] and decreased mental health confidence[94]. Finally, individuals with PTSD and pain were more likely to rate the spouse's response to the Veteran's pain as punishing[90], indicating that Veterans with PTSD and pain perceive their spouse responds to their pain in a negative manner[100].

Other Health Outcomes

Two studies reported higher healthcare utilization and costs associated with PTSD and pain compared to pain only[76,83]. However, Veterans with PTSD were less likely than Veterans without PTSD to achieve optimal attendance of weight-management therapy sessions[81]. Additionally, Veterans with PTSD and pain were more likely to be prescribed opiates for their pain[84,85]. Compared to Veterans without PTSD, this resulted in a greater number of adverse events to include opiod-related overdose and accidents, and self-inflicted or violent accidents[85]. Similarly, Veterans with PTSD and pain performed suicide-related behavior at a significantly higher rate than those with pain only[77]. In one cohort, PTSD increased the odds-ratio of suicide by 4.02 (95% CI 1.95-8.29)[87]. Finally, two studies determined that Veterans with PTSD had higher sleep disturbance than Veterans without PTSD[30,80]. The relationship between PTSD and sleep disturbance remained significant above and beyond pain interference[80]. These two studies were able to be included in meta-analysis and indicated a SMD of .80 (95% CI .57-1.02) for a large effect size.

Discussion

The articles included in this systematic review and meta-analysis offer empirical support for the growing call to research and develop treatments specific to Veterans with co-morbid pain and PTSD[71,73,74,101]. Although many previous reviews exist based on clinical experiences,

conceptual models[25,70], and a few original research publications in the Veteran population, this is the first study to systematically review the literature and synthesize the magnitude of health outcomes when pain and PTSD are co-morbid compared to Veterans without PTSD. Many Veterans with pain hold maladaptive beliefs about pain regardless of PTSD diagnosis[55]. The results from this review indicate, however, that when PTSD symptomology is layered into the pain experience, Veterans report significantly worse health outcomes to include higher pain intensity, pain catastrophizing, and disability with lower function and self-efficacy. Furthermore, Veterans with pain and PTSD consume greater healthcare utilization, are more likely to be prescribed opiods resulting in adverse effects, and are more likely to engage in suicide-related behavior compared to Veterans without PTSD.

The results of this review support the Fear Avoidance Model[29] in which individuals with a negative appraisal view an injury and pain as a threat that should be avoided. This leads to disuse, depression, and disability, which then leads to a greater pain experience. A higher pain experience then reinforces catastrophic beliefs about pain, and the fear avoidance cycle continues. The results from this meta-analysis revealed a large standardized mean difference for pain catastrophizing, which could at least partially explain the increased disability and pain in Veterans with PTSD and pain. It is notable that Veterans with PTSD had an average score of disability greater than 15 as measured by the Roland Morris Disability Questionnaire (RMDQ, 0-24)[102]; this score is considered at risk of poorer outcomes compared to a score of 10 or less[103]. Furthermore, a Pain Catastrophizing Scale (PCS) score of ≥ 16 has been proposed as an elevated score, increasing the risk of poor post-operative outcomes. According to one study reviewed[31], both Veterans with PTSD (PCS score of 28.59 ± 12.20) and without PTSD (PCS score 18.90 ± 11.24) have elevated pain catastrophizing scores. Although such elevated pain catastrophizing should be confirmed with further studies, it appears that Veterans with PTSD and pain score well above recommended cut-off scores for pain catastrophizing.

Although the timing and order about the Fear Avoidance Model has been questioned, there is empirical evidence to support the construct[104,105]. In a sample who had lower back pain following a traumatic event, avoidant beliefs and behavior contributed to greater disability[106]. Avoidance is a common impairment in individuals with PTSD, so the construct of avoiding potentially painful activities has face validity in Veterans with PTSD.

In addition to fear avoidance characteristics, Veterans with PTSD and pain demonstrated a large effect size of lower pain self-efficacy. Pain self-efficacy is the confidence to personally and actively cope with pain and is inversely related to fear of movement in patients with lower back pain[107]. According to meta-analysis, self-efficacy is a top mediator for pain and disability above and beyond pain catastrophizing[28]. Self-efficacy is one of most transcendent constructs in behavior change theories[108]. Since this characteristic is significantly lacking in Veterans with PTSD and pain and plays such an important role for health outcomes, improving self-efficacy is likely an important target for treatment.

Another cognitive target for therapy is pain acceptance. Cook, et al., determined that pain acceptance was negatively correlated with both disability as well as PTSD symptoms[109]. Acceptance Commitment Therapy (ACT) may be an appropriate therapy to address this finding. ACT is currently under trial in a Veteran population[110] and the results from this systematic review warrant further investigation in Veterans with pain and PTSD as results are promising in civilian populations for chronic pain[111,112].

Although cognitive treatments certainly have evidence for treating chronic pain, the risk for drop-out is high[39,43]. One review postulated this is because patients perceive their mental health providers are not considering the biological components of their pain experience but rather focus only on psychological contributions[39]. It may seem counter-intuitive that patients with co-morbid psychological disorders would focus more on their physical symptoms, but the evidence from this review suggests that patients with PTSD and pain consider their physical symptoms to be more concerning[32] and more central to their identity than Veterans with pain only[31]. Since

patients want to know more about their pain[48], Veterans with PTSD and pain may be a prime population to present Pain Neuroscience Education (PNE), which aims to decrease the threat of pain[47]. Patients with PTSD demonstrate enhanced sensitivity to threat as evidenced by increased amygdala plasticity[113,114], which may lead to heightened attention to pain and pain catastrophizing. PNE can decrease pain catastrophizing[48], which is one of the highest impairments in Veterans with PTSD and pain. PNE may also increase patient satisfaction with biopsychosocial interventions, since patients with pain want a biological explanation for their pain[39] and frequently feel stigmatized when providers attribute mental health problems to physical pain[36].

Limitations

There are some limitations to this review and the articles analyzed. First, the design for most of the articles preclude inferring that PTSD caused the negative health outcomes observed in these studies. Longitudinal prospective cohorts that measure PTSD symptomology as well as trauma exposure throughout military service and before chronic pain symptoms appear would be most ideal to ascertain the relationship of causation versus association. Second, there was a significant correlation between PTSD symptoms and depression in all studies that measured both conditions. In the studies that controlled for depression, the effects of PTSD symptoms on health outcomes were slightly diminished[19,30,31], but nonetheless an independent effect for PTSD could be determined[30,90]. Third, there was variability among how the studies included in this review diagnosed PTSD. Only one study[109] utilized the CAPS, which is considered the gold standard for diagnosing PTSD[88]. Therefore, the most accurate description for participants included in this review is Veterans with PTSD symptomology. This is not a significant limitation, however, as the diagnosis of PTSD is based on a set of symptoms following trauma exposure[14]. Finally, many cohorts did not specify how many participants were eligible for their study but declined to participate. This could potentially introduce selection bias if for some reason Veterans with more

severe symptomology and health outcomes participated more in these research studies than Veterans with milder PTSD symptoms.

Conclusion

In conclusion, this is the first systematic review with meta-analysis to capture the breadth of adverse health outcomes that are associated with PTSD and pain in Veterans. Although this review is unable to clarify the evidence regarding PTSD's role in the causation of negative health outcomes, this paper synthesizes and quantifies significant health effects that appear to be worse in Veterans with PTSD compared to those without PTSD or with pain only. As none of the pooled effect sizes crossed 0 in meta-analyses, the effects observed in the studies indicate that health outcomes are consistently worse for Veterans with PTSD. Many of these effects remained even after controlling for depression and ranged from medium to large effect sizes. Clinicians should consider PTSD symptomology when treating Veterans for pain as this review indicates a Veteran with PTSD has higher pain, disability, and pain catastrophizing than Veterans without PTSD. Furthermore, Veterans with PTSD have lower self-efficacy and function. Research should continue to test and develop effective treatment strategies for Veterans who have co-morbid PTSD and pain.

Table 2. 1 Search Strategy

Search Number	Search Term	Results
S28	S23 NOT S27	184
S27	S24 OR S25 OR S26	(198,860)
S26	headache	(103,043)
S25	SCI	(41,690)
S24	amput*	(54,359)
S23	S6 AND S11 AND S15 AND S22	(233)
S22	S16 OR S17 OR S18 OR S19 OR S20 OR S21	(4,810,269)
S21	function	(2,161,994)
S20	prognosis	(627,049)
S19	belief	(162,357)
S18	health outcome	(155,163)
S17	outcome	(1,975,080)
S16	disability	(378,730)
S15	S12 OR S13 OR S14	(785,379)
S14	chronic pain	(86,033)
S13	persistent pain	(11,238)
S12	pain	(785,379)
S11	S7 OR S8 OR S9 OR S10	(232,730)
S10	"Service Member"	(429)
S9	Veteran	(57,981)
S8	Soldier	(10,348)
S7	military	(185,823)
S6	S1 or S2 or S3 or S4 or S5	(77,237)
S5	post-traumatic stress disorder	(25,003)
S4	posttraumatic stress disorder	(45,302)
S3	post traumatic stress*	(46,195)
S2	post traumatic stress disorder	(25,011)
S1	PTSD	(44,916)

*Truncation used to identify all possible term endings.

Table 2. 2 Methodological Quality using the New-Castle Ottawa Quality Assessment Scale

Study	Selection (Out of 4 ★s)	Comparability (Out of 2 ★s)	Outcome (Out of 3 ★s)	Total (Out of 9)
Alschuler 2012	★★	★		**3/9**
Alschuler 2013	★★	★★		**4/9**
Becker 2015	★★★★	★★	★★	**8/9**
Finley 2015	★★★	★★	★★	**7/9**
Helmer 2009	★★	★★		**4/9**
Lew 2010	★★★	★		**4/9**
Magruder 2012	★★★	★★	★★	**7/9**
Maguen 2016	★★★★	★★	★★	**8/9**
McAndrew 2016	★	★	★	**3/9**
Morasco 2013	★★	★		**3/9**
Morasco 2016	★★★	★	★★	**6/9**
Nunnink 2012	★★	★★		**4/9**
Otis 2010	★★	★★		**4/9**
Outcalt 2014a	★★	★		**3/9**
Outcalt 2014b	★★★	★★	★★	**7/9**
Outcalt 2015	★★	★★		**4/9**
Rozet 2014	★★★★	★	★★★	**8/9**
Seal 2012	★★★	★	★★	**6/9**
Smeeding 2010	★★★★	★	★★	**7/9**
Taylor 2012	★★★		★★	**5/9**

Figure 2. 1 Study Selection Diagram

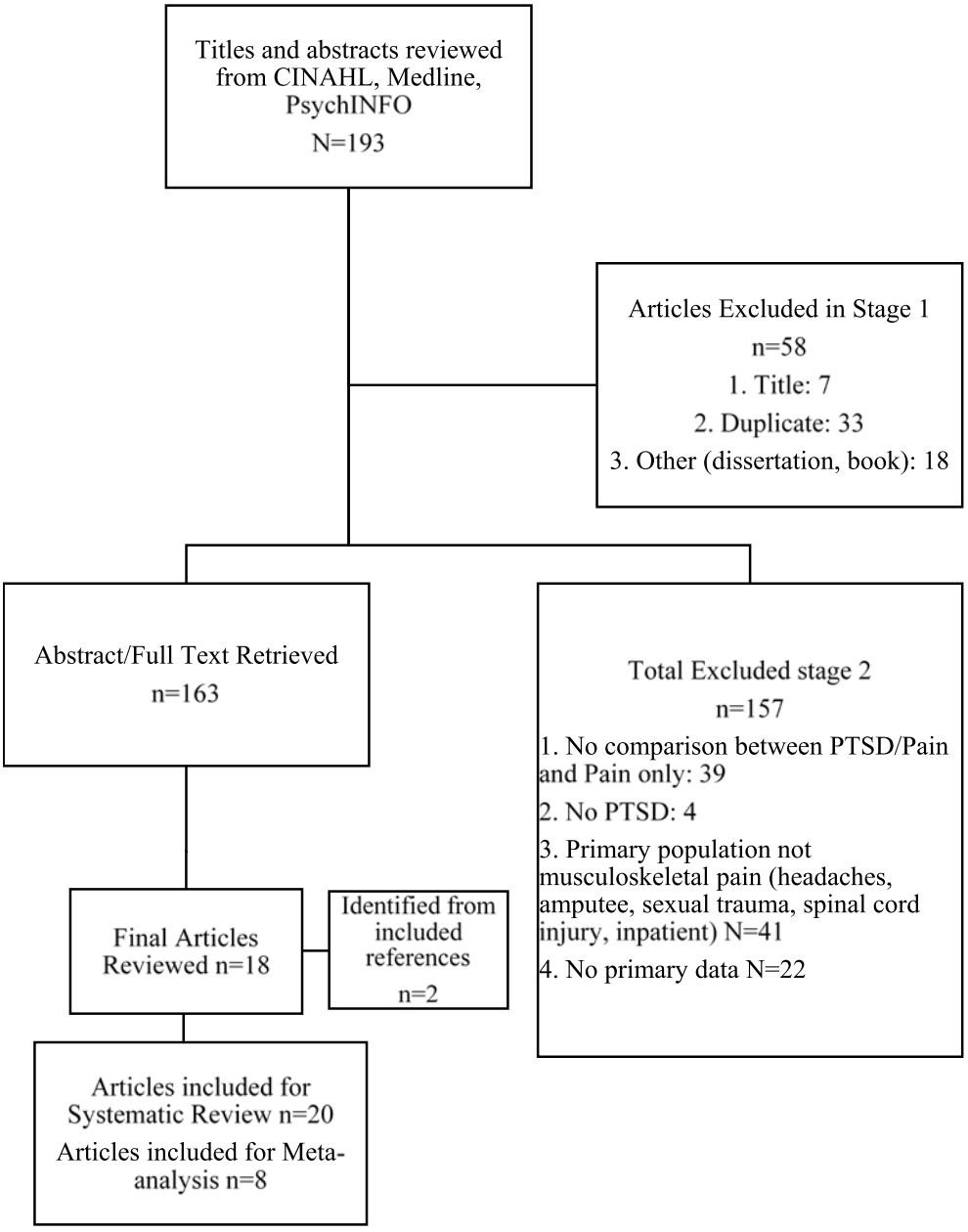


Table 2. 3 Summary of Research

Study	Study Type	Health Outcomes	Analytic Method	Results
Alschuler 2013[90] PTSD Diagnosed: PCL ≥ 50	Cross-sectional Retrospective Cohort, PTSD n=84, No PTSD n=100 Setting: Psychology Pain Management Program	Cognitive beliefs: Spouse response to Veteran's pain, West Haven-Yale Multidimensional Pain Inventory (MPI)	Multivariate Analysis of Covariance (MANCOVA)	PTSD ↑ rating significant others others with "punishing" response to their pain, p<.001
Alschuler 2012[32], PTSD Diagnosed: PCL ≥ 50	Cross-sectional, Retrospective Cohort, PTSD n=91, No PTSD n=103 Setting: Psychology Pain Management Program	Pain: McGill Pain Questionnaire (MPQ) Disability: Survey of Pain Attitudes (SOPA-Disability) Cognitive beliefs: Pain control (SOPA-control), catastrophizing, Coping Strategies Questionnaire (CSQ)	Independent t-test MANCOVA	No difference in pain between groups. No difference in disability between groups PTSD ↓ control of pain experience PTSD ↑ pain catastrophizing p<.001
Becker 2015[86] PTSD Diagnosed: International Classification of Diseases (ICD)-9	Retrospective Cohort PTSD n=348, No PTSD n=823 Setting: Veteran's Health Administration (VHA) Population Electronic Chart Review, 2003-2010	Health Outcome: Odds of achieving clinical improvement in pain	Mixed-effects modeling, adjusting for all variables tested	PTSD ↓ odds by 32% of achieving clinical improvement in pain ≥2 numeric pain rating scale p=.01

Table 2.3, continued

Study	Study Type	Health Outcomes	Analytic Method	Results
Finley 2015[77] PTSD Diagnosed: ICD-9	Retrospective Cohort, PTSD n=14,018, No PTSD n=38,426 Setting: Population-based analysis of all OIF/OEF Veterans enrolled in VHA, 2009-2011	Health Outcome: Suicide ideation, suicide attempt.	Multinomial logistic regression	PTSD ↑ odds of suicide ideation, Odds Ratio (OR) 2.3 (2.0, 2.6)
Helmer 2009[95] PTSD Diagnosed: PC-PTSD ≥ 3	Retrospective Cross-sectional, PTSD n=220, No PTSD n=200 Setting: Post-deployment clinic	Pain: Chronic, widespread pain	Chi-square, frequency analysis	PTSD ↑ frequency for chronic widespread pain (χ^2=17.89, p<.001).
Lew 2010[80] PTSD Diagnosed: ICD-9, clinical interview	Retrospective Cross-sectional, PTSD n=136, No PTSD n=64 Setting: Single VA Polytrauma Outpatient Clinic	Health Outcome: Sleep disturbance severity (0-4, 0=no disturbance, 4=severe disturbance)	Analysis of Variance (ANOVA)	PTSD ↑ sleep disturbance p<.0001
Magruder 2012[87] PTSD Diagnosed: CAPS	Retrospective Cohort, PTSD n=98, No PTSD n=718 Setting: Random sample of primary care patients from 4 VAMC in southeast	Health Outcome: Odds of suicidality	Multivariate logistic regression	PTSD ↑ odds of suicidality by 4.02 (1.95, 8.29).

OIF/OEF: Operation Iraqi Freedom/Operation Enduring Freedom

Table 2.3, continued

Study	Study Type	Health Outcomes	Analytic Method	Results
Maguen 2016[81] PTSD Diagnosed: ICD-9	Retrospective Cohort PTSD n=11,417 No PTSD n=13,482 Setting: Population-level OIF/OEF Veterans with at least 1 MOVE! visit across VHA, 2008-2013	Health Outcome: VHA MOVE! weight management program participation	Multivariate logistic regression	PTSD ↓ likelihood to achieve optimal participation (≥12 visits over 12 months) in MOVE! Program
McAndrew 2016[91] PTSD Diagnosed: PCL ≥ 50	Prospective Cohort PTSD n=24 No PTSD n=295 Setting: Army National Guard and Reserve enlisted Soldiers attending pre- and post-deployment medical processing, 2005-2011	Health Outcome: Chronic multi-symptom illness (CMI)	Analysis of frequency.	PTSD ↑ frequency of CMI (86% vs 52% without PTSD)
Morasco 2016[82] PTSD Diagnosed: ICD-9	Retrospective Cohort, PTSD n=3593 No PTSD n=19,053 Setting: Population-level analysis of all Veterans receiving chronic opiod therapy (≥90 days), 2011	Health Outcome: Risk of urine drug testing (UDT) for chronic opiod therapy (COT)	Binomial regression	PTSD ↑ risk by 19% to receive UDT Relative Risk (RR) 1.19 (1.11-1.27), p<.0001

Table 2.3, continued

Study	Study Type	Health Outcomes	Analytic Method	Results
Morasco 2013[92] PTSD Diagnosed: PCL ≥ 50	Cross-sectional, PTSD n=65, No PTSD n=136 Setting: Part of a larger study evaluating hepatitis C and substance abuse	Pain: interference and severity, Brief Pain Inventory (BPI) Cognitive Beliefs: Pain coping	Independent t-tests	PTSD ↑ pain severity and interference p<.001 PTSD ↑ illness and wellness coping strategies (5/7 strategies, p<.048)
Nunnink 2012[93] PTSD Diagnosed: Davidson Trauma Scale ≥ 40	Retrospective Cross-sectional, PTSD n=138, No PTSD n=250 Setting: OIF/OEF Veterans newly enrolling at VAMC member services	Function: physical and mental health functioning (SF-36)	Independent t-tests, multivariate linear regression	PTSD ↓ physical and mental component score p<.001 However, once adjusted for all variables, PTSD was no longer significant for physical function (p=.08)
Otis 2010[19] PTSD Diagnosed: PCL ≥ 50	Retrospective Cross-sectional, PTSD n=69, No PTSD n=73 Setting: Psychology Pain Management Program	Pain, MPQ Disability, Roland Morris Disability Questionnaire (RMDQ) Cognitive beliefs: Negative affect, West Haven Yale Multidimensional Pain Inventory-Affective Distress (WHYMPI-AD) Subscale	MANCOVA, controlled for depression	No difference in pain between groups. However, PTSD predicted Veteran experience of pain, p<.01 No difference in disability PTSD ↑ anger, irritability, and negative mood, p<.001

Table 2.3, continued

Study	Study Type	Health Outcomes	Analytic Method	Results
Outcalt 2015[30] PTSD Diagnosed: PCL ≥ 41 and PC-PTSD ≥ 1	Cross-Sectional baseline data, PTSD n=43, No PTSD n=207 Setting: Primary Care, Veterans with moderate-severe chronic pain.	Pain: severity and interference (BPI) Function/Disability: SF-12 Physical Component, Days/month of disability Cognitive Beliefs: Pain catastrophizing (CSQ), pain self-efficacy (Arthritis Self-Efficacy Scale, ASES, adapted)	Independent t-tests.	PTSD ↑ pain severity and interference, medium to large effect size p<.001 PTSD ↓ function (effect size .36, p=.028) PTSD ↑ disability (effect size .59, p=.0004) PTSD ↑ pain catastrophizing PTSD ↓ self-efficacy p<.0001, large effect size Significant effects still present but reduced after controlling for depression
Outcalt 2014a[31] PTSD Diagnosed: PCL ≥ 41 and PC-PTSD ≥ 1	Cross-sectional baseline data, PTSD n=68, No PTSD n=173 Setting: Primary Care, Veterans with moderate-severe chronic pain.	Pain: Pain severity (Graded Chronic Pain Scale) Pain interference (BPI) Disability, (RMDQ) Cognitive beliefs: Pain identity, Pain Catastrophizing Scale, self-efficacy (ASES)	Independent t-test.	PTSD ↑ pain severity and interference p<.001 PTSD ↑ disability p<.001 PTSD ↑ pain as central to identity PTSD ↑ pain catastrophizing PTSD ↓ self-efficacy (p<.001)

Table 2.3, continued

Study	Study Type	Health Outcomes	Analytic Method	Results
Outcalt 2014b[83] PTSD Diagnosed: ICD-9 or PC-PTSD ≥ 3	Retrospective Cohort, PTSD n=5874, No PTSD n=33,281 Setting: All Veterans enrolled in mid-west Veterans Integrated Service Network, 2002-2007	Health Outcome: Healthcare utilization to include primary care visits, prescriptions, specialty visits.	Negative binomial	PTSD ↑ healthcare visits and medication utilization p<.0001
Rozet 2014[84] PTSD Diagnosed: ICD-9, clinical interview	Retrospective Cohort, PTSD n=47, No PTSD n=97 Setting: All Veterans in a large northwest VAMC receiving knee arthroscopy 2007-2010	Health Outcome: Odds of chronic post-operative (>30 days) pain and opiod prescription	Univariable frequency	PTSD ↑ odds of receiving opiod prescription >30 days post-operative, OR 10.3 (1.9, 54.8) p<.001
Seal 2012[85] PTSD Diagnosed: ICD-9	Retrospective Longitudinal Cohort PTSD n=44,983 No PTSD n=96,046 Setting: Population-based analysis of all OIEF/OEF Veterans enrolled in VHA 2005-2008	Health Outcome: Relative Risk (RR) of Opiod prescription RR of Opiod-related adverse event	Poisson regression	PTSD ↑ RR of opiod prescription by 4.32 (4.17-4.49) PTSD ↑ RR of multiple adverse events: wounds, self-inflicted injuries, overdose. p<.001

Table 2.3, continued

Study	Study Type	Health Outcomes	Analytic Method	Results
Smeeding 2010[33] PTSD Diagnosed: Electronic Health Record, PTSD service-connected disability rating	Retrospective Cohort, PTSD n=63, No PTSD n=102 Setting: All patients with chronic pain attending an Integrated Health Clinic, 2001-2007	Function: SF-36	Independent t-tests	PTSD ↓ function across all domains
Taylor 2012[76] PTSD Diagnosed: ICD-9	Retrospective Cohort, PTSD n=34,375, No PTSD n=58,602 Setting: Population-based analysis of all OIEF/OEF Veterans enrolled in VHA 2008-2009	Health Outcome: Healthcare utilization, annual median cost	Descriptive, median value (Interquartile Range).	PTSD ↑ annual median healthcare costs $4978 ($2655–$9283) vs $1974 ($953–$3890) without PTSD

Figure 2. 2 Meta-analysis of Studies

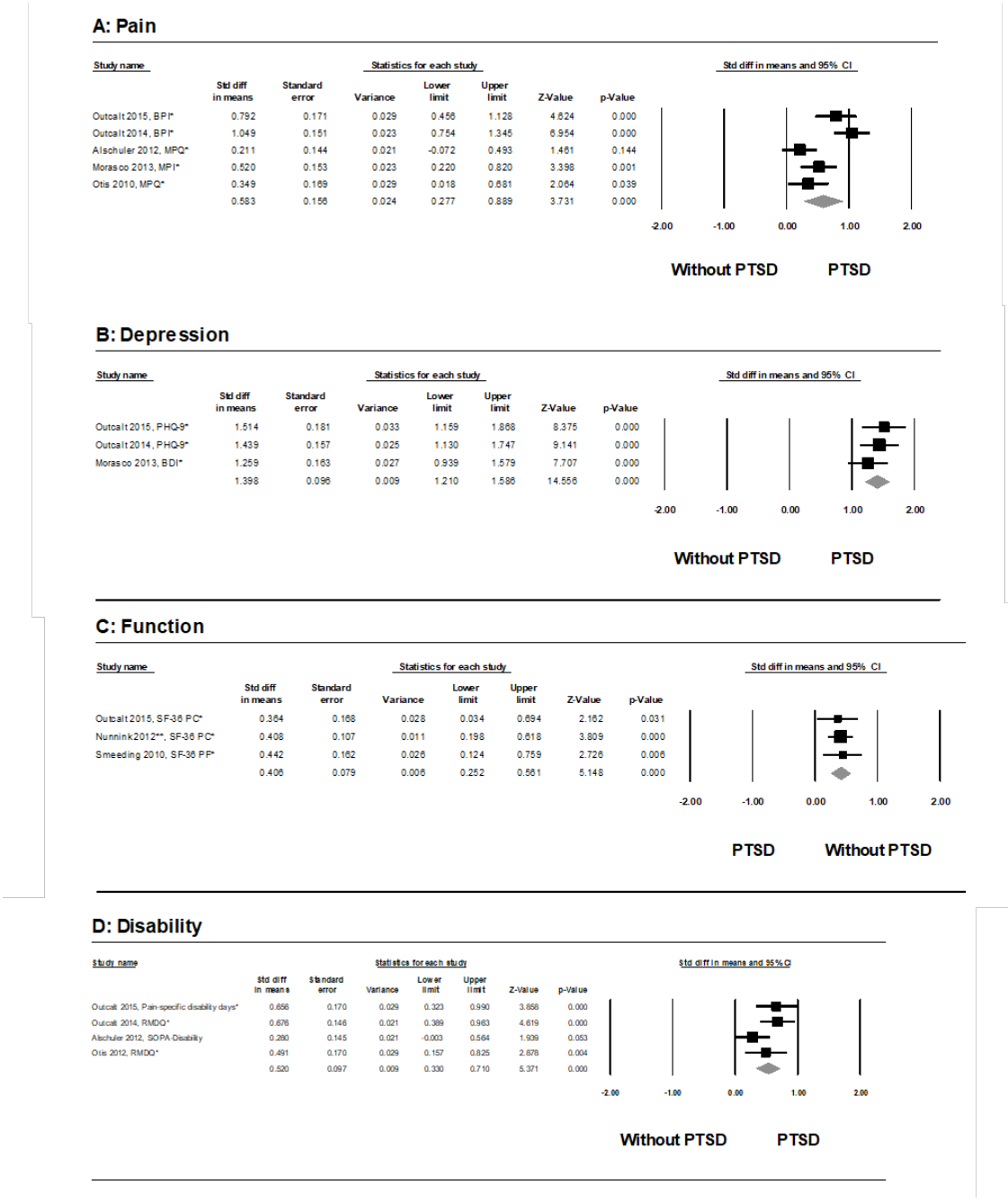


Figure 2.2, continued

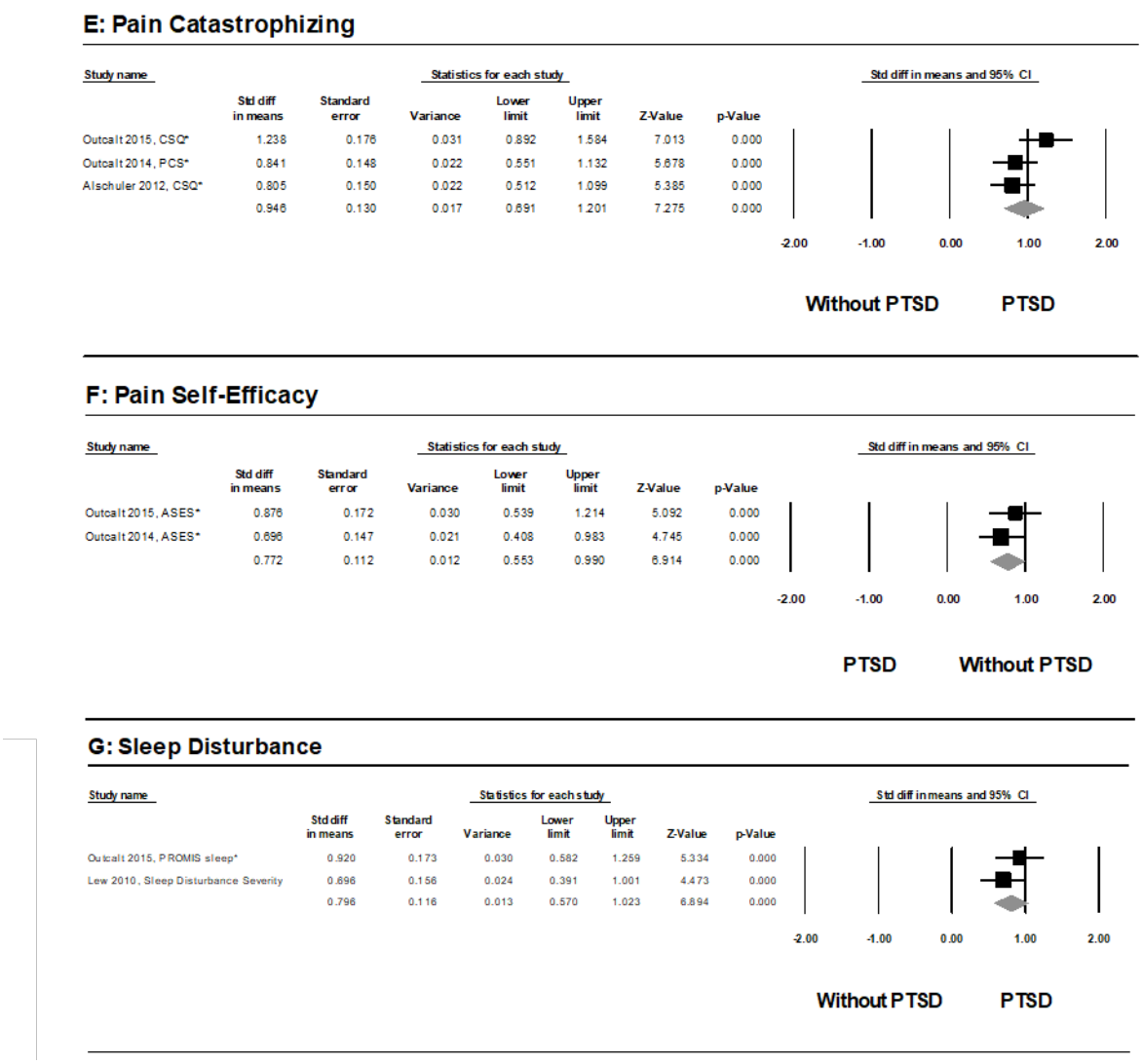


Figure 2 Legend: ASES: Arthritis self-efficacy scale; BDI: Beck depression index; BPI: Brief pain inventory; CSQ: Coping strategies questionnaire; MPQ: McGill pain questionnaire; MPI: Multidimensional pain inventory; PC: Physical component, PCS: Pain catastrophizing scale; PF: Physical function; PHQ: Patient health questionnaire; PROMIS: Patient reported outcome measurement information system; PTSD: Post-traumatic stress disorder; RMDQ: Roland Morris disability questionnaire, SOPA: Survey of Pain Attitudes.

Chapter 3: Development of a Pain Neuroscience Education Program for Veterans with Post-Traumatic Stress Disorder and Pain.

Introduction

Medical providers treating patients with post-traumatic stress disorder (PTSD) for co-morbid physical pain face a challenge in educating patients about their pain while attempting to reconcile mental and physical health concerns[37]. Attributing physical symptoms to psychological distress can be dismissive[36] or stigmatizing[42,115] to an individual with PTSD. Yet, patients with PTSD have more influential psychological characteristics—for example, higher pain catastrophizing[30-32] and lower self-efficacy[30,31]—which contribute to higher pain and disability[19,30,31]. Since PTSD appears to play a central role in the chronic pain experience[31], it could be just as problematic to ignore mental health as it is to assume psychosomatic symptoms in an individual with co-morbid pain and PTSD by failing to address psychosocial characteristics that greatly influence health outcomes. Developing interventions that address both PTSD and pain is an important target for Veteran healthcare[17].

PTSD is diagnosed after exposure to a traumatic event and experiencing the cluster of symptoms of hyper-arousal, re-experiencing, avoidance, and negative cognitions for at least 30 days beyond trauma exposure[14]. In one of the largest studies of disabled Veterans, participants revealed they wanted more education and classes for "emotional and physical pain" [116]. Several educational programs have successfully helped individuals with PTSD learn about their symptoms and have improved satisfaction with treatment[117-119]. However, when compared to a wait-list control, effect sizes of these programs are generally modest[120,121]. Furthermore, none of these programs directly addressed physical pain, which is a highly prevalent co-morbidity in Veterans with PTSD[18].

Pain Neuroscience Education (PNE) may be a valuable educational strategy that can address the symptoms of both PTSD and chronic pain. PNE uses metaphors and stories to help individuals understand the neurophysiology of pain[46]. If an individual believes that pain indicates

current tissue damage, it makes sense that the individual would avoid activities that might cause pain and, thus, potentially harm body tissues[54]. Modern neuroscience[49], however, demonstrates that on-going, chronic pain, poorly correlates with actual tissue health[122]. PNE, on the other hand, helps patients understand the role the nervous system plays in on-going pain. PNE communicates the phenomenon of increased nervous system sensitivity due to neuroplasticity resulting in maladaptive pain[53]. PNE has shown to decrease pain, disability, and pain catastrophizing beliefs in patients with fibromyalgia, chronic low back pain, chronic fatigue syndrome, and other chronic pain conditions where hypervigilance and fear avoidance are common[47]. Since pain is a protective response to potential tissue danger, PNE may be a top-down approach to decrease the threat of pain and enhance endogenous inhibition in individuals with chronic pain[50].

To date, no PNE curriculum specific to Veterans with PTSD and co-morbid pain has been developed or tested. Since culture-specific considerations are crucial to pain education[123-125], research personnel developed a PNE program written for Veterans with PTSD and chronic pain using military stories and analogies to educate the neurophysiology of pain from a Veteran perspective. The curriculum was designed to relate and connect with the experiences of Veterans[42] in efforts to increase the credibility of the materials.

A PNE curriculum specific to Veterans with PTSD and pain presents several challenges. First, healthcare providers typically underestimate a patient's ability to understand pain neurophysiology[56]. Second, patients with PTSD exhibit generalized neurocognitive deficits[57] that may complicate the delivery and understanding of PNE. Furthermore, although the purpose of using military examples is intended to connect with Veterans, it is possible using military examples could trigger PTSD symptoms. Finally, given some skepticism about psychotherapy and high drop-out rates for counter-intuitive therapies in individuals with PTSD[17], it is important to evaluate the credibility of a PNE program delivered to Veterans with PTSD and pain. The

purpose of this study was, therefore, to develop a PNE program for Veterans based on the best evidence of the neurophysiology of PTSD and pain. Secondary aims included determining if Veterans could comprehend the materials, find the program credible, and determine the impact of using military examples on PTSD symptoms.

Methods

This study followed the methods that have been reported in the literature to develop a population-specific PNE booklet[126]. After reviewing the literature for the neurophysiology of PTSD and pain, a booklet was adapted for this research following the format *Why do I Hurt* [127,128]. The neuroscience content was based on recommendations from two systematic reviews on PNE[47,48]. The PNE booklet included neuroscience education specific to PTSD to demonstrate how trauma can make the nervous system more sensitive and thus susceptible to chronic pain[22,24,37,114,129-131]. The main goal of the PNE booklet was to help Veterans who have PTSD and pain understand how the nervous system up-regulates threatening information after trauma. With a sensitive nervous system, the threshold for triggering pain and stress is lower. If Veterans can view pain and stress resulting from a sensitive nervous system, as opposed to tissue damage[49] or pathological physiology[132], then Veterans may be more willing to pursue active therapies that they frequently avoid[43,55,133].

The booklet was divided into six sections: (1) introduction to the nervous system using military examples; (2) sensitization of the nervous system[44]; (3) hypervigilance from stress hormones[24,134,135]; (4) re-experiencing trauma and pain memories from a neuromatrix perspective[49]; (5) how avoidance keeps the nervous system sensitive[29,106]; (6) practical tips to recovery. All research procedures were approved by the Institutional Review Board at a Southeast University and Veterans Affairs Medical Center (VAMC).

Medical Panel

After developing an initial draft, the research team presented an electronic version of the booklet to a medical panel consisting of PNE researchers and instructors, physical therapists, psychologists, pain physicians, primary care physicians, occupational therapists, and interdisciplinary researchers. The first version of the booklet included images created from an electronic presentation software program and images available from the copyright free domain on the internet. A feedback questionnaire based on previous research[126] and a comprehension questionnaire to determine the ability of individuals to read and understand the PNE booklet were adapted and developed for this study. The feedback questionnaire addressed clarity, credibility, helpfulness, length, and other questions to determine the utility of the PNE booklet. Participants were also given open-ended questions to identify the main messages or individual feedback for the PNE booklet. The comprehension questionnaire was a combination of identifying specific content of the booklet as well as to assess understanding of the neuroscience of pain and PTSD. The expert panel was given 40 days to read and review the booklet and complete the questionnaires anonymously online. The survey software sent weekly email reminders to participants to review and complete the questionnaires.

PTSD Panel

Based on initial feedback from the medical panel, professional images were added and, after making minor revisions, the booklets were printed. The final booklet was 39 pages and 8,381 words with a 5.9 Fleish-Kincaid reading level. The books were 8.5×11" with a font size of 12 and contained approximately 1.2 images per page to maximize readability. The printed booklets were presented to a panel of Veteran patients with PTSD and pain at a PTSD Clinic in a Southeastern VAMC. The Veteran patients at this VAMC were diagnosed with PTSD with the Clinician Administered PTSD Scale[88]. Participants were recruited from group therapy sessions. After obtaining informed consent, participants were given two weeks to read the booklet. Participants returned to the VAMC to complete feedback and comprehension questionnaires.

Additionally, some participants elected to give written and oral feedback based on their impression of the PNE booklet.

Veteran Panel

To maximize potential representation across Veteran eras, a convenience sample of Veterans irrespective of PTSD or pain was also recruited. Like the medical panel, the Veteran sample received an electronic version of the PNE booklet and had three weeks to read and complete the same questionnaires as the Veterans with PTSD and pain. A demographic questionnaire asked Veterans to report chronic pain[136] or self-report PTSD.

Adherence

Veterans with PTSD were directly asked if they read the PNE booklet. In addition, one question from the comprehension questionnaire asked participants to identify the primary example that was utilized throughout the PNE booklet and served as a proxy to determine if participants read the materials.

Statistical Analysis

Demographic characteristics among the 3 different panels were compared with independent t-tests and frequency analysis utilized Fisher's exact tests. To compare comprehension scores, a one-way analysis of covariance (ANCOVA) while controlling for number of years of education was utilized. Finally, feedback questionnaire ratings among the 3 groups were compared to determine how Veterans with PTSD perceived the PNE booklet compared to other Veterans and medical personnel with Fisher's exact tests. To control for multiple comparisons, a Benjamini-Hochberg[137] adjustment was applied to test p-values.

Results

Demographic characteristics of the medical panel are reported in Table 3.1. Overall, 89% of participants recommended the PNE booklet and 90% thought the PNE curriculum would help Veterans with PTSD and pain. The response rate for the medical panel was 46.7%. Most

medical respondents were physical therapists (72.4%, Table 3.1) and regularly use PNE in clinical practice or research (71.4%, data not shown). The entire panel believed the PNE booklet would help Veterans with PTSD and pain and believed the content of the booklet. Additionally, 100% of the panel, to include four mental health providers, did not believe the military examples would increase PTSD symptoms (Table 3.2). Feedback indicated that 34% of the panel recommended more practical tips and 24% believed the booklet was too long. Most of the remaining recommendations from the medical panel included formatting the final version with clearer sections and images to help Veterans follow the content of the PNE (Table 3.4). These recommendations were addressed by the authors of the booklet prior to writing the next version and presenting to patients with PTSD and pain.

43.5% of the Veteran sample completed the feedback and comprehension questionnaires after reading the PNE booklet. The Veteran panel attained higher levels of education than the PTSD/Pain panel (Table 3.1). The Veteran panel represented every Service of the U.S. Military (Table 3.1) with combat deployments ranging from Vietnam to Afghanistan and Iraq. Veterans who completed the questionnaires rated the booklet very positively (Table 3.2). 20% of the Veteran panel reported chronic pain.

Veterans with PTSD (n=13, 62% response rate) believed the PNE booklet was just as interesting as other participants and tolerated the length well (Table 3.2). A smaller proportion of Veterans with PTSD, however, recommended the booklet compared to the other panels ($p=.001$). In addition, more Veterans with PTSD were concerned that the PNE materials using military examples could possibly increase PTSD symptoms ($p<.001$). Across several book characteristics, Veterans with PTSD were less likely to rate the PNE as favorably as the medical and Veteran panel (Table 3.2). Veterans with PTSD were older than the medical and Veteran panels (Table 3.1).

Since most of the negative feedback from Veterans with PTSD came from one specific focus group, responses for each category of this particular support group of four compared to the remaining participants with PTSD were analyzed. The focus group rated the booklet differently than other participants with PTSD across several questions: they were less likely to recommend the book or find the military examples helpful (Table 3.2). If the focus group were excluded, Veterans with PTSD rated the PNE booklet the same as the remaining panels (data not shown).

The medical panel and Veteran panel scored higher on the comprehension questionnaire than Veterans with PTSD (88.9 vs. 85.1 vs. 78.3, p=0.018). However, after adjusting for education, comprehension scores were not statistically different (p=.121). 90% of Veterans with PTSD reported they read all the PNE booklet. 84% of participants correctly answered the identification question which served as a proxy for reading adherence. Table 3.3 identifies the main messages of the PNE booklet according to participants.

Discussion

The results from this study indicate that Veterans with PTSD and pain can comprehend neuroscience education at a comparable rate to an expert medical panel and a well-educated Veteran sample according to the comprehension evaluation designed for this study, once adjusting for years of formal education in participants. This is important because mental health providers are sometimes skeptical about an individual's ability to understand their psychological disorder[38]. Furthermore, healthcare providers typically under-estimate a patient's ability to understand neuroscience education[56]. Therefore, despite neurocognitive deficits which are prevalent in patients with PTSD[57], the results from this study indicate that a sample of Veterans with PTSD and pain are able to understand a booklet about the neuroscience of pain and PTSD and tolerated the length of the booklet better than predicted by a medical panel.

That some Veterans with PTSD and pain did not believe all the education provided in the PNE booklet may indicate that PNE challenged some beliefs of the PTSD panel. It is common

for patients in chronic pain to believe that ongoing pain indicates persistent tissue damage[55,138]. Avoidance is a core symptom in individuals with PTSD[14]. It is likely that Veterans with PTSD and pain avoid painful activities because they believe they may further harm their condition[55]. PNE, on the other hand, de-emphasizes tissues and instead educates patients that chronic pain is often the result of a hypervigilant nervous system[139]. According to a recent systematic review[47], PNE is successful in challenging these type of fear-avoidant beliefs[29] in individuals with pain. Since exercise can alleviate both pain[140-142] and PTSD symptoms[133], reducing the fear of pain is a vital step in promoting active therapies[39].

While written materials are frequently utilized to reinforce PNE messages to patients in pain[47], written materials are not necessarily endorsed as a stand-alone treatment[143]. Although there is research to suggest written PNE materials can improve pain beliefs[46], a PNE booklet was ineffective in changing pain beliefs or disability in individuals with fibromyalgia[143]. Likewise, since written materials alone did not improve PTSD symptoms in individuals after a traumatic experience[144,145], it is possible that Veterans with PTSD and pain will require a therapeutic relationship with a provider who will use the PNE book as a common reference[126].

Even though most of the concern about increasing PTSD symptoms from the PNE book came from one specific support group, using a PNE book with military examples may not be appropriate for all Veterans with combat PTSD. Although avoidance of traumatic memories can increase both PTSD and pain symptoms[106,146], there is a growing recognition that exposure therapy is not necessary for all patients with PTSD[43]. Nonetheless, the booklet attempted to use non-threatening, non-violent scenarios in the PNE booklet[147]. Furthermore, the book was developed with the assistance of military behavioral therapists who did not believe that military examples would increase PTSD. In fact, for many Veterans with PTSD, they re-live and re-experience their military combat trauma regardless of external cues[64,148]. Since Veterans with

PTSD most trust fellow Veterans with combat experience[42], the PNE book was written from a military perspective to achieve cultural relevance[149].

Utilizing focus groups to elicit feedback can be an efficient manner to gather opinions[150]. The representative nature of these opinions, however, may not extend beyond the specific focus group[150]. In focus groups, a group opinion frequently emerges. This phenomenon has been identified in PTSD support groups. Specifically, PTSD support groups that are quite homogenous may silence dissenting viewpoints that challenge the group identity[151]. Although participants in this research study filled out surveys individually, one particular group (n=4) openly discussed the survey as they were filling out their feedback questionnaires. The group also admitted that they had critically discussed the PNE booklet the week before during their therapy session. Since the majority of the criticism and negative ratings about the PNE booklet came from the 4 individuals in this specific PTSD group, it is possible that the feedback from the group represents one opinion as opposed to four unique viewpoints. Although feedback from this focus group was not dismissed, the opinions of this one group may not be representative of all Veterans with PTSD. Nonetheless, the limited sample size of this study precludes definitive conclusions to this regard.

Despite some of the critical feedback regarding the PNE curriculum, Veterans with PTSD and pain represent an ideal population for PNE because they have high pain catastrophizing beliefs[31] and altered nervous system processing[152]. PNE is recommended for patients with high catastrophizing and central sensitization[153]. Patients with PTSD and pain frequently avoid activities that might cause harm. They may also avoid ideas that conflict with their current belief system. As demonstrated in this research study, a PNE book directed towards Veterans with PTSD and pain can directly challenge patients' beliefs about pain. Veterans with PTSD and pain comprehended PNE materials and concepts as well as Veterans without PTSD and an expert medical panel after controlling for education. The PNE book for Veterans with PTSD and pain

can be an entry-point in a therapeutic relationship that demonstrates a plausible, biological explanation for why it is safe to engage in physical exercise, even in the presence of chronic pain.

Limitations

This study has some limitations. First, participants consisted of a convenience sample to read and give feedback on the PNE book. The sample in this study might not reflect the general opinion of other Veterans. Furthermore, the response rate by the panel was less than desirable[154], but comparable to overall declining response rates, particularly among medical providers[155]. Next, this study did not use a validated questionnaire to determine comprehension of the neurophysiology of pain. Although this study could have included the Pain Neurophysiology Questionnaire[56], that would have prevented PTSD-specific questions as well as basic content-identification questions to ensure participants read the materials. In addition, participants could have completed a PTSD-symptom questionnaire before and after Veterans read the book to more definitely assess whether the book increased PTSD symptoms as opposed to asking Veterans if they felt the book would increase PTSD symptoms in other Veterans. Finally, the PNE materials were longer than recommended for health communication[126]. Although Veterans with PTSD tolerated the length of the materials better than the medical panel, it would be helpful to determine if a shorter version of the PNE booklet can increase Veterans' willingness to read without compromising PNE comprehension.

Conclusion

The PNE curriculum written for this research is the first set of materials specifically designed to explain the neurophysiology of pain or PTSD in Veterans after trauma. PNE has the potential to improve both pain and PTSD symptoms in Veterans with PTSD and pain. These materials will be tested in a randomized clinical trial at a VAMC facility. Based on the results of this current research, clinicians can be confident that Veterans with PTSD and pain will be able to

comprehend PNE materials and this PNE curriculum may serve as a common reference for clinicians to discuss the neuroscience of pain and PTSD.

Table 3. 1 Panel Demographic Information

	Medical Panel n=29	Veteran PTSD/Pain Panel n=13	Veteran Panel n=20	F/Chi-square (df) p value
Age (sd)	39.6 (11.1)	55.8 (16.3)	44.9 (15.0)	6.39 (2) p=.003*
Sex Male, n (%) Female, n (%)	 19 (65.5%) 10 (34.5%)	 11 (84.6%) 2 (15.4%)	 19 (95%) 1 (5%)	 6.3 (2) p=.034*
Discipline PT (n) Mental Health (n) Other (n)	 21 (72.4%) 4 (13.8%) 4 (13.8%)	 NA	 NA	 NA
Ethnicity White, n (%) Hispanic, n (%) Asian, n (%)	 Not assessed	 13 (100%) 0 0	 18 (90%) 1 (5%) 1 (5%)	 1.3 (2) p=1.0[a]
Education Terminal Degree (%) Graduate Degree (%) Associate/Bachelor's (%) High School (%) Other (%)	 15 (51.7) 13 (44.8)	 1 (7.7%) 0 5 (38.5%) 5 (38.5%) 2 (15.4%)	 0 12 (60%) 7 (35%) 1 (5%)	 26.4 (6) p<.001* 13.0 (3) p=.002*[a]
Income >$100,000 $50,001-100,000 $10,000-50,000 <$10,000	 Not assessed	 0 6 (46.2%) 6 (46.2%) 1 (7.7%)	 5 (25%) 7 (35%) 8 (40%) 0	 4.9 (3) p=.153[a]
Military Service (%)	13 (44.8%)	100%	100%	25.2 (2), p<.001*
Service (n) Army Marines Navy Air Force Coast Guard	 Not assessed	 11 (84.6%) 0 2 (15.4%)	 16 (80%) 1 (5%) 1 (5%) 1 (5%) 1 (5%)	 2.9 (4) p=.909[a]
Deployments Vietnam (%) Gulf War I (%) Afghanistan (%) Iraq (%) Iraq/Afghanistan (%) Other (%) None (%)	 Not assessed	 6 (46.2%) 1 (7.7%) 1 (7.7%) 3 (23.1%) 1 (7.7%) 0 1 (7.7%)	 4 (20%) 1 (5%) 3 (15%) 6 (30%) 4 (20%) 1 (5%) 1 (5%)	 4.2 (6) p=.761[a]
Response Rate (%)	46.7%	62.5%	43.5%	1.93, p=.233

[a]Comparison only between Veterans with and without PTSD. *Significant at the level of α=.05

Table 3. 2 Panel Pain Neuroscience Education (PNE) Written Materials Feedback

	Medical Panel (%) n=29	Veteran PTSD/Pain (%) n=13	Veteran (%) n=20	Chi-Square (p value) PTSD (n=13) vs. All others (n=49)	Chi-Square (p value) PTSD (n=9) vs. Focus group (n=4)
Readability					
Very easy	21 (72%)	10 (77%)	19 (95%)	5.9 (2)	4.5 (2)
Somewhat easy	8 (28%)	1 (8%)	1 (5%)	p=.037	p=.077
Difficult	0	2 (15%)			
Interest-level					
Interesting	29 (100%)	11 (85%)	18 (90%)	2.18 (1)	5.3 (1)
Boring	0	2 (15%)	2 (10%)	p=.191	p=.077
Clarity					
Clear	26 (90%)	9 (69%)	18 (90%)	8.93 (2)	13.0 (1)
Not very clear	2 (7%)	0	2 (10%)	p=.008*	p=.001*
Completely confusing	1 (3%)	4 (31%)	0		
Learn					
New and helpful	18 (62%)	5 (38%)	18 (90%)	8.322 (2)	7.6 (2)
Already knew	11 (38%)	5 (38%)	1 (5%)	p=.012*	p=.028
Not helpful	0	3 (23%)	1 (5%)		
Credibility					
Believed most	29 (100%)	9 (69%)	20 (100%)	13.6 (1)	5.3 (1)
Believed some	0	4 (31%)	0	p=.001*	p=.052
Didn't believe any	0	0	0		
Order					
Easy to follow	26 (90%)	8 (62%)	19 (95%)	7.8 (2)	11.7 (2)
Mixed up	3 (10%)	4 (31%)	1 (5%)	p=.015*	p=.001*
Missing	-	1 (8%)	-		
Recommend					
Yes	29 (100%)	7 (54%)	18 (90%)	12.5 (2)	11.7 (2)
No	0	5 (39%)	1 (5%)	p=.001*	p=.001*
Missing	-	1 (8%)	1 (5%)		
Military examples					
Helpful	29 (100%)	7 (54%)	18 (90%)	15.7 (2)	7.0 (2)
Will increase PTSD	0	5 (39%)	1 (5%)	p<.001*	p=.021*
Missing	-	1 (8%)	1 (5%)		
Helpfulness					
Will help	29 (100%)	9 (69%)	19 (95%)	9.0 (1)	13.0 (1)
Will not help	0	4 (31%)	1 (5%)	p=.006*	p=.001*
Length					
Just about right	22 (76%)	10 (77%)	17 (85%)	3.8 (2)	3.1 (2)
Too long	7 (24%)	1 (8%)	2 (10%)	p=.1	p=.203
Too short	0	2 (15%)	1 (5%)		

Table 3.2, Continued

Practical tips					
Enough tips	18 (62%)	6 (46%)	17 (85%)	7.5 (3)	4.6 (3)
Wanted more tips	10 (34%)	4 (31%)	3 (15%)	p=.038	p=.194
Tips not clear	1 (3%)	2 (15%)	0		
Missing	-	1 (8%)	-		
Comprehension/ Compliance					
Correct	25 (82%)	10 (77%)	17 (85%)	4.9 (4)	1.17 (2)
Incorrect	4 (18%)	3 (23%)	3 (15%)	p=.277	p=1.0

*Denotes significance at the level of α=.05 after Benjamini-Hochberg correction.

Table 3. 3 Participant Top 3 Messages

Theme	Participant Quotation
Knowledge about the nervous system is helpful	"It's helpful to know how the nervous system works as it responds to pain and PTSD." "There are logical, and basically physical, explanations for the symptoms and pain and PTSD and by understanding them, you can better overcome them."
Helpful tips	"There are things I can do. I am not helpless to suffer with PTSD/Pain." "We must learn to manage pain and stress, and this can be done through diet, lifestyle choices, and goals. I loved you took time to talk through breathing exercises."
Change is possible	"Recovery is possible." "Trauma is not destiny."

Table 3. 4 Recommendations for booklet

Theme	Participant Quotation
Appearance of initial draft[a]	"Obvious page breaks to transition from one topic to the next. Images of real individuals." "Graphics need to be improved throughout."
Reinforce metaphors with neurobiology	"I would suggest anytime you refer to a given area of the body that in paren(theses)[sic] you put the military comparison, and vice versa. It would help me to keep focused and not have to go back and remind myself of what various parts did or were correlated to."
Clarify pain vs. PTSD	"Try to better differentiate the issues of chronic pain and PTSD within each section."

[a]These comments came only from the medical panel regarding the initial draft

Chapter 4: Effect of Chronic Low Back Pain and Post-Traumatic Stress Disorder on the Risk for Separation from the U.S. Army.

Introduction

As the number one reason for a Service Member to visit a healthcare provider[7], low back pain (LBP) disables more Soldiers annually[8] than combat operations[156]. Likewise, post-traumatic stress disorder (PTSD) is the third leading cause for a Soldier to be medically discharged from the Army[8] and contributes to disability in its own right including increased mortality[157] and poorer health outcomes[158]. As physically and mentally demanding combat operations for U.S. military forces have endured for the past 15 years, the burden of PTSD[159] and injuries[160] like LBP[161] contribute significant cost to the Department of Defense (DOD). It is estimated that Iraq and Afghanistan-era Veterans will cost the DOD $300-700 billion over the course of their lifetime due to medical costs and disability compensation[61], half of which is due to LBP and PTSD[8].

In addition to the independent burdens of PTSD and LBP, there is a growing recognition of the co-occurrence of these two conditions; 66% of Veterans seeking treatment for PTSD also have chronic pain[18]. PTSD is a risk factor for developing chronic pain, with combat-related PTSD increasing the odds of a chronic pain condition more than three-fold[27]. Likewise, chronic pain increases the likelihood of developing PTSD at a similar ratio of 3.4[26]. Veterans with co-morbid PTSD and pain have greater disability[31] and experience higher costs[76], pain, and catastrophizing beliefs[31]. Most studies examining the relationship between PTSD and pain in Veterans, however, have been cross-sectional[19,30-32].

Since medical discharge from the Army represents a significant cost and threat to military readiness[162] and greatly contributes to prolonged disability[163] and societal burden, it is critical to understand the longitudinal risk factors of LBP and PTSD, beginning with active duty service. Cross-sectional data in the Army has demonstrated that almost half of medical discharges can be attributed independently to LBP and PTSD[8]. One problem with the existing literature about co-morbid PTSD and pain[8,76], though, is the potential for selection bias[164] resulting from only studying cases who have already been medically discharged. The majority of individuals who

experience an index case of LBP do not develop chronic LBP[165] (cLBP). Similarly, only a small sub-set of individuals exposed to a traumatic experience develop PTSD[16]. Finally, not all individuals with these chronic conditions will be medically discharged. Therefore, investigating the longitudinal pathway from active duty service to medical discharge is an important step in understanding how the combination of LBP and PTSD affect disability in the military.

The purpose of this research is to examine whether the combination of cLBP and PTSD exerts a greater risk for medical discharge than when these two conditions are not present or only in isolation. This analysis will determine if the combination of cLBP and PTSD is a significant source of disability that begins during Active Duty or if it is a phenomenon primarily restricted to the Veteran community[17]. The study hypothesis was that Soldiers diagnosed with cLBP would have higher risk for medical discharge compared to Soldiers who are not diagnosed with cLBP, followed by Soldiers with PTSD, and, finally, Soldiers with both PTSD and cLBP would have the highest relative risk for medical discharge.

Methods

Participants

This retrospective cohort utilized the Total Army Injury and Health Outcomes Database (TAIHOD)[166] to examine medical disability discharges in U.S. Army Soldiers. The TAIHOD is a comprehensive database that includes administrative data for all personnel assigned to the active component of the U.S. Army as well as all medical encounters from inpatient and outpatient visits. Although it is possible for Soldiers to receive healthcare at a non-military facility, annual health examinations and insurance reconciliation ensures all medical conditions are included in the Soldier's electronic medical record. This study was amended from an IRB-approved protocol examining factors related to medical disability in U.S. Army soldiers. All Active Duty U.S. Army Soldiers were eligible for this cohort and were selected from January 1st 2002 until December 31st 2008. All members of the cohort were followed until the Soldier was medically discharged or left the Service for any other reason until December 31st, 2012 (See Figure 1).

Study Variables

Dependent Variables

The primary outcome of interest was medical disability retirement. When Soldiers are deemed unfit to continue service in the U.S. Army due to a mental or physical condition, they are referred to a Physical Evaluation Board (PEB)[167]. If the PEB determines the Soldier does not meet retention standards, the Soldier is medically discharged. As service-connected disability is a major source of financial cost and healthcare utilization in the Veterans Administration services[168], this was the study's dependent variable. Medical discharge and PEB data are included within the TAIHOD.

Independent Variables

Chronic Low Back Pain (cLBP)

The first exposure of interest was cLBP. LBP diagnoses were identified as a medical encounter with an International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9 CM) diagnosis consistent with LBP[169]. Chronic LBP was defined as a LBP diagnosis after 90 days from the initial LBP diagnosis had passed[136]. If a period of 365 days elapsed after the index LBP diagnosis, however, subsequent LBP diagnoses were considered a new incident case and evaluated separately for chronicity. Since most LBP cases resolve within approximately 4-6 weeks[170,171], cLBP[23] may represent a poor prognostic factor making one more likely to be medically discharged compared to acute LBP.

PTSD

Soldiers with the ICD-9-CM diagnosis of 309.81 for at least 3 medical encounters were considered positive for PTSD. Soldiers are routinely screened for PTSD with the Primary Care PTSD Screen[172] during primary care medical encounters[173]. Since it has been documented that Soldiers under-report and under-utilize healthcare for PTSD[174,175], this study used 3 visits to capture chronic, PTSD behavior[77,175].

History of LBP and PTSD

Soldiers who met criteria for both cLBP and PTSD exposure as defined above were considered to have both cLBP and PTSD. Although this study did not specifically measure for an overlap in calendar time, adding a temporal requirement between cLBP and PTSD diagnoses might have reduced the potential sample of the exposure of interest. Furthermore, because of delayed reporting and deployments, since this study relies on secondary analysis of medical visits, adhering to a strict temporal algorithm might not have reflected the actual co-morbidity of PTSD and cLBP symptoms in subjects. In addition, once chronic, the symptoms of these two conditions appear to remain relatively persistent and stable[165,176,177]. Therefore, it is likely that the Soldiers in this group had cLBP and PTSD concurrently. Even if the conditions were not concurrent, this group represents a unique combination of symptoms in the Army warranting investigation.

Other Covariates

The following variables were included to control for possible confounding as they have been identified as risk factors for disability, LBP, and PTSD: age[178], rank[167,178], sex[178-180], deployment history[8], military occupation specialty[8], sleep disorder diagnoses[181], and other mental health diagnoses[167]. Furthermore, obesity[182], tobacco[183], and alcohol abuse[181] were included as potential covariates due to their contribution of risk towards LBP or medical discharge. Other mental health disorders were defined by mental health ICD-9 codes[184] excluding PTSD. Military occupation specialty was divided into combat and non-combat specialties[185]. Finally, months in service was included as a continuous variable to determine the impact of time as a potential cumulative risk factor for medical discharge[178]. Misclassification was minimized through the operational definitions of the cohort in which cLBP and PTSD exposures were only selected after several diagnoses over time. This decreased the likelihood that Soldiers entered the groups of exposure through an errant medical diagnosis[186].

Statistical Analysis

This study utilized modified Poisson regression[187], which is the preferred statistical method for estimating relative risks (RRs) for rare event count data[187] (in this study, medical discharge). First, crude RRs with 95% confidence intervals were calculated evaluating medical disability for the following mutually exclusive groups: Soldiers with neither cLBP nor PTSD (group 1), Soldiers with cLBP only (group 2), Soldiers with PTSD only (group 3), and Soldiers with a history of both cLBP and PTSD (group 4). Group 1—those with neither cLBP nor PTSD—served as the reference group. Crude RRs measure the overall association between group membership and the outcome event of medical discharge. To ensure that the RRs were not biased due to confounding, this study also adjusted for potential confounding variables controlling for all covariates listed in the previous section. Statistical analysis was performed with SAS Software, version 9.3 from March-May 2016 (SAS Institute Inc, Cary, NC, USA). At the time of data analysis, the TAIHOD had data available through 2012 for this study cohort.

Results

From 2002-2008, the TAIHOD database identified 1,011,849 Active Duty Soldiers who were eligible for the cohort (Figure 4.1). Among the eligible Soldiers, 80.2% (n=811,337) had neither cLBP nor PTSD during their service; 15% (n=159,629) were determined to have cLBP only; 2.8% (n=27,940) were diagnosed with PTSD only, and 2.1% (n=20,943) had both cLBP and PTSD. The outcome of interest, Soldiers medically discharged from the U.S. Army from 2002-2012, was present in 6.7% (n=68,175) of the cohort (Figure 4.1). Sociodemographic characteristics of the cohort and groups can be found in Table 4.1.

Group 1, the reference group, had an absolute medical discharge rate of 4%. Soldiers with a diagnosis of cLBP only had a crude risk of discharge 3.29 times that of Group 1 (Table 4.2). Soldiers with PTSD only had 3.76 times the risk for medical discharge compared to the reference group. When Soldiers had both a cLBP and PTSD diagnosis during Active Duty Service, they had 5.27 times the risk for medical discharge compared to the reference group.

When adjusted for sex, age, rank, time in service, deployment, mental health, sleep disorders, alcohol abuse, tobacco use, obesity, and military occupation, the relative risks associated with the group membership variables remained significant (Table 4.2). Contrary to the study hypothesis, after adjusting for all characteristics, cLBP demonstrated a slightly greater relative risk for medical discharge than PTSD, although their confidence intervals were nearly identical. These results indicate that a Soldier who had cLBP had 3.65 times the risk of being medically discharged compared to a Soldier who had neither condition (95% CI 3.6-3.7) and a Soldier with PTSD had a RR of 3.64 (95% CI 3.5-3.8). These represent moderate effect sizes for relative risk[188]. Consistent with the study hypothesis, Soldiers who had PTSD and cLBP at any point during their service had an even greater relative risk, 5.17 (95% CI 5.01-5.33), of medical discharge compared to Soldiers who did not have either of these two diagnoses, even after adjusting for potential confounding variables. This effect size for relative risk of medical discharge in Soldiers with cLBP+PTSD is considered large[188].

According to the results, officer rank, previous deployment, self-reported alcohol use, and female sex demonstrated a protective association against medical discharge after adjusting for all covariates in the full model. On the other hand, having a sleep disorder, older age, obesity, mental health disorders, tobacco use, and combat military occupation were associated with increased risk for being medically discharged from the Army when accounting for all other variables (Table 4.3).

Discussion

The results from this retrospective cohort fill an important gap in the literature. Although the co-morbidity of LBP and PTSD is a well-recognized occurrence in both Veteran[18,19,32] and civilian populations[20,106,189], no longitudinal study has provided evidence that the presence of both PTSD and cLBP leads to a substantial increase in risk for medical discharge compared to either condition alone. This study found that a Soldier who experiences both cLBP and PTSD has over

five-times the relative risk of discharge compared to a Soldier without these conditions, even after adjusting for other potential risk factors.

Previous Veteran cohorts also demonstrate worse health outcomes when PTSD and chronic pain—of which LBP is the most prevalent pain condition[18,19,32]—are co-morbid, ranging from higher medical costs to increased suicide-related behavior[76,77,83,85]. Less than half of eligible Veterans utilize VA services[76], however. Prior to this research, the natural trajectory of active duty Soldiers with both PTSD and cLBP were unknown. The population level analysis in this study, however, confirm that the presence of both PTSD and cLBP lead to negative health outcomes beginning in active duty.

There are several theoretical constructs which may explain the results from this study. Shared vulnerability[70] suggests some individuals may be more at-risk for developing disability due to low resilience. On the other hand, the Fear Avoidance Model[29] and mutual maintenance theory[25] suggests that PTSD and pain re-enforce the chronicity of each condition. An individual with PTSD exhibits hypervigilance[134] and magnifies potential threats[190]; pain may be perceived as an on-going threat which then further elevates hypervigilance. An individual with only LBP or PTSD may be able to actively cope enough to continue active duty service. Individuals with co-morbid PTSD and pain, however, demonstrate decreased active coping abilities[32,92], likely reducing their ability to continue active duty service. A treatment that is recommended for individuals with a hypervigilant nervous system is Pain Neuroscience Education (PNE)[47]. PNE aims to help individuals understand that on-going pain is not due to damaged tissues but rather explains how neuroplasticity can promote chronic pain[191]. Since PNE has helped in LBP populations[192], it would helpful to test PNE in Active Duty Soldiers to determine if education about pain and PTSD could decrease disability when these conditions are combined.

This study had sufficient power to investigate multiple covariates that represent possible contributors to medical discharge from the Army. The results from this study are consistent with the biopsychosocial model[193] in which a combination of psychosocial and physical factors appear

to influence disability[194-198]. Similar to other research, Soldiers who had mental health[167,199] visits had a 20% greater risk of medical discharge. Other than the primary exposures of interest in this study, however, the variable which raised the risk of medical discharge the most was having a sleep disorder diagnosis, which increased the risk of medical discharge by more than 50% when all other variables are held constant. In the literature, poor sleep is frequently reported in subjects with cLBP[200,201] and PTSD[202]. The results from this study support the relationship between poor sleep, cLBP, PTSD, and disability, but the design from this study does not elucidate which variable appears to initiate the path to medical discharge.

Some of the results from this study at first glance appear surprising. First, Soldiers who deployed were 50% less likely to be discharged than Soldiers who never deployed, when controlling for all other variables. Deployment has been labeled as a risk factor for discharge[8,203] and would certainly contribute to the likelihood of being exposed to combat trauma—and hence, PTSD[179]—or LBP[204]. This finding, however, has been reported as the "healthy warrior effect,"[59,205] in which Soldiers with poorer health or injuries are less likely to meet medical standards to deploy and therefore would be more likely to be discharged from the Army.

Additionally, according to the results from this cohort, alcohol use appears to be protective against medical discharge when controlling for all other variables. Alcohol use is typically under-reported in the military[206], however. It is possible that individuals who drink moderately would be more willing to report alcohol use to a medical provider than a Soldier who abuses alcohol to self-treat symptoms of PTSD or pain, masking the contribution of alcohol to disability.

Higher rank, particularly the rank of officers, also provides protection from medical discharge and is likely related to education, socioeconomic status, and more control over their work environment than lower ranks[167,178]. Finally, keeping all other factors equal, females were less likely to be medically discharged from the Army when accounting for cLBP and PTSD status. This is a very interesting finding since female sex has been implicated independently as a

risk factor for PTSD[179], LBP[180], and medical discharge[178]. While female Soldiers might be at higher risk for PTSD and LBP, the results from this cohort indicate that when holding all other characteristics equal, females were not observed to have higher risk of medical discharge relative to male Soldiers.

Other research supports that PTSD contributes to chronic pain at a greater rate in males than females[27]. This finding may be due to different types of trauma that males and females experience[207-209]. Some theories also suggest this could be a result of how females cope with stress following trauma. "Tend or befriend"[210] proposes that female Soldiers might be more likely to seek social support and possibly medical help following a traumatic experience than male Soldiers and would therefore achieve some amount of protection from disability. Results from the literature, however, demonstrate that male and female Soldiers and Veterans utilize mental health services equally[211,212]. Furthermore, female Soldiers generally experience less social support in the military than males[179,213] which makes their relative resilience to medical discharge in the presence of cLBP and PTSD quite intriguing. Although it was beyond the aim of this cohort, future investigation into this phenomenon is certainly warranted.

Limitations

As with any observational research, there are limitations within this study. First, the results of this study may not generalize to non-military populations. In addition, this study relied on secondary analysis of data entered by various medical providers and their judgment for ICD-9-CM diagnoses. It is not uncommon for Soldiers to receive the diagnosis of PTSD through self-report measures[172,175], even though the Clinician Administered PTSD Scale is considered the gold standard for PTSD diagnosis[88]. As with chronic LBP, however, this study utilized a more stringent operational definition of 3 PTSD visits which should increase the specificity of classification into the PTSD group(s) in this study. Furthermore, the methods in this study did not analyze whether PTSD precedes cLBP or the other way around on the pathway towards medical discharge. Further research and design could test whether the presence of LBP serves as

a risk factor for developing PTSD or whether PTSD serves as a risk factor for cLBP in the Army. Even if this study did attempt to control for initial timing of PTSD or cLBP diagnoses, it is not uncommon for delayed reporting of PTSD[214,215] due to potential stigma and not having the time to seek treatment[174].

Finally, it was not possible to ascertain the nature of how individuals were injured. It is possible that Soldiers with a history of both cLBP and PTSD experienced more severe, combat-related injuries, which could contribute to their risk of medical discharge. Only a small percentage of war-time medical evacuations involving injuries to the spine, however, are due to severe combat injuries[161,216].

Conclusion

In conclusion, PTSD and cLBP independently remain a significant target for therapies in the U.S. Army Soldier, as they contribute a three-fold increased risk of medical discharge than when these conditions are not present. Since the most common trajectory for both acute LBP and trauma exposure is recovery without disability, Soldiers with cLBP or PTSD possibly represent a vulnerable population at-risk for disability and medical discharge from the Service. When cLBP and PTSD converge during active duty service, the relative risk for medical discharge rises five-fold compared to a Soldier who does not have either of these conditions. Future research to evaluate therapies directed to this high-risk group and determine if they can prevent medical discharge, which incurs a substantial financial and military readiness burden, may be an important next step. Future research to further investigate the chronological relationship between PTSD, cLBP, and other possible mediators along the pathway to medical discharge may also provide informative details for potential therapeutic options.

Figure 4. 1 Cohort Flow Diagram of Active Duty U.S. Army Soldiers from 2002-2012

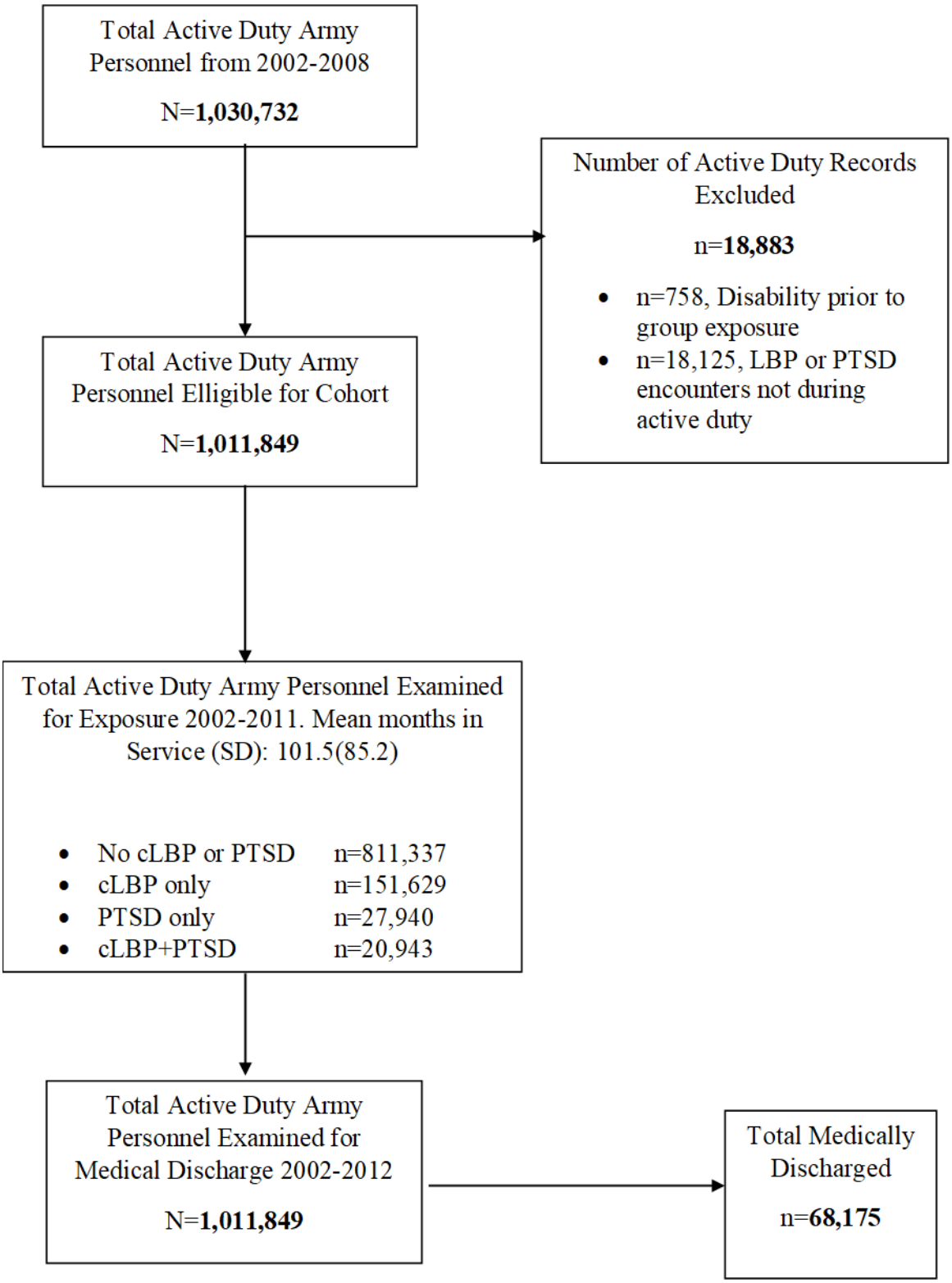


Table 4. 1 Sociodemographic and Military Service Characteristics of Active Duty U.S. Army Soldiers from 2002-2008 (n=1,011,849[a]).

Characteristic	Soldiers without cLBP/PTSD (%)	Soldiers with cLBP (%)	Soldiers with PTSD (%)	Soldiers with cLBP+PTSD (%)	Total
Sex					
Female	121,914 (15.0)	33,794 (22.3)	3150 (11.3)	3136 (15.0)	161,994 (16.0)
Male	689,375 (85.0)	117,835 (77.7)	24,790 (88.7)	17,807 (85.0)	849,807 (84.0)
Age					
18-29	537,097 (66.2)	66,890 (44.1)	16,479 (59.0)	9012 (43.0)	629,478 (62.2)
30-39	179,211 (22.1)	46,244 (30.5)	8240 (29.5)	7197 (34.4)	240,892 (23.8)
40+	94,724 (11.7)	38,485 (25.4)	3221 (11.5)	4734 (22.6)	141,164 (14.0)
Rank					
E1-E4	403,778 (49.8)	55,107 (36.3)	12,846 (46.0)	7614 (36.4)	479,345 (47.4)
E5-E9	310,919 (38.3)	78,597 (51.8)	13,642 (48.8)	11,942 (57.0)	415,100 (41.0)
Officer	96,601 (11.9)	17,915 (11.8)	1452 (5.2)	1387 (6.6)	117,355 (11.6)
Military Occupational Specialty					
Combat	196,134 (24.2)	26,508 (17.5)	9595 (34.3)	6478 (30.9)	238,715 (23.6)
Support	615,203 (75.8)	125,121 (82.5)	18,345 (65.7)	14,465 (69.1)	773,134 (76.4)
Deployment History					
Yes	510,400 (62.9)	101,209 (66.7)	25,408 (90.9)	18,610 (88.9)	655,627 (64.8)
No	300,937 (37.1)	50,420 (33.3)	2532 (9.1)	2333 (11.1)	356,222 (35.2)
Obesity Diagnosis					
Yes	119,669 (14.7)	45,044 (29.7)	7384 (26.4)	7945 (37.9)	180,042 (17.8)
No	691,668 (85.3)	106,585 (70.3)	20,556 (73.6)	12,998 (62.1)	831,807 (82.2)

Table 4.1, continued

Mental Health Diagnoses[b]					
Yes	245,966 (30.3)	73,010 (48.2)	25,155 (90.0)	19,549 (93.3)	363,680 (35.9)
No	544,519 (69.7)	68,982 (51.8)	2452 (10.0)	1114 (6.7)	648,169 (64.1)
Sleep Disorder Diagnoses					
Yes	125,863 (15.5)	56,823 (37.5)	17,058 (61.1)	16,416 (78.4)	216,160 (21.4)
No	685,474 (84.5)	94,806 (62.5)	10,882 (38.9)	4527 (21.6)	795,689 (78.6)
Alcohol Use					
Yes	82,443 (10.2)	15,815 (10.4)	8874 (31.8)	5647 (27.0)	112,779 (11.1)
No	728,894 (89.8)	135,814 (89.6)	19066 (68.2)	15,296 (73.0)	899,070 (88.9)
Tobacco Use					
Yes	213,962 (26.4)	59,983 (39.6)	15,180 (54.3)	12,277 (58.6)	301,402 (29.8)
No	597,375 (73.6)	91,646 (60.4)	12,760 (45.7)	8666 (41.4)	710,447 (70.2)
Number Discharged (%)	36,247 (4.5)	22,297 (14.7)	4697 (16.8)	4934 (23.6)	68,175 (6.7)
Group Total (%)	811,337 (80.2)	151,629 (15.0)	27,940 (2.8)	20,943 (2.1)	1,011,849 (100)

[a]Note, 374 Soldiers had missing values and therefore did not contribute to some demographic totals.

[b]Excluding PTSD diagnosis.

Table 4. 2 Crude and Adjusted Relative Risk (RR) for Independent Variables

Group	Total Number Soldiers	Number Soldiers with Medical Discharge (%)	Unadjusted Relative Risk (95% CI)	Adjusted Relative Risk[a] (RR) (95% CI)	P value of Adjusted RR
No cLBP or PTSD	811,337	36,247 (4.5)	1 (ref)	1	
cLBP	151,629	22,297 (14.7)	3.29 (3.24-3.34)	3.65 (3.59-3.72)	<.0001*
PTSD	27,940	4697 (16.8)	3.76 (3.66-3.87)	3.64 (3.53-3.75)	<.0001*
cLBP+PTSD	20,943	4934 (23.6)	5.27 (5.14-5.41)	5.17 (5.01-5.33)	<.0001*

[a]Adjusted for sex, age, rank, time in service, deployment, mental health, sleep disorders, alcohol use, tobacco use, obesity, and military occupation. Medical discharge % calculated as number of Soldiers in group that were discharged divided by total number of Soldiers in that group.

*Denotes significance at the level of $\alpha = .05$

CI: Confidence Interval

Table 4. 3 Adjusted Relative Risk for Covariates

Characteristic	Adjusted Relative Risk (95% CI)	95% CI Lower Limit	95% CI Upper Limit	P
Sex (Female vs. Male)	0.85	0.84	0.87	<.0001*
Age 30-39 vs. 18-29 >40 vs. 18-29	 1.47 1.12	 1.44 1.07	 1.49 1.16	<.0001* <.0001*
Rank E5-E9 vs. E1-E4 Officer vs. E1-E4	 0.98 0.35	 0.96 0.34	 1.00 0.37	 .075 <.0001*
Military Occupational Specialty Combat vs. Support	1.15	1.13	1.17	<.0001*
Deployment History[a]	0.52	0.51	0.52	<.0001*
Obesity Diagnosis[a]	1.3	1.28	1.32	<.0001*
Mental Health Diagnoses[b]	1.24	1.22	1.26	<.0001*
Sleep Disorder Diagnoses[a]	1.57	1.54	1.60	<.0001*
Alcohol Use[a]	0.72	0.70	0.73	<.0001*
Tobacco Use[a]	1.15	1.14	1.17	<.0001*

[a]Co-morbidities treated as dichotomous variables: yes versus no.

[b]All mental health diagnoses excluding PTSD.

*Denotes significance at the level of $\alpha = .05$

CI: Confidence Interval; vs: versus.

Chapter 5: Veterans with Chronic Low Back Pain and Trauma Exposure have Elevated Stress but Equal Sensitivity Levels Regardless of Post-Traumatic Stress Disorder Diagnosis

Introduction

Many research trials evaluating quantitative sensory testing (QST) have demonstrated that individuals with post-traumatic stress disorder (PTSD) have higher pain thresholds than healthy subjects without PTSD[217-220]. Some authors have attributed this observation to stress-induced hypoalgesia, in which general or trauma-specific stressors activate endogenous inhibition requiring a greater amount of nociceptive input to induce pain in individuals with PTSD[72]. Higher pain threshold and decreased pain ratings among individuals with PTSD is a fascinating phenomenon given that Veterans with PTSD generally report higher pain levels[19,30,31,92] and are more likely to have chronic, widespread pain compared to Veterans without PTSD[95].

In addition, Veterans with PTSD have higher disability[19,30,31], pain catastrophizing beliefs[30-32], and opiod use[85] compared to their counterparts without PTSD. Veterans with PTSD also have lower self-efficacy and function[30,31]. Clinicians may have some difficulty, therefore, reconciling clinical observations that individuals with PTSD report greater subjective pain when objective findings in research have reported the opposite effect[72].

There are two gaps in the literature which may help to explain the apparent discrepancy. First, many individuals with PTSD included in QST research may not represent the typical patient with PTSD because it was not reported if subjects had baseline chronic pain during QST[218,220,221]. In fact, most patients with post-traumatic stress disorder (PTSD) also have chronic pain[18]. Therefore, excluding individuals with chronic pain in experimental pain studies[218] may explore important mechanisms of nociceptive processing but fail to translate to a clinician treating patients with co-morbid PTSD and pain.

Second, many of the negative pain-related outcomes attributed to PTSD may be due to how PTSD is diagnosed in some observational studies that have reported worse outcomes in Veterans with PTSD[19,30-32]. In these studies, Veterans were dichotomized to PTSD status based

on exceeding cut-off scores of the PTSD Check-list[89]. None of the above studies, however, assessed exposure to traumatic events. Furthermore, PTSD symptoms in these studies[19,32] were correlated to many other psychosocial variables that are known to confer poor prognosis, like pain catastrophizing[96]. In fact, one study in patients with chronic low back pain (LBP) found that some participants had significant levels of PTSD symptomology, even though they had not experienced trauma before[20].

It is possible, then, that PTSD symptomology in patients with chronic LBP is really a sign of a hypervigilant nervous system. Recent research has proposed a hypervigilant nervous system as a core contributor to both chronic pain and PTSD symptoms[22,131]. A hypervigilant nervous system may result in central sensitization, which is the up-regulation of nociceptive afferents coupled with impaired endogenous inhibition[222]. This results in an amplified pain experience and is common in many chronic pain states to include chronic LBP[223]. LBP is routinely the most common pain condition among Veterans with PTSD[18,19] and central sensitization may help explain why Veterans with PTSD are more likely to have LBP than Veterans without PTSD[92].

Indeed, central sensitization has been reported in some Veterans with PTSD[152]. However, since these Veterans did not have co-morbid chronic pain and given the ample evidence that finds hypoalgesia in individuals with PTSD[72], it is important to investigate the sensory profiles of Veterans with PTSD and chronic pain. Furthermore, since a hypervigilant nervous system has been proposed as a common source of persistent symptoms for both PTSD[37] and chronic LBP[23], it will be beneficial to explore if PTSD symptoms uniquely contribute to pain and sensory profiles of Veterans with chronic LBP. Because central sensitization is common in individuals who have chronic LBP, regardless of PTSD status[224], the negative outcomes in the literature attributed to PTSD symptomology might be due to characteristics associated with central sensitization rather than trauma. The purpose of this paper is to explore PTSD

symptomology and pain-related beliefs and pressure sensitivity levels in Veterans with LBP but no PTSD diagnosis compared to Veterans with LBP and PTSD diagnosis. It was hypothesized that a substantial portion of Veterans without a PTSD diagnosis would still display relevant symptoms of PTSD.

Methods

Participants

This report is a secondary analysis of a randomized-controlled trial evaluating the effectiveness of pain neuroscience education[47] compared to traditional education about LBP[225] and PTSD/stress[119] in Veterans and Service Members with chronic LBP. This study examines the baseline characteristics of participants comparing subjects with PTSD to those with LBP only. Participants were included if they were between the ages of 18-65 and had LBP for longer than 3 months duration. Subjects were excluded if they met the following criteria: neurogenic LBP (sensory, motor, and reflex deficits consistent to a nerve root and crossed-straight leg raise test that reproduces radicular symptoms)[226] or back pain consistent with red flags[227]; bipolar disorder, personality disorder, or schizophrenia[228]; substance abuse within the last 6 months[229]; unstable suicidal ideation[230]; spine surgery in the past 12 months; or a complete trial of physical therapy for LBP within the previous 3 months.

Participants were recruited from a physical therapy clinic in a Veterans Affairs Medical Center (VAMC). This study was approved by the respective VA and Department of Defense institutional review boards.

Outcomes

Pain Pressure Threshold (PPT): Patients were tested in the prone position with a pillow under their shins to achieve approximately 15 degrees of knee flexion. A research personnel who was blinded to PTSD status applied a digital algometer probe (SBMEDIC Electronics, Sweden) with a gradual increase in force (40 kPa/s) 5 cm lateral to the spinous process of L3 of the most

symptomatic side until the participant reported the pressure as painful and pressed a button attached to the algometer[50,231]. This procedure was performed three times at the low back and averaged to determine the patient's PPT with 30 seconds between repetitions. The procedure was then performed at the suprascapular region contralateral to the side tested in the low back, mid-way between the posterior border of the acromion and the 7th spinous process of the cervical spine[50,232]. Reliability testing resulted in Intraclass Coefficient, two-way random with measurements averaged=.93.

PTSD Check-list for DSM 5 (PCL)*:* The PCL is a 20-item checklist that measures the clusters of symptoms associated with PTSD according to the revised DSM 5[233]. Scores range from 0-80. The recommended cut-off score for PTSD is 33[234]. Participants were placed in the PTSD group if they indicated on self-report a PTSD diagnosis and scored ≥33 on the PCL.

Pain Catastrophizing Scale (PCS): The PCS measures pain catastrophizing which is defined as an exaggerated negative appraisal of noxious stimuli[235]. The PCS has good validity and excellent reliability in a LBP population[236]. Catastrophizing has been identified as an important construct in both PTSD populations[237] and chronic LBP patients[238].

Roland-Morris Disability Questionnaire (RMDQ)*:* The RMDQ is a subjective measure of disability recommended for LBP[239]. Users are asked to identify among 24 activities or statements that are influenced by their back pain. The answers provide a score between 0 and 24, with higher scores representing more disability. The RMDQ has acceptable validity, reliability, and responsiveness compared to other disability constructs[102].

Numeric Pain Rating Scale (NPRS)*:* The NPRS is an 11-point scale used to rate subjective pain intensity. It is commonly used in LBP research and offers a brief and efficient measurement of pain[240,241]. The NPRS is a reliable and valid measure of adult pain[242]. This study's scale was anchored at 0, "no pain at all", to 10, "the worst pain you could imagine."

Pain Self-Efficacy Questionnaire (PSEQ)*:* The PSEQ is a questionnaire that measures an individual's self-perceived confidence to cope with physical activities "despite the pain."[243] Many studies demonstrate that individuals who have low self-efficacy have higher disability[28].

Brief Survey of Pain Attitudes (SOPA-35): SOPA-35 is a valid, reliable, and sensitive questionnaire that measures beliefs about pain across 7 domains[99]. Analysis will be performed across sub-scales with particular exploration of the harm sub-scale[244] to assess whether participants believe that pain means damage or whether they believe exercise will make their condition worse.

Stressometer: The stressometer is a short, one-questionnaire scale that measures patient distress on a scale from 0-10. The stressometer is valid and responsive and correlates with more in-depth assessments of psychological stress[245,246].

Sociodemographic questionnaire: Participants were asked whether they had experienced a traumatic event based on common categories taken from the Life Events Checklist[247].

Statistical analysis

Sociodemographic characteristics between participants who had PTSD and chronic LBP compared to chronic LBP only were examined with independent t-tests for continuous variables and chi-square for categorical or frequency analysis. When possible, Fisher's exact test was used for frequency analysis. Group differences for sensory testing were analyzed using a General Linear Model (GLM) to allow for testing the contribution of the covariates of gender and pain. Bivariate correlation analysis was also performed to determine the relationship between PTSD symptomology and pain-related beliefs and variables. The Kolmogorov-Smirnov test was used to examine normality of variables prior to analysis. The frequency distributions were also inspected visually for approximate normal distribution. Outcomes that failed to meet normality assumptions were assessed with the non-parametric Mann-Whitney U test. Statistical

significance was set at .05 using a 2-tailed test. All data were analyzed with Statistical Package for Social Sciences (IBM, version 24).

Results

A total of 33 Veterans were analyzed in this study. Seventeen participants (52%) indicated by self-report that they had been diagnosed with PTSD and tested above the cut-off score for PTSD (PCL ≥ 33). Out of the 16 participants (37.5%) who had never been diagnosed with PTSD, 6 still scored above the cut-off for PTSD symptomology. Participants who scored above the cut-off for PTSD symptoms but did not indicate a self-report diagnosis of PTSD were analyzed in the no PTSD group according to the study's operational definitions. 97% of participants reported a history of at least one traumatic event (Table 5.1). 82.4% and 56.3% of Veterans with and without PTSD, respectively, had previously deployed at least one time, although this difference was not statistically significant. Most Veterans had served in the Army (75.8%). Table 5.1 describes the sociodemographic characteristics of the participants.

Veterans with diagnosed PTSD were more likely to report co-morbid neck/thoracic spinal pain in addition to LBP compared to Veterans without PTSD (p=.039, Table 5.1). Participants with and without PTSD were similar across sociodemographic characteristics to include equal likelihood of reporting current depression (Table 5.1). The only outcome that Veterans with or without PTSD differed was PTSD symptoms (Table 5.2). Veterans with PTSD had higher levels of PTSD than Veterans without a PTSD diagnosis (p<.001). Participants had similar levels of stress, pain, disability, pain self-efficacy, pain catastrophizing, and beliefs about pain (SOPA, Table 5.2). If participants were classified into groups based solely on cut-off scores of the PCL (≥ 33), participants who scored above the threshold had significantly higher levels of stress and pain catastrophizing beliefs (data not shown).

Veterans with or without PTSD did not have statistically different PPT values for the low back or the suprascapular region, even after adjusting for gender and pain. PPT values for the

low back were not significantly correlated with any outcomes measured for this study ($|r|<0.2$, $p>.05$ for all values, Table 5.3). PTSD symptoms were positively correlated with pain catastrophizing beliefs (Table 5.3).

Discussion:

This paper provides evidence that Veterans without a PTSD diagnosis with chronic LBP are as likely to have experienced a traumatic event as Veterans with PTSD, given that 97% of participants in this study reported exposure to a traumatic life event. Although participants with a PTSD diagnosis had higher levels of post-traumatic stress symptomology as measured by the PCL, the results from this study did not provide evidence that Veterans with PTSD differed in levels of pain-catastrophizing, pain, disability, or pain self-efficacy despite significant differences reported in other research[30,31]. Furthermore, this study did not provide evidence that participants with PTSD and LBP have lower or higher pain thresholds than Veterans without PTSD.

Like previous research[248], this study confirms the importance of pain catastrophizing beliefs in the relationship between co-morbid PTSD and chronic pain. PTSD symptoms were positively correlated with pain-catastrophizing beliefs. On average, Veterans with and without PTSD had elevated pain-catastrophizing beliefs[249]. The association between pain-catastrophizing scores and PTSD symptoms could partially explain why this study failed to find a significant difference among outcomes between Veterans with and without PTSD. When participants were dichotomized by PCL scores, Veterans scoring at or above the cutoff of 33 had significantly higher pain-catastrophizing beliefs and self-reported stress levels. This indicates that regardless of a formal PTSD diagnosis or trauma history, individuals who score higher on PTSD symptomology are more likely to have higher pain catastrophizing beliefs.

This analysis reveals the importance of PTSD symptomology within the context of chronic pain that shares many similarities to the Fear Avoidance Model (FAM)[29]. The FAM

proposes that individuals with high pain catastrophizing beliefs avoid potentially harmful situations that may cause pain, leading to disuse, deconditioned tissues, and greater disability. In addition to pain catastrophizing beliefs, avoidance of potentially harmful situations is also a core tenet of PTSD[14]. Interestingly, 37.5% of participants who have never been diagnosed with PTSD still report clinically relevant PTSD symptoms as measured by the PCL (≥ 33). This finding may indicate fear-avoidant beliefs or hypervigilance in participants who are not diagnosed with PTSD yet display high levels of PTSD symptomology.

Since Veterans have greater awareness and assign less stigma towards PTSD than other mental health disorders[42], addressing PTSD or stress symptoms may be an acceptable way to navigate pain catastrophizing beliefs and potential nervous system sensitivities that are common in chronic pain patients[24]. Veterans routinely complete the Primary Care PTSD (PC-PTSD) screen[83]. The PC-PTSD Screen is a 4-item questionnaire that assesses the 4 tenets of PTSD: hyperarousal, avoidance, intrusive thoughts, and negative cognitions like depression[14]. A recent study found that for each PTSD symptom endorsed on the PC-PTSD Screen by chronic pain patients, pain and disability incrementally increased[250].

Addressing fear-avoidance beliefs is a critical component of managing LBP in Physical Therapy[251,252]. A systematic review has shown that Pain Neuroscience Education (PNE) is beneficial in reducing fear-avoidance beliefs[47]. PNE may represent a novel therapy to help Veterans and Soldiers understand the neurobiological link between PTSD hyperarousal and nervous system hypervigilance[22]. PNE decreases pain catastrophizing by helping individuals understand that on-going pain can be attributed to a sensitive nervous system rather than damaged tissues. Routinely utilizing the PC-PTSD screen in military physical therapy settings might be an efficient manner to identify patients who would benefit from PNE or other additional psychosocial management strategies[252]. Although this study did not specifically utilize the PC-

PTSD Screen, a similar efficient tool used in this research was the stressometer[246], which was correlated with PTSD symptoms.

The results of this study did not provide evidence, however, that PTSD symptoms or psychosocial characteristics like pain self-efficacy contributed to hypersensitivity or altered pain pressure thresholds. This was somewhat surprising given the reported relationship between pain self-efficacy and pain pressure thresholds[253,254]. One reason for this could be that traumatic experiences were consistent across all participants whether they were diagnosed with PTSD or not. Research has shown altered pain sensory profiles in individuals who have experienced traumatic exposure regardless of PTSD diagnosis[255]. In other words, it may be that trauma and stress contribute to altered pain sensory profiles independent of PTSD. This study was not powered or able to detect this relationship, however, nor did it have sufficient individuals who had not experienced trauma previously to examine the relationship between trauma exposure and PPT. However, this study did find that Veterans with PTSD were more likely to have current neck/thoracic pain in addition to LBP. This may indicate more widespread pain, which has been found previously in Veterans with PTSD[95].

Another reason for the failure of this study to find evidence for a relationship between PPT and PTSD status could be the inherent limitations of PPT. A meta-analysis on the relationship between pain and quantitative sensory testing determined that PPT only explains approximately 2% of the variance associated with pain or disability in LBP[256]. Although PPT is the easiest to clinically administer and was the most significant sensory difference between chronic LBP patients with and without trauma in one study[255], PPT measures only one static component of nociceptive processing. A more dynamic measure like diffuse noxious inhibitory control might be more appropriate to determine hypersensitivity or central sensitization in Veterans with or without PTSD[257].

Finally, it was interesting to note that, on average, participants in this research study scored below functionally normal values of pain self-efficacy (PSEQ<40)[258], regardless if they were diagnosed with PTSD. Pain self-efficacy is a major protective factor against disability[28]. In one study with Active Duty Soldiers with LBP, self-efficacy accounted for 40% of the variance in predicting duty status, above and beyond physical measures[259]. In addition to low self-efficacy, Veterans presenting to physical therapy for LBP also reported moderate levels of stress[260]. Addressing pain from a stress or post-traumatic stress approach may be an important paradigm for Veterans with chronic LBP[17].

Limitations

In addition to the lack of dynamic QST procedures, this study also has other limitations. Most participants had current neck pain, making the suprascapular region an inadequate control site to assess for possible central sensitization. In addition, since Veterans were included from a study that consented participants to receive education about pain and stress/PTSD, it is possible that physical therapists referred Veterans with elevated stress and PTSD symptomology compared to the average Veteran with chronic LBP, representing a possible selection bias. Furthermore, this study did not employ a control group to compare PPT values in a non-painful population. Finding higher PPT values in a pain-free population, however, would not have been very surprising[248] or informing since study participants presented with a complaint of chronic LBP. The sample size was limited and this study may have been able to show more significant effects between Veterans with and without PTSD with a larger sample, although all effect sizes were still only small or moderate. In addition, since combat was one of the most common types of trauma reported among participants, the results from this study may not apply to non-military individuals and the heterogeneity of trauma types might also mask sensitivity differences that could be specific to certain trauma exposures. As mentioned previously, this study did not have a sufficient sample to explore the relationships between specific traumas and PPT. Finally, the

cross-sectional design of this study limits the ability to infer a causal or temporal relationship between PTSD and pain symptoms.

Conclusion

In this study, 97% of participants attending physical therapy for chronic LBP had experienced a traumatic event. 37.5% of participants who had not been diagnosed with PTSD still reported relevant PTSD symptoms above the recommended cut-off score for PTSD. Veterans with PTSD were more likely to have neck pain in addition to LBP compared to Veterans without PTSD. Veterans with PTSD had higher levels of PTSD symptomology than Veterans without a PTSD diagnosis. Otherwise, Veterans with and without PTSD had similar pain, beliefs about pain, disability, and PPT values.

Table 5. 1 Sociodemographic characteristics of participants by PTSD and Veteran status

Characteristic	Veterans PTSD n=17	Veterans No PTSD n=16	P value
Age, Years (sd)	41.9 (7.4)	40.9 (11.9)	.78
Gender			.398
M (%)	12 (70.6%)	14 (87.5%)	
F (%)	5 (29.4%)	2 (12.5%)	
Race			.919
African American, n (%)	1 (5.9%)	1 (6.3%)	
Hispanic, n (%)	3 (17.6%)	2 (12.5%)	
White, n (%)	13 (76.5%)	13 (81.3%)	
Education, Years (sd)	14.5 (2.3)	13.6 (2.2)	.29
Service			.137
Army	15 (88.2%)	10 (62.5%)	
Navy	1 (5.9%)	1 (6.3%)	
Marines	1 (5.9%)	3 (18.8%)	
Air Force	0 (0%)	2 (12.5%)	
Deployment[a], n, (%)	14 (82.4%)	9 (56.3%)	.141
Persian Gulf, n (%)	2 (11.8%)	0 (0%)	
Iraq, n (%)	10 (58.8%)	6 (37.5%)	
Afghanistan, n (%)	7 (41.2%)	2 (12.5%)	
Iraq and Afghanistan, n (%)	4 (23.5%)	1 (6.3%)	
Other, n (%)	2 (11.8%)	3 (18.8%)	
Trauma[a], n (%)	17 (100%)	15 (93.8%)	.485
Combat, n (%)	13 (76.5%)	8 (50%)	
Sexual Assault, n (%)	5 (29.4%)	1 (6.3%)	
Personal Violence, n (%)	7 (41.2%)	6 (37.5%)	
MVA, n (%)	7 (41.2%)	8 (50%)	
Natural disaster, n (%)	3 (17.6%)	3 (18.8%)	
Other, n (%)	3 (17.6%)	3 (18.8%)	
Duration of LBP, months (sd)	114.5 (92.6)	84.7 (88.7)	.353
Depression, n (%)	14 (82.4%)	11 (68.8%)	.438
Presence of neck pain, n (%)	16 (94.1%)	10 (62.5%)	.039*
# Co-morbidities, (sd)	8.6 (4.2)	7.2 (4.9)	.40
+PTSD Symptoms (PCL≥33) n (%)	17 (100%)	6 (37.5%)	<.001*

[a]Note, individual traumas and deployments may add up to greater than 100% as some individuals reported more than one type of trauma and more than one deployment.

*Denotes significance at the level of α=.05

Table 5. 2 Comparison of self-reported outcome measures by PTSD and Veteran status

Outcome	Veterans PTSD n=17	Veterans No PTSD n=16	t	Effect size[a]	P value
PTSD Checklist	54.1 (12.9)	31.9 (18.7)	4.0	1.39	<.001*
Pain NPRS					
Current	5.5 (1.7)	5.4 (1.8)	.26	.06	.80
Best	3.6 (1.7)	3.9 (2.3)	.41	-.15	.69
Worst	8.1 (1.1)	7.8 (1.5)	.83	.23	.42
RMDQ	11.1 (5.4)	11.9 (6.1)	.41	-.14	.69
PCS	26.0 (14.1)	19.7 (11.3)	1.4	.49	.17
Stress	7.5 (2.2)	5.9 (3.0)	1.8	.61	.09
SOPA: Control	1.7 (.70)	1.6 (.58)	.46	.16	.65
SOPA: Disability	2.3 (.81)	2.4 (.76)	.47	-.13	.64
SOPA: Harm	2.1 (.73)	1.9 (.54)	.98	.31	.33
SOPA: Emotion	2.6 (.80)	2.1 (.79)	1.6	.63	.12
SOPA: Medication	2.4 (1.1)	2.4 (1.0)	.04	.00	.97
SOPA: Solicitude	1.1 (1.1)	1.3 (1.1)	.50	-.18	.62
SOPA: Cure	1.6 (.73)	1.8 (.60)	.79	-.30	.43
PSEQ	35.9 (10.8)	32.2 (14.4)	.85	.29	.40

RMDQ: Roland Morris Disability Questionnaire; PCS: Pain catastrophizing scale; NRS: Numeric rating scale; SOPA: Survey of Pain Attitudes; PSEQ: Pain self-efficacy questionnaire.

[a]Cohen's d effect size. Positive effect sizes indicate a higher standardized mean difference favoring Veterans with PTSD. Negative effect sizes indicate Veterans with PTSD have a lower standardized mean than Veterans without PTSD.

*Denotes significance at the level of α=.05

Table 5. 3 Pain Pressure Threshold (PPT) by PTSD Status

Test	Veterans PTSD n=17	Veterans No PTSD n=16	F	Effect size[d]	P value
Mean PPT Low Back, kPA (95% CI)	269.7 (200.8-338.6)	222.9 (151.8-293.9)	.93	.34	.34
Mean PPT Low Back[a], kPA (95% CI)	272.6 (202.0-343.1)	219.8 (147.1-292.5)	1.1	.37	.30
Mean PPT Shoulder, kPA (95% CI)	296.4 (206.2-386.6)	273.6 (180.7-366.6)	.28	.12	.72
Mean PPT Shoulder[b], kPA (95% CI)	310.6 (220.0-401.1)	266.9 (170.2-363.5)	.44	.24	.51
Forward Bend[e], cm	29.2 (21.6-36.9)	28.4 (20.5-36.2)	N/A[c]	.06	.51

CI: Confidence interval. Cm: Centimeter. kPA: Kilopascals.

[a]The results were analyzed adjusting for gender.

[b]The results were analyzed adjusting for gender and neck pain.

[c]Forward bend was not normally distributed and therefore was tested with the non-parametric Mann Whitney U test.

[d]Cohen's d effect size. Positive effect sizes indicate a higher standardized mean difference favoring Veterans with PTSD.

[e]Note, a lower number indicates greater range of motion.

Table 5. 4 Intercorrelations between PTSD symptoms and pain-related outcomes and beliefs

Outcome	1	2	3	4	5	6	7	8	9	10	11
1. PTSD Checklist	1										
2. Pain NPRS	.17	1									
3. RMDQ	.05	.40*	1								
4. PCS	.61*	.35*	.34	1							
5. Stress	.56*	.07	-.04	.28	1						
6. SOPA: Harm	.30	.09	.47*	.47*	.18	1					
7. SOPA: Control	-.32	-.01	-.01	-.34	-.27	-.22	1				
8. PSEQ	-.14	-.37*	-.62*	-.45*	.10	-.55*	.19	1			
9. PPT Low back	.15	.16	-.10	.07	-.09	-.11	-.20	-.02	1		
10. PPT Shoulder	.19	-.04	-.05	.12	-.08	-.24	-.23	.01	.70*	1	
11. FB	.07	.07	.23	.09	-.08	.29	.10	-.35*	-.17	-.08	1

NRS: Numeric rating scale; RMDQ: Roland Morris Disability Questionnaire; PCS: Pain catastrophizing scale; SOPA: Survey of pain attitudes; PSEQ: Pain self-efficacy questionnaire; PPT: Pain pressure threshold; FB: Forward bend test.

*Denotes significance at the level of α=.05

Chapter 6: Pain Neuroscience Education Improves Pain Self-Efficacy and Stress in Veterans with Chronic Low Back Pain

Introduction

Although stress may be a common characteristic in life, dysregulation of stress can have dire consequences for an individual's health[10]. In addition to the negative effects on general health and wellness, chronic stress dysregulation plays a prominent role in chronic pain conditions[24], specifically chronic low back pain (LBP)[52]. In the military, increased stress is the normative condition, particularly with recent increases in combat deployments[11].

When stress from combat or other traumas becomes excessive or persistent, individuals can develop post-traumatic stress disorder (PTSD). PTSD is defined as a cluster of symptoms following trauma exposure that includes hypervigilance, negative cognitions, re-experiencing trauma reminders, and avoidance that persist for greater than 30 days[14]. Although these symptom clusters are specifically tied to a traumatic experience for a PTSD diagnosis, it is common for individuals with chronic LBP to exhibit PTSD symptoms[20]. The consequences of chronic stress and post-traumatic stress (PTS) symptoms include dysregulation of the hypothalamus-pituitary-adrenal (HPA) axis[135]. Acutely, stress hormones like cortisol can help inhibit nociception and decrease pro-inflammatory cytokines[24,261]. Following chronic stress dysregulation, however, the HPA axis becomes dysfunctional and hypocorticolism ensues[24]. This contributes to a hypervigilant nervous system characteristic of central sensitization[53] and is prominent in a number of chronic states in which deficiencies in cortisol regulation have been identified[24]. Central sensitization may play a relevant role in maintaining chronic LBP symptoms[23] and is believed to be a primary contributor of symptoms for a substantial proportion of patients with chronic LBP[224,262].

Patient education is a common and top strategy for managing LBP[263]. Traditionally, patient education has been approached from a biomedical perspective that outlines pathoanatomical causes and treatments for LBP[225]. Although this type of education is still

common[35], it is not recommended by clinical practice guidelines[263]. Traditional biomedical back school education may contribute to increased protective strategies and feelings of vulnerability[35]. Since this type of education is still common in military settings[34], it is not surprising that many Veterans strongly believe that pain is a sign of tissue damage and avoid activities that may cause pain[55]. Given that avoidance is a core tenet of PTSD[14], it is also not surprising that traditional back education is particularly ineffective in Veterans with PTSD[34].

On the other hand, because changes to low back tissues do not fully explain LBP outcomes[264], treatments targeting psychosocial characteristics[252] and stress[265,266] are recommended for managing LBP. Psychosocial characteristics frequently explain more variance regarding pain and disability than physical factors[259,267]. Approaching physical pain from a psychological perspective, however, has led to high drop-out rates in clinical trials and there is speculation that participants in pain desire a medical explanation for their symptoms[39]. In addition, patients with psychosocial symptoms frequently feel dismissed and stigmatized by providers who may attribute physical symptoms to psychosocial characteristics[36].

Pain Neuroscience Education (PNE), on the other hand, may represent an appropriate education strategy for military Service Members who have chronic LBP and psychosocial stress. Instead of focusing on anatomy and pathology of body tissues, PNE educates patients about the neurophysiology of pain using stories and metaphors[46]. PNE is effective in a number of chronic pain conditions like fibromyalgia, chronic LBP, chronic fatigue syndrome, and chronic neck pain[47]. Some research proposes that PNE helps decrease the pain experience by top-down modulation of the nervous system by decreasing the threat and perceived danger of on-going pain[49,50]. After PNE, patients may be less likely to believe that persisting pain indicates current tissue damage and harm[192]. Instead, patients understand that the nervous system can become sensitive and amplify the pain experience even after body tissues have healed.

PNE has not been tested in military populations. Since education should be culturally relevant[125], a PNE curriculum using military examples and stories was developed for this research. In addition, the impact of PNE on self-reported stress or PTSD symptoms has not been specifically tested in a clinical trial. The purpose of this research is to determine if PNE is more effective than traditional education about back pain and stress management in reducing stress, pain, maladaptive beliefs about pain, and disability in military Service Members with chronic LBP attending physical therapy.

Methods

Participants

Military Service Members and Veterans with chronic LBP (symptoms > 3 months duration)[136] were referred to participate in this clinical trial. Participants were included if they were between the ages of 18-65. Although individuals with PTSD were purposefully sampled to examine PNE effectiveness on stress symptoms—in particular, PTSD symptoms—a PTSD diagnosis was not required to participate in this study. Subjects were excluded if they met the following criteria: neurogenic LBP (sensory, motor, and reflex deficits consistent to a nerve root and crossed-straight leg raise that reproduces radicular symptoms)[226] or back pain consistent with red flags[227]; bipolar disorder, personality disorder, or schizophrenia[228]; substance abuse within the last 6 months[229]; unstable suicidal ideation[230]; spine surgery in the past 12 months; or a complete trial of physical therapy for LBP within the previous 3 months.

Participants were recruited from physical therapy clinics in a Veterans Affairs Medical Centers (VAMC) and an Active Duty Military Treatment Facility located on an Army base. This study was approved by the respective Veterans Affairs (VA) and Department of Defense institutional review boards.

Study Procedures

After individuals consented to participate in the research study, participants were scheduled to complete baseline testing. After baseline measures, participants were randomly allocated to the experimental (PNE) or traditional group by opening opaque, sealed, consecutively numbered envelopes which were prepared by a researcher not involved in this study. Participants completed a 4-week intervention by attending a weekly education and exercise session for one hour each week. Upon completing the intervention, participants completed follow-up testing at four weeks. Finally, participants returned at eight weeks to complete self-reported outcome measures. All measurements were assessed by a physical therapist who was blinded to group allocation.

Primary Outcome Measures

PTSD Check-list for DSM 5 (PCL): The PCL is a 20-item checklist that measures the clusters of symptoms associated with PTSD according to the revised DSM 5[233]. Scores range from 0-80 with higher numbers indicating higher PTSD symptomology. The recommended cut-off score for PTSD is 33[234]. Participants were considered to have PTSD if they indicated on self-report a PTSD diagnosis and scored ≥33 on the PCL. The minimal clinically important difference (MCID) is at least 10 points[268].

Stressometer: The stressometer is a short, one-item scale that measures patient distress on a scale from 0-10. The stressometer is valid and responsive and correlates with more in-depth assessments of psychological stress[245,246]. A score of 4 or higher is considered positive for moderate distress[260].

Roland-Morris Disability Questionnaire (RMDQ): The RMDQ is a subjective measure of disability recommended for LBP[239]. Users are asked to identify among 24 activities or statements that are influenced by their back pain. The answers provide a score between 0 and 24, with higher scores representing more disability. The RMDQ has acceptable validity, reliability, and

responsiveness compared to other disability constructs[102]. The MCID for the RMDQ is a 30% reduction in baseline scores[241].

Numeric Pain Rating Scale (NPRS): The NPRS is an 11-point scale used to rate subjective pain intensity. The NPRS has been shown to have good validity and reliability[242]. The scale ranges from 0 to 10 and has been shown to have acceptable responsiveness in patients with LBP[240]. This study's scale was anchored at 0, "no pain at all", to 10, "the worst pain you could imagine." The MCID for the NPRS is 2[241].

Secondary Outcome Measures

Objective Outcome Measures

Spinal flexion*:* Participants were asked to bend forward at the waist while keeping their knees straight and attempting to touch the floor[139]. The distance from the floor to the patient's most distal finger-tip was measured to the nearest tenth of a centimeter (cm). Participants were instructed to stop "whenever you feel you need to stop." Participants completed this procedure two times and the measures were averaged.

Pain Pressure Threshold (PPT): Patients were tested in the prone position with a pillow under their shins to achieve approximately 15 degrees of knee flexion. A research physical therapist applied a digital algometer probe (SBMEDIC Electronics, Sweden) with a gradual increase in force 5 cm lateral to the spinous process of L3 of the most symptomatic side until the participant reported the pressure as painful and pressed a button attached to the algometer[50,231]. This procedure was performed three times at the low back and averaged to determine the patient's PPT with approximately 30 seconds rest between repetitions. The procedure was then performed at the suprascapular region contralateral to the side tested in the low back, mid-way between the posterior border of the acromion and the 7th spinous process of the cervical spine[50,232].

All physical measures were completed by a physical therapist who was blinded to participant treatment-group allocation (reliability testing resulted in Intraclass Coefficient, two-way random with measurements averaged=.93).

Pain Catastrophizing Scale (PCS): The PCS measures pain catastrophizing which is defined as an exaggerated negative appraisal of noxious stimuli[235]. The PCS has good validity and excellent reliability in a LBP population[236]. Catastrophizing has been identified as an important construct in both PTSD populations[237] and chronic LBP patients[238].

Pain Self-Efficacy Questionnaire (PSEQ): The PSEQ is a questionnaire that measures an individual's self-perceived confidence to cope with physical activities "despite the pain."[243] Many studies demonstrate that individuals who have low self-efficacy have higher disability[28]. The MCID for the PSEQ is 5[269].

Brief Survey of Pain Attitudes (SOPA-35): SOPA-35 is a valid, reliable, and sensitive questionnaire that measures beliefs about pain across 7 domains[99]. This study was particularly interested in the harm sub-scale[244] to assess whether patient's beliefs that pain means harm changes after the intervention.

Post-program questionnaire:

This study adapted a questionnaire to assess the satisfaction and acceptability of the intervention[270] on a numerical scale from 0-10 with 10 indicating "strongly agree" and 0 "strongly disagree."

1. This is the first time I have received this education [Novelty].
2. The education program helped explain why I have chronic pain after post-traumatic stress (or stress) [Explain].
3. The education program applies personally to my symptoms [Applies].

4. The education program treated my symptoms as real and helped me understand why I have post-traumatic stress (or stress) and pain symptoms [Symptoms real].
5. I am satisfied in the way the education program explained why common treatments for pain can help after stress [Satisfied].
6. The education program connected with me personally as a Veteran and with my experiences in the Armed Forces [Connected].
7. The education program implied that chronic pain after post-traumatic stress (or stress) means that my physical pain is only a mental health problem [Mental health problem].
8. I believe I was in the experimental education group.

Intervention

Experimental education:

Participants attended a PNE session that lasted approximately 30 minutes, once a week for 4-weeks. The education was based on *Why do I Hurt?*[127] and was adapted for military Service Members. The education included content recommended by a systematic review[48] and compared the nervous system to a military radar which becomes sensitive and hypervigilant following an attack. Participants also received a PNE booklet developed for this research and were asked to read through the booklet at home.

Traditional education:

Similar to the experimental arm, participants attended an education session that lasted approximately 30 minutes, once a week for 4-weeks. The education was based on one traditional "Back School"[225] session followed by 3 stress management sessions adapted from the VA National Center for PTSD[271]. A research panel of mental health specialists and physicians rated the modules from the PTSD Coach[119] and reviewed the education materials developed to provide traditional and standard of care education for stress and post-traumatic stress symptoms in

military Veterans. Participants in the traditional group also received a booklet that was similar in length to the experimental education. The traditional booklet was from "*Afterdeployment.org*"[272].

Both education programs included recommendations for sleep hygiene[273], the importance of exercise[274], breathing[275]/relaxation techniques[276], and setting goals. To maintain treatment fidelity, physical therapists utilized a printed slide presentation and followed a standardized outline for each participant.

Exercise program:

Immediately following each education session, participants completed an exercise circuit based on the "Back to Fitness" program[277]. To allow for different activity levels across participants, research subjects were given the option of performing an easy, moderate, or difficult exercise in each of the 10 exercises from the "Back to Fitness" program. Participants performed each exercise for 1-minute each, followed by a 5-minute cool-down period. Participants received an ordinal score for each exercise completed; "1" for easy, "2" for moderate, "3" for difficult, and "0" if they did not complete any of the options for the exercise. Participants received an average exercise completion score for all exercise sessions. Higher numbers indicate completion of exercises deemed more difficult and challenging, whereas lower numbers indicate potentially easier and less threatening exercises.

Participants in the research program attended individual education and exercise sessions except for 9 individuals who attended group sessions (PNE, n=4, Traditional, n=5, all of which were Active Duty Soldiers due to provider scheduling requirements).

Statistical analysis

Sociodemographic characteristics and baseline measures between the experimental and traditional groups were analyzed with independent t-tests for continuous variables and chi-square for categorical or frequency analysis. When possible, Fisher's exact test was completed for

frequency analysis. For primary and secondary outcome measures, data were analyzed with a 2-factor (treatment group and time) repeated measures analysis of variance (ANOVA) using a General Linear Model (GLM) with three time-points: baseline, 4-weeks, and 8-weeks. A group by time interaction was assessed for outcome measures with a plan for post-hoc testing between baseline to 4-weeks and baseline to 8-weeks for variables with a significant interaction. Physical measures were only tested at baseline and 4-weeks. Furthermore, a one-way ANOVA between treatment conditions for the post-program questionnaire and exercise completion score was planned. The contribution of age, co-morbidities, and medication use during testing for objective outcome measures was assessed by adding these variables as a covariate into the GLM. The Kolmogorov-Smirnov test was used to examine normality of variables prior to analysis. The frequency distributions were also inspected visually for approximate normal distribution. Outcomes that failed to meet normality assumptions were assessed with the non-parametric Mann-Whitney U test. Finally, Cohen's d effect sizes were calculated based on the between-group differences for the change scores from baseline to immediately following the intervention at 4-weeks to provide a clinically interpretable effect between interventions. Statistical significance was set at .05 using a 2-tailed test. All data were analyzed with Statistical Package for Social Sciences (IBM, version 24).

Results

In total, 45 Veterans and Soldiers consented to participate in the research project (Figure 6.1). The experimental group included 17 participants and 20 participants were allocated to the control group. For participants who began the treatment protocol, two individuals in the experimental and two in the control group dropped out of the research study with reasons that can be found in Figure 6.1. Five participants failed to schedule the initial treatment session after completing baseline testing. Complete data analysis for repeated measures was available for 13 participants in the experimental group and 16 in the control group. Table 6.1 displays

sociodemographic characteristics of study participants. Groups were similar across all characteristics. 90% of participants reported at least one traumatic event and on average participants had at least moderate levels of stress ($\geq 4/10$[260]).

Primary Outcome measures

There was a main effect for time for both pain and disability across both groups. Although the experimental group had a greater reduction in disability, the overall GLM ANOVA failed to find a significant group by time interaction. At the 8-week follow-up, however, the experimental group achieved a greater proportion (69.2% vs 27.8%) of reducing disability by at least 30%, which is the MCID. PTSD symptoms decreased in both groups (main effect for time). When comparing only participants with PTSD, the experimental group achieved a large effect of reducing PTSD symptoms that exceeded the MCID; however, this difference was not statistically significant (Figure 6.3). Participants in the experimental group reported decreased levels of stress following the intervention whereas the control group's perceived levels of stress did not change (Figure 6.4).

Secondary outcomes:

The PNE group significantly improved pain self-efficacy compared to traditional education (Cohen's d=1.21, large effect). Post hoc testing revealed significantly higher pain self-efficacy immediately following the intervention for the experimental group (Figure 6.5). Although the PNE group's PSEQ scores were almost 10 points higher than the control group, the 8-week difference between groups did not maintain significance after post-hoc testing (Figure 6.5). In addition, the PNE group was much less likely to believe that pain indicates tissue damage or that exercise is harmful (SOPA-Harm, Figure 6.6). Participants in the experimental group believed they had greater control of their pain after the treatment (SOPA-Control, Table 6.2). Both groups reported decreased pain catastrophizing after the study (main effect for time, p=.01).

Although there was also a significant main effect for group with decreased PCS scores in the PNE group, the group by time interaction was not significant (Table 6.2).

Both groups increased their PPT scores for the low back as well as suprascapular region, but participants in the PNE group were able to tolerate higher levels of pressure in their low back before rating the sensation as painful (Table 6.3). Both groups increased their ability to reach forward towards the ground after the intervention (main effect for time).

Participants in both groups were equally as likely to report that they had not previously received the type of education in their respective research group (Novelty, Figure 6.2). Participants in both groups believed the education applied to their symptoms personally and did not feel that the education programs implied physical pain is due to a mental health problem. Participants in the PNE group, however, reported greater satisfaction in understanding the relationship between pain and stress compared to the control group. PNE participants thought their symptoms were treated as "real" to a greater degree than traditional stress education. Participants in the experimental group were more satisfied with the explanations that PNE gave for why stress management strategies can help with pain and stress. Furthermore, participants in the experimental group believed that PNE from a military perspective connected with them personally more than traditional stress education (Figure 6.2).

Participants who dropped out after beginning the intervention had significantly lower pain than participants who completed the therapy program (p=.043, Table 6.6). Furthermore, participants who did not complete the research study reported significantly higher levels of stress and were more likely to believe that it is appropriate to use medications for pain (SOPA-medication, Table 6.6). Participants who completed baseline testing but failed to begin treatment were less likely to believe that it is appropriate to seek help from family (SOPA-solicitude, p=.039, Table 6.6). 83% (5/6) of participants who completed baseline testing but did not begin treatment and 80% (4/5) of participants who dropped out had PTSD. Otherwise, participants who

failed to begin treatment or who failed to complete the research study were similar across sociodemographic characteristics and baseline outcomes to participants who began and completed the research program.

Success of participant blinding

Participants in the traditional and PNE groups were equally likely to believe they were in the experimental group, indicating successful participant blinding (Figure 6.2, p=.23).

Discussion

The experimental group consisting of PNE achieved superior outcomes across several important domains compared to a control group of traditional pain and stress education. Although the average disability did not significantly differ between groups after the intervention, a significantly higher proportion of participants in the experimental group achieved the recommended minimal improvement of 30% reduction in disability[241] compared to the control group at the 8-week follow-up. After the intervention, the PNE group had higher pain self-efficacy with a large effect size. Participants in the PNE group had a higher PPT in their low back following the intervention. Furthermore, participants in the PNE group were better satisfied with the explanation of their symptoms, and believed the education personally connected with their military experiences than traditional stress education. Although the experimental group did not achieve significantly lower PTSD symptoms, this study did not have enough participants with PTSD to statistically detect a difference between the interventions. However, the results from this study do support that PNE from a stress perspective decreases perceived levels of stress and on average decreased PTSD symptoms by more than the MCID for participants with a PTSD diagnosis.

This is the first study to demonstrate that PNE effectively reduces self-reported stress, although it was also somewhat surprising that the control group, which received evidenced-based recommendations and skills for stress management from the National PTSD Center reported

increased stress following the intervention. It could be that participants in the control group attended to their stress levels more following explicit education about stress. A similar phenomenon has been reported with pain in which hearing words associated with pain activate the pain neuromatrix[278]. Regardless of the mechanism, reducing stress has important implications in many clinical conditions. Dysregulated stress is linked to several chronic pain conditions like chronic LBP, fibromyalgia, chronic fatigue syndrome, and temporomandibular joint dysfunction[24]. In addition, dysregulated stress has also been identified as an important contributor to many psychiatric disorders[279]. Making the connection between psychosocial stressors and physical symptoms frequently challenges clinicians[37,41] and makes patients feel stigmatized[36]. According to the results of this research, PNE may be a logical bridge between psychosocial stressors and physical symptoms.

The results of this study add to the literature that PNE is an effective intervention for individuals with chronic LBP[139,192,280], although this is the first time PNE has been tested in a military population and the first trial to demonstrate PNE can improve PTSD symptoms equally as well as education from the National PTSD Center. A strength of this research is the design by allocating equal education contact between the experimental and control group. This design helps to postulate treatment mechanisms in military members with chronic LBP. Previous research that lacked a control group with equitable educational contact could not definitively conclude improvements were specific to PNE[280,281]. Since participants in both groups received the same total time in education, completed the same exercise program, and even received many of the same recommendations for coping with stress and pain, this study may suggest that the results were specific to the content of PNE.

A primary goal of PNE is to decrease the threat associated with pain. Ultimately, PNE contends that the nervous system produces pain to respond to potential tissue danger[49]. Therefore, if individuals perceive a greater threat, they may experience higher pain to ensure

protection from danger. PNE challenges the belief that on-going, persistent pain is directly attributable to damaged tissues. Instead, on-going pain can be explained by a hypersensitive nervous system. If participants believe the message of PNE, they may feel that their tissues are safe to exercise, even in the presence of on-going pain. The results from this study indicate that participants in the experimental arm did, in fact, change their beliefs about pain as indicated by the SOPA-Harm subscale. Participants in the PNE group were less likely to believe that pain was a sign of damage and that exercise might be harmful after the intervention.

Another finding that possibly informs mechanisms for improvement in the PNE group is changes in pain pressure thresholds (PPT). Participants in the PNE group tolerated significantly higher levels of pressure in their low back before they rated the stimulus as painful. If participants in the experimental group were less vigilant to danger in their tissues, then it might take more force to activate the pain neuromatrix[49] after learning how a hypervigilant nervous system contributes to pain. PNE has improved PPT values in patients with whiplash[282] but not fibromyalgia[50]; a recent trial[283] also found improvements in individuals with spinal pain but with a smaller effect size than the current study.

According to the current study, a large effect of PNE in military members with chronic LBP is improving pain self-efficacy. Improving pain self-efficacy is one of the top targets for PNE[284]. Beyond PNE research, self-efficacy is one of the most transcendent constructs influencing health behavior change[285] and is one of the top mediators of disability[28]. Since participants in the experimental group were more likely to understand the connection between pain and stress, they might have been more confident in implementing recommended strategies that were common to both groups, indicated by high pain self-efficacy scores. In addition, since PNE emphasizes that tissues are safe to move, even in the presence of pain, it is likely that participants would be more confident to move despite pain, corresponding to the earlier discussion about improvements in the SOPA-Harm scale. A previous study found that PNE

alone, but not combined with a traditional exercise program, improved pain self-efficacy scores[286]. Ryan, et al, reported that an exercise program delivered by therapists who may hold biomedical beliefs may contradict lessons delivered by PNE. The results from this study support that adding exercises with a PNE perspective has a beneficial effect to PNE in improving pain self-efficacy. Although pain self-efficacy scores were not significantly different after post-hoc testing in the repeated measures ANOVA for the 8-week follow-up, the experimental group had higher pain self-efficacy that exceeded the MCID of 5 points[269] at both the 4-week and 8-week follow-up compared to the control group and had an average PSEQ score that is considered "normal:" $\geq 40/60$[258].

Another reason why the PNE intervention in this trial was effective in Veterans and Soldiers could be because the PNE curriculum was delivered using military examples and stories that connected with the participants. Participants rated the experimental education as connecting personally with their experiences as a military member to a greater degree than the control education. It is critical to communicate about pain in a culturally relevant and specific way[123,125]. Although the control education also used military images and came from Veteran resources[119,272], participants in the experimental group may have personally reflected on the education and lessons in the PNE intervention due to the narrative form of stories which encourages personal reflection[287]. Further qualitative inquiry on what messages participants understood from PNE would be helpful.

Finding effective treatments for co-morbid pain and PTSD has been reported as challenging[17]. Exercise is an effective therapy for both low back pain[141] and PTSD[133]. A main barrier to implementing exercise therapy, however, is that military members will avoid activities like exercise if it is painful[55]. Avoidance of possible dangers is a core symptom of PTSD. Another symptom that is central to PTSD is hypervigilance[134]. Co-morbid pain and PTSD might be due to a hypervigilant nervous system that becomes more sensitive to potential dangers[22,131,190].

PNE is recommended for patients with a hypersensitive nervous system[153], and the results from this study indicate that patients with PTSD might be a population that could particularly benefit from PNE.

Since participants in the experimental group decreased their PTSD symptoms by a large effect size compared to traditional stress and pain education, the fact that at least 80% of the participants who did not initiate or complete treatment had PTSD potentially represents a missed opportunity. Drop-outs for participants with pain and PTSD have been reported as high as 50% in previous research[17,75] and approximately 30% for participants with PTSD in general[133]. In this study, only 13.5% of participants who began therapy dropped out. Although this relatively low rate of drop-outs may indicate perceived legitimacy of treatments by research participants, the rate of individuals who consented to participate in this study but failed to complete study requirements was 30.4%. Since a higher proportion of participants who did not begin or did not complete treatment had PTSD, it is possible that the overall drop-out rate would have been higher even if all participants began treatment after consenting to research. The results of this study indicate potential treatment resistance for individuals with PTSD. In addition, participants who dropped out could have believed they did not need thorough treatment (they had lower pain) or may have desired a more traditional biomedical approach that included pharmacological interventions (drop-outs were more likely to believe medications should be used for pain than completers, SOPA-Medication sub-scale). Further research is needed to determine if brief PNE interventions, or written PNE materials alone, might be able to influence outcomes in a group of patients who may be less likely to commit to a longitudinal intervention. Currently, research is mixed on the effectiveness of PNE written materials alone[46,143].

Limitations:

One of the main limitations of this study is a small sample size. Despite appearing to favor the experimental group, several outcomes lacked sufficient confidence to statistically

determine the effectiveness of PNE, likely due to a small sample size. Although this study lacked statistical power for some of the outcomes, it is possible that this same lack of power failed to statistically identify important prognostic differences between the groups at baseline. For example, on average the experimental group was younger, more educated, and had a shorter duration of back pain. The experimental group, however, also had higher service-connected disability, where higher numbers indicate more mental and physical health disability incurred from military service. Although these differences were not statistically significant, a larger sample could more definitively demonstrate that the results from this study were due to the intervention rather than participant intrinsic characteristics that favored the experimental group despite randomization.

In addition, although this study found improvements in PPT in the experimental group, PPT is considered a static measure that explains only a small amount of variance in individual's pain and disability[256]. A more dynamic measure like diffuse noxious inhibitory control[257] might be a more appropriate quantitative sensory test (QST) to determine improvements in top-down, or endogenous inhibition[50]. Another limitation is only having an 8-week follow-up; however, this study will analyze healthcare utilization pending a formal VAMC healthcare utilization data request that will be submitted so that all participants can be followed for 6 months following their final research appointment. The results from this RCT may not generalize to civilian populations, although it would be interesting to determine if PNE can be similarly adapted to affect PTSD in different trauma settings.

Conclusion:

PNE was more effective than traditional stress and pain education in improving disability, stress, pain-pressure thresholds, pain self-efficacy, and beliefs about pain. Future research should confirm the results of this study in a larger sample, particularly regarding PTSD symptoms. Future research should also recruit and analyze Active Duty Soldiers separately to

increase participant homogeneity and develop greater confidence in the effect sizes for PNE in Soldiers. In addition, it may help to remove patho-anatomical education about the spine and purely include psychosocial education in the control group to determine if PNE's effectiveness was due to its superiority over traditional stress education or due to the deleterious effects of education that focuses on tissues. Finally, it would also be helpful to have an exercise-only group to separate the effects of the education versus supervised exercise.

Figure 6. 1 Participant Flow through the Randomized Controlled Trial

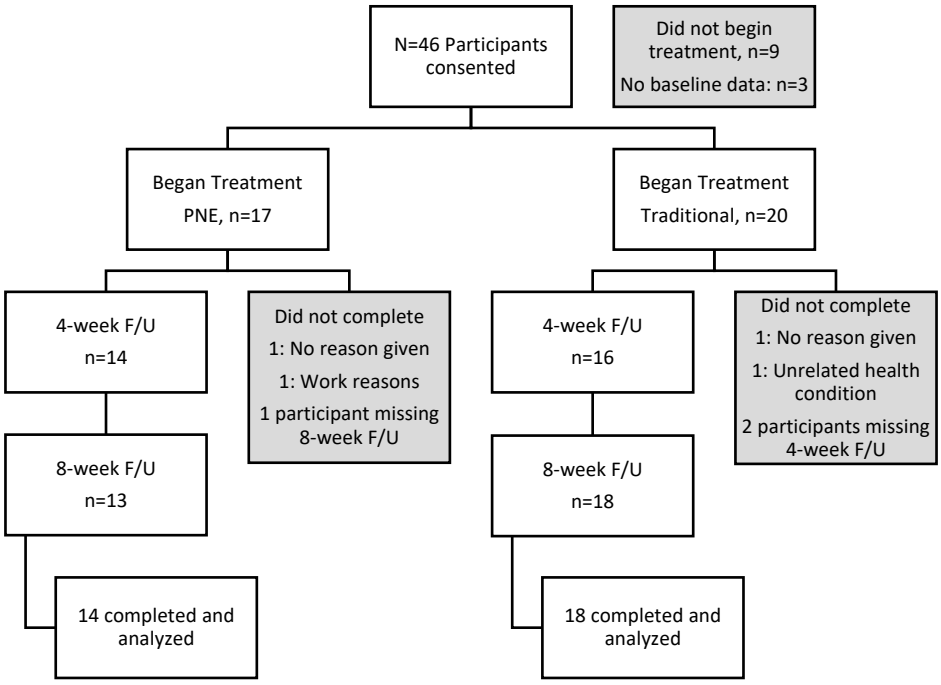


Table 6. 1 Baseline sociodemographic characteristics of participants.

Characteristic	Experimental Group, PNE n=14	Control Group, Traditional n=18	P value
Age, Years (sd)	36.7 (9.8)	42.6 (11.1)	.13
Gender, M (%) F (%)	12 (85.7%) 2 (14.3%)	14 (77.8%) 4 (22.2%)	.67
Race African American (%) Hispanic (%) White (%)	 1 (7.1%) 3 (21.4%) 10 (71.4%)	 3 (16.7%) 4 (22.2%) 11 (61.1%)	.70
Education, Years (sd)	14.6 (1.8)	13.3 (2.1)	.09
Service Army (%) Navy (%) Marines (%) Air Force (%)	 10 (71.4%) 2 (14.3%) 2 (14.3%) 0	 14 (77.8%) 0 1 (5.6%) 2 (11.1%)	.23
Previous Deployment (%)	9 (64.3%)	10 (44.4%)	.73
Previous Trauma (%)	13 (92.9%)	14 (77.8%)	.36
PTSD Diagnosis (%)	5 (35.7%)	5 (27.8%)	.71
Current Depression (%)	8 (57.1%)	11 (61.1%)	1.0
Active Duty (%)	4 (28.6%)	5 (27.8%)	1.0
Duration of LBP, Months (sd)	53.5 (60.7)	105.4 (101.3)	.15
Co-morbidities, # (sd)	6.4 (5.8)	6.3 (4.9)	.94
% Service Connected Disability (sd)	42.9 (41.6)	22.8 (34.1)	.16

M: Male; F: Female; PTSD: Post-traumatic stress disorder; LBP: Low back pain; sd: Standard deviation. PNE: Pain Neuroscience Education.

Table 6. 2 Study Outcome Group by Time Effects. PNE, n=13; Traditional, n=16

Outcome	Baseline	4-weeks	8-weeks	Effect size[d]	F	P value
PCL (0-80)						
PNE (sd)	33.8 (23.4)	23.5 (19.6)	24.8 (18.1)	-0.76	1.8	.18
Traditional (sd)	34.8 (22.5)	32.8 (25.6)	31.6 (25.0)			
PCL (0-80)[e]						
PNE (sd)	56.4 (12.2)	41.4 (17.6)	40.0 (14.7)	-1.25[f]	3.3	.097
Traditional (sd)	56.0 (14.4)	58.6 (21.1)	58.4 (12.0)			
Stress (0-10)						
PNE (sd)	6.7 (2.2)	5.5 (2.1)	5.4 (1.9)	-.93[f]	3.2	.047*
Traditional (sd)	5.6 (3.5)	6.8 (2.2)	6.4 (3.0)			
Pain NPRS (0-10)						
Experimental (sd)	4.8 (1.3)	3.5 (1.8)	3.5 (1.5)	-.18	.23	.76
Traditional (sd)	6.2 (1.8)	5.0 (2.5)	5.3 (2.9)			
RMDQ (0-24)						
PNE (sd)	10.8 (5.5)	7.7 (4.4)	7.7 (6.0)	-.60	.55	.52
Traditional (sd)	12.8 (4.8)	11.3 (5.3)	11.1 (6.6)			
PCS (0-52)						
PNE (sd)	18.4 (13.7)	9.2 (7.6)	11.9 (11.3)	-.76	2.1	.134
Traditional (sd)	26.3 (12.1)	24.8 (12.1)	22.7 (12.7)			
SOPA (0-4)						
SOPA: Control						
PNE (sd)	1.8 (.56)	2.7 (.40)[a]	2.8 (.81)[b]	1.49[f]	6.8	.006*
Traditional (sd)	1.6 (.73)	1.6 (.62)	1.5 (1.1)			
SOPA: Disability						
PNE (sd)	2.0 (.72)	1.7 (.81)	1.8 (.91)	-.22	.15	.86
Traditional (sd)	2.5 (.72)	2.3 (.83)	2.4 (.93)			
SOPA: Harm						
PNE (sd)	2.0 (.59)	1.0 (.59)[a]	1.2 (.65)[b]	-1.52[f]	9.7	<.001*
Traditional (sd)	2.2 (.72)	2.0 (.74)	2.1 (.69)			
SOPA: Emotion						
PNE (sd)	2.1 (1.0)	2.1 (.96)	2.2 (.74)	.02	.03	.97
Traditional (sd)	2.2 (.78)	2.1 (.93)	2.1 (.94)			
SOPA: Medication						
PNE (sd)	2.2 (.84)	1.9 (.93)	1.9 (1.0)	-.71	2.6	.096
Traditional (sd)	2.6 (1.0)	2.6 (.84)	2.7 (.76)			
SOPA: Solicitude						
PNE (sd)	1.3 (1.2)	1.0 (.80)	1.0 (.94)	-.23	1.3	.27
Traditional (sd)	1.1 (1.1)	1.0 (1.0)	1.3 (1.2)			
SOPA: Cure						
PNE (sd)	1.5 (.58)	1.5 (.72)	1.5 (.60)	-.44	1.6	.21
Traditional (sd)	1.8 (.82)	1.5 (1.0)	1.7 (.83)			
PSEQ (0-60)						
PNE (sd)	36.1 (9.5)	42.0 (11.7)[a]	42.0 (12.4)[c]	1.21[f]	3.8	.028*
Traditional (sd)	34.6 (13.3)	30.0 (11.3)	32.0 (16.1)			

PCL: Post-traumatic stress disorder checklist; RMDQ: Roland Morris Disability Questionnaire; PCS: Pain catastrophizing scale; PNE: Pain Neuroscience Education; NPRS: Numeric pain rating scale; SOPA: Survey of Pain Attitudes; PSEQ: Pain self-efficacy questionnaire.

*Denotes group by time significance at the level of $\alpha = .05$. [a]Significant difference between groups at 4-weeks after post-hoc tests. [b] Significant difference between groups at 8-weeks after post-hoc tests. [c]p=.07. [d]Cohen's d effect sizes were calculated based on the between-group differences for the change scores from baseline to 4-weeks. Negative effect sizes indicate a greater decrease in scores from baseline favoring the experimental group. Positive effect sizes indicate a greater increase in scores from baseline favoring the experimental group. [e]PCL scores among participants with PTSD, PNE: n=5, Traditional: n=5. [f]Indicates a large effect size.

Table 6. 3 Objective Outcome Measures

Test	Baseline	4-weeks	Effect size	P value
Mean PPT Low Back, kPA PNE (sd) Traditional (sd)	 259.1 (157.7) 257.2 (141.8)	 380.4 (145.4) 267.7 (203.8)	 .78	 .02[a]*
Mean PPT Shoulder, kPA PNE (sd) Traditional (sd)	 340.8 (225.9) 284.8 (177.9)	 393.6 (185.6) 254.7 (147.0)	 .61	 .08
Forward Bend[b], cm from floor PNE (sd) Traditional (sd)	 20.0 (15.1)*[c] 32.5 (12.6)	 12.1 (10.9) 28.8 (16.1)	 .51	 .19
Exercise Score PNE (sd) Traditional (sd)	 -- --	 18.5 (4.8) 15.4 (3.4)	 .77	 .065

PPT: Pain Pressure Threshold. PNE: Pain Neuroscience Education. kPA: Kilopascals. Sd: Standard deviation. Cm: Centimeters.

*Denotes significance at the level of α =.05. [a]Mann Whitney U test of change scores from baseline to 4-week follow-up due to PPT values failing to meet test assumptions of normality.

[b]Note, a lower number indicates greater range of motion. [c]Significantly different at baseline.

Table 6. 4 Percentage of Participants meeting Minimal Clinically Important Difference (MCID) for Outcomes

Outcome	MCID	PNE	Traditional	P value
Disability, RMDQ 4-weeks	Yes (%) No (%)	8 (57.1%) 6 (42.9%)	4 (25%) 12 (75%)	.135
Disability, RMDQ 8-weeks	Yes (%) No (%)	9 (69.2%) 4 (30.8%)	5 (27.8%) 13 (72.2%)	.033*
Pain, NPRS 4-weeks	Yes (%) No (%)	8 (57.1%) 6 (42.9%)	6 (37.5%) 10 (62.5%)	.46
Pain, NPRS 4-weeks	Yes (%) No (%)	4 (30.8%) 9 (69.2%)	4 (22.2%) 14 (77.8%)	.69
PCL, 4-weeks	Yes (%) No (%)	5 (35.7%) 9 (64.3%)	2 (12.5%) 14 (87.5%)	.20
PCL, 8-weeks	Yes (%) No (%)	4 (30.8%) 9 (69.2%)	2 (12.5%) 14 (87.5%)	.36
PSEQ, 4-weeks	Yes (%) No (%)	8 (57.1%) 6 (42.9%)	1 (6.3%) 15 (93.8%)	.00*
PSEQ, 8-weeks	Yes (%) No (%)	8 (61.5%) 5 (38.5%)	4 (22.2%) 14 (77.8%)	.06

MCID: Minimal clinically important difference. RMDQ: Roland Morris Disability Questionnaire. NPRS: Numeric pain rating scale. PCL: Post-traumatic stress disorder checklist. PSEQ: Pain self-efficacy questionnaire. *Denotes significance at the level of α =.05

Table 6. 5 Sociodemographic Characteristics for Participants by Treatment Initiation and Completion Status

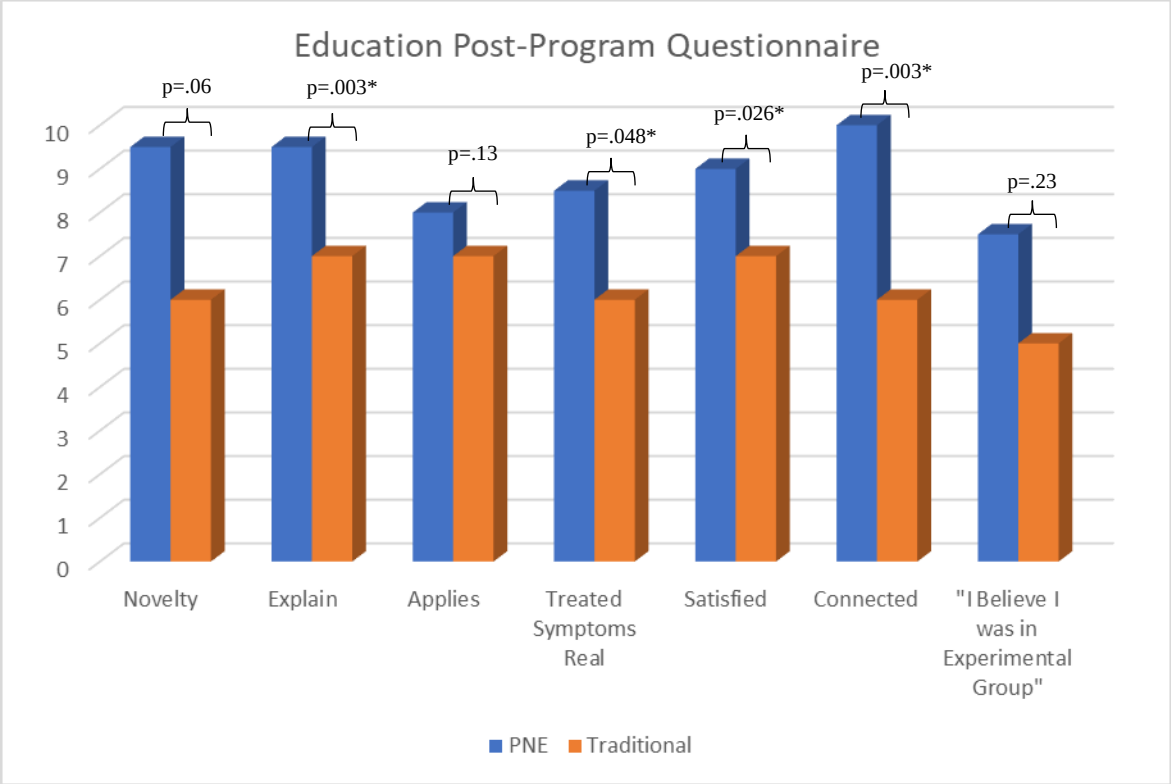
Characteristic	Non-starters n=6	Starters n=37	P value	Non-Completers n=5	Completers n=32	P value
Age, Years (sd)	36.8 (7.0)	38.9 (10.7)	.65	31.8 (6.8)	40.0 (10.8)	.11
Education, Years (sd)	14.8 (2.7)	13.6 (2.0)	.24	12.0 (0)	13.9 (2.0)	.079[a]
Previous Trauma (%)	6 (100%)	31 (83.8%)	.57	4 (80%)	27 (84.4%)	1.0
PTSD Diagnosis (%)	5 (83.3%)	15 (40.5%)	.08	4 (80%)	11 (34.4%)	.14
Depression (%)	4 (66.7%)	22 (59.5%)	1.0	3 (60%)	19 (59.4%)	1.0
Active Duty (%)	2 (33.3%)	11 (29.7%)	1.0	2 (40%)	9 (28.1%)	.62
Duration of LBP, Months (sd)	69.0 (55.7)	82.6 (82.8)	.75	78.4 (45.0)	83.5 (88.9)	.90
Co-morbidities, (sd)	6.33 (4.8)	6.2 (4.97)	.96	5.4 (3.4)	6.3 (5.2)	.70
% Service Connected Disability (sd)	62.5 (47.9)	32.2 (37.9)	.15	36.0 (39.1)	31.6 (38.3)	.81

Table 6. 6 Baseline Outcomes for Participants by Treatment Initiation and Completion Status

Characteristic	Non-starters n=	Starters n=	P value	Non-Completers n=	Completers n=	P value
PCL	47.3 (16.9)	35.9 (21.4)	.22	42.2 (15.8)	34.9 (22.1)	.49
Pain NPRS Current	4.7 (1.6)	5.3 (1.8)	.42	3.8 (1.8)	5.5 (1.7)	.043*
RMDQ	11.1 (5.4)	11.9 (6.1)	.49	9.4 (4.7)	12.5 (5.2)	.22
PCS	24.3 (15.6)	22.5 (12.7)	.75	21.0 (13.8)	22.7 (12.7)	.78
Stress	7.3 (2.8)	6.4 (2.7)	.46	8.8 (1.3)	6.0 (2.7)	.035*
SOPA: Medication SOPA: Solicitude	1.8 (.70) .27 (.30)	2.5 (.95) 1.2 (1.1)	.063 .039*	3.4 (.49) 1.6 (.74)	2.4 (.93) 1.1 (1.1)	.027* .33
PSEQ	34.0 (18.2)	34.5 (11.9)	.94	.29		.40

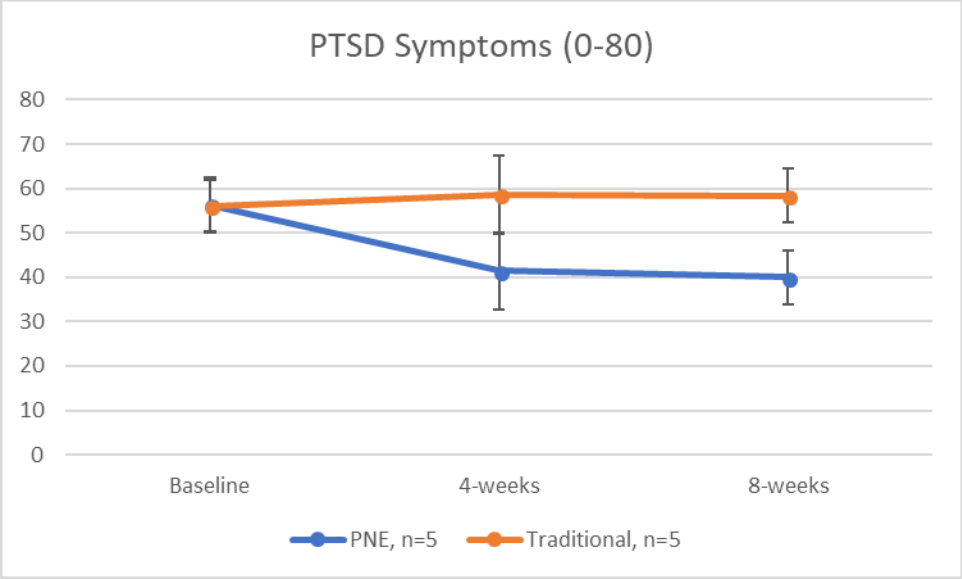
PCL: Post-traumatic stress disorder checklist. RMDQ: Roland Morris Disability Questionnaire. NPRS: Numeric pain rating scale. PCS: Pain catastrophizing scale. SOPA: Survey of Pain Attitudes. PSEQ: Pain self-efficacy questionnaire. *Denotes significance at the level of $\alpha = .05$

Figure 6. 2 Post-Program Questionnaires about Education



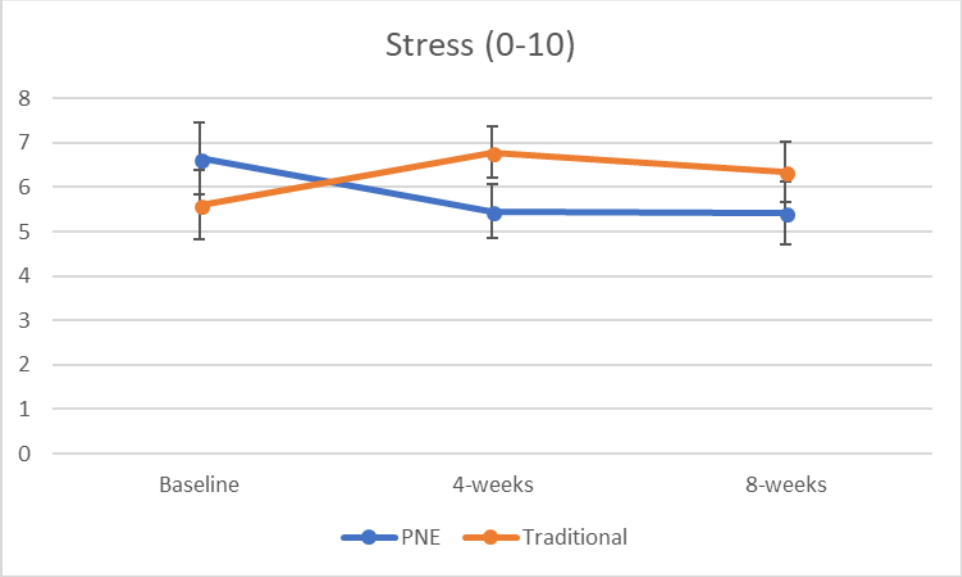
*Denotes between group significance at the level of α =.05. Mann Whitney U test.

Figure 6. 3 Group by Time Effects for Post-Traumatic Stress Disorder (PTSD) Symptoms



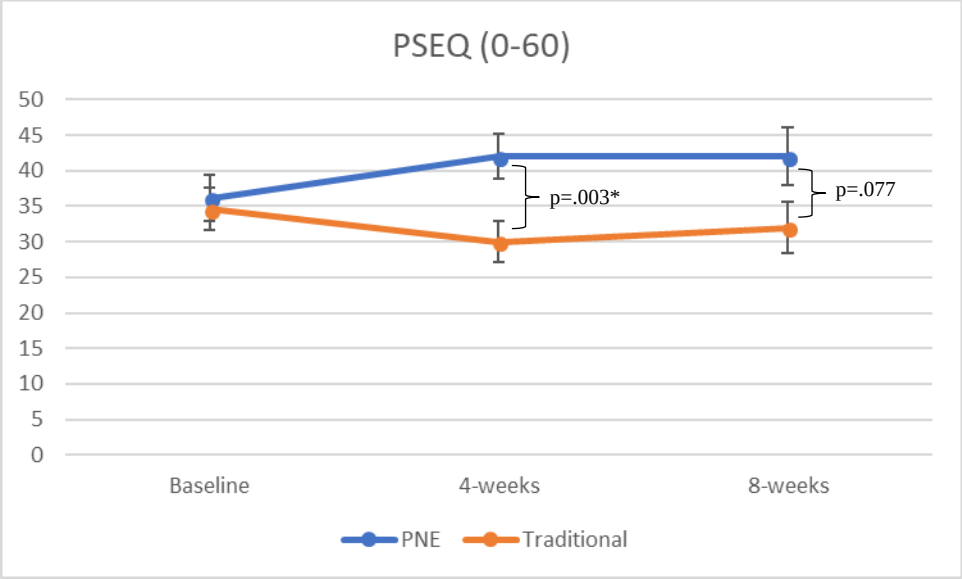
Group by Time Interaction, p=.097

Figure 6. 4 Group by Time Effects for Stress



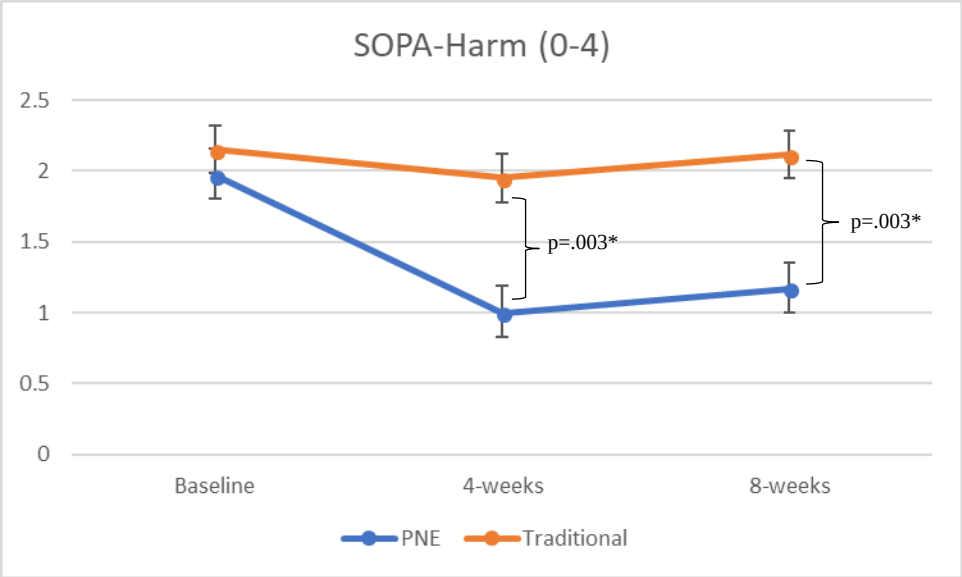
Overall Group by Time Interaction, p=.047*

Figure 6. 5 Group by Time Effects for Pain Self-Efficacy



Overall group by time interaction p= .028, significant at α =.05. *Denotes significant p value after Bonferroni correction.

Figure 6. 6 Group by Time Effects for SOPA-Harm Beliefs



*Overall group by time interaction significant at α =.05. p values given after Bonferroni correction.

Chapter Seven: Summary of Findings

Purpose:

1. Develop a PNE curriculum for Veterans with PTSD and pain and determine if Veterans can comprehend PNE materials (Chapter 3).

   Hypothesis: Veterans with PTSD and pain would be able to successfully comprehend a PNE curriculum and would find the materials helpful for pain and PTSD.

2. Determine if co-morbid PTSD and chronic LBP increases disability in Active Duty Soldiers compared to chronic LBP alone (Chapter 4).

   Hypothesis: Soldiers with LBP and PTSD would have a higher relative risk of medical discharge compared to Soldiers without these conditions.

3. Determine if Veterans and Soldiers with PTSD and LBP have poorer health outcomes compared to Veterans and Soldiers without PTSD (Chapters 2 and 5).

   Hypothesis: Veterans and Soldiers with PTSD will have higher pain and disability than Service Members without PTSD. Service Members with PTSD will have greater negative beliefs about pain. Finally, Service Members with PTSD will have lower pain pressure threshold values than Service Members without PTSD.

4. Determine the effectiveness of PNE for Veterans and Soldiers with chronic LBP (Chapter 6).

   Hypothesis: PNE will improve pain, stress, disability, and pain-related beliefs and outcomes to a greater degree than traditional education about pain and stress.

Summary of Findings

1. Develop a PNE curriculum for Veterans with PTSD and pain and determine if Veterans can comprehend PNE materials (Chapter 3).

   Finding: This dissertation demonstrated that Veterans with PTSD can comprehend the neuroscience of pain and PTSD at a comparable level to a highly educated Veteran and medical panel without PTSD when controlling for years of education. Since a proportion of participants were concerned that using military examples in PNE might increase PTSD symptoms, however, results from Chapter 3 suggested that the PNE materials developed for this dissertation should be tested in a clinical trial to ensure they do not increase PTSD symptoms.

2. Determine if co-morbid PTSD and chronic LBP increases disability in Active Duty Soldiers compared to chronic LBP alone (Chapter 4).

   Finding: A U.S. Army Soldier with a history of both PTSD and chronic LBP is more than 5 times at risk for being medically disabled compared to Soldiers without these two conditions, even after controlling for other important demographic characteristics and co-morbidities. Therefore, the results from this dissertation support implementing an intervention that targets PTSD and chronic LBP in Active Duty Soldiers to attempt to reduce disability related to these conditions.

3. Determine if Veterans and Soldiers with PTSD and LBP have poorer health outcomes compared to Veterans and Soldiers without PTSD (Chapters 2 and 5).

   Finding: A systematic review and meta-analysis demonstrated that Veterans with PTSD have higher depression and pain-catastrophizing beliefs for a large effect size compared to Veterans without PTSD. Furthermore, Veterans with PTSD have significantly lower pain self-efficacy with a large effect size. Compared to Veterans without PTSD, Veterans with PTSD have higher pain and disability.

These results, however, were not confirmed in Veterans presenting to physical therapy. In fact, this dissertation revealed that many of the negative outcomes previously attributed to PTSD in the literature may be due to the correlation between PTSD symptoms and pain catastrophizing beliefs rather than from trauma. Furthermore, Veterans with chronic LBP do not appear to have different sensitivity levels to pressure based on PTSD symptoms.

4. Determine the effectiveness of PNE for Veterans and Soldiers with LBP. (Chapter 6).

   Finding: At 8-weeks, participants in the experimental arm viewed themselves as less disabled compared to the control group. In addition, the experimental group perceived lower levels of stress following the intervention. The results from this RCT indicate that PNE improves Service Members' confidence to increase participation in social, work, and life roles despite the pain as measured by the PSEQ. Because participants receiving PNE were less likely to view pain as harmful following the intervention, the mechanism for these improvements could be due to a top-down reconceptualization of pain. This is supported by increased pain pressure thresholds in the experimental group following PNE.

   Furthermore, the PNE curriculum personally connected with participants to a greater degree than traditional pain and stress education. Likewise, participants in the experimental group were more satisfied with how the connection between pain and stress were made by PNE compared to traditional education. In addition, participants in the experimental group believed they had greater control of their pain following the PNE intervention compared to traditional education about stress. Although pain improved equally in both groups, this study was not primarily powered to show a difference in pain and

therefore did not have sufficient statistical evidence to confidently conclude PNE improves pain more than traditional pain and stress education.

Synthesis of Results and Future Research Implications

All individuals experience stressors in life[12]. For many Service Members and Veterans, cumulative high levels of stress can lead to PTSD. Although PTSD by itself can be quite disabling, this dissertation provides evidence that PTSD and co-morbid pain lead to many negative health outcomes compared to a Veteran who has pain but no PTSD (Chapter 2). LBP is one of the top reasons for a Service Member to seek healthcare[7] and, when combined with PTSD, raises the risk for medical discharge from the U.S. Army by more than 5 times even when controlling for other co-morbidities (Chapter 4). Compounding the problem, once Service Members leave the service, they avoid activities that might be painful because they believe they could be damaging tissues[55].

If Veterans believe that pain indicates tissue damage, then according to the common-sense model[54] it is understandable that Veterans would avoid painful activities. According to longitudinal imaging research of anatomical tissues, however, psychosocial characteristics like depression were more influential in identifying new onset of LBP in Veterans than changes to the spine[264]. Focusing on patho-anatomical tissues, though, can promote over-protection of the spine and increase disability[139] and feelings of vulnerability[35]. PNE, on the other hand, contends that the brain ultimately produces pain to protect body tissues from potential danger[49]. Therefore, from a PNE perspective, promoting beliefs that on-going pain is synonymous with damaged tissues will only promote continued pain as a protective response to change behavior. One purpose of PNE, then, is to decrease the threat of pain by showing individuals how a hypersensitive nervous system can be responsible for pain even after tissues heal. Indeed, a hypervigilant nervous system has been proposed for co-morbid PTSD and pain[131], chronic LBP[23], and chronic stress disorders[24]. This dissertation aimed to determine if PNE in the context of

stress could be effective in reducing many of the negative beliefs about pain and improve a Service Member's willingness to engage in active rehabilitation and exercise.

This dissertation demonstrated that Veterans with PTSD can comprehend the neuroscience of pain and PTSD at a comparable level to a highly educated Veteran and medical panel without PTSD when controlling for years of education. Since a proportion of participants were concerned that using military examples in PNE might increase PTSD symptoms, however, results from Chapter 3 suggested that the PNE materials developed for this dissertation should be tested in a clinical trial to ensure they do not increase PTSD symptoms. The results from this research demonstrated conclusively that the PNE curriculum developed for Veterans does not increase PTSD symptoms. In fact, the PNE curriculum used in this dissertation decreased PTSD symptoms more than traditional education about PTSD and stress from the National PTSD Center[119] (Chapter 6). Although this difference was not statistically significant due to a lack of power and only 5 participants with PTSD in each group, the difference exceeded the MCID for PTSD symptoms and was a large effect size (Chapter 6). Nonetheless, the results from Chapter 3 revealed that the PNE curriculum might best be utilized with a patient-clinician therapeutic alliance rather than a stand-alone resource, although this should be tested in a prospective trial.

Since the longitudinal cohort in Chapter 4 determined that co-morbid PTSD and LBP significantly increased the risk for medical disability from the U.S. Army (Chapter 4), this dissertation aimed to determine the effectiveness of PNE in Active Duty U.S. Soldiers with PTSD and LBP as well as in Veterans who have already separated from the Service. In addition, since clinical experience has shown some resistance to PNE in activity duty Soldiers, this dissertation set out to determine if Veterans and Soldiers believed PNE personally applied to their symptoms or if they believed PNE implied their pain was due to a mental health disorder.

Chapter 5 determined that Veterans with and without PTSD had, on average, elevated pain catastrophizing beliefs. Veterans with and without PTSD were equally as likely to report

current depression, high levels of stress, and have a history of traumatic events. Furthermore, Chapter 5 aimed to elucidate the sensory profile of Veterans with PTSD since previous research has been conflicted as to whether individuals with PTSD display signs of hypo- or hyper-sensitivity. This dissertation did not find evidence to conclude that Veterans with chronic LBP have different sensitivity as demonstrated by PPTs based on the presence of PTSD. In addition, 37.5% of participants scored above cut-offs for PTSD despite no formal PTSD diagnosis. Because of the presence of PTSD symptoms among many participants without a PTSD diagnosis and elevated baseline stress levels for most participants, the results from the dissertation support including PNE from a stress-perspective for Service Members with or without PTSD.

The final study in this dissertation aimed to determine the effectiveness of PNE in Service Members with chronic LBP with or without co-morbid PTSD compared to traditional education about pain and stress. Following PNE, participants in the experimental group reported decreased stress and saw themselves as less disabled. In addition, the results from the RCT provide evidence that PNE greatly improves Service Members' confidence to increase active participation despite the pain as measured by the PSEQ. Furthermore, participants that received PNE were more likely to be satisfied with the explanation given for the relationship between psychosocial stressors and chronic pain from a PNE perspective compared to traditional stress and pain education. Consistent with the intent of PNE, participants in the experimental arm were less likely to believe that exercise is harmful after receiving PNE compared to traditional pain and stress education.

Clinical Implications

The results from the research completed in this dissertation have several clinical implications. First, the preliminary studies provide additional evidence (Chapter 4) that SMs with co-morbid PTSD and LBP likely require tailored management that addresses both pain and PTSD symptoms as recommended in the literature[288]. PNE tailored to a military population appears to

be an effective intervention for Service Members with PTSD and chronic LBP. Based on the results of this dissertation, on average, clinicians can be confident that PNE from a military perspective reduces PTSD symptoms at least as well as from the National Center for PTSD, although results indicate that a higher powered study would find a large effect favoring PNE for PTSD symptoms.

In addition, exercise is efficacious for both chronic LBP[141] and PTSD symptoms[133]. Veterans may avoid exercising, however, when they have pain for fear of harming tissues[55]. PNE appears to decrease these fears (SOPA-Harm) and greatly improve confidence for engaging in physical activity and exercise for Service Members. Furthermore, the results from this dissertation provide objective evidence that PNE may cause Service Members' nervous system to process nociceptive information as less threatening when considering the increase in PPT values following the intervention. Decreasing fear associated with exercise and pain is a major goal following injury[29]. Therefore, clinicians should strongly consider educating Service Members who have chronic LBP from a PNE perspective as opposed to traditional patho-anatomic education[263,289].

Although PNE has been used in several research studies including participants with LBP[139,192,280,286], this is the first research study to investigate the effectiveness of PNE in Veterans or Soldiers with LBP. Furthermore, this is the first study to demonstrate that PNE specifically reduces stress symptoms. The results from this dissertation can alleviate concerns that educating patients with PNE may imply that physical symptoms are the result of mental health disorders. In fact, it appears that PNE is a more effective bridge between psychosocial stressors and physical symptoms compared to traditional stress education (Chapter 6). Therefore, clinicians should consider PNE for Service Members who appear to have elevated psychosocial stressors.

Although PTSD is a common psychosocial disorder in Soldiers and Veterans[233] and is correlated with stress (Chapter 5), the results from this dissertation indicate that Service Members

with chronic LBP stand to benefit from PNE regardless of PTSD status. In addition, this dissertation found that 37.5% of Veterans without a formal PTSD diagnosis still display significant PTSD symptomology. Furthermore, PTSD symptoms are correlated with pain catastrophizing beliefs in Veterans with LBP (Chapter 5). Pain catastrophizing beliefs have been shown to significantly contribute to chronic pain[267,290] and are a prime target for PNE interventions[46]. Since short, validated PTSD screening questionnaires are regularly utilized in the VA and Active Duty military treatment facilities[83,174,175], clinicians may consider utilizing PTSD screening to serve as a proxy for identifying Service Members who might benefit from PNE to target stress and pain. The hyperarousal symptoms identified in the PC-PTSD screen[172] might indicate a hypervigilant nervous system that is not uncommon in patients with chronic LBP[224].

Future Research

Future research should determine if PC-PTSD screening can effectively identify military Service Members who would benefit from PNE. Furthermore, it would be helpful to repeat the results from the RCT in a larger sample to confirm the results from this dissertation and have sufficient power to analyze results among sub-groups (PTSD versus no PTSD; Soldiers versus Veterans). In addition, a future study might consider removing the patho-anatomical education and include only biopsychosocial stress education to clarify specific educational content that is most responsible for the results found in this dissertation. Also, it would be helpful to have an exercise-only group to help elucidate specific mechanisms for the outcomes found in Chapter 6.

Based on the feedback from participants in Chapter 3, a qualitative study examining participant interpretations of PNE compared to clinician views of PNE delivery would be fascinating and beneficial. It would also be helpful to develop military PNE for other conditions that are frequently co-morbid with chronic pain, like mild traumatic brain injury[291].

Conclusion:

PTSD symptoms are common in Veterans with chronic LBP, even among those who have never been diagnosed with PTSD before. Veterans without PTSD can effectively comprehend PNE written from a military perspective. The results from this dissertation demonstrate that PNE using military examples connects with participants more than traditional education about pain and stress. Clinicians can be confident that PNE from a military perspective decreases PTSD symptoms at least as well as education from the National Center for PTSD.

PNE from a military and stress perspective was effective in reducing stress and disability in Veterans and Soldiers with chronic LBP. Participants who received PNE were less likely to believe that pain was harmful and that active rehabilitation in the presence of pain should be avoided. Following PNE, participants believed they had greater control of their pain. The research from this dissertation provided evidence that these results may be due to a less hypervigilant nervous system given that participants in the experimental arm were able to tolerate higher levels of nociception prior to reporting pressure as painful in their low back. PNE from a military and stress perspective appears to be an effective bridge between physical and psychosocial symptoms and helps reduce stress as well as pain-related disability in Veterans and Soldiers with chronic LBP.

Appendices

Appendix A: Participant Demographic Information

Thank you for your participation in this study. Please provide the most appropriate answer to

each question. Please complete ALL questions. There is no right or wrong answer. All information will be handled in confidence and no personal data will be collected.

1. What is your age? _____ years

2. What is your gender? _____ male _____ female

3. What is your ethnic background?

- ☐ African-American
- ☐ Hispanic
- ☐ White, non-Hispanic
- ☐ Asian
- ☐ Other: Please specify: _____

4. What is your educational background?

- ☐ Post-graduate education (Masters, doctorate, etc.)
- ☐ Graduate (Bachelors)
- ☐ High school
- ☐ Other. Please specify: _____

5. Which of the following describes your income best?

- ☐ Less than $10 000 per year
- ☐ Between $10 0000 and $50 000 per year
- ☐ Between $50 000 and $100 000 per year
- ☐ More than $100 000 per year

6. Describe your military service:

- ☐ Army
- ☐ Marines
- ☐ Navy
- ☐ Air Force
- ☐ Coast Guard

8. Describe your combat military deployments:

- ☐ Korea
- ☐ Vietnam
- ☐ Persian Gulf
- ☐ Iraq
- ☐ Afghanistan
- ☐ Other. Please specify: _____
- ☐ None

9. Have you personally experienced any of the following traumatic life events?

- ☐ Combat-related trauma
- ☐ Personal violence
- ☐ Military sexual trauma/Unwanted sexual assault
- ☐ Motor Vehicle Crash
- ☐ Natural Disaster
- ☐ Other. Please specify: _____
- ☐ Prefer not to answer

10. When did you experience this trauma (Check all that apply)?

- ☐ While serving in the military
- ☐ After serving in the military
- ☐ Before serving in the military
- ☐ Other. Please specify: _____

11. Have you ever been diagnosed with PTSD?

- ☐ Yes
- ☐ No
- ☐ Unsure

If “No”, you have not been diagnosed with PTSD, please skip to question # 13

12. If **Yes**, How long have you had PTSD symptoms? ____(# of years) _____ (# of months)

13. How did you injure your low back?

- ☐ Traumatic injury or accident (non-combat)
- ☐ Traumatic injury (combat)
- ☐ Gradual onset with physical activities
- ☐ Unknown
- ☐ Other. Please specify: _____

14. Have you used any of the following treatments for your **back pain**? (Check all that apply)

Opiod painkillers (prescription medications such as Vicodin, Lortab, Norco, hydrocodone, codeine, Tylenol #3 or #4, fentanyl, Duragesic, MS Contin, Percocet, Tylox, OxyContin, oxycodone, methadone, tramadol, Ultram, Dilaudid)	❑ Yes	❑ No
If you checked yes, are you currently using this medication?	❑ Yes	❑ No
Injections (such as epidural steroid injections, facet injections)	❑ Yes	❑ No
Exercise therapy	❑ Yes	❑ No
Psychological counseling, such as cognitive behavioral therapy, **for your back pain.**	❑ Yes	❑ No
Low-back Surgery	❑ Yes	❑ No

15. HOW LONG HAVE YOU HAD THIS EPISODE OF LOW BACK PAIN?

(fill in the blank) _____ YEARS _____ MONTHS

16. How does this pain affect your sleeping at night? (Check one)

❑ Does not affect

❑ Affects some, but I can sleep most of the night

❑ Cannot sleep well due to back pain

❑ Cannot sleep well due to issues other than back pain

17. How would you describe your cigarette smoking or tobacco use? **(Check one)**

❑ Never smoked/used tobacco

❑ Current smoker/tobacco user

❑ Used to smoke/use tobacco, but have quit now

18. The following is a list of common health problems. In the first column indicate if you currently have any of these conditions, or if you have ever had them in the past. In the second column indicate if you are ***currently* receiving treatment for the problem. In the last column indicate if the problem limits any of your daily activities.**

	Do you or have you had the problem?	Do you currently receive treatment for this problem?	Does this problem limit your daily activities?
Heart Disease	□ Yes □ No	□ Yes □ No	□ Yes □ No
High Blood Pressure	□ Yes □ No	□ Yes □ No	□ Yes □ No
Lung Disease	□ Yes □ No	□ Yes □ No	□ Yes □ No
Diabetes	□ Yes □ No	□ Yes □ No	□ Yes □ No
Vascular disease (Peripheral Arterial Disease, Vascular Claudication)	□ Yes □ No	□ Yes □ No	□ Yes □ No
Cancer	□ Yes □ No	□ Yes □ No	□ Yes □ No
Depression	□ Yes □ No	□ Yes □ No	□ Yes □ No
Dizziness or Vertigo	□ Yes □ No	□ Yes □ No	□ Yes □ No
Osteoarthritis	□ Yes □ No	□ Yes □ No	□ Yes □ No
Rheumatoid Arthritis	□ Yes □ No	□ Yes □ No	□ Yes □ No
Allergies	□ Yes □ No	□ Yes □ No	□ Yes □ No
Upper back and/or neck pain	□ Yes □ No	□ Yes □ No	□ Yes □ No
Drug or alcohol problem	□ Yes □ No	□ Yes □ No	□ Yes □ No
TBI or concussion	□ Yes □ No	□ Yes □ No	□ Yes □ No
Other Medical Problems *(please specify)* _____ _____			

Appendix B: Post-Traumatic Stress Disorder (PTSD) in Veterans, A Pain Neuroscience Approach, Evaluation

Please check **one** box in each question which describe your reactions to the booklet.

1. The booklet was very easy to read ❑
   The booklet was somewhat easy to read ❑
   The booklet was difficult to read ❑

2. I found the booklet interesting ❑
   I found the booklet boring ❑

3. I thought the information in the booklet was clear ❑
   I thought the information in the booklet was not very clear ❑
   I thought the information in the booklet was completely confusing ❑

4. I learned some new, helpful things ❑
   I knew most of it already ❑
   I didn't really find the booklet helpful ❑

5. I believed most of what the booklet said ❑
   I believed some of what the booklet said ❑
   I did not really believe any of what the booklet said ❑

6. There are enough practical tips ❑
   I wanted more practical tips ❑
   The practical tips were not clear ❑

7. The order of the contents was easy to follow ❑
   The contents seemed jumbled ❑

8. I would tell a friend or family member to read the booklet ❑
   I would not recommend the booklet ❑

9. The military examples are helpful ❑
   The military examples will increase PTSD symptoms ❑

10. I think the booklet will help people ❑
    I don't think the booklet will help people ❑

11. (Remember the recommendation is to read 1-2 sections at a time over 2 weeks.) With this in mind:
    The booklet is about right ❑
    The booklet is too long ❑
    The booklet is too short ❑

12. I read the entire booklet ❑
    I read most of the booklet ❑
    I did not read the booklet ❑

Appendix C Post-Traumatic Stress Disorder (PTSD) in Veterans: A Pain Neuroscience Approach, Review Questionnaire

Thank you for your participation in this study. Please provide the most appropriate answer to each question. Please do your best and answer the questions from memory. This questionnaire is designed to measure how difficult some of the concepts are to understand in the booklet you just read.

1. It is helpful for the nervous system to develop some sensitivity to danger messages in the short-term; however, if this response lasts too long or too strongly, it is not helpful.
   - ☐ True
   - ☐ False

2. When the body releases stress hormones during a dangerous event, the hormones are not useful and damages the brain.
   - ☐ True
   - ☐ False
3. It is helpful for PTSD symptoms to avoid any type of memory or trigger of a Veteran's trauma.
   - ☐ True
   - ☐ False
4. During recovery from PTSD and pain, activities that are painful should always be avoided.
   - ☐ True
   - ☐ False
5. Physical exercise only benefits the body: muscles, joints, cardiovascular system, etc… but has no significant effect on the brain.
   - ☐ True
   - ☐ False

6. According to the book you just read, a primary purpose of the nervous system is to:
   - ☐ Tell your brain exactly what is going on in your tissues.
   - ☐ Transmit pain signals from the body to the brain.
   - ☐ Like an alarm, protect you with pain and stress responses.
   - ☐ Fight infections and produce immune cells.

7. When your nervous system is extra sensitive, it means the following part of your brain has turned up the sensitivity of the danger alarm:
    - ☐ Command and Control Center
    - ☐ Supply Officer
    - ☐ Radar Operator
    - ☐ Chemical Officer

8. This book used the following example to help describe pain and PTSD:
    - ☐ Pain and PTSD is like a smoke detector.
    - ☐ Pain and PTSD is like a home alarm system that becomes too sensitive.
    - ☐ Pain and PTSD is from increased nervous system sensitivity, similar to increased security measures after the Pearl Harbor attack.
    - ☐ Pain and PTSD are normal responses and so there is nothing that should be done to try and change your nervous system.

9. During a trauma:
    - ☐ The brain is unable to remember any details from a trauma because of coping mechanisms.
    - ☐ Stress hormones amplify (turn-up) memories and help your brain to remember traumatic events.
    - ☐ If you develop PTSD, it is impossible to make new memories.
    - ☐ Pain is automatically produced by the brain.

10. What is the brain map?
    - ☐ When you use your nervous system enough times, it makes a path that gets wider and wider each time you use your brain map.
    - ☐ The brain map is not possible to change once it is set.
    - ☐ The brain map helps you figure out if you are “left-brained” or “right-brained”.

11. According to the booklet you just read, all of the following ways are helpful strategies to improve pain and PTSD symptoms EXCEPT:
    - ☐ Exercise
    - ☐ Mental imagery
    - ☐ Quality sleep
    - ☐ Avoiding painful activities

Appendix D: Traditional Post-Traumatic Stress Disorder (PTSD) Education Assessment

After reviewing the educational material about PTSD, please choose the one statement that best describes your reaction.

1. ❑ The information is accurate.
   ❑ The information contained some errors.
   ❑ The information is not appropriate for patients with PTSD.

2. ❑ The information provided is in accordance with clinical practice and guidelines.
   ❑ Only some of the information is in accordance with clinical practice and guidelines.
   ❑ The information included is not in accordance with clinical practice and guidelines.

3. ❑ No key information about PTSD is missing for patient education occurring in a primary care or physical therapy clinic.
   ❑ Some key information about PTSD is missing for patient education occurring in a primary care or physical therapy clinic.
   ❑ The information about PTSD for patient education occurring in a primary care or physical therapy clinic is missing significant content.

4. ❑ The recommended "do's" included in this information is appropriate and complete for a patient with PTSD.
   ❑ The recommended "do's" is mostly appropriate and complete but I would add some additional key "do's".
   ❑ The recommended "do's" is not appropriate for a patient with PTSD.

5. ❑ The recommended "don'ts" included in this information is appropriate and complete for a patient with PTSD.
   ❑ The recommended "don'ts" is mostly appropriate and complete but I would add some additional key "don'ts".
   ❑ The recommended "don'ts" is not appropriate for a patient with PTSD.

6. Based on the educational materials you just read, describe your opinion about including this type of education by Physical Therapists to patients who have pain and PTSD.

❑Physical Therapists should not educate patients about PTSD because it is not in their scope of practice or training.

❑Physical therapists should include this type of patient education about PTSD but only in a controlled, supervised environment like a research program.

❑It is appropriate for Physical Therapists to include this type of patient education about PTSD in clinical practice.

7. Describe your opinion about Physical Therapists educating patients about PTSD *in general*.

❑Physical Therapists should not educate patients about PTSD because it is not in their scope of practice or training.

❑ PTs can educate patients about PTSD depending on the topic.

❑ Physical Therapists should educate patients about PTSD as this will improve overall coordination of care for the patient.

8. Describe your opinion regarding the following topics: It is appropriate for Physical Therapists to educate patients with PTSD with the following skill

Mindfulness	Agree ❑	Unsure ❑	Disagree ❑
Resilience	Agree ❑	Unsure ❑	Disagree ❑
Self-efficacy	Agree ❑	Unsure ❑	Disagree ❑
Coping Skills	Agree ❑	Unsure ❑	Disagree ❑
Optimism	Agree ❑	Unsure ❑	Disagree ❑
Cognitive restructuring for pain.	Agree ❑	Unsure ❑	Disagree ❑
Prolonged exposure in vivo for pain.	Agree ❑	Unsure ❑	Disagree ❑

9. What percent of your patients have physical pain?
❑ 0-25%
❑ 26-50%
❑ 51-75%
❑ 76-100%

10. What describes your desires about pain education?
❑ I wish I had more knowledge how to educate patients with PTSD about pain.
❑ I have adequate knowledge about educating patients with PTSD about pain, I just do not have the time to routinely include it.
❑ Educating PTSD patients about pain is not a problem for me.

11. Which of the following modules from the *PTSD Coach Online* is most important for educating Veterans with PTSD to cope with avoidance (Please select only one):

- ❑ Change feelings by changing thoughts
- ❑ Learn to be assertive

- ❑ Weigh the pros and cons
- ❑ Change negative thinking patterns
- ❑ Learn to problem solve
- ❑ Deal with trauma reminders
- ❑ Look carefully at your thoughts

Based on your choice, do you feel this type of skill should be taught by Primary Care Providers?
❑ Yes
❑ No

Based on your choice, do you feel this type of skill should be taught during Physical Therapy Care?
❑ Yes
❑ No

12. Which of the following modules from the *PTSD Coach Online* is most important for educating Veterans with PTSD to cope with hypervigilance (Please select only one):

- ❑ Change feelings by changing thoughts
- ❑ Learn to be assertive
- ❑ Weigh the pros and cons
- ❑ Change negative thinking patterns
- ❑ Learn to problem solve
- ❑ Deal with trauma reminders
- ❑ Look carefully at your thoughts
- ❑ Relax through breathing
- ❑ Relax your body
- ❑ Relax through visualization

Based on your choice, do you feel this type of skill should be taught by Primary Care Providers?
❑ Yes
❑ No

Based on your choice, do you feel this type of skill should be taught during Physical Therapy Care?
❑ Yes
❑ No

13. Which of the following modules from the *PTSD Coach Online* is most important for educating Veterans with PTSD to cope with negative thoughts (Please select only one):

- ❑ Be in the moment
- ❑ Change feelings by changing thoughts
- ❑ Learn to be assertive

- ❑ Weigh the pros and cons
- ❑ Change negative thinking patterns
- ❑ Learn to problem solve
- ❑ Deal with trauma reminders
- ❑ Look carefully at your thoughts
- ❑ Relax through breathing
- ❑ Relax your body
- ❑ Relax through visualization
- ❑ Plan something enjoyable
- ❑ Notice your thoughts and feelings

Based on your choice, do you feel this type of skill should be taught by Primary Care Providers?
❑ Yes
❑ No

Based on your choice, do you feel this type of skill should be taught during Physical Therapy Care?
❑ Yes
❑ No

14. Which of the following modules from the *PTSD Coach Online* is most important for educating Veterans with PTSD to cope with re-experiencing (Please select only one):

- ❑ Be in the moment
- ❑ Deal with trauma reminders
- ❑ Relax your body
- ❑ Change feelings by changing thoughts
- ❑ Look carefully at your thoughts
- ❑ Weigh the pros and cons
- ❑ Change negative thinking patterns
- ❑ Relax through breathing

Based on your choice, do you feel this type of skill should be taught by Primary Care Providers?
❑ Yes
❑ No

Based on your choice, do you feel this type of skill should be taught during Physical Therapy Care?
❑ Yes
❑ No

Would you add any information to the material that was emailed to you in order to be part of standard educational materials for PTSD in a Primary Care or Physical Therapy setting?

_____
_____

_____

Is there any information in the material that was emailed to you that you would remove or is inaccurate?

_____
_____
_____

Is there any information in the material that was emailed to you that you believe is not appropriate to be delivered by a Physical Therapist?

_____
_____
_____

Appendix E: Activity Log

Please let us know approximately how much time you spend each day performing the following activities.

NOTE, this log does NOT include the time you spend at your Physical Therapy appointments!

Please keep an accurate log. This log is not meant to grade you but instead to help us understand how this program and education influences your activity levels. Thank you!

Week 1	Exercise (walking, biking, running, etc…), (minutes)	PTSD/Pain Education booklet (minutes)	Other PTSD/Pain Education readings, websites, applications (site-minutes)
Example	*Walking, 15 min*	*10 min*	*PTSD Coach, 15 min*
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			
Week 2	Exercise (minutes)	Education booklet (minutes)	Other education (site-minutes)
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			

Activity Log

Please let us know approximately how much time you spend each day performing the following activities.

NOTE, this log does NOT include the time you spend at your Physical Therapy appointments!

Please keep an accurate log. This log is not meant to grade you but instead to help us understand how this program and education influences your activity levels. Thank you!

Week 3	Exercise (walking, biking, running, etc…), (minutes)	PTSD/Pain Education booklet (minutes)	Other PTSD/Pain Education readings, websites, applications (site-minutes)
Example	*Walking, 15 min*	*10 min*	*PTSD Coach, 15 min*
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			
Week 4	Exercise (minutes)	Education booklet (minutes)	Other education (site-minutes)
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			

Appendix F: Participant Exercise Program

Choose the **1** exercise for each number that you feel you could confidently perform for 1 minute:

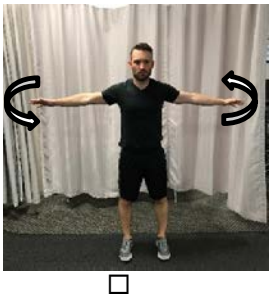
1. **Warm-up**

☐ Walk in place

☐ Walk with high knees

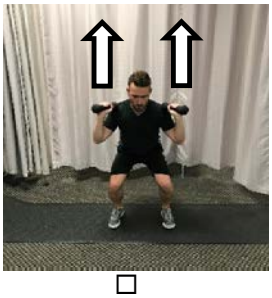
☐ Jog in place

2. **Arms**



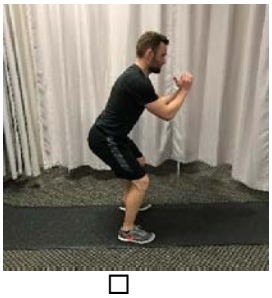
☐ Arm circles

☐ Arm raise with weights

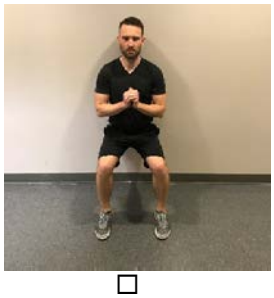


☐ Squat/arm-raise w/ weights

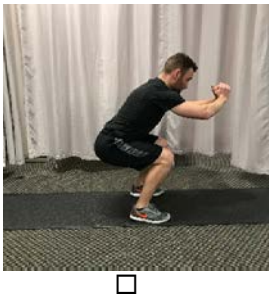
3. **Legs**



☐ Mini squat



☐ Wall squats

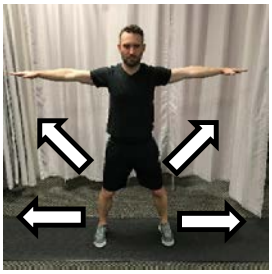


☐ Full squat

1. **Side hip muscles**

☐
Side steps (slow)

☐
Side shuffle (quicker)



☐
Half jumping-jack

2. **Chest Muscles**

☐
Wall push-up

☐
Knee push-up

☐
Full push-up

3. **Side Abdominals**

☐
Diagonal trunk curl

☐
Side plank on knees

☐
Side plank

4. **Hip Muscles (Side)**

☐
Clam-shell

☐
Leg raise

☐
Band side steps

1. **Hip Muscles (back)**

☐
Leg raise, bent knee

☐
Leg raise, straight knee

☐
Alternating arm/leg lift

2. **Abdominals**

☐
Abdominal Crunch

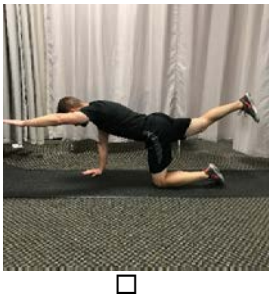
☐
Plank on knees

☐
Full plank

3. **Hip/back Muscles**

☐
Back bridge

☐
Back bridge with leg raise



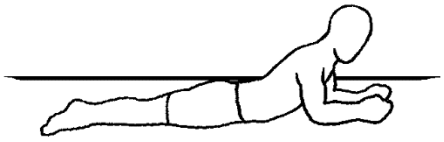
☐
Alternating arm and leg

1. Cool down stretch #1

2. Cool down stretch #2

3. Cool down stretch #3

or



Since your last visit, any changes in your medications or medical treatments for back pain or PTSD/mental health?

Type	Yes/No	Dose	Frequency
Medication:			
Medication:			
Medication:			
Acupuncture			
Massage			
Chiropractor			
Counseling			
Injection			
Other:			

Appendix G: Pain and Post-Traumatic Stress Disorder (PTSD) Education Post-Program Questionnaire

For each number, please indicate how much you agree or disagree with each statement. Lower numbers mean you strongly disagree. The number 5 means you neither agree nor disagree. Higher numbers mean you strongly agree.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

1. This is the first time I have received this education.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

2. The education program helped explain why I have chronic pain after PTSD.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

3. The education program applies personally to my symptoms.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

4. The education program treated my symptoms as real and helped me understand why I have PTSD and pain symptoms.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

5. I am satisfied in the way the education program explained why common treatments for pain can help after being diagnosed with PTSD.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

6. The education program connected with me personally as a Veteran and with my experiences in the Armed Forces.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

7. The education program only applies to Veterans with exaggerated symptoms, not me personally.

Strongly Disagree					**Neutral**					**Strongly Agree**
0	1	2	3	4	5	6	7	8	9	10

8. The education program implied that chronic pain after PTSD diagnosis means that my physical pain is only a mental health problem.

Strongly Disagree					**Neutral**					**Strongly Agree**
0	1	2	3	4	5	6	7	8	9	10

9. I have already heard most of this education before.

Strongly Disagree					**Neutral**					**Strongly Agree**
0	1	2	3	4	5	6	7	8	9	10

10. I believe I was in the experimental education group.

Strongly Disagree					**Neutral**					**Strongly Agree**
0	1	2	3	4	5	6	7	8	9	10

Appendix H: Pain and Stress Education Post-Program Questionnaire

For each number, please indicate how much you agree or disagree with each statement. Lower numbers mean you strongly disagree. The number 5 means you neither agree nor disagree. Higher numbers mean you strongly agree.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

1. This is the first time I have received this education.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

2. The education program helped explain why I have chronic pain after stress or trauma.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

3. The education program applies personally to my symptoms.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

4. The education program treated my symptoms as real and helped me understand why I have stress and pain symptoms.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

5. I am satisfied in the way the education program explained why common treatments for pain can help after stress.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

6. The education program connected with me personally as a Soldier and with my experiences in the military.

Strongly Disagree **Neutral** **Strongly Agree**

0 1 2 3 4 5 6 7 8 9 10

7. The education program only applies to Soldiers with exaggerated symptoms, not me personally.

Strongly Disagree					**Neutral**					**Strongly Agree**
0	1	2	3	4	5	6	7	8	9	10

8. The education program implied that chronic pain after stress means that my physical pain is only a mental health problem.

Strongly Disagree					**Neutral**					**Strongly Agree**
0	1	2	3	4	5	6	7	8	9	10

9. I have already heard most of this education before.

Strongly Disagree					**Neutral**					**Strongly Agree**
0	1	2	3	4	5	6	7	8	9	10

10. I believe I was in the experimental education group.

Strongly Disagree					**Neutral**					**Strongly Agree**
0	1	2	3	4	5	6	7	8	9	10

References

1. Waddell G. Low back pain: a twentieth century health care enigma. *Spine (Phila Pa 1976).* 1996;21(24):2820-2825.
2. Deyo RA, Mirza SK, Turner JA, Martin BI. Overtreating chronic back pain: time to back off? *The Journal of the American Board of Family Medicine.* 2009;22(1):62-68.
3. Hoy D, Bain C, Williams G, et al. A systematic review of the global prevalence of low back pain. *Arthritis and rheumatism.* 2012;64(6):2028-2037.
4. Katz JN. Lumbar disc disorders and low-back pain: socioeconomic factors and consequences. *The Journal of bone and joint surgery American volume.* 2006;88 Suppl 2:21-24.
5. Deyo RA, Mirza SK, Martin BI. Back pain prevalence and visit rates: estimates from U.S. national surveys, 2002. *Spine (Phila Pa 1976).* 2006;31(23):2724-2727.
6. Hart LG, Deyo RA, Cherkin DC. Physician office visits for low back pain. Frequency, clinical evaluation, and treatment patterns from a U.S. national survey. *Spine (Phila Pa 1976).* 1995;20(1):11-19.
7. Armed Forces Health Surveillance Center. Absolute and Relative Morbidity Burdens Attributable to Various Illnesses and Injuries, U.S. Armed Forces, 2014. *MSMR.* 2015;22(4):5.
8. Gubata ME, Piccirillo AL, Packnett ER, Cowan DN. Military occupation and deployment: descriptive epidemiology of active duty u.s. Army men evaluated for a disability discharge. *Military Medicine.* 2013;178(7):708-714 707p.
9. Hourani LL, Williams TV, Kress AM. Stress, mental health, and job performance among active duty military personnel: findings from the 2002 Department of Defense Health-Related Behaviors Survey. *Mil Med.* 2006;171(9):849-856.
10. McEwen BS, Seeman T. Protective and Damaging Effects of Mediators of Stress: Elaborating and Testing the Concepts of Allostasis and Allostatic Load. *Annals of the New York Academy of Sciences.* 1999;896(1):30-47.
11. Lane ME, Hourani LL, Bray RM, Williams J. Prevalence of perceived stress and mental health indicators among reserve-component and active-duty military personnel. *Am J Public Health.* 2012;102(6):1213-1220.
12. Horn SR, Charney DS, Feder A. Understanding resilience: New approaches for preventing and treating PTSD. *Experimental neurology.* 2016;284(Pt B):119-132.
13. Pierce ME, Pritchard LM. Lower stress-reactive cortisol in female veterans associated with military status but not PTSD. *Stress (Amsterdam, Netherlands).* 2016;19(5):486-491.
14. Association D-AP. Diagnostic and statistical manual of mental disorders. *Arlington: American Psychiatric Publishing.* 2013.
15. Benjet C, Bromet E, Karam EG, et al. The epidemiology of traumatic event exposure worldwide: results from the World Mental Health Survey Consortium. *Psychological Medicine.* 2016;46(2):327-343.
16. Kessler RC, Sonnega A, Bromet E, Hughes M, Nelson CB. Posttraumatic stress disorder in the National Comorbidity Survey. *Archives of general psychiatry.* 1995;52(12):1048-1060.
17. Otis JD, Keane TM, Kerns RD, Monson C, Scioli E. The development of an integrated treatment for veterans with comorbid chronic pain and posttraumatic stress disorder. *Pain Medicine.* 2009;10(7):1300-1311.

18. Shipherd JC, Keyes M, Jovanovic T, et al. Veterans seeking treatment for posttraumatic stress disorder: what about comorbid chronic pain? *J Rehabil Res Dev.* 2007;44(2):153-166.
19. Otis JD, Gregor K, Hardway C, Morrison J, Scioli E, Sanderson K. An examination of the co-morbidity between chronic pain and posttraumatic stress disorder on U.S. Veterans. *Psychological services.* 2010;7(3):126-135.
20. DeCarvalho LT. Important missing links in the treatment of chronic low back pain patients. *Journal of Musculoskeletal Pain.* 2010;18(1):11-22.
21. Demyttenaere K, Bruffaerts R, Lee S, et al. Mental disorders among persons with chronic back or neck pain: results from the World Mental Health Surveys. *Pain.* 2007;129(3):332-342.
22. Scioli-Salter ER, Forman DE, Otis JD, Gregor K, Valovski I, Rasmusson AM. The shared neuroanatomy and neurobiology of comorbid chronic pain and PTSD: therapeutic implications. *Clin J Pain.* 2015;31(4):363-374.
23. Wand BM, O'Connell NE. Chronic non-specific low back pain–sub-groups or a single mechanism? *BMC musculoskeletal disorders.* 2008;9(1):11.
24. Hannibal KE, Bishop MD. Chronic stress, cortisol dysfunction, and pain: a psychoneuroendocrine rationale for stress management in pain rehabilitation. *Physical therapy.* 2014;94(12):1816-1825.
25. Sharp TJ, Harvey AG. Chronic pain and posttraumatic stress disorder: mutual maintenance? *Clinical psychology review.* 2001;21(6):857-877.
26. Roy-Byrne P, Smith WR, Goldberg J, Afari N, Buchwald D. Post-traumatic stress disorder among patients with chronic pain and chronic fatigue. *Psychol Med.* 2004;34(2):363-368.
27. Afari N, Ahumada SM, Wright LJ, et al. Psychological trauma and functional somatic syndromes: a systematic review and meta-analysis. *Psychosomatic medicine.* 2014;76(1):2.
28. Lee H, Hubscher M, Moseley GL, et al. How does pain lead to disability? A systematic review and meta-analysis of mediation studies in people with back and neck pain. *Pain.* 2015;156(6):988-997.
29. Vlaeyen JW, Linton SJ. Fear-avoidance model of chronic musculoskeletal pain: 12 years on. *Pain.* 2012;153(6):1144-1147.
30. Outcalt SD, Kroenke K, Krebs EE, et al. Chronic pain and comorbid mental health conditions: independent associations of posttraumatic stress disorder and depression with pain, disability, and quality of life. *Journal of behavioral medicine.* 2015;38(3):535-543.
31. Outcalt SD, Ang DC, Wu J, Sargent C, Yu Z, Bair MJ. Pain experience of Iraq and Afghanistan Veterans with comorbid chronic pain and posttraumatic stress. *J Rehabil Res Dev.* 2014;51(4):559-570.
32. Alschuler KN, Otis JD. Coping strategies and beliefs about pain in veterans with comorbid chronic pain and significant levels of posttraumatic stress disorder symptoms. *European Journal of Pain.* 2012;16(2):312-319.
33. Smeeding SJ, Bradshaw DH, Kumpfer K, Trevithick S, Stoddard GJ. Outcome evaluation of the Veterans Affairs Salt Lake City Integrative Health Clinic for chronic pain and stress-related depression, anxiety, and post-traumatic stress disorder. *Journal of alternative and complementary medicine (New York, NY).* 2010;16(8):823-835.
34. Wallbom A. *A pilot study to identify barriers to treatment in OIF/OEF veterans with PTSD and low back pain in establishing transdisciplinary complementary interventions.* DTIC Document;2009.

35. Darlow B, Dowell A, Baxter GD, Mathieson F, Perry M, Dean S. The enduring impact of what clinicians say to people with low back pain. *The Annals of Family Medicine.* 2013;11(6):527-534.
36. Morgan AJ, Reavley NJ, Jorm AF, Beatson R. Experiences of discrimination and positive treatment from health professionals: A national survey of adults with mental health problems. *Australian and New Zealand Journal of Psychiatry.* 2016;50(8):754-762.
37. McFarlane AC. Stress-related musculoskeletal pain. *Best practice & research Clinical rheumatology.* 2007;21(3):549-565.
38. Wahl O, Aroesty-Cohen E. Attitudes of mental health professionals about mental illness: A review of the recent literature. *Journal of Community Psychology.* 2010;38(1):49-62.
39. Bailey KM, Carleton RN, Vlaeyen JW, Asmundson GJ. Treatments addressing pain-related fear and anxiety in patients with chronic musculoskeletal pain: a preliminary review. *Cognitive behaviour therapy.* 2010;39(1):46-63.
40. Henderson C, Noblett J, Parke H, et al. Mental health-related stigma in health care and mental health-care settings. *The lancet Psychiatry.* 2014;1(6):467-482.
41. Synnott A, O'Keeffe M, Bunzli S, Dankaerts W, O'Sullivan P, O'Sullivan K. Physiotherapists may stigmatise or feel unprepared to treat people with low back pain and psychosocial factors that influence recovery: a systematic review. *Journal of physiotherapy.* 2015;61(2):68-76.
42. Mittal D, Drummond KL, Blevins D, Curran G, Corrigan P, Sullivan G. Stigma associated with PTSD: perceptions of treatment seeking combat veterans. *Psychiatric rehabilitation journal.* 2013;36(2):86-92.
43. Najavits LM. The problem of dropout from "gold standard" PTSD therapies. *F1000prime reports.* 2015;7:43.
44. Louw A, Puentedura E. *Therapeutic Neuroscience Education: Teaching Patients about Pain: a Guide for Clinicians.* International Spine and Pain Institute; 2013.
45. Liu SH, Yang RS, al-Shaikh R, Lane JM. Collagen in tendon, ligament, and bone healing. A current review. *Clinical orthopaedics and related research.* 1995(318):265-278.
46. Gallagher L, McAuley J, Moseley GL. A randomized-controlled trial of using a book of metaphors to reconceptualize pain and decrease catastrophizing in people with chronic pain. *Clin J Pain.* 2013;29(1):20-25.
47. Louw A, Zimney K, Puentedura EJ, Diener I. The efficacy of pain neuroscience education on musculoskeletal pain: A systematic review of the literature. *Physiotherapy theory and practice.* 2016;32(5):332-355.
48. Louw A, Diener I, Butler DS, Puentedura EJ. The effect of neuroscience education on pain, disability, anxiety, and stress in chronic musculoskeletal pain. *Archives of physical medicine and rehabilitation.* 2011;92(12):2041-2056.
49. Moseley GL. A pain neuromatrix approach to patients with chronic pain. *Man Ther.* 2003;8(3):130-140.
50. Van Oosterwijck J, Meeus M, Paul L, et al. Pain physiology education improves health status and endogenous pain inhibition in fibromyalgia: a double-blind randomized controlled trial. *Clin J Pain.* 2013;29(10):873-882.
51. Griep EN, Boersma JW, Lentjes EG, Prins AP, van der Korst JK, de Kloet ER. Function of the hypothalamic-pituitary-adrenal axis in patients with fibromyalgia and low back pain. *The Journal of rheumatology.* 1998;25(7):1374-1381.
52. Geiss A, Rohleder N, Kirschbaum C, Steinbach K, Bauer HW, Anton F. Predicting the failure of disc surgery by a hypofunctional HPA axis: evidence from a prospective study on patients undergoing disc surgery. *Pain.* 2005;114(1-2):104-117.

53. Latremoliere A, Woolf CJ. Central sensitization: a generator of pain hypersensitivity by central neural plasticity. *The Journal of Pain.* 2009;10(9):895-926.
54. Bunzli S, Smith A, Schutze R, Lin I, O'Sullivan P. Making Sense of Low Back Pain and Pain-Related Fear. *The Journal of orthopaedic and sports physical therapy.* 2017;47(9):628-636.
55. Dobscha SK, Corson K, Leibowitz RQ, Sullivan MD, Gerrity MS. Rationale, design, and baseline findings from a randomized trial of collaborative care for chronic musculoskeletal pain in primary care. *Pain medicine (Malden, Mass).* 2008;9(8):1050-1064.
56. Moseley L. Unraveling the barriers to reconceptualization of the problem in chronic pain: the actual and perceived ability of patients and health professionals to understand the neurophysiology. *The journal of pain : official journal of the American Pain Society.* 2003;4(4):184-189.
57. Scott JC, Matt GE, Wrocklage KM, et al. A quantitative meta-analysis of neurocognitive functioning in posttraumatic stress disorder. 2014.
58. McEwen BS, Bowles NP, Gray JD, et al. Mechanisms of stress in the brain. *Nature neuroscience.* 2015;18(10):1353-1363.
59. Wilson J, Jones M, Fear NT, et al. Is previous psychological health associated with the likelihood of Iraq War deployment? An investigation of the "healthy warrior effect". *American journal of epidemiology.* 2009;169(11):1362-1369.
60. Turk DC. Clinical effectiveness and cost-effectiveness of treatments for patients with chronic pain. *Clin J Pain.* 2002;18(6):355-365.
61. Bilmes L. Soldiers returning from Iraq and Afghanistan: The long-term costs of providing veterans medical care and disability benefits. 2007.
62. Tong D, Beirne R. Combat body armor and injuries to the head, face, and neck region: a systematic review. *Mil Med.* 2013;178(4):421-426.
63. Holland SR, Apodaca A, Mabry RL. MEDEVAC: survival and physiological parameters improved with higher level of flight medic training. *Mil Med.* 2013;178(5):529-536.
64. Kane SF, Saperstein AK, Bunt CW, Stephens MB. When war follows combat veterans home. *The Journal of family practice.* 2013;62(8):399-407.
65. Sundin J, Fear NT, Iversen A, Rona RJ, Wessely S. PTSD after deployment to Iraq: conflicting rates, conflicting claims. *Psychol Med.* 2010;40(3):367-382.
66. Hoge CW, McGurk D, Thomas JL, Cox AL, Engel CC, Castro CA. Mild traumatic brain injury in US soldiers returning from Iraq. *New England Journal of Medicine.* 2008;358(5):453-463.
67. Susskind O, Ruzek JI, Friedman MJ. The VA/DOD Clinical Practice Guideline for Management of Post-Traumatic Stress (update 2010): development and methodology. *J Rehabil Res Dev.* 2012;49(5):xvii-xxviii.
68. Cifu DX, Taylor BC, Carne WF, et al. Traumatic brain injury, posttraumatic stress disorder, and pain diagnoses in OIF/OEF/OND Veterans. *Ethnicity.* 2013;137:22.
69. Norman SB, Stein MB, Dimsdale JE, Hoyt DB. Pain in the aftermath of trauma is a risk factor for post-traumatic stress disorder. *Psychological Medicine.* 2008;38(04):533-542.
70. Asmundson GJ, Hadjistavropolous HD. Addressing shared vulnerability for comorbid PTSD and chronic pain: A cognitive-behavioral perspective. *Cognitive and Behavioral Practice.* 2006;13(1):8-16.
71. Lewis JD, Wassermann EM, Chao W, Ramage AE, Robin DA, Clauw DJ. Central sensitization as a component of post-deployment syndrome. *NeuroRehabilitation.* 2011;31(4):367-372.

72. Moeller-Bertram T, Keltner J, Strigo IA. Pain and post traumatic stress disorder - review of clinical and experimental evidence. *Neuropharmacology.* 2012;62(2):586-597.
73. Gibson CA. Review of posttraumatic stress disorder and chronic pain: the path to integrated care. *J Rehabil Res Dev.* 2012;49(5):753-776.
74. Otis JD, Keane TM, Kerns RD. An examination of the relationship between chronic pain and post-traumatic stress disorder. *Journal of Rehabilitation Research & Development.* 2003;40(5):397-405.
75. Plagge JM, Lu MW, Lovejoy TI, Karl AI, Dobscha SK. Treatment of comorbid pain and PTSD in returning veterans: a collaborative approach utilizing behavioral activation. *Pain Medicine.* 2013;14(8):1164-1172.
76. Taylor BC, Hagel EM, Carlson KF, et al. Prevalence and costs of co-occurring traumatic brain injury with and without psychiatric disturbance and pain among Afghanistan and Iraq War Veteran VA users. *Medical care.* 2012;50(4):342-346.
77. Finley EP, Bollinger M, Noel PH, et al. A national cohort study of the association between the polytrauma clinical triad and suicide-related behavior among US Veterans who served in Iraq and Afghanistan. *Am J Public Health.* 2015;105(2):380-387.
78. Wells G, Shea B, O'Connell D, et al. Newcastle-Ottawa quality assessment scale cohort studies. 2014.
79. Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011]. 2011. www.cochrane-handbook.org. Accessed 12/07/2017.
80. Lew HL, Pogoda TK, Hsu PT, et al. Impact of the "polytrauma clinical triad" on sleep disturbance in a department of veterans affairs outpatient rehabilitation setting. *American journal of physical medicine & rehabilitation / Association of Academic Physiatrists.* 2010;89(6):437-445.
81. Maguen S, Hoerster KD, Littman AJ, et al. Iraq and Afghanistan veterans with PTSD participate less in VA's weight loss program than those without PTSD. *J Affect Disord.* 2016;193:289-294.
82. Morasco BJ, Peters D, Krebs EE, Kovas AE, Hart K, Dobscha SK. Predictors of urine drug testing for patients with chronic pain: Results from a national cohort of U.S. veterans. *Substance abuse.* 2016;37(1):82-87.
83. Outcalt SD, Yu Z, Hoen HM, Pennington TM, Krebs EE. Health care utilization among veterans with pain and posttraumatic stress symptoms. *Pain medicine (Malden, Mass).* 2014;15(11):1872-1879.
84. Rozet I, Nishio I, Robbertze R, Rotter D, Chansky H, Hernandez AV. Prolonged opioid use after knee arthroscopy in military veterans. *Anesthesia and analgesia.* 2014;119(2):454-459.
85. Seal KH, Shi Y, Cohen G, et al. Association of mental health disorders with prescription opioids and high-risk opioid use in US veterans of Iraq and Afghanistan. *Jama.* 2012;307(9):940-947.
86. Becker WC, Ganoczy D, Fiellin DA, Bohnert AS. Buprenorphine/Naloxone dose and pain intensity among individuals initiating treatment for opioid use disorder. *Journal of substance abuse treatment.* 2015;48(1):128-131.
87. Magruder KM, Yeager D, Brawman-Mintzer O. The role of pain, functioning, and mental health in suicidality among Veterans Affairs primary care patients. *Am J Public Health.* 2012;102 Suppl 1:S118-124.
88. Blake DD, Weathers FW, Nagy LM, et al. The development of a Clinician-Administered PTSD Scale. *Journal of traumatic stress.* 1995;8(1):75-90.

89. Wilkins KC, Lang AJ, Norman SB. Synthesis of the psychometric properties of the PTSD checklist (PCL) military, civilian, and specific versions. *Depress Anxiety.* 2011;28(7):596-606.
90. Alschuler KN, Otis JD. Significant others' responses to pain in veterans with chronic pain and clinical levels of post-traumatic stress disorder symptomatology. *European journal of pain (London, England).* 2013;17(2):245-254.
91. McAndrew LM, Helmer DA, Phillips LA, Chandler HK, Ray K, Quigley KS. Iraq and Afghanistan Veterans report symptoms consistent with chronic multisymptom illness one year after deployment. *J Rehabil Res Dev.* 2016;53(1):59-70.
92. Morasco BJ, Lovejoy TI, Lu M, Turk DC, Lewis L, Dobscha SK. The relationship between PTSD and chronic pain: mediating role of coping strategies and depression. *Pain.* 2013;154(4):609-616.
93. Nunnink SE, Fink DS, Baker DG. The impact of sexual functioning problems on mental well-being in US veterans from the Operation Enduring Freedom and Operation Iraqi Freedom (OEF/OIF) conflicts. *International Journal of Sexual Health.* 2012;24(1):14-25.
94. Villano CL, Rosenblum A, Magura S, Fong C, Cleland C, Betzler TF. Prevalence and correlates of posttraumatic stress disorder and chronic severe pain in psychiatric outpatients. *J Rehabil Res Dev.* 2007;44(2):167-178.
95. Helmer DA, Chandler HK, Quigley KS, Blatt M, Teichman R, Lange G. Chronic widespread pain, mental health, and physical role function in OEF/OIF veterans. *Pain medicine (Malden, Mass).* 2009;10(7):1174-1182.
96. Sullivan MJL, Thorn B, Haythornthwaite JA, et al. Theoretical perspectives on the relation between catastrophizing and pain. *The Clinical Journal of Pain.* 2001;17(1):52-64.
97. Nicolaidis C, Chianello T, Gerrity M. Development and preliminary psychometric testing of the centrality of pain scale. *Pain medicine (Malden, Mass).* 2011;12(4):612-617.
98. Tan G, Nguyen Q, Cardin SA, Jensen MP. Validating the use of two-item measures of pain beliefs and coping strategies for a veteran population. *The journal of pain : official journal of the American Pain Society.* 2006;7(4):252-260.
99. Jensen MP, Turner JA, Romano JM. Pain belief assessment: A comparison of the short and long versions of the surgery of pain attitudes. *The Journal of Pain.* 2000;1(2):138-150.
100. Kerns RD, Turk DC, Rudy TE. The West Haven-Yale Multidimensional Pain Inventory (WHYMPI). *Pain.* 1985;23(4):345-356.
101. Bosco MA, Gallinati JL, Clark ME. Conceptualizing and Treating Comorbid Chronic Pain and PTSD. *Pain research and treatment.* 2013;2013:174728.
102. Davies CC, Nitz AJ. Psychometric properties of the Roland-Morris Disability Questionnaire compared to the Oswestry Disability Index: a systematic review. *Physical therapy reviews.* 2009;14(6):399-408.
103. Cairns MC, Foster NE, Wright CC, Pennington D. Level of distress in a recurrent low back pain population referred for physical therapy. *Spine (Phila Pa 1976).* 2003;28(9):953-959.
104. Wideman TH, Adams H, Sullivan MJ. A prospective sequential analysis of the fear-avoidance model of pain. *Pain.* 2009;145(1-2):45-51.
105. Bergbom S, Boersma K, Linton SJ. Both early and late changes in psychological variables relate to treatment outcome for musculoskeletal pain patients at risk for disability. *Behaviour research and therapy.* 2012;50(11):726-734.

106. Ruiz-Párraga GT, López-Martínez AE. The role of experiential avoidance, resilience and pain acceptance in the adjustment of chronic back pain patients who have experienced a traumatic event: A path analysis. *Annals of Behavioral Medicine.* 2015;49(2):247-257.
107. Ferrari S, Chiarotto A, Pellizzer M, Vanti C, Monticone M. Pain Self-Efficacy and Fear of Movement are Similarly Associated with Pain Intensity and Disability in Italian Patients with Chronic Low Back Pain. *Pain practice : the official journal of World Institute of Pain.* 2015.
108. Glanz K, Rimer BK, Viswanath K. *Health behavior and health education: theory, research, and practice.* John Wiley & Sons; 2008.
109. Cook AJ, Meyer EC, Evans LD, et al. Chronic pain acceptance incrementally predicts disability in polytrauma-exposed veterans at baseline and 1-year follow-up. *Behaviour research and therapy.* 2015;73:25-32.
110. Lang AJ, Schnurr PP, Jain S, et al. Evaluating transdiagnostic treatment for distress and impairment in veterans: a multi-site randomized controlled trial of Acceptance and Commitment Therapy. *Contemporary clinical trials.* 2012;33(1):116-123.
111. Vowles KE, Witkiewitz K, Sowden G, Ashworth J. Acceptance and commitment therapy for chronic pain: evidence of mediation and clinically significant change following an abbreviated interdisciplinary program of rehabilitation. *Journal of Pain.* 2014;15(1):101-113.
112. Johnston M, Foster M, Shennan J, Starkey NJ, Johnson A. The Effectiveness of an Acceptance and Commitment Therapy Self-help Intervention for Chronic Pain. *Clinical Journal of Pain.* 2010;26(5):393-402.
113. Rauch SL, Shin LM, Phelps EA. Neurocircuitry models of posttraumatic stress disorder and extinction: human neuroimaging research--past, present, and future. *Biological psychiatry.* 2006;60(4):376-382.
114. Mahan AL, Ressler KJ. Fear conditioning, synaptic plasticity and the amygdala: implications for posttraumatic stress disorder. *Trends in neurosciences.* 2012;35(1):24-35.
115. Aggarwal NR. Attitudes of students towards people with mental ill health and impact on learning and well-being. *Journal of Research in Special Educational Needs.* 2012;12(1):37-44.
116. Franklin M, Fales A, Akramov B, et al. 2015 Wounded Warrior Project@ Survey: Report of Findings. 2015:1-181.
117. Gray MJ, Elhai JD, Frueh BC. Enhancing patient satisfaction and increasing treatment compliance: patient education as a fundamental component of PTSD treatment. *The Psychiatric quarterly.* 2004;75(4):321-332.
118. Pratt S, Rosenberg S, Mueser K, et al. Evaluation of a PTSD psychoeducational program for psychiatric inpatients. *Journal of Mental Health.* 2005;14(2):121-127.
119. Kuhn E, Greene C, Hoffman J, et al. Preliminary evaluation of PTSD Coach, a smartphone app for post-traumatic stress symptoms. *Mil Med.* 2014;179(1):12-18.
120. Miner A, Kuhn E, Hoffman JE, Owen JE, Ruzek JI, Taylor CB. Feasibility, acceptability, and potential efficacy of the PTSD Coach app: A pilot randomized controlled trial with community trauma survivors. *Psychological trauma : theory, research, practice and policy.* 2016;8(3):384-392.
121. Engel CC, Litz B, Magruder KM, et al. Delivery of self training and education for stressful situations (DESTRESS-PC): a randomized trial of nurse assisted online self-management for PTSD in primary care. *General hospital psychiatry.* 2015;37(4):323-328.

122. Finan PH, Buenaver LF, Bounds SC, et al. Discordance between pain and radiographic severity in knee osteoarthritis: findings from quantitative sensory testing of central sensitization. *Arthritis and rheumatism.* 2013;65(2):363-372.
123. Sharma S, Pathak A, Jensen MP. Words that describe chronic musculoskeletal pain: implications for assessing pain quality across cultures. *Journal of pain research.* 2016;9:1057-1066.
124. Lasch KE, Wilkes G, Montuori LM, Chew P, Leonard C, Hilton S. Using focus group methods to develop multicultural cancer pain education materials. *Pain management nursing : official journal of the American Society of Pain Management Nurses.* 2000;1(4):129-138.
125. Phaneth S, Panha P, Sopheap T, Harlacher U, Polatin P. Education as Treatment for Chronic Pain in Survivors of Torture and Other Violent Events in Cambodia: Experiences With Implementation of a Group-Based "Pain School" and Evaluation of Its Effect in a Pilot Study. *Journal of Applied Biobehavioral Research.* 2014;19(1):53-69.
126. Louw A, Butler DS, Diener I, Puentedura EJ. Development of a preoperative neuroscience educational program for patients with lumbar radiculopathy. *American journal of physical medicine & rehabilitation / Association of Academic Physiatrists.* 2013;92(5):446-452.
127. Louw A. Why Do I Hurt? A Patient Book About the Neuroscience of Pain. 2013.
128. Louw A, Diener I, Landers MR, Puentedura EJ. Preoperative pain neuroscience education for lumbar radiculopathy: a multicenter randomized controlled trial with 1-year follow-up. *Spine.* 2014;39(18):1449-1457.
129. Admon R, Milad MR, Hendler T. A causal model of post-traumatic stress disorder: disentangling predisposed from acquired neural abnormalities. *Trends in cognitive sciences.* 2013;17(7):337-347.
130. *Wall and Melzack's textbook of pain.* 6th ed.. ed. Philadelphia, PA: Philadelphia, PA : Elsevier/Saunders; 2013.
131. Miller L. Neurosensitization: A model for persistent disability in chronic pain, depression, and posttraumatic stress disorder following injury. *NeuroRehabilitation.* 2000;14(1):25-32.
132. Asmundson GJ, Katz J. Understanding the co-occurrence of anxiety disorders and chronic pain: state-of-the-art. *Depress Anxiety.* 2009;26(10):888-901.
133. Rosenbaum S, Sherrington C, Tiedemann A. Exercise augmentation compared with usual care for post-traumatic stress disorder: a randomized controlled trial. *Acta psychiatrica Scandinavica.* 2015;131(5):350-359.
134. Schell TL, Marshall GN, Jaycox LH. All symptoms are not created equal: the prominent role of hyperarousal in the natural course of posttraumatic psychological distress. *J Abnorm Psychol.* 2004;113(2):189-197.
135. Morris MC, Compas BE, Garber J. Relations among posttraumatic stress disorder, comorbid major depression, and HPA function: a systematic review and meta-analysis. *Clinical psychology review.* 2012;32(4):301-315.
136. Deyo RA, Dworkin SF, Amtmann D, et al. Report of the NIH Task Force on Research Standards for Chronic Low Back Pain. *Spine (03622436).* 2014;39(14):1128-1143 1116p.
137. Benjamini Y, Hochberg Y. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the royal statistical society Series B (Methodological).* 1995:289-300.
138. Walsh DA, Radcliffe JC. Pain beliefs and perceived physical disability of patients with chronic low back pain. *Pain.* 2002;97(1–2):23-31.

139. Moseley GL, Nicholas MK, Hodges PW. A randomized controlled trial of intensive neurophysiology education in chronic low back pain. *The Clinical journal of pain.* 2004;20(5):324-330.
140. Yu SH, Park SD. The effects of a neck musculoskeletal intervention on neck pain levels and depression in post-traumatic stress disorder patients. *J Phys Ther Sci.* 2015;27(6):1975-1978.
141. Hayden JA, van Tulder MW, Tomlinson G. Systematic review: strategies for using exercise therapy to improve outcomes in chronic low back pain. *Annals of internal medicine.* 2005;142(9):776-785.
142. Hoffman MD, Shepanski MA, Mackenzie SP, Clifford PS. Experimentally induced pain perception is acutely reduced by aerobic exercise in people with chronic low back pain. *J Rehabil Res Dev.* 2005;42(2):183-190.
143. van Ittersum MW, van Wilgen CP, van der Schans CP, Lambrecht L, Groothoff JW, Nijs J. Written pain neuroscience education in fibromyalgia: a multicenter randomized controlled trial. *Pain practice : the official journal of World Institute of Pain.* 2014;14(8):689-700.
144. Scholes C, Turpin G, Mason S. A randomised controlled trial to assess the effectiveness of providing self-help information to people with symptoms of acute stress disorder following a traumatic injury. *Behaviour research and therapy.* 2007;45(11):2527-2536.
145. Turpin G, Downs M, Mason S. Effectiveness of providing self-help information following acute traumatic injury: randomised controlled trial. *The British journal of psychiatry : the journal of mental science.* 2005;187:76-82.
146. Sterling M, Chadwick BJ. Psychologic processes in daily life with chronic whiplash: relations of posttraumatic stress symptoms and fear-of-pain to hourly pain and uptime. *Clin J Pain.* 2010;26(7):573-582.
147. Robertson C, Klein S, Bullen H, Alexander DA. An evaluation of patient satisfaction with an information leaflet for trauma survivors. *Journal of traumatic stress.* 2002;15(4):329-332.
148. Periyakoil VS. A never-ending battle. *New England Journal of Medicine.* 2015;373(25):2399-2401.
149. Koenig CJ, Maguen S, Monroy JD, Mayott L, Seal KH. Facilitating culture-centered communication between health care providers and veterans transitioning from military deployment to civilian life. *Patient education and counseling.* 2014;95(3):414-420.
150. Sim J. Collecting and analysing qualitative data: issues raised by the focus group. *Journal of advanced nursing.* 1998;28(2):345-352.
151. Weinberg H, Nuttman-Shwartz O, Gilmore M. Trauma groups: An overview. *Group Analysis.* 2005;38(2):187-202.
152. Moeller-Bertram T, Strigo IA, Simmons AN, Schilling JM, Patel P, Baker DG. Evidence for acute central sensitization to prolonged experimental pain in posttraumatic stress disorder. *Pain medicine (Malden, Mass).* 2014;15(5):762-771.
153. Diener I, Kargela M, Louw A. Listening is therapy: Patient interviewing from a pain science perspective. *Physiotherapy theory and practice.* 2016;32(5):356-367.
154. Burns KE, Duffett M, Kho ME, et al. A guide for the design and conduct of self-administered surveys of clinicians. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne.* 2008;179(3):245-252.
155. Cunningham CT, Quan H, Hemmelgarn B, et al. Exploring physician specialist response rates to web-based surveys. *BMC medical research methodology.* 2015;15:32.

156. DeBruyne NF, Leland A. American War and Military Operations Casualties: Lists and Statistics. *Congressional Research Service January.* 2015;2.
157. Boscarino JA. External-cause mortality after psychologic trauma: the effects of stress exposure and predisposition. *Comprehensive psychiatry.* 2006;47(6):503-514.
158. Barrett DH, Doebbeling CC, Schwartz DA, et al. Posttraumatic stress disorder and self-reported physical health status among U.S. Military personnel serving during the Gulf War period: a population-based study. *Psychosomatics.* 2002;43(3):195-205.
159. Wilson IH, Freer TH. Unseen scars of conflict. *The Lancet.* 2010;375(9711):277-277.
160. Skeehan CD, Tribble DR, Sanders JW, Putnam SD, Armstrong AW, Riddle MS. Nonbattle injury among deployed troops: an epidemiologic study. *Mil Med.* 2009;174(12):1256-1262.
161. Cohen SP, Nguyen C, Kapoor SG, et al. Back pain during war: an analysis of factors affecting outcome. *Archives of internal medicine.* 2009;169(20):1916-1923.
162. Gizzi J. Retired Adm. Mullen: Health Costs Threaten Military Readiness. *Newsmax.* 2014.
163. Rosen MI, Ablondi K, Black AC, et al. Work outcomes after benefits counseling among veterans applying for service connection for a psychiatric condition. *Psychiatric services (Washington, DC).* 2014;65(12):1426-1432.
164. Pearce N, Checkoway H, Kriebel D. Bias in occupational epidemiology studies. *Occupational and environmental medicine.* 2007;64(8):562-568.
165. Armed Forces Health Surveillance Center. Low Back Pain, Active Component, U.S. Armed Forces, 2000-2009. *MSMR.* 2010;17(7):5.
166. Amoroso PJ, Yore MM, Weyandt B, Jones BH. Chapter 8. Total Army injury and health outcomes database: a model comprehensive research database. *Mil Med.* 1999;164(8 Suppl):1-36.
167. Schoenfeld AJ, Goodman GP, Burks R, Black MA, Nelson JH, Belmont PJ, Jr. The Influence of Musculoskeletal Conditions, Behavioral Health Diagnoses, and Demographic Factors on Injury-Related Outcome in a High-Demand Population. *The Journal of bone and joint surgery American volume.* 2014;96(13):e106.
168. Autor DH, Duggan MG, Lyle DS. Battle scars? The puzzling decline in employment and rise in disability receipt among Vietnam era veterans. *The American Economic Review.* 2011;101(3):339-344.
169. Cherkin DC, Deyo RA, Volinn E, Loeser JD. Use of the International Classification of Diseases (ICD-9-CM) to identify hospitalizations for mechanical low back problems in administrative databases. *Spine.* 1992;17(7):817-825.
170. Pengel LH, Herbert RD, Maher CG, Refshauge KM. Acute low back pain: systematic review of its prognosis. *BMJ (Clinical research ed).* 2003;327(7410):323.
171. da CMCL, Maher CG, Hancock MJ, McAuley JH, Herbert RD, Costa LO. The prognosis of acute and persistent low-back pain: a meta-analysis. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne.* 2012;184(11):E613-624.
172. Cameron RP, Gusman D. The primary care PTSD screen (PC-PTSD): development and operating characteristics. *Primary Care Psychiatry.* 2003;9(1):9-14.
173. Bliese PD, Wright KM, Adler AB, Cabrera O, Castro CA, Hoge CW. Validating the primary care posttraumatic stress disorder screen and the posttraumatic stress disorder checklist with soldiers returning from combat. *Journal of consulting and clinical psychology.* 2008;76(2):272-281.

174. Hoge CW, Castro CA, Messer SC, McGurk D, Cotting DI, Koffman RL. Combat duty in Iraq and Afghanistan, mental health problems, and barriers to care. *The New England journal of medicine.* 2004;351(1):13-22.
175. Hoge CW, Grossman SH, Auchterlonie JL, Riviere LA, Milliken CS, Wilk JE. PTSD treatment for soldiers after combat deployment: low utilization of mental health care and reasons for dropout. *Psychiatric services (Washington, DC).* 2014;65(8):997-1004.
176. Nash WP, Boasso AM, Steenkamp MM, Larson JL, Lubin RE, Litz BT. Posttraumatic stress in deployed Marines: Prospective trajectories of early adaptation. *Journal of Abnormal Psychology.* 2015;124(1):155-171.
177. Orcutt HK, Erickson DJ, Wolfe J. The course of PTSD symptoms among Gulf War veterans: a growth mixture modeling approach. *Journal of traumatic stress.* 2004;17(3):195-202.
178. Bell NS, Schwartz CE, Harford T, Hollander IE, Amoroso PJ. The changing profile of disability in the US Army: 1981-2005. *Disability and health journal.* 2008;1(1):14-24.
179. Xue C, Ge Y, Tang B, et al. A meta-analysis of risk factors for combat-related PTSD among military personnel and veterans. *PLoS ONE.* 2015;10(3).
180. Knox J, Orchowski J, Scher DL, Owens BD, Burks R, Belmont PJ. The incidence of low back pain in active duty United States military service members. *Spine.* 2011;36(18):1492-1500.
181. Lippa SM, Fonda JR, Fortier CB, et al. Deployment-related psychiatric and behavioral conditions and their association with functional disability in OEF/OIF/OND veterans. *Journal of traumatic stress.* 2015;28(1):25-33.
182. Kardouni JR, Shing TL, Rhon DI. Risk Factors for Low Back Pain and Spine Surgery: A Retrospective Cohort Study in Soldiers. *Am J Prev Med.* 2016;51(5):e129-e138.
183. Talcott GW, Ebbert JO, Klesges RC, et al. Tobacco Research in the Military: Reflections on 20 Years of Research in the United States Air Force. *Mil Med.* 2015;180(8):848-850.
184. Branch AFHS. Mental Disorders and Mental Health Problems, Active Component, U.S. Armed

Forces, 2000-2011. *MSMR.* 2012;19(6):7.
185. Kirin SJ, Winkler JD. *The Army Military Occupational Specialty Database.* DTIC Document;1992.
186. Gologorsky Y, Knightly JJ, Lu Y, Chi JH, Groff MW. Improving discharge data fidelity for use in large administrative databases. *Neurosurgical focus.* 2014;36(6):E2.
187. Zou G. A modified poisson regression approach to prospective studies with binary data. *American journal of epidemiology.* 2004;159(7):702-706.
188. Ferguson CJ. An effect size primer: A guide for clinicians and researchers. *Professional Psychology: Research and Practice.* 2009;40(5):532.
189. Clapp JD, Beck JG, Palyo SA, Grant DM. An examination of the synergy of pain and PTSD on quality of life: additive or multiplicative effects? *Pain.* 2008;138(2):301-309.
190. van Marle HJ, Hermans EJ, Qin S, Fernandez G. From specificity to sensitivity: how acute stress affects amygdala processing of biologically salient stimuli. *Biological psychiatry.* 2009;66(7):649-655.
191. Louw A, Puentedura ELJ, Zimney K. Teaching patients about pain: It works, but what should we call it? *Physiotherapy theory and practice.* 2016;32(5):328-331.
192. Moseley GL. Joining forces -- combining cognition -- targeted motor control training with group or individual pain physiology education: a successful treatment for chronic low

back pain. *Journal of Manual & Manipulative Therapy (Journal of Manual & Manipulative Therapy).* 2003;11(2):88-94.
193. Truchon M. Determinants of chronic disability related to low back pain: towards an integrative biopsychosocial model. *Disabil Rehabil.* 2001;23(17):758-767.
194. Truchon M, Fillion L. Biopsychosocial determinants of chronic disability and low-back pain: a review. *Journal of occupational rehabilitation.* 2000;10(2):117-142 126p.
195. Van Nieuwenhuyse A, Somville PR, Crombez G, et al. The role of physical workload and pain related fear in the development of low back pain in young workers: evidence from the BelCoBack Study; results after one year of follow up. *Occupational and environmental medicine.* 2006;63(1):45-52.
196. Ramond A, Bouton C, Richard I, et al. Psychosocial risk factors for chronic low back pain in primary care--a systematic review. *Family practice.* 2011;28(1):12-21.
197. Hagen KB, Tambs K, Bjerkedal T. A prospective cohort study of risk factors for disability retirement because of back pain in the general working population. *Spine (Phila Pa 1976).* 2002;27(16):1790-1796.
198. Tubach F, Leclerc A, Landre MF, Pietri-Taleb F. Risk factors for sick leave due to low back pain: a prospective study. *Journal of occupational and environmental medicine / American College of Occupational and Environmental Medicine.* 2002;44(5):451-458.
199. Brooks DE, Agochukwu UF, Arrington ED, Mok JM. Psychological distress in the active duty military spine patient. *Mil Med.* 2013;178(10):1059-1064.
200. Tang NK, Wright KJ, Salkovskis PM. Prevalence and correlates of clinical insomnia co-occurring with chronic back pain. *Journal of sleep research.* 2007;16(1):85-95.
201. Kelly GA, Blake C, Power CK, O'Keeffe D, Fullen BM. The association between chronic low back pain and sleep: a systematic review. *Clin J Pain.* 2011;27(2):169-181.
202. Lang KP, Veazey-Morris K, Andrasik F. Exploring the role of insomnia in the relation between PTSD and pain in veterans with polytrauma injuries. *J Head Trauma Rehabil.* 2014;29(1):44-53.
203. Gubata ME, Piccirillo AL, Packnett ER, Niebuhr DW, Boivin MR, Cowan DN. Risk factors for back-related disability in the US Army and Marine Corps. *Spine (Phila Pa 1976).* 2014;39(9):745-753.
204. Konitzer LN, Fargo MV, Brininger TL, Lim Reed M. Association between back, neck, and upper extremity musculoskeletal pain and the individual body armor. *Journal of hand therapy : official journal of the American Society of Hand Therapists.* 2008;21(2):143-148; quiz 149.
205. Piccirillo AL, Packnett ER, Cowan DN, Boivin MR. Risk factors for disability discharge in enlisted active duty Army soldiers. *Disabil Health J.* 2016;9(2):324-331.
206. Sheppard SC, Forsyth JP, Earleywine M, Hickling EJ, Lehrbach MP. Improving base rate estimation of alcohol misuse in the military: a preliminary report. *Journal of studies on alcohol and drugs.* 2013;74(6):917-922.
207. Breslau N, Chilcoat HD, Kessler RC, Peterson EL, Lucia VC. Vulnerability to assaultive violence: further specification of the sex difference in post-traumatic stress disorder. *Psychol Med.* 1999;29(4):813-821.
208. Chung H, Breslau N. The latent structure of post-traumatic stress disorder: tests of invariance by gender and trauma type. *Psychol Med.* 2008;38(4):563-573.
209. Driscoll MA, Higgins DM, Seng EK, et al. Trauma, social support, family conflict, and chronic pain in recent service veterans: does gender matter? *Pain medicine (Malden, Mass).* 2015;16(6):1101-1111.

210. Taylor SE, Klein LC, Lewis BP, Gruenewald TL, Gurung RA, Updegraff JA. Biobehavioral responses to stress in females: tend-and-befriend, not fight-or-flight. *Psychological review.* 2000;107(3):411-429.
211. Goldzweig CL, Balekian TM, Rolon C, Yano EM, Shekelle PG. The state of women veterans' health research. *Journal of General Internal Medicine.* 2006;21(S3):S82-S92.
212. Hourani L, Williams J, Bray RM, Wilk JE, Hoge CW. Gender Differences in Posttraumatic Stress Disorder and Help Seeking in the U.S. Army. *Journal of women's health (2002).* 2016;25(1):22-31.
213. Rosen LN, Wright K, Marlowe D, Bartone P, Gifford RK. Gender differences in subjective distress attributable to anticipation of combat among U.S. Army soldiers deployed to the Persian Gulf during Operation Desert Storm. *Mil Med.* 1999;164(11):753-757.
214. Prigerson HG, Maciejewski PK, Rosenheck RA. Combat trauma: trauma with highest risk of delayed onset and unresolved posttraumatic stress disorder symptoms, unemployment, and abuse among men. *J Nerv Ment Dis.* 2001;189(2):99-108.
215. Andrews B, Brewin CR, Stewart L, Philpott R, Hejdenberg J. Comparison of immediate-onset and delayed-onset posttraumatic stress disorder in military veterans. *J Abnorm Psychol.* 2009;118(4):767-777.
216. Cohen SP, Griffith S, Larkin TM, Villena F, Larkin R. Presentation, diagnoses, mechanisms of injury, and treatment of soldiers injured in Operation Iraqi Freedom: an epidemiological study conducted at two military pain management centers. *Anesthesia and analgesia.* 2005;101(4):1098-1103, table of contents.
217. Pitman RK, van der Kolk BA, Orr SP, Greenberg MS. Naloxone-reversible analgesic response to combat-related stimuli in posttraumatic stress disorder. A pilot study. *Arch Gen Psychiatry.* 1990;47(6):541-544.
218. Kraus A, Geuze E, Schmahl C, et al. Differentiation of pain ratings in combat-related posttraumatic stress disorder. *Pain.* 2009;143(3):179-185.
219. Defrin R, Ginzburg K, Solomon Z, et al. Quantitative testing of pain perception in subjects with PTSD–implications for the mechanism of the coexistence between PTSD and chronic pain. *Pain.* 2008;138(2):450-459.
220. Geuze E, Westenberg HG, Jochims A, et al. Altered pain processing in veterans with posttraumatic stress disorder. *Arch Gen Psychiatry.* 2007;64(1):76-85.
221. Schmahl C, Meinzer M, Zeuch A, et al. Pain sensitivity is reduced in borderline personality disorder, but not in posttraumatic stress disorder and bulimia nervosa. *The world journal of biological psychiatry : the official journal of the World Federation of Societies of Biological Psychiatry.* 2010;11(2 Pt 2):364-371.
222. Woolf CJ. Central sensitization: implications for the diagnosis and treatment of pain. *Pain.* 2011;152(3):S2-S15.
223. Smart KM, Blake C, Staines A, Doody C. The Discriminative validity of "nociceptive,""peripheral neuropathic," and "central sensitization" as mechanisms-based classifications of musculoskeletal pain. *The Clinical journal of pain.* 2011;27(8):655-663.
224. Smart KM, Blake C, Staines A, Thacker M, Doody C. Mechanisms-based classifications of musculoskeletal pain: part 1 of 3: symptoms and signs of central sensitisation in patients with low back (+/- leg) pain. *Man Ther.* 2012;17(4):336-344.
225. Linton SJ, Kamwendo K. Low back schools. A critical review. *Phys Ther.* 1987;67(9):1375-1383.
226. Williams C, Hancock MJ, Ferreira M, Ferreira P, Maher CG. A literature review reveals that trials evaluating treatment of non-specific low back pain use inconsistent criteria to

identify serious pathologies and nerve root involvement. *The Journal of manual & manipulative therapy.* 2012;20(2):59-65.
227. Downie A, Williams CM, Henschke N, et al. Red flags to screen for malignancy and fracture in patients with low back pain: systematic review. *BMJ (Clinical research ed).* 2013;347:f7095.
228. Ising HK, Veling W, Loewy RL, et al. The validity of the 16-item version of the Prodromal Questionnaire (PQ-16) to screen for ultra high risk of developing psychosis in the general help-seeking population. *Schizophrenia bulletin.* 2012;38(6):1288-1296.
229. Fiellin DA, Reid MC, O'Connor PG. Screening for alcohol problems in primary care: a systematic review. *Archives of internal medicine.* 2000;160(13):1977-1989.
230. Posner K, Brown GK, Stanley B, et al. The Columbia–Suicide Severity Rating Scale: initial validity and internal consistency findings from three multisite studies with adolescents and adults. *American Journal of Psychiatry.* 2011;168(12):1266-1277.
231. Farasyn A, Meeusen R. The influence of non-specific low back pain on pressure pain thresholds and disability. *European journal of pain (London, England).* 2005;9(4):375-381.
232. Neziri AY, Curatolo M, Limacher A, et al. Ranking of parameters of pain hypersensitivity according to their discriminative ability in chronic low back pain. *PAIN®.* 2012;153(10):2083-2091.
233. Hoge CW, Riviere LA, Wilk JE, Herrell RK, Weathers FW. The prevalence of post-traumatic stress disorder (PTSD) in US combat soldiers: a head-to-head comparison of DSM-5 versus DSM-IV-TR symptom criteria with the PTSD checklist. *The Lancet Psychiatry.* 2014;1(4):269-277.
234. Bovin MJ, Marx BP, Weathers FW, et al. Psychometric properties of the PTSD Checklist for Diagnostic and Statistical Manual of Mental Disorders-Fifth Edition (PCL-5) in veterans. *Psychol Assess.* 2016;28(11):1379-1391.
235. Sullivan MJ, Bishop SR, Pivik J. The pain catastrophizing scale: development and validation. *Psychological assessment.* 1995;7(4):524.
236. George SZ, Valencia C, Beneciuk JM. A psychometric investigation of fear-avoidance model measures in patients with chronic low back pain. *The Journal of orthopaedic and sports physical therapy.* 2010;40(4):197-205.
237. Ciccone DS, Kline A. A longitudinal study of pain and pain catastrophizing in a cohort of National Guard troops at risk for PTSD. *Pain.* 2012;153(10):2055-2060.
238. Wertli MM, Eugster R, Held U, Steurer J, Kofmehl R, Weiser S. Catastrophizing-a prognostic factor for outcome in patients with low back pain: a systematic review. *The spine journal : official journal of the North American Spine Society.* 2014;14(11):2639-2657.
239. Boissoneault J, Mundt J, Robinson M, George SZ. Predicting Low Back Pain Outcomes: Suggestions for Future Directions. *The Journal of orthopaedic and sports physical therapy.* 2017;47(9):588-592.
240. Childs JD, Piva SR, Fritz JM. Responsiveness of the numeric pain rating scale in patients with low back pain. *Spine (Phila Pa 1976).* 2005;30(11):1331-1334.
241. Ostelo RW, Deyo RA, Stratford P, et al. Interpreting change scores for pain and functional status in low back pain: towards international consensus regarding minimal important change. *Spine (Phila Pa 1976).* 2008;33(1):90-94.
242. Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: Visual analog scale for pain (vas pain), numeric rating scale for pain (nrs pain), mcgill pain questionnaire (mpq), short-form mcgill pain questionnaire (sf-mpq), chronic pain grade scale (cpgs),

short form-36 bodily pain scale (sf-36 bps), and measure of intermittent and constant osteoarthritis pain (icoap). *Arthritis care & research.* 2011;63(S11).
243. Nicholas M. Self-efficacy and chronic pain. Paper presented at: annual conference of the British Psychological Society. St. Andrews1989.
244. Moseley GL, Nicholas MK, Hodges PW. A randomized controlled trial of intensive neurophysiology education in chronic low back pain. *Clin J Pain.* 2004;20(5):324-330.
245. Ryan DA, Gallagher P, Wright S, Cassidy EM. Sensitivity and specificity of the Distress Thermometer and a two-item depression screen (Patient Health Questionnaire-2) with a 'help' question for psychological distress and psychiatric morbidity in patients with advanced cancer. *Psycho-oncology.* 2012;21(12):1275-1284.
246. Keegan D, Byrne K, Cullen G, Doherty GA, Dooley B, Mulcahy HE. The Stressometer: A Simple, Valid, and Responsive Measure of Psychological Stress in Inflammatory Bowel Disease Patients. *Journal of Crohn's & colitis.* 2015;9(10):881-885.
247. Gray MJ, Litz BT, Hsu JL, Lombardo TW. Psychometric properties of the life events checklist. *Assessment.* 2004;11(4):330-341.
248. Vaegter HB, Andersen TE, Harvold M, Andersen PG, Graven-Nielsen T. Increased Pain Sensitivity in Accident-related Chronic Pain Patients With Comorbid Posttraumatic Stress. *Clin J Pain.* 2018;34(4):313-321.
249. Riddle DL, Wade JB, Jiranek WA, Kong X. Preoperative Pain Catastrophizing Predicts Pain Outcome after Knee Arthroplasty. *Clinical orthopaedics and related research.* 2010;468(3):798-806.
250. Langford DJ, Theodore BR, Balsiger D, et al. Number and Type of Post-Traumatic Stress Disorder Symptom Domains Are Associated With Patient-Reported Outcomes in Patients With Chronic Pain. *The journal of pain : official journal of the American Pain Society.* 2018.
251. Nicholas MK, Linton SJ, Watson PJ, Main CJ. Early identification and management of psychological risk factors ("yellow flags") in patients with low back pain: a reappraisal. *Phys Ther.* 2011;91(5):737-753.
252. Nicholas MK, George SZ. Psychologically informed interventions for low back pain: an update for physical therapists. *Physical therapy.* 2011;91(5):765.
253. Johnson MH, Stewart J, Humphries SA, Chamove AS. Marathon runners' reaction to potassium iontophoretic experimental pain: pain tolerance, pain threshold, coping and self-efficacy. *European journal of pain (London, England).* 2012;16(5):767-774.
254. Lindback Y, Tropp H, Enthoven P, Gerdle B, Abbott A, Oberg B. Association between pain sensitivity in the hand and outcomes after surgery in patients with lumbar disc herniation or spinal stenosis. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society.* 2017;26(10):2581-2588.
255. Tesarz J, Gerhardt A, Leisner S, Janke S, Treede RD, Eich W. Distinct quantitative sensory testing profiles in nonspecific chronic back pain subjects with and without psychological trauma. *Pain.* 2015;156(4):577-586.
256. Hübscher M, Moloney N, Leaver A, Rebbeck T, McAuley JH, Refshauge KM. Relationship between quantitative sensory testing and pain or disability in people with spinal pain—A systematic review and meta-analysis. *Pain.* 2013;154(9):1497-1504.
257. Arendt-Nielsen L, Yarnitsky D. Experimental and clinical applications of quantitative sensory testing applied to skin, muscles and viscera. *The Journal of Pain.* 2009;10(6):556-572.

258. Ferrari S, Vanti C, Costa F, Fornari M. Can physical therapy centred on cognitive and behavioural principles improve pain self-efficacy in symptomatic lumbar isthmic spondylolisthesis? A case series. *Journal of bodywork and movement therapies.* 2016;20(3):554-564.
259. Roberts AJ, Dew A, Bridger R, Etherington J, Kilminster S. Predicting low back pain outcome following rehabilitation for low back pain. *Journal of back and musculoskeletal rehabilitation.* 2015;28(1):119-128.
260. Ma X, Zhang J, Zhong W, et al. The diagnostic role of a short screening tool--the distress thermometer: a meta-analysis. *Supportive care in cancer : official journal of the Multinational Association of Supportive Care in Cancer.* 2014;22(7):1741-1755.
261. Diener SJ, Wessa M, Ridder S, et al. Enhanced stress analgesia to a cognitively demanding task in patients with posttraumatic stress disorder. *J Affect Disord.* 2012;136(3):1247-1251.
262. O'Neill S, Manniche C, Graven-Nielsen T, Arendt-Nielsen L. Generalized deep-tissue hyperalgesia in patients with chronic low-back pain. *European Journal of Pain.* 2007;11(4):415-420.
263. Delitto A, George SZ, Van Dillen LR, et al. Low back pain. *The Journal of orthopaedic and sports physical therapy.* 2012;42(4):A1-57.
264. Jarvik JG, Hollingworth W, Heagerty PJ, Haynor DR, Boyko EJ, Deyo RA. Three-year incidence of low back pain in an initially asymptomatic cohort: clinical and imaging risk factors. *Spine.* 2005;30(13):1541-1548.
265. Schell E, Theorell T, Hasson D, Arnetz B, Saraste H. Stress biomarkers' associations to pain in the neck, shoulder and back in healthy media workers: 12-month prospective follow-up. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society.* 2008;17(3):393-405.
266. Sullivan MJ, Feuerstein M, Gatchel R, Linton SJ, Pransky G. Integrating psychosocial and behavioral interventions to achieve optimal rehabilitation outcomes. *Journal of occupational rehabilitation.* 2005;15(4):475-489.
267. Severeijns R, Vlaeyen JW, van den Hout MA, Weber WE. Pain catastrophizing predicts pain intensity, disability, and psychological distress independent of the level of physical impairment. *Clin J Pain.* 2001;17(2):165-172.
268. Weathers FW, Litz BT, Keane TM, Palmieri PA, Marx BP, Schnurr PP. The PTSD Checklist for DSM-5 (PCL-5). 2013; www.ptsd.va.gov. Accessed May 8, 2018.
269. Chiarotto A, Vanti C, Cedraschi C, et al. Responsiveness and Minimal Important Change of the Pain Self-Efficacy Questionnaire and Short Forms in Patients With Chronic Low Back Pain. *The journal of pain : official journal of the American Pain Society.* 2016;17(6):707-718.
270. Pincus T, Anwar S, McCracken LM, et al. Delivering an Optimised Behavioural Intervention (OBI) to people with low back pain with high psychological risk; results and lessons learnt from a feasibility randomised controlled trial of Contextual Cognitive Behavioural Therapy (CCBT) vs. Physiotherapy. *BMC Musculoskelet Disord.* 2015;16:147.
271. Understanding PTSD and PTSD Treatment. 2018; https://www.ptsd.va.gov/public/understanding_ptsd/booklet.pdf.
272. Ruzek JI, Hoffman J, Ciulla R, Prins A, Kuhn E, Gahm G. Bringing Internet-based education and intervention into mental health practice: afterdeployment.org. *European Journal of Psychotraumatology.* 2011;2:10.3402/ejpt.v3402i3400.7278.

273. Seyffert M, Lagisetty P, Landgraf J, et al. Internet-Delivered Cognitive Behavioral Therapy to Treat Insomnia: A Systematic Review and Meta-Analysis. *PLoS One.* 2016;11(2):e0149139.
274. Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc.* 2011;43(7):1334-1359.
275. Schmidt JE, Joyner MJ, Carlson CR, Hooten WM. Cardiac autonomic function associated with treatment adherence after a brief intervention in patients with chronic pain. *Applied psychophysiology and biofeedback.* 2013;38(3):193-201.
276. Kwekkeboom KL, Gretarsdottir E. Systematic review of relaxation interventions for pain. *Journal of nursing scholarship : an official publication of Sigma Theta Tau International Honor Society of Nursing.* 2006;38(3):269-277.
277. Moffett JK, Frost H. Back to Fitness Programme: The manual for physiotherapists to set up the classes. *Physiotherapy.* 2000;86(6):295-305.
278. Richter M, Eck J, Straube T, Miltner WH, Weiss T. Do words hurt? Brain activation during the processing of pain-related words. *Pain.* 2010;148(2):198-205.
279. Ehlert U, Gaab J, Heinrichs M. Psychoneuroendocrinological contributions to the etiology of depression, posttraumatic stress disorder, and stress-related bodily disorders: the role of the hypothalamus-pituitary-adrenal axis. *Biological psychology.* 2001;57(1-3):141-152.
280. Moseley L. Combined physiotherapy and education is efficacious for chronic low back pain. *Australian Journal of Physiotherapy.* 2002;48(4):297-302.
281. Pires D, Cruz EB, Caeiro C. Aquatic exercise and pain neurophysiology education versus aquatic exercise alone for patients with chronic low back pain: a randomized controlled trial. *Clinical rehabilitation.* 2015;29(6):538-547.
282. Van Oosterwijck J, Nijs J, Meeus M, et al. Pain neurophysiology education improves cognitions, pain thresholds, and movement performance in people with chronic whiplash: a pilot study. *Journal of rehabilitation research and development.* 2011;48(1):43-58.
283. Malfliet A, Kregel J, Coppieters I, et al. Effect of Pain Neuroscience Education Combined With Cognition-Targeted Motor Control Training on Chronic Spinal Pain: A Randomized Clinical Trial. *JAMA neurology.* 2018.
284. Louw A, Puentedura EJ, Zimney K, Schmidt S. Know Pain, Know Gain? A Perspective on Pain Neuroscience Education in Physical Therapy. *The Journal of orthopaedic and sports physical therapy.* 2016;46(3):131-134.
285. Sheeran P, Maki A, Montanaro E, et al. The impact of changing attitudes, norms, and self-efficacy on health-related intentions and behavior: A meta-analysis. *Health psychology : official journal of the Division of Health Psychology, American Psychological Association.* 2016;35(11):1178-1188.
286. Ryan CG, Gray HG, Newton M, Granat MH. Pain biology education and exercise classes compared to pain biology education alone for individuals with chronic low back pain: a pilot randomised controlled trial. *Man Ther.* 2010;15(4):382-387.
287. Haigh C, Hardy P. Tell me a story--a conceptual exploration of storytelling in healthcare education. *Nurse education today.* 2011;31(4):408-411.
288. Giummarra MJ, Casey SL, Devlin A, et al. Co-occurrence of posttraumatic stress symptoms, pain, and disability 12 months after traumatic injury. *Pain reports.* 2017;2(5):e622.

289. Wilson D, Williams M, Butler D. Language and the pain experience. *Physiotherapy research international : the journal for researchers and clinicians in physical therapy.* 2009;14(1):56-65.
290. Wertli MM, Burgstaller JM, Weiser S, Steurer J, Kofmehl R, Held U. Influence of catastrophizing on treatment outcome in patients with nonspecific low back pain: a systematic review. *Spine (Phila Pa 1976).* 2014;39(3):263-273.
291. Otis JD, McGlinchey R, Vasterling JJ, Kerns RD. Complicating factors associated with mild traumatic brain injury: impact on pain and posttraumatic stress disorder treatment. *Journal of clinical psychology in medical settings.* 2011;18(2):145-154.

CURRICULUM VITAE

Timothy M Benedict, DPT, OCS
MAJ, US Army

EDUCATION

Doctoral Student, Rehabilitation Science, University of Kentucky, Lexington, KY --Present--
DPT, US Army-Baylor Program, San Antonio, TX 2009
BS Electrical Engineering, United States Military Academy, West Point NY 2002

TEACHING RESPONSIBILITIES

Assistant Instructor, Anatomy and Dry-Needling at the COL Douglas A. Kersey Advanced Clinical and Operational Practice Course._____2014
Introduction to Dry-Needling in the Military Treatment Facility.
Assistant/Lead Instructor for introductory-level Dry Needling Course, accredited by Texas Physical Therapy Association (TPTA) 23 CCU's. _____2013

MILITARY EMPLOYMENT

Intern Director, Fort Hood, TX	2014—2015
OIC Bennett Physical Therapy, Fort Hood, TX	2012—2014
Brigade Combat Team Physical Therapist, 3 BCT 25 ID	2010—2012
Assistant OIC Schofield Barracks Physical Therapy	2009—2010
Student, US Army-Baylor Doctoral Program in Physical Therapy	2006—2009
Executive Officer, HHC CJTF-76, Bagram Afghanistan	2005—2006
Executive Officer, HSC SETAF, Vicenza, Italy	2004—2005
Platoon Leader, B Company, 1-508th 173rd ABN BDE, OIF 1	2003—2004

PUBLICATIONS

Childs JD, Teyhen DS, **Benedict TM**, et al. Effects of sit-up training versus core stabilization exercises on sit-up performance. *Med Sci Sports Exerc.* 2009;41(11):2072-2083.

PROFESSIONAL HONORS

Student Leadership Award AMEDD Officer Basic Course, Fort Sam Houston, TX 2006
Commandant's List Infantry Officer Basic Course, Fort Benning, GA 2002
COL David Greathouse Research Award: 2008
The effects of traditional sit-up training versus core stabilization exercises on sit-up performance in US Army Soldiers