The Pennsylvania State University
The Graduate School
College of Health and Human Development

ANKLE BRACES AND ITS EFFECTS ON FUNCTIONAL PERFORMANCE MEASURES IN A RESERVE OFFICERS’ TRAINING CORPS

A Dissertation in
Kinesiology
by
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Submitted in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

August 2017
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ABSTRACT

Musculoskeletal injuries sustained during physical training and sports-related activities are the greatest threat to military force readiness. Injuries sustained during physical training are one of the principal reasons for the inability of service men and women to be deployed and for the almost 25 million limited duty days accrued annually. Ankle sprains have been shown to be a leading cause for military disability and are a long-term health care issue, potentially leading to a medical discharge. Military parachuting studies have demonstrated the benefits of using an outside-the-boot ankle brace to reduce the risk for sustaining an ankle injury, but the use of ankle bracing on other performance measures in the military have not been established. The first chapter of this dissertation focused on reviewing existing literature that investigated the effects of ankle bracing on functional performance measures in civilian populations. It was concluded in the literature that ankle braces, used in healthy physically active populations, have little statistical impact on balance and functional performance measures. The second chapter of this dissertation focused on reviewing how ankle braces effect performance measures in military specific populations. At this point, only one study has specifically evaluated how these devices affect performance measures, and the remaining studies focused only on the reduction of ankle injuries. Due to the lack of literature available, the purpose of this study was to investigate the effects of ankle braces on dynamic balance and three functional performance measures in a Reserve Officers’ Training Corps. This randomized crossover study indicated significant results in which ankle braces do create negative effects for balance reach distances, max jump height, max jump distance, and obstacle course completion time. This is the first study to evaluate ankle braces in a military sample while wearing battle dress uniform, combat boots, and a loaded rucksack.
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ACKNOWLEDGEMENTS

I would like to begin by thanking my dissertation committee for their support and guidance on this project. Dr. Peter Bordi, Dr. Wayne Sebastianelli, and LTC Theodore Croy, due to your hard work and dedication, I was successfully able to complete my dissertation on a subject that is very close to me. Ted, I want to especially thank you for sticking by me from the beginning at UVA. Without your vision and ideas during my time, working on my thesis, this current project would not exist.

Dr. Buckley, Dr. Vairo, and Dr. Miller, thank you very much for all your counsel and tireless work to help me get to where I am today. This project had seen its fair share of roadblocks and I thank all of you for sticking with me through this journey. Thank you all for your time and effort.

I would like to thank the ROTC program, the Cadre, office staff, and the cadets and midshipmen at Penn State. Specifically, to the Army ROTC Cadets and the Naval Midshipmen who were willing to give up their mornings to help me with my project. I want to thank Penn State Army ROTC Commander LTC Richard Garey and Naval ROTC Marine Option Commander Captain Duane Blank. You have helped me push this project through and without your aid; this would not have been a possibility. I would also like to thank Gunnery Sergeant Mindo Estrella and Second Lieutenant Kevin Redmond for their support of this project.

I want to thank Dr. Michael Gay for his motivation and support through the tough times that I had throughout these past four years. It has been a privilege to be your student during my undergraduate career as well as working alongside you. You have
taught me a lot about myself and I can never repay that. Thank you for everything you have done.

Finally, I want to thank you family and friends for their help and support. I love you all very much. Thanks mom and dad for helping me get to this point. Thank you Lisa for giving me the opportunity to go back to school so that I could get this degree. I could not have gotten through this without you and Max.
SECTION I: MANUSCRIPT I

THE COMPARATIVE EFFECTS OF ANKLE BRACING ON FUNCTIONAL PERFORMANCE
Clinical Scenario

Ankle sprains represent a common musculoskeletal injury encountered in physical activity that clinicians are tasked with preventing, and treating. Due to the prevalence of this injury, various ankle braces have been designed to prophylactically protect the joint, and reduce the incidence of repetitive sprains. While an abundance of literature exists focusing on the efficacy of braces in preventing ankle sprains in young, health and physically active populations, there is a scarcity of evidence specific to the impact of these apparatuses on functional performance; therefore the purpose of this critically appraised topic (CAT) is to investigate the effects of ankle braces on functional performance measures in such individuals. The outcomes of this CAT will assist sport rehabilitation specialists with informed clinical decision making in managing young, healthy and physically active populations using ankle braces.

Focused Clinical Question

Do ankle braces hinder functional performance measures when compared to an unbraced condition in a young, healthy, and physically active population?

Summary of Search, “Best Evidence” Appraised, and Key Findings

- A minimum of level II evidence research studies were surveyed for this CAT.\textsuperscript{1,2}
- For this CAT, one randomized controlled trial\textsuperscript{3} and three prospective cohort studies were selected.\textsuperscript{4-6}
- One study found a statistically significant main effect of increased agility run times while participants wore ankle braces.\textsuperscript{4}
Another study demonstrated a statistically significant decrease in vertical jump height.\textsuperscript{6}

No other statistically significant findings were reported among studies comparing unbraced with braced conditions.\textsuperscript{3-6}

- The following functional performance measures were used in this CAT; Sargent chalk test, Vertec vertical jump, soccer ball kicking accuracy, right-boomerang run test, SEMO, 40-yard dash, S 180 agility test, and T-Test.\textsuperscript{3,4,6}

- Brace conditions included in this study were; unbraced, lace-up, semi-rigid, and Seattle Ankle Orthosis (SAO) braces.

A statistically significant decrease in ankle range of motion (ROM) was reported while wearing braces.\textsuperscript{6}

- Plantarflexion (PF), dorsiflexion (DF), eversion (EV), and inversion (IV)

**Clinical Bottom Line**

Current data indicates young, healthy and physically active individuals may experience varied performance effects when executing specific functional performance tasks (Appendix A-J) while wearing ankle braces. Generally, bracing does not appear to cause statistically significant impairments to performance on most functional tasks; however, decrements were noted to yield increases in agility run time, and decreases in vertical jump height which may create real world deficits. A subsequent effect size analysis noted a brace may result in decreased ankle PF, DF, EV, and IV ROM, which may underpin noted performance deficits. **Strength of Recommendation:** A grade of B\textsuperscript{7} or moderate level of evidence exists demonstrating that ankle braces may have varied
impacts on functional performance measures. While we base this statement from the literature’s reported statistical significance, we offer an independent post-hoc analysis of the measures, which may provide a mechanism lending to clinical significance to consider as a supplement to our current strength of recommendation.

**Search Strategy**

**Terms Used to Guide Search Strategy**

- **Patient/Client group:** Young, healthy and physically active individuals
- **Intervention (or assessment):** Ankle braces
- **Comparison:** Unbraced or no ankle brace
- **Outcomes:** Functional performance measures

**Sources of Evidence Search**

- PubMed
- The Cochrane Library
- CINAHL
- PEDro
- SPORTDiscus

**Inclusion and Exclusion Criteria**

**Inclusion Criteria**

- Original research studies evaluating the use of ankle braces during functional performance
- Limited to English language
- Limited to human participants
- Limited to the previous 15 years (2002 – 2016)
- A minimum of level II evidence

**Exclusion Criteria**

- Research studies that did not compare a braced condition to an unbraced condition
- Research studies that did not assess functional performance measures
- Research studies reporting duplicate outcomes data
- Pilot or case studies
- Animal-model experiments

**Results of Search**

Thirty-two articles were identified incorporating the related keywords in the defined electronic databases. Most publications did not incorporate an ankle brace intervention or did not utilize functional performance measures; furthermore, some studies did not incorporate a control condition or sampled an injured population. Of these, only four articles were selected to be included in this CAT (Figure 1).

---

[Diagram: Flowchart showing the search process and exclusion criteria]

**Figure 1:** QUORUM-Statement flow diagram illustrating the results of the literature search
The included articles were classified per the Centre for Evidence-Based Medicine (Oxford, UK). Results of the literature search are listed in Table 1.

Table 1: Summary of Experimental Designs

<table>
<thead>
<tr>
<th>Level of Evidence</th>
<th>Experimental Design</th>
<th>Number Located</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Randomized Controlled Trial</td>
<td>1</td>
<td>Putnam et al(^3)</td>
</tr>
<tr>
<td>II</td>
<td>Prospective Cohort</td>
<td>3</td>
<td>Ambegaonkar et al(^4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hardy et al(^5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Parsley et al(^6)</td>
</tr>
</tbody>
</table>

A PEDro score was used to scrutinize the lone randomize controlled trial.\(^8\) To bolster the qualitative appraisal of the included works, the Downs and Black’s revised checklist was used for assessing methodological quality for all articles employed in this CAT (Table 2).\(^9\)

Table 2: Downs and Black’s revised checklist for measuring study quality (scores by article)

| Article          | 1 | 2 | 3 | 4 | 5* | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27** | Total |
|------------------|---|---|---|---|----|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|------|-------|
| Ambegaonkar et al\(^4\) | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 15  |
| Hardy et al\(^5\) | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 15  |
| Parsley et al\(^6\) | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 13  |
| Putnam et al\(^3\) | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 15  |

1 = yes; 0 = no, or unable to be determined based on available information
*2 = yes; 1 = partially; 0 = no
**5 point scale; 0 = no
Best Evidence

Table 3 identifies the best available evidence based on the literature review. All studies were ranked at a minimum of level II evidence, and incorporated the use of an ankle brace compared to an unbraced condition during various functional performance measures. Comparison to other bracing conditions were also included in this review. Post-hoc analyses were conducted using effect sizes and were categorized according to Cohen. \(^{10}\)

Table 3: Characteristics of Included Research Studies

<table>
<thead>
<tr>
<th>Study design</th>
<th>Ambegaonkar et al(^4)</th>
<th>Hardy et al(^5)</th>
<th>Parsley et al(^6)</th>
<th>Putnam et al(^3)</th>
</tr>
</thead>
</table>
| Participants | 10 healthy volunteers (4 males, 6 females) 
Age: 25.6 ± 2.8 years | 36 physically active, healthy male and female college-aged volunteers (18 males, 18 females) 
Age: 23.6 ± 2.7 years | 24 physically active, healthy male participants 
Age: 20.9 ± 2.7 years | 20 recreational and collegiate soccer players (5 males, 15 females) 
Age: 23.0 ± 4.8 years |
<p>| Subjects included if they did not report | | | | |
| (1) A previous experience wearing an ankle stabilizer. | Subjects included if they did not report | Subjects included if they did not report | Subjects included if they did not report | |
| (2) A history of any ankle injury in the previous 1-year period. | (1) Somatosensory condition that could impair balance. | (1) A previous history of musculoskeletal injury to the knees or ankles. | (1) Male |
| Subjects were excluded if they were not | (2) Previous head injury resulting in a loss of consciousness. | Subjects excluded if they were not | (2) Physically active |
| (1) Healthy | | (2) Physically active | |
| | | | (2) A history of cardiovascular medical problems |</p>
<table>
<thead>
<tr>
<th>intervention Investigated (Control &amp; Experimental)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control:</td>
</tr>
<tr>
<td>(1) Unbraced (nonsupport condition)</td>
</tr>
<tr>
<td>Experimental:</td>
</tr>
</tbody>
</table>

Subjects excluded if they were not

1. Healthy college-aged volunteers
2. Physically active
3. Lower extremity injury or feelings of “giving way” that resulted in any time loss of physical activity from practice or competition within the past year.
4. Feelings of either ankle giving way at the time of the study and unrelated to previous injury.
5. Flu-like or cold-like symptoms within the past 6 weeks.
6. Pregnancy
7. Unable to perform the Star Excursion Balance Test (SEBT) during the practice session.

Subjects excluded if they were not
1. Healthy soccer players who had been actively involved in organized soccer throughout the past 2 years.
<table>
<thead>
<tr>
<th>Outcome Measures (Primary &amp; Secondary)</th>
<th>Main Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 performance measures:</td>
<td>No significant differences between vertical jump test height ($F_{1,1.9} = 1.42, P = .27$) or dynamic balance scores ($F_{3,2.7} = 2.43, P = .08$) across ankle support conditions.</td>
</tr>
<tr>
<td>(1) Vertical jump test (Sargent Chalk Jump)</td>
<td>Bracing condition had no statistical effect on any of the SEBT directional measures ($P &gt; .05$)</td>
</tr>
<tr>
<td>(2) The Right-Boomerang Run Test</td>
<td>Vertical jump significant main effect for brace condition ($P &lt; .01$) All three brace conditions significantly reduced vertical jump height compared to the unbraced</td>
</tr>
<tr>
<td>(3) The Modified Bass Test of Dynamic Balance</td>
<td>For the first testing session there were no statistical differences found between unbraced and braced conditions between all performance measures</td>
</tr>
<tr>
<td>SEBT measured in 8 directions.</td>
<td>Accuracy shooting at a target with a soccer ball</td>
</tr>
<tr>
<td>3 performance measures:</td>
<td>40 yard dash</td>
</tr>
<tr>
<td>(1) Anterior</td>
<td>S180° run</td>
</tr>
<tr>
<td>(2) Anterior-Medial</td>
<td>T test</td>
</tr>
<tr>
<td>(3) Medial</td>
<td>Self-reported questionnaire for attitude towards ankle brace.</td>
</tr>
<tr>
<td>(4) Posterior-Medial</td>
<td></td>
</tr>
<tr>
<td>(5) Posterior</td>
<td></td>
</tr>
<tr>
<td>(6) Posterior-Lateral</td>
<td></td>
</tr>
<tr>
<td>(7) Lateral</td>
<td></td>
</tr>
<tr>
<td>(8) Anterior-Lateral</td>
<td></td>
</tr>
<tr>
<td>4 performance measures:</td>
<td></td>
</tr>
<tr>
<td>(1) Accuracy shooting</td>
<td></td>
</tr>
<tr>
<td>(2) 40 yard dash</td>
<td></td>
</tr>
<tr>
<td>(3) S180° run</td>
<td></td>
</tr>
<tr>
<td>(4) T test</td>
<td></td>
</tr>
<tr>
<td>Non-weight bearing range of motion (ROM):</td>
<td></td>
</tr>
<tr>
<td>(1) Plantarflexion (PF)</td>
<td></td>
</tr>
<tr>
<td>(2) Dorsiflexion (DF)</td>
<td></td>
</tr>
<tr>
<td>(3) Inversion (IV)</td>
<td></td>
</tr>
<tr>
<td>(4) Eversion (EV)</td>
<td></td>
</tr>
<tr>
<td>Ankle Brace; McDavid Inc.</td>
<td></td>
</tr>
<tr>
<td>Testing conducted over two testing session. Subjects completed performance tasks in each bracing condition on both days.</td>
<td></td>
</tr>
</tbody>
</table>
Agility run time (seconds) was significantly different across ankle support conditions ($F_{3,27} = 3.55, P = .03$). Post hoc pairwise comparison significantly different between control and semi-rigid brace ($P = .03$)

There was a trend toward significance between the control and Swede-O ($P = .06$) and between the control and tape ($P = .07$)

Agility run effect size’s suggest increases in run times while wearing an ankle stabilizer compared to the control (tape, $d = .33$; Soft-Shell Lace-up, $d = .41$; Semi-rigid, $d = .43$)

<table>
<thead>
<tr>
<th>Agility run time (seconds) was significantly different across ankle support conditions ($F_{3,27} = 3.55, P = .03$). Post hoc pairwise comparison significantly different between control and semi-rigid brace ($P = .03$).</th>
<th>No significant main effect for agility ($P = .70$) or BESS test on either firm ($P = .60$) or foam ($P = .25$) surfaces. Significant main effects were found for all 4 ROM measures while wearing a brace condition compared to the control. All 3 braces significantly reduced ROM compared to the control in DF ($P &lt; .04$), PF ($P &lt; .01$), IV ($P &lt; .01$), and EV ($P &lt; .01$). The lace-up brace compared to the SAO allowed for significantly more DF ($P = .05$), PF ($P &lt; .01$), and EV ($P &lt; .01$) but significantly less IV ($P &lt; .01$). The SAO allowed for significantly more PF ($P = .05$) and EV ($P &lt; .01$) but significantly less IV ($P &lt; .01$) compared to the semi-rigid brace. No statistical differences between the SAO and the</th>
</tr>
</thead>
<tbody>
<tr>
<td>There was a trend toward significance between the control and Swede-O ($P = .06$) and between the control and tape ($P = .07$). Agility run effect size’s suggest increases in run times while wearing an ankle stabilizer compared to the control (tape, $d = .33$; Soft-Shell Lace-up, $d = .41$; Semi-rigid, $d = .43$)</td>
<td>For the second testing session there were no statistical differences found between unbraced and braced conditions between all performance measures (Accuracy shooting ($P = .65$), 40 yard dash ($P = .13$), $S180^\circ$ run ($P = .58$), and T test ($P = .34$). There were no statistical differences found between testing session 1 or 2 ($P = .50$)</td>
</tr>
<tr>
<td>Level of Evidence</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>---</td>
</tr>
<tr>
<td>Validity Score</td>
<td>II</td>
</tr>
<tr>
<td>Conclusion</td>
<td>N/A</td>
</tr>
<tr>
<td>Ankle braces do not affect all performance measures. Depending on the style and type of ankle brace, may limit specific activities.</td>
<td>It has been determined that individuals can use prophylactic ankle braces without consequences to dynamic balance during a reaching task. Ankle braces should not alter a healthy individual’s ability to balance under dynamic conditions.</td>
</tr>
<tr>
<td>Ankle braces with rigid medial and lateral sides may limit motions of inversion and eversion while participating in activity. Clinicians may utilize ankle braces as a device that provides protection, comfort and is cost efficient without affecting a patients' functional performance.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Implications for Practice, Education, and Future Research

Ankle injuries during physical activity are the most common type of musculoskeletal injury during activity, with up to 85% of these injuries classified as ankle sprains. To reduce the incidence of sprains, especially in those with a history of ankle injury, the use of prophylactic ankle braces in young, healthy physically active populations is common. Despite empirical data suggesting ankle bracing as an efficacious injury prevention intervention, the values of patients, clients, sport rehabilitation specialists, and related administrative personnel may influence the decision to employ or refute the use of such apparatuses due to concern for hindering functional performance capacity. Though anecdotal, such concerns should be considered from the perspective of the sport rehabilitation specialist as a means to address the multifaceted components encountered with clinical decision making given the impact braces may have on athletic capacity, or task-specific aptitude with an individual’s participation in sports, or technical job-related demands, respectively.

Based on the results of our surveying the literature, inferences from statistically significant findings suggest that ankle bracing may only yield specific impairments with the Right-Boomerang Run Test and vertical jump height using the Vertec system when compared to an unbraced control condition; therefore, it appears that ankle bracing does not appear to significantly impede most functional performance tasks as determined from various balance, sprint, agility, and sport-specific activities. Both Ambegaonkar et al and Parsley et al suggested their noted performance deficits may have been attributed to potential decreases in joint ROM while wearing the ankle apparatuses. Ankle braces have been shown to decrease talocrural and subtalar joint ROM by mean differences of
14.9° for IV, 14.4° for EV, 3.2° for DF, and 9.3° for PF in a lace-up braced condition when compared to an unbraced condition. Similarly, a semi-rigid braced condition has been found to further restrict ankle ROM by mean differences of 20.2° for IV and 19.8° for EV when compared with an unbraced condition. In an effort to investigate if a similar trend existed in the current appraised articles of this CAT, we used the data of Parsley et al to conduct a post-hoc analyses of ankle ROM when comparing unbraced and braced conditions (Figure 2). Based on our post-hoc findings ankle bracing produces large magnitude decreases in PF with a lace-up apparatus, and large magnitude decreases in IV when wearing an SAO (Figure 2). While ankle braces are designed to limit extreme ROM, particularly in the frontal plane, for preventing injury, it may be that concomitant functional performance deficits may arise from these joint excursion decrements.

![Figure 2: Post-Hoc Ankle Range of Motion Analysis. Unbraced vs Braced Conditions](image-url)
As the result of decreases in joint ROM, impairments to agility run time and vertical jump height may be associated with braces hindering the stretch-shortening cycle at the ankle. This cycle is characterized by a constant transfer from the pre-activated and eccentrically lengthened muscle-tendon complex to the concentric push-off, which is utilized in most activities such as running or hoping. As the muscle lengthens, elastic energy is stored until it is used to help generate increased force during the shortening or push-off phase of locomotion. Bracing the ankle, which restricts ROM in the sagittal and frontal planes, may impede the ability of the triceps surae muscolotendinous unit and other lower extremity musculature to generate forces necessary for peak performance when compared with an unbraced condition.

To aid in clinical decision-making, employing not only statistical significance as a means to discern whether ankle braces definitely impairs functional performance but recognizing the magnitude of change represents an additional factor to consider for weighing statistical in conjunction with potential clinical significance. The heterogeneity of measures presented across the literature in this CAT prevented collapsing the data for an abbreviated meta-analyses; however, given the means and standard deviations found among the research studies, as with the ROM measures, we were able to calculate effect sizes, and associated 95% confidence intervals to provide additional insights for drawing informed conclusions from our focused clinical question. It is also important to note that the type of braces used in these included studies differed by style of brace and by manufacturer. When appraising an array of different ankle braces among available studies, it is paramount to appreciate the variance in bracing types (e.g. rigid, semi-rigid or lace-up) and materials used. These minor design and construction differences may
produce greater ROM restrictions compared to another brace leading to statistically significant differences on functional performance and balance measures, while also making it challenging for direct comparisons.

Our post-hoc analysis of balance focused on three different field tests (Figure 3).

These measures were assessed using either reach distances, an error scoring system that summed total errors or subtracting penalties from a max 100 points. Our calculated effect sizes trended towards either a neutral or small negative effect while wearing a
brace condition. This held true except for the Modified Bass Test where individuals demonstrated a large positive effect size while wearing a lace-up brace condition but moderate impairment while wearing a semi-rigid brace. The Modified Bass Test forces participants to jump to new positions compared to the more stationary SEBT and BESS test. Due to the restrictive nature of ankle braces, the lace-up condition may have provided additional stability to subjects while they completed the task, while the semi-rigid ankle brace may have created too much restriction and impeded the ability of participants to complete the task successfully.

The neutral to small effect sizes noted with SEBT outcomes may be attributed to participants using a compensatory knee or hip joint movement strategy to offset limited ankle ROM in maintaining comparable reach distances when compared with an unbraced condition. With a more static balance test like the BESS, which requires minimal ankle joint excursion, the influence of a brace on performance in this task may not have been a significant factor. An improvement in the Modified Bass Test with a lace-up brace may be potentially explained by the apparatus augmenting joint stability as well as improving proprioception and neuromuscular control while performing this specific task; however, the contrasting deficit noted with this same task while wearing a semi-rigid brace may be attributed to an increased limitation in ankle ROM when compared with a lace-up brace. Compared to the SEBT, and BESS, the Modified Bass Test requires an individual to propel the center-of-mass in a series of directions similar to a single-leg hop test. Greater ROM limitations placed upon the ankle in a semi-rigid brace would theoretically result in a greater negative impact on the stretch-shortening cycle that may be interpreted as
yielding a moderate performance deficit in this task when compared with a less restrictive lace-up brace.

Effect sizes for sprint and agility run tasks are presented in Table 6 and show only two functional performance measures with trends for small, negative effect sizes. Both brace conditions of the Right-Boomerang Run Test increased run times compared to the unbraced condition. Although only one functional performance measure indicates an increase in run times, Figure 4 depicts a negative trend for most measures while wearing ankle braces.

Figure 4: Post-Hoc Sprint and Agility Measures. Unbraced vs Braced Conditions
By placing ankle braces on the lower limb, it is possible that normal movement patterns are limited by these devices and in doing so limits the ability of the ankle to propel the body with the same amount of force. Also, ankle braces that are designed with more rigid medial and lateral side-supports may limit subtalar motion of the ankle, decreasing the ability for the participant to move quickly from side-to-side. While not statistically significant, Putnam et al.\(^3\) presented data that those wearing ankle braces had an increased 40-yard dash time of between 0.11 and 0.12 seconds. During competition, this difference in time may be the reason for winning or losing an event. For those individuals serving in various emergency services and military positions, any deficit in sprint or agility speed may pose unforeseen risks greater than musculoskeletal ankle sprain, such as not being able to move as quickly away from the blast radius of an explosive device. Even though most functional performance measures did not show clinical or statistical significance, specialists working with individuals in a competitive environment should understand that negative effects may arise.

Post-hoc analyses of vertical jump height and sport-specific activities are presented in Figure 5. A trend towards a small negative effect was found in all Vertec jump comparisons, as well as session one soccer ball kicking accuracy in those individuals wearing ankle braces. Limiting ROM and subsequently reducing the ability for the ankle to propel or generate force, an individual may not be able to jump as high or place their lower extremity in the proper position to make accurate shots. For example, if a football wide receiver is wearing ankle braces and has to make a vertical leap to catch a football; ankle braces may limit the ability for that athlete to jump high enough to catch the ball. In addition, from a clinical standpoint, it is paramount that any devices that are
added to an athlete or individual do not place them in a position of greater danger. If the athlete cannot propel themselves out of harms-way due to the restrictive nature of the ankle braces, this may create an injury at another location other than the ankle.

Vertical Jump & Sport Specific Activity
Unbraced vs Braced Conditions

![Effect Size with 95% Confidence Intervals](image)

* Small Effect Size $\geq 0.2 < 0.5^{10}$
** Medium Effect Size $\geq 0.5 < 0.8^{10}$
*** Large Effect Size $\geq 0.8^{10}$

UB: Unbraced
LU: Lace-Up
SR: Semi-Rigid
SAO: Seattle Ankle Orthosis

Figure 5: Post-Hoc Vertical Jump and Sports Specific Activities. Unbraced vs Braced Conditions

There are limitations associated with this CAT, including variability in the types of functional performance test used, especially as it pertains to measures of vertical jump, agility and balance. While this may limit the inferences from this specific body of work, it does appropriately reflect the myriad of different methods a practitioner may employ in real world clinical or applied settings. It should also be noted that with a 95% confidence interval, effect sizes trended towards neutral or negative outcomes but still crossed the zero line, indicating not statistically significant effect sizes but should be noted for
potentially clinically significant effects. Other limitations stem from using articles only published in the English language, and the fact that our outcomes are currently limited to young, healthy, and physically active individuals; therefore, practitioners should use caution in extrapolating our findings to other populations not represented in this CAT. In addition, some articles were eliminated from this study because it was not clearly defined whether a physically active population or sample was being used, thus this may have removed some studies relevant to this CAT. Based on these limitations, further research should be conducted as a means to better clinical decision making when weighing the advantages and disadvantages of using such apparatuses. Nonetheless, the outcomes of this CAT may help sports medicine professionals, athletes, and other individuals who participate in sports or physical activities become more aware of the potential impact ankle braces may have on functional performance.
References


SECTION II: MANUSCRIPT II

PROPHYLACTIC ANKLE BRACING IN MILITARY SETTINGS: A REVIEW OF THE LITERATURE
ABSTRACT

**Background:** Within athletics and the military, ankle sprains are one of the most common injuries with the potential for long-term functional deficits. Incidence rates for ankle sprains within the military are one of the leading causes of limited duty days, especially during basic combat training, parachute-training exercises, and in cadet populations. In 2008, the Department of Defense U.S. Army Center for Health Promotion and Preventative Medicine (USACHPPM) report recommended that military personnel should wear semi-rigid ankle braces during parachuting, basketball, soccer and other similar high-risk activities to reduce ankle sprain injuries. This recommendation was developed using a majority of athletic references with limited data stemming from military works. Of these included military studies, none presented data on ankle braces and their effects on performance, especially in military specific environments. The purpose of this review was to provide an up-to-date account on the use of ankle braces in military populations and effects on performance measures. **Methods:** A comprehensive online systematic review of the literature was conducted to delineate the current use of ankle braces in the military and how they specifically affect functional performance measures. The scope of this study eliminated military studies that were not prospective in nature or did not incorporate subjects wearing military equipment (i.e. combat boots etc.) **Findings:** It was determined that little progress has been made in validating the use of semi-rigid ankle braces in military populations other than in instances such as parachuting and only in reducing the number ankle injuries. To date, only one study has looked specifically at the use of ankle braces and its effects on performance measures in a military sample. **Discussion:** With the high incidence rate and increased risk for subsequent re-injury, ankle sprains are an economic and force readiness burden to the United States Armed Forces. This current study was conducted to determine whether additional literature was available for the use of ankle braces on performance measures in the military. It was determined that there is a scarcity of information currently available on the use of ankle braces in military populations, outside of parachuting activities. The Department of Defense recommendation of using semi-rigid ankle braces may ultimately be beneficial to a multitude of high-risk military activities, but further research must be conducted to determine possible detrimental performance effects.
The Department of Defense employs over 1.3 million active duty and over 826,000 reserve service members.\textsuperscript{1,2} For these service men and women, some of the greatest risks to their health and force readiness occur while they are exposed to physical training and other extracurricular activities such as sports. Just as in athletics, musculoskeletal injuries are considered a large medical problem associated with force readiness and limited duty days in the military.\textsuperscript{3,4} Abt et al\textsuperscript{5} followed U.S. Army Special Operations Forces for a 1-year period and found that the three most common events where injuries occurred were; all types of physical training (57.7%), recreational activity/sports (11.5%) and tactical training (15.4%). Service members injured during combat only accounted for 3.8% of all injuries recorded during this 1-year period.\textsuperscript{5} Injury surveillance of two U.S. military units indicate that physical training exposes military service members to the greatest risk for injury.\textsuperscript{6} Ruscio et al\textsuperscript{7} in an article pertaining to injury prevention priorities, determined that sports and physical training accounted for the second leading cause of injury, behind falls, at 15.8%.

In the military, injuries to the ankle are one of the most commonly reported and leading causes of limited duty days in both training and combat.\textsuperscript{5,8-10} It is also important to note that there is a greater likelihood for ankle sprain injury in those individuals unaccustomed to military activities. Ankle injury rates are also highest in advanced units; basic trainees\textsuperscript{6,11-13}, cadets\textsuperscript{14,15} and special forces\textsuperscript{5,16}. Almeida et al\textsuperscript{12} in 1999 reported that ankle sprains, of all reported injuries, had the highest incidence of injury during physical training in army trainees. Following an ‘Army Brigade Combat Team’ over 15 months during Operation Iraqi Freedom, Belmont et al\textsuperscript{13} determined that ankle injuries had the
highest incidence rate among all musculoskeletal injuries at 15.30 per 1,000 combat years. This was lower than 34.95 per 1,000 person years reported in an epidemiological study for ankle sprain injuries in active duty service members.\textsuperscript{17} Carow et al\textsuperscript{15} in 2014 monitored a cadet population over the course of an academic year and reported that of all injuries ankle sprains were the most common academic-year injury with 36%. During their 6 week Cadet Basic Training program, ankle sprains were the second highest reported injury with 48 of 196 injuries.\textsuperscript{15} The Eagle Tactical Athlete Program, developed by Sell et al\textsuperscript{16} recruited soldiers from the 101st Airborne where ankle sprains were determined to be the highest reported injury.\textsuperscript{16}

The Department of Defense (DoD) issued a U.S. Army Center for Health Promotion and Preventative Medicine (USACHPPM) report, NO. 21-KK-08QR-08 in 2008, recommending that “semi-rigid” ankle braces should be utilized during participation in high-risk physical activity.\textsuperscript{18} This included physical activities such as airborne operations (parachuting), basketball, soccer and other similar high-risk activities.\textsuperscript{18} Unfortunately, this USACHPPM recommendation was largely supported by athletics related studies, with only 8 of 26 references incorporating military populations.\textsuperscript{19-26} Ankle braces were incorporated in six of these eight studies, but only incidences of ankle sprains were collected with no performance measurements evaluated.\textsuperscript{19-21, 23, 25, 26} Only one of these studies did not present data on the parachute ankle brace but looked at treatment, using an ankle brace, after an acute inversion ankle sprain.\textsuperscript{23}

Many factors are currently unknown about the effects of ankle bracing and performance measures in military service members. The USACHPPM recommendation
is to use prophylactic semi-rigid ankle braces during high-risk activities, it is imperative to understand the effects on injury prevention and functional performance measures such as time to complete an objective, ankle strength, power and balance. To our knowledge, there is currently a void in the literature of the effects of ankle braces on military service members’ functional performance. It is the purpose of this paper to systematically identify peer-reviewed articles that answer our clinical questions: (1) Do ankle braces effect functional performance measures while participating in military specific activities or (2) other performance measures while wearing military specific uniform and gear (e.g. combat boots, ruck sack, etc...)?

**METHODS**

**Search Strategy**

This systematic review was completed using the guidelines provided by the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) statement. Studies were evaluated by all members of the investigatory team.

In February of 2016, we performed an online search using the following databases: (1) Web of Science, (2) CINAHL, (3) Cochrane Database, (4) PEDro Database, (5) Science Direct, (6) PubMED and (7) SPORTDiscus. Also included were military sources used in the 2008 DoD recommendation for the use of semi-rigid ankle braces. The search strategy was developed with the purpose of acquiring studies that used military subjects and incorporated ankle braces as an intervention. Studies were also reviewed for performance measures while in military gear and ankle braces.

The following terms were used in each Boolean search of databases: (1) *military OR army or navy OR marines OR ‘air force’ OR ‘coast guard’ OR reserve OR ‘national*
guard’ OR academy OR cadet, (2) ankle OR ‘ankle joint’, (3) brace OR ‘outside the boot’ OR ‘parachute brace’ OR stabilizer OR semi-rigid, (4) 1 AND 2 AND 3. Incorporating the search terms ‘functional performance’ or performance resulted in a return too narrow to evaluate.

Online searches were limited to peer-reviewed journal articles from 1985 to February 3, 2016. Only original research articles that were published in English, with full abstract and text were reviewed in this study. One investigator evaluated all articles based on titles and distributed suitable abstracts to the other two investigators.

Included Studies

For this study there was no blinding of the study author, place of publication or database results. The inclusion criteria was as follows:

(1) The study must use healthy military subjects.

(2) The study used ankle braces of any design or fabrication. This includes braces that are categorized as non-rigid, semi-rigid and rigid. Braces can be worn inside or outside the military boot.

(3) The design study must be prospective.

There were no restrictions on subject age, sex or military rank. Review articles and case studies were exclude. Any type of conference abstract were not reviewed on the basis of their limited availability in these electronic databases. One article was included from the USACHPPM recommendation for further analysis based on its military population and ankle brace utilization.21

Study Quality Assessment
All studies were independently evaluated using the PEDro (Physiotherapy Evidence Database) scale for methodologic quality. This is a 10-point assessment, with higher PEDro scores indicating higher-quality study design (Table 1). Differences in scoring were resolved using the mean of all three investigators scores, with any discrepancies resolved by consensus. Overall scores were calculated by summing the criteria for a score out of 10.

Table 1: PEDro scale used for analysis of articles to determine internal validity of suspected or known randomized clinical trials

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)</td>
</tr>
<tr>
<td>1</td>
<td>Allocation was concealed</td>
</tr>
<tr>
<td>1</td>
<td>The groups were similar at baseline regarding the most important prognostic indicators</td>
</tr>
<tr>
<td>1</td>
<td>There was blinding of all subjects</td>
</tr>
<tr>
<td>1</td>
<td>There was blinding of all therapists who administered the therapy</td>
</tr>
<tr>
<td>1</td>
<td>There was blinding of all assessors who measured at least one key outcome</td>
</tr>
<tr>
<td>1</td>
<td>Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups</td>
</tr>
<tr>
<td>1</td>
<td>All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by “intent to treat”</td>
</tr>
<tr>
<td>1</td>
<td>The results of between-group statistical comparisons are reported for at least one key outcome</td>
</tr>
<tr>
<td>1</td>
<td>The study provides both point measures and measures of variability for at least one key outcome</td>
</tr>
</tbody>
</table>

**Final Score** 10

RESULTS

Search Strategy

We initially identified 274 electronic articles that met our original search strategy, with one additional article added from the original Department of Defense
recommendation. Figure 1 identifies the strategy used to screen and assess individual articles for this review.

**Search Process**

<table>
<thead>
<tr>
<th>Total number of articles screened: n = 274</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web of Science: n = 122</td>
</tr>
<tr>
<td>CINAHL: n = 34</td>
</tr>
<tr>
<td><em>Cochrane</em> Central Register of Controlled Trials: n = 11</td>
</tr>
<tr>
<td>PEDro: n = 0</td>
</tr>
<tr>
<td>Science Direct: n = 47</td>
</tr>
<tr>
<td>PubMed: n = 41</td>
</tr>
<tr>
<td><em>SPCR</em>DIScuss: n = 18</td>
</tr>
<tr>
<td>Other: n = 1</td>
</tr>
</tbody>
</table>

**Excluded**

- Based on title: n = 238
  - No ankle brace used
  - No military sample
  - Injured sample
- Duplicate: n = 13
- Based on abstract: n = 12
  - No military sample
  - No ankle brace used
  - Systematic Review
  - Retrospective Design
- Based on full text: n = 6
  - Systematic review article
  - Not military sample
  - Only Injured sample

A total of 11 full texts were pulled for comprehensive examination. After obtaining each article and evaluation of full text, four articles were removed for being systematic reviews of the literature. The first three articles were removed from further review because they were systematic reviews of the parachute ankle brace or general risk factors associated with parachuting.\textsuperscript{20, 29, 30} The fourth was a systematic review of recommendations for the military and other active populations which included the original 2008 DoD recommendation to use ankle braces during high-risk activities.\textsuperscript{3} Another article was
removed from further analysis because its subject population did not perform military specific activities while wearing an ankle brace but rather evaluated military cadets while participating in basketball. A final article was removed because it was a prospective study on the effects of ankle bracing after ankle ligament sprain. Five articles were used for the purposes of this review.

**Included Studies Characteristics**

Of the five articles that were obtained, three used military personnel completing the U.S. Army Basic Airborne Course. The fourth article incorporated Israeli border police fighters and the fifth article used military institution cadets. One article explicitly did not recruit females as part of their study, two studies did not identify if women were recruited, and one study stated that females were recruited. Four of the five articles’ primary purpose was to identify injury differences between braced and non-braced conditions while wearing the parachute ankle brace. The parachute ankle brace has previously been analyzed in the systematic review by Knapik et al for its effectiveness of reducing ankle injuries. Due to this recent systematic review of the parachute ankle brace and injury rates, further analyses of this specific topic was not evaluated. Of the five articles acquired in this systematic review of the literature, only one identified any effects of ankle braces on performance measures in military subjects (Table 2). Newman et al assessed the effects of prophylactic ankle braces on dynamic reach distance and obstacle performance times.
Table 2: Evaluated articles and their characteristics pertaining to ankle brace use in a military setting

<table>
<thead>
<tr>
<th>Authors</th>
<th>PEDro Score</th>
<th>Study Design</th>
<th>Study Population</th>
<th>Intervention</th>
<th>Main Outcome(s)</th>
<th>Dependent Variable(s)</th>
<th>Duration of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amoroso et al(^{38})</td>
<td>5</td>
<td>Randomized controlled trial</td>
<td>All U.S. Army Airborne School Trainees</td>
<td>The parachute ankle brace</td>
<td>Injuries associated with parachute landings between brace condition</td>
<td>Number of and location injuries and risk ratio for non-braced group</td>
<td>3 - weeks</td>
</tr>
<tr>
<td>Amoroso et al(^{22})</td>
<td>N/A</td>
<td>Prospective cohort</td>
<td>U.S. Army Airborne School Trainees</td>
<td>An outside-the-boot ankle brace</td>
<td>Injuries associated with parachute landings between brace condition</td>
<td>Number and location of injuries and risk ratio for unbraced group</td>
<td>3 - weeks</td>
</tr>
<tr>
<td>Knapik et al(^{37})</td>
<td>N/A</td>
<td>Prospective cohort</td>
<td>U.S. Army Airborne School Trainees</td>
<td>The parachute ankle brace</td>
<td>Injuries associated with parachute landings between brace condition</td>
<td>Number and location of injuries, ankle injuries and extrinsic risk factors (i.e. wind speed, jump type)</td>
<td>Not specified</td>
</tr>
<tr>
<td>Mann et al(^{24})</td>
<td>N/A</td>
<td>Prospective cohort</td>
<td>Israeli border police fighters</td>
<td>The parachute ankle brace</td>
<td>Ankle sprain injuries associated with physical training course between brace condition</td>
<td>Number of ankle sprains and recurrent ankle sprains following completion of physical training course</td>
<td>3 months</td>
</tr>
<tr>
<td>Newman et al&lt;sup&gt;36&lt;/sup&gt;</td>
<td>6</td>
<td>Randomized controlled trial</td>
<td>Healthy male cadets</td>
<td>McDavid 195R Ultralite Ankle Guard</td>
<td>Performance measures between brace conditions</td>
<td>Time to complete military obstacle course Dynamic reach distance</td>
<td>3 trials over 3 testing days</td>
</tr>
</tbody>
</table>
DISCUSSION

This review of the literature demonstrated a lack of evidence that adequately supports the USACHPPM recommendation for using semi-rigid ankle braces during high-risk activities. It is important for investigators to determine if the athletics studies included in the DoD recommendation are translatable to a military setting which assess the effects of ankle braces on factors other than ankle sprain injury reduction in parachuting. This recommendation, supported by a limited cohort of military studies, does not successfully illustrate how ankle braces effect military personnel during military specific tasks. In the military, current ankle bracing research has been limited to their effects on reducing ankle sprain injuries and the incorporation of the parachute ankle brace. There is little to no data available on how other styles and types of braces effect incidences of ankle sprains nor the effects on functional performance tasks in the military.

Amoroso et al\textsuperscript{34} in 1994 completed one of the earliest studies comparing military parachutists while wearing the parachute ankle brace and no ankle brace. This group chose to delve into this activity because of ankle injuries representing a predominate injury in both military and civilian parachuting. There were 745 subjects that completed the 3-week parachute training. Ankle sprains accounted for the largest percent of injuries, 32.4\%, and lateral/ATF sprains alone accounted for 21.6\% of all injuries.\textsuperscript{34} There was also a statistically significant risk ratio between non-brace and brace conditions in terms of inversion sprain injuries, 6.3:1 (p = 0.04).\textsuperscript{34} The parachute ankle brace consists of a hard plastic outer shell lined with air bladders on both medial and lateral sides of the ankle. This prevents extreme ankle inversion and eversion while allowing plantarflexion and dorsiflexion.\textsuperscript{25}
In a subsequent study, Amoroso et al\textsuperscript{19} reported that ankle injuries were the predominant injury, accounting for 40.5\% of all injuries and of those 53\% were inversion or lateral anterior talofibular sprains.\textsuperscript{19} The outside-the-boot brace used for this study reduced the incidence of ankle sprains by 85\% and did not cause other types of injuries.\textsuperscript{19} In a separate retrospective study conducted by Luippold et al\textsuperscript{35}, the parachute ankle brace was assessed during US Army trainee Jump School. This team concluded that wearing the parachute ankle brace reduced the risk of ankle injury by 40\% while not reducing any other injuries.\textsuperscript{35} This is similar to a previous study that demonstrated a 40-55\% reduction in ankle injuries\textsuperscript{25}, while a separate study places the relative risk ratio without brace to with brace of ankle injury at 2.93:1.\textsuperscript{26}

Knapik et al\textsuperscript{33} in 2008, evaluated the parachute ankle brace and its effectiveness to reduce injuries on landing. This study also led to similar conclusions, with the parachute ankle brace reducing the incidence of ankle injuries on landings. While wearing the parachute ankle brace, trainees had an ankle sprain injury incidence of 8.4 per 1,000 jumps.\textsuperscript{33} This statistic nearly doubles in those trainees that did not wear the parachute ankle brace, 16.7 per 1,000 jumps.\textsuperscript{33} Currently, the military research that has been conducted on parachuting has demonstrated the need for a protective device to reduce ankle injury while completing parachute landings.\textsuperscript{19, 33, 34}

Mann et al\textsuperscript{21} monitored Israeli border police fighters to evaluated the effects of the parachute ankle brace on injury. Differentiating itself from the other parachute brace studies, subjects were randomized into brace condition during a three month advanced commanding course. During this time, subjects wore braces during physical training and other activities associated with military duty. There were statistically significant
differences between bracing condition, with 58.5% of the no brace group sustaining an ankle sprain, while there were only 18% of the braced group. This study may have had the opportunity to record and report on functional performance measures during training but only reported additional details on the quality of the brace.\textsuperscript{21}

In the military, the parachute ankle brace is removed immediately or shortly after parachuting, providing no further protective measures during subsequent high-risk activities. This is unlike athletic events where prophylactic ankle braces are worn during the entirety of the competition to reduce the risk of injury. It is noted that the DoD states that semi-rigid ankle braces have been recommended for high-risk physical activities such as basketball, soccer and other similar activities.\textsuperscript{18} In these events and other similar activities, an ankle brace is not removed during competition unless for extenuating circumstances. Parachute ankle braces are thus limited in their functional role of being able to provide adequate protection beyond the act of parachuting.

Parachute ankle braces are not designed to be worn for extended periods of time or for military specific tasks outside the act of parachuting itself. Moreover, the parachute ankle brace has had little evaluation for any effects on military specific functional performance. It is stated in a 2013 Static Line and Parachuting Techniques and Training manual, that the parachute ankle brace should only be used for short distances if necessary after landing, due to the tactical situation.\textsuperscript{36} Mann et al\textsuperscript{21} states the parachute ankle brace was comfortable during walking however comfort was reduced when subjects were made to run during their military activities. The mechanism whereby the parachute brace reduces ankle injury is currently unknown. It has been speculated though that the rigid external brace acts as a splint, effectively reducing ankle inversion and eversion motions upon
impact. This reduces excessive range of motion at the ankle limiting the exposure for injury.  

Military ankle bracing studies have primarily focused on reducing injury while wearing the parachute ankle with little focus on functional performance measures. This contrasts to athletic and civilian populations, where there have been many studies evaluating potential functional performance interactions while wearing ankle braces. Parsley et al\textsuperscript{37} indicated that of the three prophylactic ankle braces tested, none had a detrimental effect on agility and balance with also no clinical meaningful restriction in vertical jump. Although, this group did find range of motion restrictions while wearing an ankle brace.\textsuperscript{37} Another study assessing the Star Excursion Balance Test and reach distances showed no statistically significant deficits while wearing a prophylactic ankle brace.\textsuperscript{38} Eils et al\textsuperscript{39} conducted a prospective analysis of ten commercially available ankle braces and concluded that all significantly restricted range of motion compared to the no-brace condition. It is the purpose of prophylactic ankle bracing to restrict excessive inversion of the subtalar joint while allowing normal sagittal plane performance.\textsuperscript{40-42} 

Cordova et al\textsuperscript{43} performed a meta-analysis of 17 randomized controlled trials. These studies used cross-over designs to measure bracing effects (tape, semi-rigid and lace-up) on performance measures. Sprint speed was effected most by lace-up braces with a performance impairment of 1%, while a 1% decrease was found in all bracing conditions for vertical jump height.\textsuperscript{43} Agility was only negatively affected by 0.5% while wearing all bracing conditions.\textsuperscript{43} It was concluded by the authors that these negative effects may be trivial for most individuals but may have a greater effect on elite athletes. Bot et al\textsuperscript{44} conversely indicated in a systematic review of the literature, that ankle bracing hardly
affects or has no effect on vertical jump height, running speed, agility and broad jump performance. This group did conclude though that due to differences in ankle brace design, increased restriction in plantarflexion may consequently impair athletic performance especially in vertical jump height.\textsuperscript{44}

There is a scarcity of data to establish ankle braces as an effective tool to reduce ankle injuries in anything other than military parachuting activities. The research used to establish the DoD ankle brace recommendation relied heavily on sports that require no military like equipment such as basketball, soccer and volleyball.\textsuperscript{18} These sports do not place athletes in situations where they will be carrying a heavy load or equipment while trying to perform their intended activity. It is unfounded to believe these populations’ best replicate the types of situations that military service members are placed in during physical training and combat. Although athletics and military training are similar, differences in footwear, equipment and functional requirements necessitate further evaluation of ankle braces in military-specific settings and tasks.

There is a dearth of data available to the effects of ankle bracing on performance measures and tasks in the military, and this is only reinforced by a comprehensive 2015 text, \textit{Musculoskeletal Injuries in the Military}\textsuperscript{45}. In this text only one article is presented that reports on any performance related measures while wearing an ankle brace in the military.\textsuperscript{32} This study recruited healthy male cadets at the Virginia Military Institute where cadets wore in-the-boot ankle braces while completing performance tasks. Testing was conducted over three sessions approximately one week apart. Cadets were randomized in to one of three bracing conditions (bilateral, unilateral and no brace) during each session. Testing included a modified Star Excursion Balance Test (SEBT) (anterior, posterior and posterior
medial) to evaluate reach distances and time to complete a military obstacle course. In this study, it was determined that bilateral prophylactic ankle braces, worn inside a military boot, reduced reach distances in the anterior (4.2 ± 8.1%), posterior (4.9 ± 9.0%) and composite (2.6 ± 6.7%) reach directions.\textsuperscript{32} In the anterior reach direction there was a small negative effect size for wearing bilateral ankle braces compared to the control of no ankle braces (ES = -0.47, CI = -.93 to -.01).\textsuperscript{32} On the military obstacle course there were no effects of ankle brace condition on time.\textsuperscript{32}

This study is the first known research to identify ankle-bracing effects on functional performance in a military sample. It was concluded that there were significant effects on dynamic reach distances but none were found in completing the military obstacle course based on time in seconds.\textsuperscript{32} Limitations to this study included a small sample of only 37 cadets, no females and testing performed in only Army Combat Uniforms with no loads such as a rucksack. Further studies need to be conducted to address a larger sample population and military specific activities while wearing loads comparable to that found in combat and other military situations.

**CONCLUSION**

The USACHPPM recommendation of wearing ankle braces during high-risk activities may be beneficial for service members in reducing the rate of ankle injuries, specifically ankle sprains.\textsuperscript{18} Unfortunately, this is largely limited to data that is derived from one type of ankle brace and the very unique situation of parachuting. There are not enough studies that replicate military specific activities and utilize military populations for the evaluation of ankle braces during various performance measurements. This
recommendation implies that it is not limited to just parachuting but to a range of high-risk physical activities, i.e. basketball, soccer and other similar activities. For the military, it is imperative that further research is conducted to identify any possible effects on performance that prophylactic ankle bracing may have using military specific populations. Developing a better understanding of how ankle braces influence various performance measures specific to military tasks and equipment, may help to better support this Department of Defense recommendation.
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SECTION II: MANUSCRIPT III

THE EFFECTS OF PROPHYLACTIC ANKLE BRACING IN RESERVE OFFICERS’ TRAINING CORPS CADETS AND MIDSHIPMEN DURING FUNCTIONAL PERFORMANCE MEASURES
ABSTRACT

Background: Ankle sprains are one of the most common injuries found in both civilian and military populations. Such injuries are the leading cause of limited duty days, especially during basic combat training, parachute training exercises, cadet populations. The Department of Defense U.S. Army Center for Health Promotion and Preventative Medicine (USACHPPM) recommends that military personnel wear semi-rigid ankle braces during parachuting, basketball, soccer and other similar high-risk activities to reduce ankle sprain risk. It has been previously reported that ankle braces create deficits in reach excursions but no differences in time to complete a military obstacle course. This study aimed to assess the influence an inside-the-boot ankle brace has on military personnel using a loaded rucksack on dynamic reach distances and functional performance measures. Methods: Thirty-two healthy Reserve Officers’ Training Corps (ROTC) subjects from a university setting participated in this randomized crossover study. (Female = 12, Male = 20, 20.5 ± 2.5 yrs., 173.4 ± 11.1 cm, 73.1 ± 10.7 kg) Subjects were placed in two ankle-bracing conditions, bilateral lace-up brace and no brace. Findings: Bracing condition had a statistically significant effect on normalized dynamic reach in the anterior ($P=0.01$, -3.4 ± 7.1%), posterior-medial ($P=0.02$, -3.1 ± 7.3%) directions and overall composite reach ($P=0.003$, -2.8 ± 5.1%). Functional performance measures were also negatively impacted in the bracing condition with decreases in vertical jump height ($P=0.001$, -2.3 ± 3.5 cm) and broad jump distance ($P=0.007$, -5.5 ± 10.8 cm) and increased obstacle course completion time ($P=0.002$, 0.90 ± 1.5 seconds). Post-hoc clinical effect sizes were calculated. All reach directions and functional performance measures were not statistically significant. Discussion: Ankle braces in military combat boots create a negative outcome for dynamic reach tasks. This study concluded that with a loaded rucksack, ankle braces might cause negative impacts on functional performance measures. While wearing ankle braces, translation of these negative dynamic reach and functional performance outcomes will have an effect on range of motion, jumping, sprint, and agility activities.
Background

Ankle sprains, specifically injury to the lateral ankle ligaments are one of the most common injuries sustained.\textsuperscript{1-3} Lateral ankle sprains have been traditionally been attributed to excessive inversion and plantar flexion forces, but recent studies have indicated foot inversion and internal rotation the primary mechanism for injury.\textsuperscript{4} This injury produces 4.4 million emergency department visits per year, with an estimate 25,000 lateral ankle sprain occurring each day in the United States.\textsuperscript{5,5} Musculoskeletal injuries sustained in the military, have an impact on the ability to complete mission objectives and maintain force-readiness.

Musculoskeletal injuries are the greatest risks to health and force-readiness for military service members.\textsuperscript{5-8} Physical training and related activities such as sports are considered primary factors for generating limited-duty-days and decreasing force readiness.\textsuperscript{7,9,10} Musculoskeletal injuries account for approximately 25 million limited-duty-days annually according to the Department of Defense.\textsuperscript{7} In the Army, the principal reason military service members are unable to deploy is because of musculoskeletal injuries with an estimated 68,000 soldiers unable to deploy due to non-combat related injuries, contributing to 2.2 million medical encounters.\textsuperscript{6} Twenty-two thousand male recruits annually attend basic training at the Marine Corps Recruit Depot in San Diego, California and experience an estimated 53,000 lost training days due to injury, resulting in approximately $16.5 million in injury-related expenses.\textsuperscript{11} Women have demonstrated a higher incidence rate for all injuries compared to men and over twice the limited duty days during basic combat training.\textsuperscript{12} Songer et al\textsuperscript{13} in 2000 estimated that annual military medical disability payments were anywhere between $1.2 billion to $1.5 billion. The Army alone has an estimated lifetime cost of new disabilities compensated at approximately $500 million annually.\textsuperscript{13}

In the military, ankle sprains are one of the most common musculoskeletal injuries sustained during physical training and active duty.\textsuperscript{14-16} It has been reported that ankle injury rates are the highest in basic trainees\textsuperscript{14,17}, cadets\textsuperscript{18}, and special forces\textsuperscript{10,19}. Knapik et al\textsuperscript{20} revealed that
behind fractures, ankle sprains are the second leading cause of limited duty days with an average of 16.7 days per injury. In the cadet population at West Point, Waterman et al\textsuperscript{18} found that ankle sprain injuries occurred at an overall injury rate of 58.4 per 1000 person-years, with 82.7\% of ankle injuries occurring at the lateral ligament complex. Scott et al\textsuperscript{21} found a 29.3\% incident rate of injuries to the ankle in an Army ROTC unit.

In studies of athletic populations, the effect of ankle braces on lower extremity balance and functional performance have largely been established.\textsuperscript{22} Static and dynamic balance assessed using the SEBT\textsuperscript{23}, Modified Bass\textsuperscript{24}, and BESS\textsuperscript{25} tests, have shown no negative statistically significant effects comparing a brace to no brace condition. Functional performance measures, such as jump distance and agility time, are unaffected by the use of ankle braces.\textsuperscript{24-26} The literature only indicates small statistically significant differences in vertical leap tests while wearing ankle braces, but these differences have not been demonstrated to be clinically meaningful.\textsuperscript{22,25}

Due to the research that has been conducted in civilian populations, Newman et al\textsuperscript{27} in 2012 evaluated the effects of ankle braces on balance and functional performance in a military population. It was determined that ankle brace conditions compared to a no brace condition, do indicate smaller reach distances obtained during a dynamic balance task but no statistically significant results on obstacle course performance time.\textsuperscript{27} In this novel study, male cadets were evaluated while wearing their combat uniforms and boots, with no external load such as a rucksack or weapon. In military populations, loaded rucksacks and other gear are regularly carried during physical training and active duty deployments. This increase in mass could affect how ankle braces impact balance and functional performance measures.

The purpose of this study was to determine if the use of a lace-up ankle brace inside a military combat boot with a loaded rucksack would have an effect on functional performance measures and dynamic balance. Our hypothesis is that the use of this lace-up ankle brace would
have small detrimental effects on dynamic balance compared to the no brace condition and no overall deficits on any of the functional performance measures while wearing an ankle brace.

**Methods**

This study utilized a randomized crossover design. The dependent variables assessed in this study were functional performance measures and dynamic balance. Functional performance was tested by vertical jump, broad jump, and a 30-meter obstacle course. Dynamic balance was assessed using a modified Star Excursion Balance Test (SEBT). Bilateral ankle braces and no ankle braces were the two independent variable conditions. All subjects performed each functional performance and dynamic balance tasks in both the braced and unbraced condition.

For dynamic balance, the dependent variables were anterior, posterior, posterior medial, and composite reach. Composite reach was calculated by adding each reach direction by brace condition and dividing by three. Statistical analysis was also run normalized to subject limb length by dividing each excursion distance by a participant’s leg length, and then by multiplying by 100. These normalized values are viewed as a percentage of excursion distance in relation to a participant’s leg length. Functional performance dependent variables included vertical jump height (cm), broad jump distance (cm), and obstacle course time (seconds). Vertical jump height was calculated by taking the jump height minus the standing reach of each subject.

**Subjects**

Subjects were thirty-two healthy, physically active, current ROTC cadets or midshipmen (male = 20, female = 12, height = 173.4 ± 11.1 cm, mass = 73.1 ± 10.7 kg, age = 20.5 ± 2.5 years). Sixteen were midshipmen from the Naval ROTC and 16 were cadets from the Army ROTC. (Table 1) Subjects filled out a health history questionnaire as well as previous history of ankle sprain injury and were included if they had no current injury to the lower extremity within the past six months. History of ankle sprain injury was reported in 14 of 32 subjects sustaining one or more (Naval = 7, Army = 7).
Table 1. Demographic Information.

<table>
<thead>
<tr>
<th>Category</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Army ROTC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(male = 8, female = 8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>19.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170.8</td>
<td>11.5</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>71.8</td>
<td>10.9</td>
</tr>
<tr>
<td><strong>Naval ROTC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(male = 12, female = 4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>21.5</td>
<td>3.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>175.9</td>
<td>10.5</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>74.4</td>
<td>10.6</td>
</tr>
</tbody>
</table>

Abbreviations; cm, centimeter; kg, kilogram

All subjects signed an informed consent form after the purpose and procedure of the study were explained. All subjects were currently enrolled as students at The Pennsylvania State University and were active members of ROTC. The study was approved through The Institutional Review Board of the Pennsylvania State University.

**Instruments**

For the bracing condition, the McDavid Ankle Brace w/Straps, model 195 (McDavid Sports/Medical Products, Woodridge, IL) was used. (Figure 1) Sizes ranged from small to extra-large and fitting was determined by the manufactures specification for brace to shoe size.

![Figure 1. McDavid Ankle Brace](image-url)
Subjects were instructed to remove their boots and place the ankle brace over the sock. After the brace was laced and strapped over the sock, the boot was then reapplied, concealing the bracing condition from the primary investigator. Subjects wore standard issued battle dress uniforms from their respective branch of service. All subjects wore uniforms that included a blouse, trousers, t-shirt, and combat boots. They also wore a rucksack weighing 20.5 kg. Combat boots were not standardized for this study, avoiding issues related to subjects being unaccustomed to a prescribed boot. Each subject was tested in the same indoor multisport facility on campus. Subjects completed the balance and functional performance tests on the artificial turf at an indoor athletic facility.

Dynamic balance was assessed in three directions using a modified SEBT in anterior, posterior, and posterior medial (Figure 2a). The modified SEBT was performed with using four standard tape measures and tested with increments in centimeters. A goniometer was used to create the 45° angle needed for the posterior medial reach.28

Three measures of functional performance were evaluated for this study. Vertical jump was tested using the Vertec Vertical Jump Trainer (Sports Imports; Columbus, Ohio, USA). This is considered by many to be the “gold standard” for the measurement of vertical jump height, with a reported ICC = 0.997.29 (Figure 2b) Broad jump was assessed using a standard tape measure with increments in centimeters and has a reported ICC=0.91.30 (Figure 2c) A goniometer was used to establish the correct angle to place the tape measurer. The obstacle course, adapted from Mala et al31, was implemented following the guidelines for set-up. (Figure 2d) Only total time to complete the course was collected and overall weight carried and the mass of the grappling dummy were lowered due to availability of materials. The casualty drag was conducted using a 54.4 kg grappling dummy (Combat Sports International, Lenexa, KS). Each subject was timed using a standard stopwatch, the Sportline Giant Sportimer (EB Sport Group, Yonkers, NY). This stopwatch was able to give time in minutes, seconds, and milliseconds.
Testing procedures

University approved informed consent was signed and collected prior to testing procedures being presented and demonstrated. Subjects were randomly assigned a testing group and starting bracing condition following consent. A certified athletic trainer instructed subjects on how to apply the brace according to the manufacturer’s instructions. Testing was completed in one testing session, over the course of approximately two hours. Tests were numbered and subjects were randomly assigned a starting position at one of four testing stations. Subjects completed tests in numerical sequence. After completing all four tests in the first bracing condition, subjects would switch into the other condition and complete all four tests once more. After completing each test in both bracing conditions, subjects were released from the study. There were no timed rest periods between trials or tests. Once a subject had completed a set of
trials, they would then move to the next sequential test and would begin once the examiner at that station was ready.

Dynamic reach distance was assessed using a modified SEBT\textsuperscript{27}, comparing the no brace to the bilateral brace condition. Before the subject was tested, a demonstration on how to do the modified SEBT in all three direction was performed and subjects were then given three practice trials in each direction before proceeding to official testing. The following criteria was used to standardize testing; hands could be used however necessary to maintain balance, the heel could not be lifted during any reach, toe tap needed to touch the tape measure, and all movements would begin and end from the starting position with feet together and toes or heels on the tape line. Three measurements were recorded in each direction with both limbs. Dominant limb was established with the question “which foot do you kick a soccer ball with?” Reach distance was recorded by identifying the maximum distance the distal end of the boot tapped on the tape measure. The test was not counted if the heel on the stance limb lifted or the subject moved or fell out of position.

Vertical jump was assessed using the Vertec, with jump height measured in half-inch increments. The Vertec system was positioned on the turf field and weighted down by two 45-lb plates and was checked to be level prior to testing. A demonstration was on how to attempt the vertical leap task. Subjects were asked to stand parallel to the Vertec and reach as high as they could with their dominant arm. This distance was measured prior to subjects attempting the first set of three jumps, giving their standing reach height. Subjects were then given one practice jump without a rucksack to prevent fatigue with the added load. The testing procedure required the subject to stand parallel with the Vertec system and flags, with both feet flat on the ground. Subjects were then asked to jump as high as they could using any stationary jump strategy they chose (i.e. off one leg or two). The subject was asked to reach up with their dominant arm and
strike the flags. The jump height was recorded. A failed attempt included non-stationary jumps or if a subject failed to hit any flags. The subject performed three trials in each bracing condition.

Broad jump distances were assessed using a tape measure in centimeter increments. The tape measure was laid out perpendicular to the starting line. A demonstration of the broad jump was provided and subjects were given one practice attempt without a loaded rucksack. Subjects would leap forward from a stationary position with both toes at the edge of the starting line. On landing parallel to the tape measure, subjects were instructed to stand still for a measurement to be taken. Measurements were taken from the closest heel to the starting line. If a subject took steps or fell after a jump, that measurement was not taken and the leap was re-attempted. Subjects performed three trials in both bracing conditions.

The obstacle course was evaluated with changes from the original to timing procedures, weight of the casualty drag, and equipment worn by subjects. For this study, times were only collected at the completion of the entire obstacle course and not at specific locations along the course. The weight of the casualty drag was decreased from 79.5 kg to 54.4 kg because of grappling dummy access. Subjects only wore their battle dress uniform, combat boots, and rucksack.

Obstacle course procedures were demonstrated prior to any formal attempts. Subjects were given one practice run at sub-maximal effort prior to recorded attempts. This was completed without the loaded rucksack to avoid additional fatiguing effects. The obstacle course was begun with subjects in the prone position at the starting line. On the command “go”, timing would begin and subjects would stand to complete a 30-meter sprint at which point they made a left hand turn around the most distant cone. This was followed by a 27-meter zigzag sprint running on the outside of the cones. Once the closest cone was rounded, subjects progressed to a 10-meter casualty drag. The grappling dummy was to remain on the ground but no other restrictions were prescribed on how a subject was to move it across the finish line. Once the
grappling dummy was moved fully across the finish line, the time would be stopped and recorded. Subjects completed two recorded attempts of the obstacle course in both bracing conditions.

Statistical analysis

Descriptive statistics, including group means and standard deviations were calculated for participant characteristics and dependent variables. Paired t-tests with 95% confidence intervals were used to evaluate statistical differences between each dependent variable (bracing conditions (brace and no brace)). Post-hoc clinical effect sizes were calculated with 95% confidence intervals. Level of significance was set \textit{a priori} at p<0.05. Post-hoc testing could not be performed because there were fewer than three groups.

Results

Thirty-two subjects consented to be involved in this study, with all subjects completing the one session of testing. There were no dropouts or injuries sustained over the course of this data collection. There was a statistically significant difference for age (F_{1,30} = 6.5, p = 0.016) found between groups. No other significant results were found for demographic information between groups.

Statistically significant differences were found for reach distance using the SEBT in centimeters. The ankle bracing condition had a statistically significant negative effect on SEBT results when the data was normalized to leg length; anterior reach (t_{31} = -2.7, p = 0.011), posterior medial reach (t_{31} = -2.4, p = 0.022), and composite reach (t_{31} = -3.1, p 0.004). Between bracing conditions, posterior reach was not statistically significant, p = 0.13. (Table 2)
Table 2. Statistical Differences in Reach Distances on the Star Excursion Balance Test Between Brace Condition

<table>
<thead>
<tr>
<th>Reach Distance</th>
<th>Braced</th>
<th>No Brace</th>
<th>P-value</th>
<th>Mean with 95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>75.8 ± 6.7</td>
<td>79.1 ± 9.8</td>
<td>0.011</td>
<td>-3.4 (-5.9, -0.83)</td>
</tr>
<tr>
<td>Posterior</td>
<td>82.3 ± 12.1</td>
<td>84.9 ± 12.9</td>
<td>0.13</td>
<td>-2.0 (-4.6, 0.64)</td>
</tr>
<tr>
<td>Post Medial</td>
<td>84.6 ± 11.7</td>
<td>87.7 ± 11.5</td>
<td>0.022</td>
<td>-3.1 (-5.7, -0.47)</td>
</tr>
<tr>
<td>Composite</td>
<td>81.1 ± 8.4</td>
<td>83.9 ± 8.6</td>
<td>0.004</td>
<td>-2.8 (-4.7, -0.98)</td>
</tr>
</tbody>
</table>

Means of three trials and standard deviation values in each reaching direction.

Statistical significance was also found in each of the functional performance measures.

Vertical jump height (t31 = -2.3, p = 0.001), broad jump (t31 = -5.5, p = 0.007), and obstacle course completion (t31 = 0.90, p = 0.002). (Table 3)

Table 3. Statistical Differences in Functional Performance Measures Between Brace Condition

<table>
<thead>
<tr>
<th>Functional Performance Task</th>
<th>Braced</th>
<th>No Brace</th>
<th>P-value</th>
<th>Mean with 95 % Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Jump (cm)*</td>
<td>31.3 ± 10.1</td>
<td>33.7 ± 10.1</td>
<td>0.001</td>
<td>-2.3 (-3.6, -1.1)</td>
</tr>
<tr>
<td>Broad Jump (cm)*</td>
<td>148.4 ± 34.7</td>
<td>153.8 ± 34.0</td>
<td>0.007</td>
<td>-5.5 (-9.3, -1.6)</td>
</tr>
<tr>
<td>O-Course Time</td>
<td>27.3 ± 0.75</td>
<td>26.4 ± 0.76</td>
<td>0.002</td>
<td>0.90 (0.37, 1.4)</td>
</tr>
</tbody>
</table>

*Means of three trials and standard deviation values for functional performance task. †Means of two trials and standard deviation values for functional performance task. Abbreviations; cm, centimeter.

No statistically significant post-hoc effect sizes were found in any of the functional performance measures (table 4) or dynamic reach directions (table 5). Post-hoc analysis of
functional performance measures resulted in the following; vertical jump height $d = -0.23$ (95% CI = -0.72, 0.26), broad jump distance $d = -0.16$ (95% CI = -0.65, 0.33), and obstacle course time $d = 0.21$ (95% CI = -0.28, 0.70).

**Table 4: Post-Hoc Functional Performance Analysis**

**Functional Performance Measures**

![Graph showing effect sizes for different tasks]

Dynamic balance assessed by the SEBT, also demonstrated no statistically significant clinical effect sizes. Normalized reach distances were as follows; anterior reach $d = -0.40$ (95% CI = -0.89, 0.10), posterior reach $d = -0.16$ (95% CI = -0.65, 0.33), posterior-medial reach $d = -0.27$ (95% CI = -0.75, 0.23), and composite reach $d = -0.33$ (95% CI = -0.82, 0.17).

**Table 5. Post-Hoc Normalized SEBT Reach Distance Analysis**

**Dynamic Balance - Reach**

![Graph showing effect sizes for different reach directions]
Discussion

This study found that the use of ankle braces inside a military combat boot with a loaded rucksack, cause statistically significant deficits in dynamic reach distances and functional performance measures. On the SEBT, statistically significant deficits in normalized reach distance were found in the anterior, posterior-medial, and composite reach. The brace condition also demonstrated statistically significant decreases in vertical jump height and broad jump distances, and an increase in time to complete the obstacle course.

There was a significant decrease in dynamic reach in the anterior, posterior medial and composite reach directions. These decreases in dynamic reach, while bilaterally braced, could be accounted for by the decrease in both dorsiflexion of the stance limb as well as a decrease in plantarfexion in the reach limb. By placing an ankle brace on each limb, this potential decrease in ankle range of motion may produce overall deficits in the ability for the subject to reach further as in the no brace condition. When performing the SEBT, subjects are required to stand in a stationary position and reach out as far as they can with their non-stance limb. In doing so the subject’s center of gravity and support changes. When adding a 20 kg load to this task, it becomes more difficult to maintain balance due to a shift in the center of gravity posteriorly. Subjects may experience a greater challenge for the quadriceps muscle group to be able to maintain the body’s position while completing the anterior reach excursion due to this added weight. In addition, when completing the posterior-medial reach, the introduction of a rotational challenge may hinder the subject’s ability to reach as far. While completing the posterior reach, subjects flex at the waist and move the rucksack more directly over the stance limb, potentially improving their ability to maintain balance. Further research must be conducted to evaluate a loaded rucksack with the SEBT, but previous studies have indicated that subjects while wearing a military backpack have greater center of pressure movement compared to an unloaded condition.
Previous studies have shown that ankle braces restrict range of motion at the ankle.\textsuperscript{25,34-36} These results are similar to the Newman et al.\textsuperscript{27} study evaluating ankle braces, with reach deficits occurring in the anterior, posterior, and composite excursions.\textsuperscript{27} For the military, this may hinder the ability of service members to move into different functional positions, especially with weight added. Tasks such as moving from a standing to kneeling position back to a standing position may be more difficult and should be evaluated with full military equipment. In addition, the ability for service members to place their foot in the proper position for rope climbing may be impacted and should be evaluated in a future study. This potential limitation for getting into different positions may reduce the effectiveness of the service member or the ability for these individuals to traverse difficult terrain.

Three functional performance measures were evaluated in this study. These measures were selected to assess general performance tasks that many military service members must execute on a daily basis whether that is during physical training or active duty. In the military, it has been indicated that as mass increases, systematic decrements performance occur in tasks such as long-distance runs, short sprints, agility runs, ladder climbs, and obstacle course performance.\textsuperscript{37} The vertical jump test used in this study may replicate the ability for subjects to be able to jump onto or up to a ledge of a wall, movements that are practiced during military training and in combat. Although not shown to be clinically meaningful in civilian populations, it has been demonstrated that vertical leap can create statistically significant negative impacts while wearing ankle braces.\textsuperscript{22,25} This study concluded that vertical jump height was significantly impacted while in the braced condition. Overall, the no brace condition saw an increase in jump height of roughly 2.4 centimeters, which is nearly an inch difference. Service members regularly scale wall obstacles during physical training activities and must be able to climb in combat situations. Bracing has been revealed to affect range of motion of the ankle in civilian
populations\textsuperscript{25}, with the addition of a military combat boot, the capacity for these subjects to place their ankle in the proper position to propel themselves vertically is shown to be impaired.

Broad jump was significantly affected while wearing bilateral ankle braces. The purpose of the broad jump was to mimic situations where subjects in military situations would have to leap across obstacles, such as barriers or dangerous terrain. It has been reported that current Marine assault loads vary from about 97 to 135 pounds of equipment, with a recommendation of a maximum of only 50 pounds.\textsuperscript{38} This additional mass will produce greater rates of fatigue in military populations, thus causing performance deficits compared to an unloaded condition. Subjects in the bilateral bracing condition demonstrated marked deficits in broad jump distances of 5.4 centimeters or 2.1 inches. A deficit in the broad jump could impair a service member from completing his/her mission effectively when trying to traverse difficult terrain.

The obstacle course used in this study differed from the one previous used in Newman et al\textsuperscript{27}, so a direct comparison cannot be made. In the previous study, it was determined that bracing condition did not influence completion times on the obstacle course. The obstacle course used for the previous study was a military institute conditioning course with eight unique tasks. Subjects were made to crawl, jump, climb, and leap over a military specific obstacle course, but did not wear a loaded rucksack. For the obstacle course design of this study, subjects were made to start in a prone position, sprint forward and zigzag around cones, and then simulate a casualty drag. Subjects were significantly slower while in the braced condition by 0.9 seconds compared to the no brace condition. This result is different from previous civilian studies that indicate no significant performance deficits on sprint and agility tasks.\textsuperscript{22,24-26}

Post-hoc analysis indicated a potentially different result from this study. In each SEBT normalized dynamic reach excursion and functional performance measure, no effect size was statistically significant. As can be seen on tables 4 and 5, all values cross zero rendering these
results potentially not clinically meaningful. It should be noted these results trend negatively and may only need a larger sample size to obtain a statistically significant effect size value.

The impetus for this line of research began with the 2008 Department of Defense recommendation for the use of prophylactic “semi-rigid” ankle braces during high risks activities, such as parachuting, basketball, soccer, and other similar high-risk activities. Unfortunately, this recommendation was largely supported by athletic related studies, with only 8 of 26 references incorporating military populations. It is important that further research be pursued to determine if the use of ankle braces affects real-world military situations. Power analysis originally indicated a sample size of 36 subjects. Because this study only recruited 32 subjects, our statistical analysis may be underpowered with the number of subjects recruited. A larger sample size would help to eliminate any statistical errors. In addition, these tasks may have been novel to subjects, especially the Star Excursion Balance Test. This task was new for the subject sample and could affect how subjects performed during only one testing session. It is also important to note that subjects wore their own brand of military combat boot. For the Naval ROTC, many of these midshipmen were relegated to a limited style of combat boot selection due to Marine protocols, whereas the Army ROTC cadets have a much larger selection for combat boot. Due to the smaller sample size, this was unable to be evaluated but future research should evaluate any interaction boot brand and style may have while wearing an in-the-boot ankle brace.

Conclusion

ROTC subjects placed in the ankle bracing condition demonstrated statistically significant differences in dynamic balance and functional performance measures. Dynamic reach distance results, generally coincided with those results found in the previous study from 2012. Ankle braces will negatively affect dynamic reach while in a military combat boot. In regards to our other functional performance measures, statistically significant negative effects were found in vertical jump height, broad jump distance, and time to complete the obstacle course. A direct
comparison for time to complete the obstacle course cannot be made with this study and the
previous\textsuperscript{27}, but does indicate that with the addition of a loaded rucksack, performance times
increase in a bilateral bracing condition. Although negative statistically significant results were
found in this study, clinical effect sizes did not indicate significance. Additional research should
be conducted, with larger sample sizes, to determine any true effects ankle braces have on
military populations.
References


SECTION III: APPENDICES
APPENDIX A

The Problem

Statement of the Problem

Ankle sprains are very common in the military and in athletics. Due to the prevalence of this injury, methods for trying to reduce the rate of lateral ankle sprains have been developed. Ankle bracing comes in many styles such as lace-up, semi-rigid, and rigid. In civilian populations it has been shown that the use of ankle braces have limited effects on functional performance measures. There have been deficits recorded in range of motion and balance but very few studies indicate clinically significant results in vertical jump, horizontal leap, sprint, and agility measures. This indicates that in a sports or athletic population prophylactic ankle bracing can provide injury-reducing properties while not influencing overall performance.

When applying these braces questions should be proposed on what are the unforeseen consequences of adding a device to a military boot. The Department of Defense in response to lateral ankle sprains has recommended the use of prophylactic ankle bracing. To date only one study has specifically evaluated this topic. In this study, ankle braces negatively affected Star Excursion Balance Test reach distances while in combat uniform and boot but did not affect time to complete a military obstacle course. Limitations to this study were that subjects were not in a loaded condition and no females were included.

During physical training and military activity, service members are required to carry heavy loads. It is important to understand the impact a loaded rucksack may have on subjects while wearing an in-the-boot ankle brace. The differences in activities and
equipment worn by military service members must be evaluated to determine whether the
results from civilian athletic populations are translatable.

**Research Question and Experimental Hypothesis**

*Manuscript 1*

Research Question:

Do ankle braces hinder functional performance measures when compared to an unbraced
condition in a young, healthy, and physically active population?

Experimental Hypothesis:

Ankle braces will not have significant impacts on functional performances measures
when compared to an unbraced condition in young, healthy, and physically active
populations.

*Manuscript 2*

Research Question:

Do ankle braces effect functional performance measures while participating in military
specific activities or (2) other performance measures while wearing military specific
uniform and gear (e.g. combat boots, ruck sack, etc...)?

Experimental Hypothesis:

As in civilian populations, ankle braces will not have a statistically significant effect on
military specific functional performance measures while wearing military specific
uniforms and equipment.

*Manuscript 3*

Research Question:
Does the use of an external lace-up ankle brace inside a military combat boot with a loaded rucksack would have an effect on functional performance measures and dynamic balance?

**Experimental Hypothesis:**

The use of an inside-the-boot ankle brace will have decrease reach distances on the Star Excursion Balance Test but will have little to no impact on functional performance measures included in this study.

**Assumptions**

*Manuscript 3*

- The subjects will perform to the best of their abilities during testing
- The brace will allow the subjects to complete the testing
- The brace will be comfortable to allow participants to complete the study
- Subjects will test the study as a true test of physical abilities

**Delimitations**

- Subjects were currently enrolled in ROTC
- Age group 18 – 35
- Males and Females
- Healthy participants with no lower extremity injury within the past 6 months
- Battle Dress Uniforms with 20 kg rucksack

**Limitations**

- Previous experience with using a prophylactic ankle brace
- Experience level in the ROTC program
• Combat boots were not standardized for participants
• Did not meet subject power threshold for this study

**Operational Definitions**

• Reserve Officers’ Training Corps – Program at that trains young cadets and midshipmen to become officers in the United States Military.
• Lateral ankle sprain – Generally an inversion with internal rotation or plantarflexion injury resulting in damage to the lateral ligaments of the ankle.
• Lace-up ankle brace – Can be constructed from many types of materials and consists of a medial and lateral support straps that allow only dorsiflexion and plantarflexion.
• Prophylactic ankle bracing – Bracing designed to prevent the occurrence or reoccurrence of injury due to plantarflexion and inversion mechanisms.
• Battle Dress Uniform – Military regulation uniform allowed per service branch. This includes blouse, trousers, t-shirt, and combat boots.
• Combat boot – Any military regulation combat boot allowed per service branch.
• Rucksack – Device or backpack used to carry military equipment
• Vertical jump – A stationary jumping task in which the subject jumps vertically and reaches as high as possible.
• Horizontal leap – A bilateral jumping task in which the subjects propel themselves forward to record how far they can leap.
• Obstacle Course – A military obstacle course that tests various aspects of performance such as agility, sprint speed, and vertical jump.
• Dynamic Balance – The body maintains equilibrium while going from one balance position to another.

• Star Excursion Balance Test – A dynamic balance task that places a subject in a single limb stance with the unloaded limb reaching in various excursion directions.

**Significance of the Study**

Ankle bracing is a common means of reducing the incidence of ankle sprains, especially for the lateral ligament complex. Sports and athletic studies have indicated that the use of prophylactic ankle bracing has little impact on functional performance measures. This line of research has evaluated the current literature in regards to the effects of ankle bracing on range of motion, dynamic balance, and functional performance measures. It was concluded that in young, healthy, and physically active civilian populations, ankle braces have little impact on these outcomes and is in line with what previous research has determined. In regards to military populations, little data has been collected on the effects of ankle bracing on functional performance activities, specifically those during military tasks. Currently, only one published work has assessed these effects and determined that ankle braces do affect dynamic reach distances but not obstacle course performance time. Finally, this randomized cross-over study evaluated the effects of bracing in a military sample while wearing a loaded rucksack. Ankle braces negatively impacted excursion reach distances on the Star Excursion Balance Test and during each functional performance measure. These results indicate that further research should be conducted during military specific activities to assess overall effects.
APPENDIX B
LITERATURE REVIEW

Introduction

In sports medicine, ankle sprains are one of the most common injuries that occur. It has been estimated that each day worldwide there is one inversion ankle sprain for every 10,000 person-days.\textsuperscript{1-3} Based on the current estimated United States population, as of January 1, 2015, this would equate to approximately 32,000 new ankle sprains each day. Soboroff et al\textsuperscript{1} in 1984 estimated that there is an aggregate healthcare cost of $2 billion dollars annually for ankle sprains. Adjusting for inflation, using the Bureau of Labor Statistics inflation calculator from 1984 to 2014, this total raises to $4.4 billion in today’s dollars.\textsuperscript{1,2,4,5}

Incidence rates have been calculated for sub-populations in regards to ankle sprain injuries. A meta-analysis from 2013 has provided greater understanding of these various differences. Women have an incidence rate of 13.6 per 1,000 exposures, while men sustain only 6.94 ankle sprain injuries per 1,000 exposures.\textsuperscript{6} Adults have an overall lower incidence rate for ankle injuries, 0.72 per 1,000 exposures, when compared to 1.94 in adolescents and 2.85 in children.\textsuperscript{6} Waterman et al\textsuperscript{3} evaluated the incidence rate of ankle sprain injuries reported to emergency departments within the United States from 2002 and 2006. It was estimated that there would be 2.15 ankle sprains per 1,000 person-years.\textsuperscript{3} Based on this study, male peak incidence rate occurred between fifteen and nineteen years of age, while females tended to be younger at ten to fourteen years of age.\textsuperscript{3} In a male only study, Willems et al\textsuperscript{7} followed 241 physical education students
prospectively for 1 to 3 years. During this time, 18% of subjects sustained an inversion ankle sprain, with the dominant limb involved 59% of the time. It was determined that those sustaining ankle sprain injuries had a greater propensity for decreased cardiorespiratory endurance and slower overall running speeds.\(^7\)

Nearly half of all ankle sprains reporting to emergency rooms for treatment are related to athletics.\(^3\) Acute lateral ankle sprains are accepted as being one of the most common ligamentous sports injury, accounting for 85% of ankle injuries.\(^8\) Fong et al\(^9\) presented data from a review of injuries in 43, ankle sprains were the most common injury reported in 33 sports (76.7%) followed by fractures in 7 sports (16.3%). From 2005-2006, more than 7.1 million students in the U.S. participated in high school athletics.\(^10\) It was determined that ankle injuries were the most common injuries among these U.S. high school sports athletes.\(^10\) Of the sports surveyed, ankle injuries accounted for 22.6% of all injuries or an injury rate of 5.23 injuries per 10,000 athlete exposures.\(^10\) Epidemiology data from National Collegiate Athletic Association (NCAA), indicates that approximately 11,000 ankles sprains occur annually in the 15 sports evaluated.\(^11\) Ankle ligament sprains accounted for the highest injury percentage of all injuries reported in 13 of 15 sports.\(^11\)

Injuries are the leading cause of hospitalizations and outpatient visits within the United States Military. Injuries account for approximately 25 million limited duty days annually according to the Department of Defense.\(^12\) Military training has been demonstrated as a main cause of these limited duty days and decreases overall force readiness.\(^12\) 22,000 male recruits attend basic training at the Marine Corps Recruit Depot in San Diego, California with an estimated 53,000 lost training days due to injury,
resulting in approximately $16.5 million in injury related expenses.\textsuperscript{13} Women have also demonstrated a higher incidence rate for all injuries compared to men and over twice the limited duty days during basic combat training.\textsuperscript{14} The ankle, second only to the knee, accounted for 16\% of all injuries sustained during this basic training period.\textsuperscript{14} In other military literature, ankle injuries accounted for 10.9\% to 15.1\% of all musculoskeletal injuries in military personnel.\textsuperscript{15,16} Ankle sprains were the second leading cause of limited duty days with an average of 16.7 days per injury.\textsuperscript{17} Strowbridge and Burgess\textsuperscript{16} reported that ankle sprains lead to nearly 40 days of rehabilitation per injury. Ankle sprain injuries can be as high as 30-60\% of all reported injuries related to military parachuting activities.\textsuperscript{12} Active-duty members of the U.S. military from 1998 to 2006, made 423,581 ambulatory visits for ankle sprains, equating to an incidence rate of 34.95 per 1,000 person years.\textsuperscript{18} Waterman et al\textsuperscript{19} observed that the ankle sprain incidence rate increased to 58.4 per 1,000 person year in United States Military Academy cadets. Women in this study had an incidence rate of 96.4 per 1,000 person years compared to men at 52.7 per 1,000 person years.\textsuperscript{19} It is the purpose of this literature review to provide a greater understanding of the effects ankle sprain injury and prophylactic bracing have on both civilian and military populations.

**Anatomy**

**Anatomy – Functional Anatomy**

The ankle is comprised of three unique joints: the talocrural joint, subtalar joint and distal tibiofibular syndesmosis. Motion at the ankle is a coordinated effort between these structures and allows for sagittal plane (plantarflexion-dorsiflexion), frontal plane (inversion-eversion) and transverse plane (internal-external rotation) movements.\textsuperscript{20} In
addition, coupled rearfoot motion is best described as pronation and supination. In the open kinetic chain, pronation consists of dorsiflexion, eversion and external rotation while supination consists of plantarflexion, inversion and internal rotation. These coupled motions change slightly in the closed kinetic chain, with sagittal plane movements switching to allow for pronation and supination. Stability at the ankle is generally comprised of congruity of the articular surfaces when the joints are loaded, static ligamentous restraints and musculotendinous units which allow for dynamic stabilization.

**Anatomy – Talocrural Joint**

The articulation of the dome of the talus, medial malleolus, the lateral malleolus, and along with the inferior portion of the posterior tibiofibular ligament articulate to form the talocrural or tibiotalar joint. This joint is sometimes referred to as the “mortise’ joint and may be thought of as a hinge joint, in isolation, that allows the motions of plantarflexion and dorsiflexion. Isolated movement at the talocrural joint is generally in the sagittal plane but small amounts of transverse and frontal plane motion also can occur due to the oblique axis of rotation.

During full loading of the ankle complex, the articular surfaces become the primary stabilizers against excessive talar rotation and translation. The malleoli that grip the trochlea of the talus is strongest during dorsiflexion of the foot. This movement causes the anterior part of the trochlea posteriorly between the malleoli, spreading the tibia and fibula slightly apart. Contribution from the ligaments surround the talocrural joint is crucial for joint stability. Ligamentous support includes the anterior talofibular ligament (ATFL), posterior talofibular ligament (PTFL) calcaneofibular ligament (CFL)
and deltoid ligament. The lateral aspect of the ankle is supported by the ATFL, PTFL and CFL while the medial aspect is supported by the deltoid ligament.\(^2\) From in vitro kinematic studies the ATFL prevents anterior displacement of the talus from the mortise and excessive inversion and internal rotation of the talus on the tibia.\(^2\) The PTFL restricts both inversion and internal rotation of the loaded talocru al joint.\(^2\) Restriction of excessive supination of both the talocru al and subtalar joint excessive inversion and internal rotation of the rearfoot is created by the CFL.\(^2\)

**Anatomy – Subtalar Joint**

Articulations between the talus and calcaneus form the subtalar joint of the ankle. Pronation and supination are allowed within this joint. The subtalar joint is an intricate structure consisting of two separate joint cavities. The posterior subtalar joint is formed between the inferior posterior facet of the talus and the superior posterior facet of the calcaneus.\(^2\) The head of the talus, the anterior-superior facets, the sustentaculum tali of the calcaneus and the concave proximal surface of the tarsal navicular form the anterior subtalar joint.\(^2\) Separate ligamentous joint capsules are found within the anterior and posterior subtalar joints and are separated from each other by the sinus tarsi and canalis tarsi.\(^2\)

The ligamentous support of the subtalar joint is broken into three groups: (1) deep ligaments, (2) peripheral ligaments and (3) retinacula. The deep ligaments consist of the cervical and interosseous ligaments. These two ligaments stabilize the subtalar joint and have been termed the “cruciate ligaments of the subtalar joint.”\(^2\) The cervical ligament lies anterior and lateral to the interosseous ligament and runs from the cervical tubercle of the calcaneus anteriorly and medially to the talar neck.\(^2\) The interosseous ligament
originates on the calcaneus and runs superiorly and medially to its insertion on the talar neck. The peripheral ligaments are composed of the CFL and lateral talocalcaneal (LTCL) and fibulotalcaneal (FTCL) ligaments. The CFL is important in preventing excessive inversion and internal rotation of the calcaneus in relation to the talus. The inferior extensor retinacula (IER) may also provide support to the lateral aspect of the subtalar joint by its lateral root. The bifurcate ligament is also a static supporter of the lateral ankle complex. It consists of two branches: (1) dorsal calcaneocuboid and (2) dorsal calcaneonavicular. This ligament helps to resist supination of the midfoot and is often injured in conjunction with other lateral ligaments in a lateral ankle sprain.

**Anatomy – Distal Tibiofibular Joint**

This distal tibiofibular syndesmosis is a compound fibrous joint that is a union of the distal tibia and fibula by means of the interosseous membrane and the anterior, interosseous and posterior tibiofibular ligaments. These ligaments, along with the inferior transverse ligament, form strong connections between the distal regions of the tibia and fibula. The posterior aspect of the malleolar mortise is deepened by the inferior transverse ligament and is in contact with the trochlea of the talus. The joint allows for limited movement due to its syndesmotic joint classification but also accessory gliding is crucial to normal mechanics throughout the entire ankle complex. A thick interosseous membrane and the anterior and posterior inferior tibiofibular ligaments help to stabilize this joint. The anterior and posterior tibiofibular ligaments are often injured in conjunction with eversion injuries that results in what is called a “high-ankle sprain.”

**Anatomy – Muscles, Tendons and Innervation**
The ankle complex receives some of its stability and stiffness from muscles and tendons. When contracted, musculotendinous units generate stiffness, which leads to dynamic protection of joints. Many times the muscles that cross the ankle complex are defined by their concentric actions; however, when considering their role in providing dynamic stability it may be helpful to think of their eccentric actions. The four compartments of the lower leg include the lateral, anterior, deep and superficial posterior compartments.

The lateral compartment of the lower leg is the narrowest of the leg compartments and contain both the peroneus longus and brevis muscles. These muscles are integral in controlling supination of the rearfoot and eversion of the ankle, which help to protect against lateral ankle sprains. It is bounded by the lateral surface of the fibula, the anterior and posterior intermuscular septa, and the deep fascia of the leg. As the tendons of these muscles travel distally behind the lateral malleolus, they enter a common synovial sheath that passes behind the superior fibular retinaculum. These muscles will insert on to the foot and create the actions mentioned above. The lateral compartment is innervated by the superficial peroneal nerve, which is a terminal branch of the common peroneal nerve.

The anterior compartment musculature of the lower leg includes the anterior tibialis, extensor digitorum longus, extensor hallucis longus and peroneus tertius. These muscles may also contribute to the dynamic stability of the lateral ankle of the rearfoot. During contraction, these muscles may slow down the platarflexion action of supination and thus prevent injury to the lateral ligaments. The anterior compartment are primarily considered dorsiflexors of the ankle.
The ankle complex’s motor and sensory supply originate within the lumbar and sacral plexus. Motor supply travels from these two plexus into the sciatic nerve, branching to form the tibial and common peroneal nerves. The ankle receives innervation from the tibial, deep peroneal and superficial peroneal nerves. The sensory supply originates from these three as well as two other sensory nerves: the sural and saphenous nerves. Lateral ligaments and the joint capsule of the talocrural and subtalar joints are innervated by mechanoreceptors that contribute to proprioception.

**Anatomy - Pathophysiology Lateral Ankle Sprain**

Most commonly, lateral ankle sprains occur due to excessive supination of the rearfoot with an externally rotated lower leg soon after contact during gait or from landing. Lateral ankle ligaments are strained due to excessive inversion and internal rotation of the rearfoot, coupled with external rotation of the lower leg. If the ligaments tensile strength is exceeded, a ligamentous injury or sprain will occur. Increasing plantarflexion at initial contact appears to increase the likelihood of suffering a lateral ankle sprain. Current analysis techniques have also stated, in both real time injury mechanics and in laboratory studies, that the mechanism of injury for lateral ankle sprains is inversion and internal rotation. Findings have indicated inversions velocities up to 1,752 degrees/second and maximum inversion angles of up to 142°.

Of those ligaments located on the lateral side of the ankle complex, the ATFL is the first ligament to be damaged during an ankle sprain, followed by the CFL. Once the ATFL is ruptured, in cadaveric studies, the amount of rearfoot transverse plane motion increases dramatically while causing increased stress on the remaining ligaments. Damage to the talocrural joint capsule concurrently with ligamentous injury
is also common with lateral ankle sprains. The incidence of subtalar joint injury has been reported to be as high as 80% among patients suffering acute lateral ankle sprains.\textsuperscript{43} The PTFL is rarely injured due to its anatomical location on the lateral ankle and its injury is generally associated with ankle fractures or dislocations.\textsuperscript{43}

The literature has also questioned whether the peroneal muscles are able to respond quickly enough to protect the lateral ligaments from being injured.\textsuperscript{44} It has been estimated that after landing, the span of inversion motion may last as little as 40 milliseconds.\textsuperscript{32} Peroneal reaction time has also been estimated to take up to 146 milliseconds to respond to a stimulus.\textsuperscript{45} If the peroneal muscle group is to protect dynamically against lateral ankle sprains, preparatory muscle activation before foot contact with the ground is necessary.\textsuperscript{33} Current research has concluded that peroneal reaction time (PRT) is delayed in those individuals who have suffered previous ankle sprains compared to the healthy limb or a control group.\textsuperscript{5} It was also determined that individuals classified as chronic ankle instability (CAI) had significant reduced PRT.\textsuperscript{5} This is in disagreement with Munn et al\textsuperscript{46} that concluded that PRT was unaffected in those with SAI compared with a control group or the uninvolved limb.

Most lateral ankle sprains produce only mild pain and discomfort with minimal disability.\textsuperscript{8} These sprains may also cause long-term debilitation, decreased performance, and time away from sport or activity.\textsuperscript{6} Following an acute lateral ankle sprain, pain, swelling and ecchymosis are common. It is common for an individual to also have feelings of instability while ambulating. This may contribute to the reduced mobility and function of the ankle following injury.\textsuperscript{6} Unfortunately, many of these acute lateral ankle
sprains will result in subsequent ankle injury. Approximately 30% to 70% of initial ankle sprains will result in the development of chronic ankle instability.\textsuperscript{47,48}

**Chronic Ankle Instability**

Recurring instability of the ankle in patients following lateral ankle sprain was originally assessed by Freeman.\textsuperscript{47} His hypothesis was that, secondary to ankle ligament injury, proprioceptive deficits affected the muscles of the lower leg and led to deficits in function and continued “giving way” feeling within the ankle joint.\textsuperscript{49} This original hypothesis has been expanded and defined as chronic ankle instability (CAI).\textsuperscript{50,51}

CAI has been associated with clinical, functional and subjective disability, including patients with mechanical laxity at the talocrural joint. Chronic mechanical instability can be attributed to tissue damage to the lateral ankle ligaments.\textsuperscript{47} A major predictor of the development of CAI is mechanical ankle laxity.\textsuperscript{52} Tissue healing within the lateral ligaments may begin around six weeks and three months after initial sprain. After one year follow-up residual mechanical laxity occurred in 3-31\% of patients.\textsuperscript{53} Healing and recovery time are generally not consistent with current clinical return to play or activity practices. Clinicians frequently push for fast returns to functional activities, knowing that the injured ligaments have not had adequate time to heal.\textsuperscript{47} Further or subsequent injury following an acute lateral ankle sprain may lead to inadequate time for scar tissue to lay down and ultimately lead to mechanical insufficiencies in the talocrural and subtalar joints.\textsuperscript{22,47} This can lead to alterations in arthrokinematics, joint laxity, synovial and degenerative changes of the joints in patients with recurrent ankle sprains and CAI.\textsuperscript{22,52}
Arthrokinematic insufficiency can also be a contributing factor to mechanical instability within the ankle complex and may impair any of the three joints. It has been suggested by Mulligan\textsuperscript{30} that individuals with CAI may have an anteriorly and inferiorly displaced distal fibula. This may cause laxity within the ATFL due to the lateral malleolus being stuck in this new position. Once the rearfoot begins to supinate, the talus can go through a greater arc of motion the ATFL becomes taut. With the ATFL in a slack position, there is a greater risk for instability and recurrent ankle sprain.\textsuperscript{54,55} Restricted range of motion in ankle dorsiflexion has been reported a predisposing factor for lateral ankle sprain.\textsuperscript{56} No allowing the talocrural joint into full dorsiflexion, the joint will not reach its closed-pack position during stance. This will result in the ankle being able to invert and internally rotate more easily.\textsuperscript{22} After an acute ankle sprain, Green et al\textsuperscript{57} demonstrated that altered arthokinematics may limit dorsiflexion and with specific rehabilitation patients were able to regain dorsiflexion quicker than those who did not receive treatment.

Pathologic laxity generally occurs due to injury of the ATFL or CFL after an acute lateral ankle sprain.\textsuperscript{58} ATFL injury is often assessed by determining the amount of anterior displacement of the talus from the tibiofibular mortise. In the absence of the ATFL, the talus is able to excessively supinate, with a large internal rotation component in relation to the tibia.\textsuperscript{59} CFL integrity is best assessed by inverting the talus with the talocrural joint in a plantarflexed position and to determine the amount of talar tilt present.\textsuperscript{22} An injury to the CFL also causes pathologic laxity of the subtalar and talocrural joints. Many CFL injuries are accompanied by injury to the subtalar joint capsule, cervical ligament and other lateral ligaments.\textsuperscript{60} Aberrant motion at the ankle
joint from mechanical laxity may result in long-term osteoarthritic changes. Seventy-eight percent of cases of ankle osteoarthritis were reportedly associated with a history of recurrent lateral ankle sprain, which is a higher percentage when compared to other large joints.61

The ability to sense motion at the joint is diminished due to the initial damage of the lateral ankle ligaments.22,35 Muscle surrounding the joint may also be affected when damage occurs to the mechanoreceptors of the lateral ligaments, which may affect postural control.62,63 Clinical deficits have been identified in dynamic and static balance, as well as subjective instability. Subjective instability is most commonly associated with sensory input from the structures surrounding the ankle joint and can be found in those that have not had an acute ankle sprain.47 Dynamic and static balance receives input from mechanoreceptors of the ligaments, muscles, tendons and skin. Healthy individuals need this redundancy to establish force position, joint position, stretch and tension. Those individuals that have been identified as having ankle instability generally have deficits in sensing vibration, joint position and force sense.5,64,65 With proper treatment, rehabilitation and healing lateral ligaments may regain mechanical stability; however, repair of the neurological structures within the tissue is not thought to occur.22,53

Ankle Bracing

Bracing - Categories

Braces are generally broken into three categories at the ankle: (1) rigid, (2) semi-rigid and (3) soft or non-rigid.66,67 Rigid ankle braces generally provide the greatest protection against inversion and eversion range of motion. The lateral and medial supports are commonly made from a non-flexible material such as a composite plastic or
metal and allows for only dorsiflexion and plantarflexion. Semi-rigid ankle braces are comprised of struts or stabilizers made of thermoplastic materials and placed along both the medial and lateral sides while attached by Velcro straps in multiple locations. These braces generally allow for more motion with inversion and eversion compared to rigid ankle braces. Soft or non-rigid ankle braces are typically made out of a canvas or neoprene-type material, which generally can easily be slipped on or off with some having laces to make the brace tighter. According to many brace manufactures, semi-rigid and soft braces are intended to be used for prophylactic purposes in sports to prevent new or recurrent injuries. Prophylactic is defined, by Merriam-Webster.com, as: (1) guarding from or preventing the spread or occurrence of disease or infection or (2) tending to prevent or ward off.

**Bracing – Prevention**

Prevention of lateral ankle sprains is important to clinicians, researchers and those affected by this type of injury. Ankle bracing has increasingly been used as a prophylactic device to reduce the overall risk for lateral ankle sprain both acute and recurrent. Individuals who participate in athletic activities are particularly susceptible to ankle injuries. Of all reported ankle injuries, 86% are sprains. Several epidemiological studies have shown that about 10-28% of all sports injuries are ankle sprains. Many studies have been conducted determining the effects of ankle bracing on acute and recurrent injury rates. Tropp et al reported that male soccer players who wore a brace over a six-month season had a significantly reduced rate of ankle sprain compared to the control group of no ankle braces. Surve et al also studied male soccer players with a previous history of ankle sprain. This group was compared to a group of
soccer players with no previous injury history. All were randomly assigned to a bracing condition of ankle brace or no ankle brace. Those that were randomly assigned to the no ankle brace group had significantly higher rates of ankle sprains in both those with a history of ankle sprain and those with no previous history of ankle sprain. Rovere et al performed a study on 360 football players over six seasons of collegiate play. This study compared ankle taping versus bracing. Those that wore ankle taping suffered 159 initial ankle sprains and 23 recurrent sprains. Those that wore ankle braces incurred 37 initial ankle sprains and only 1 recurrent ankle sprain.

Previously reviewed studies suggest that semi-rigid and soft ankle braces are capable of reducing the incidence of ankle sprain injury. External ankle braces have also been found to reduce the risk of recurrent ankle sprains to a certain extent. Ubell et al found that bracing prevented forced inversion by placing the ankle joint in a neutral position and eliminated inversion of the talus and calcaneus before impact. Bracing has a unique advantage over other prevention methods, such as taping, because it can be self-applied and does need the expertise of a clinician to apply the device. In addition, braces generally cause less skin irritation due to decreased rubbing and chance for allergic reactions due to the components of the tape and adhesive. Patients generally have a higher satisfaction level when using a brace compared to tape after ankle injury. Semi-rigid and lace-up ankle braces also can be retightened and adjusted whenever the athlete needs it to be to provide the same amount of support when it was originally applied.

**Bracing - Range of Motion**
Joint kinetics, kinematics or range of motion has been studied with the use of ankle braces. Previous literature has generally compared ankle braces to other ankle braces or from ankle brace to ankle taping.\textsuperscript{68} After application of ankle braces, especially for prophylactic purposes, a significant restriction in range of motion is obtained.\textsuperscript{32,81-84} It was also determined that the soft or non-rigid ankle brace showed loosening over time during exercise, while the semi-rigid versions tended to maintain their structural integrity.\textsuperscript{85} Studies also tend to use measures of ankle range of motion displacement either passively or actively. Current, literature suggests that studies that test dynamically may simulate real world movements and displacement more effectively that those studies confined to passive range of motion testing.\textsuperscript{68}

Greene and Wight\textsuperscript{82} studied the effect of three different prophylactic ankle braces on restriction of ankle range of motion. It was determined that the two semi-rigid ankle braces provided the greatest post-application restriction compared with the soft or non-rigid brace. Gross et al\textsuperscript{83} in contrast showed no significant difference for ankle inversion range of motion immediately after application between the soft and semi-rigid ankle braces. Both braces also showed no significant loosening after ten minutes of exercise.

Green and Wight\textsuperscript{82} also determined that the effectiveness of the three prophylactic ankle braces over a 90 minute softball practice. In the semi-rigid braces they found range of motion restrictions of 46\% after 20 minutes, 45\% after 40 minutes and 44\% after 90 minutes of activity.\textsuperscript{82} The soft brace that was included in this study saw a range of motion restriction of 30\% post-application to 8\% after 90 minutes of sports activity.\textsuperscript{82} Anderson et al\textsuperscript{86} also found significant decreases in ankle inversion range of motion after exercise while wearing a non-rigid ankle brace. Parsley et al\textsuperscript{87} evaluated the effects of ankle
braces on ankle range of motion and determined that all three braces used in the study significantly reduced ankle inversion range of motion. It was also noted in the study that the semi-rigid ankle braces reduced ankle eversion greatest and all three braces reduced plantarflexion and dorsiflexion ranges of motion significantly. Cordova et al in a meta-analysis found that the use of semi-rigid ankle braces provided the most significant restriction of ankle inversion and eversion range of motion, before and after exercise.

Kinematically, ankle braces also may have effects on joints of the lower extremity. It has been shown that ankle braces do reduce range of motion within the sagittal plane. Sagittal plane displacement is important in the lower extremity, especially after the initial 100 ms of landing to absorb and reduce vertical impact forces. If the ankle brace reduces this ability to absorb vertical impact forces, injury could potentially result higher in the lower extremity. Simpson et al looked at the effects of an ASO lace-up brace on kinematics of the lower extremity. It was found that the ankle brace did create greater peak vertical impact force magnitude and rate of application. In addition, greater knee flexion angle at impact with less tibial internal and external rotation were displayed. This group determined that the use of a common lace-up ankle brace did not adversely affect knee joint kinematics and that it may potentially improve lower extremity alignment during landing.

Bracing - Strength

Strength of the musculature surrounding the talocrural and subtalar joints is very important for lower extremity function. It has been stated that following an ankle sprain, the mechanoreceptors within the musculotendinous unit may not recover and may contribute to an overall decrease in muscle strength and force. Commonly, strength
measurement at this joint requires the use of a handheld dynamometer or potentially an isokinetic device, such as the Biodex System, to measure force produced at the ankle.95

One study investigated isokinetic, isotonic and isometric plantarflexion and dorsiflexion.96 For testing purposes, isometric results were the least reliable method to determine plantarflexion and dorsiflexion force.96 In another study, isometric ankle eversion and inversion measurements were obtained at 0°.97 It was found that there were not statistical differences between the healthy control and those with chronic ankle instability. Several studies have determined the test retest reliability of the Biodex System for isokinetic measurements for ankle plantarflexion and dorsiflexion.98,99

Regrettably, few studies have determined the validity of the Biodex System for inversion and eversion forces.95 Undertaking an exhaustive review of the literature, no studies were found that utilized ankle strength measurements such as a dynamometer or Biodex System while wearing an ankle brace. The closest study that was found, utilized ankle taping and its effects on plantarflexion forces.93 This study indicated that there were no statistical strength differences between braced and non-braced conditions while plantarflexion occurred.93 It seems it would be imperative for a study to determine any strength deficits that may occur while wearing an ankle brace.

**Bracing - Functional Performance Tasks and Measures**

Performance is an important factor when assessing the appropriateness of using an external device. If an external device, such as an ankle brace, only provides minimal protection while decreasing performance measures, individuals will not use that device for activities.68 Burks et al100 provided one of the first studies that looked at the effects of ankle bracing on performance. In this study, 30 healthy collegiate athletes were run
through four unique performance tasks: (1) the broad jump, (2) vertical leap, (3) 10-yard shuttle run and (4) 40-yard sprint. A significant decrease in performance was found when using the Swede-O brace when compared to the no support group in vertical jump (4.6%), broad jump (3.6%), and sprint (3.2%). Robinson et al. also saw a significant difference in the time it took to run through a basketball court obstacle course wearing modified high-top basketball shoes with plastic stiffeners. It was concluded that the increased support limited range of motion, effectively decreasing overall performance on the agility course. In other related studies, no negative effects were found for sprinting speed. Robbins and Waked determined that semi-rigid and rigid devises probably couldn’t resist the forces associated with sprain and in general interfered with normal movement patterns which hindered performance. This paper also suggested that the addition of a prophylactic ankle bracing device may actually lead to an increased incidence of injury due to interference in normal gait mechanics.

Newman et al. published on the effects of prophylactic ankle bracing on functional performance measures. This study had cadet subjects complete three days of testing in three bracing conditions, bilateral brace, unilateral brace on the dominant limb, and no brace. The functional performance tasks that were completed included a modified Star Excursion Balance Test for reach distance and performance on a military obstacle course for overall time to complete. It was concluded that anterior ($p = 0.004$) and posterior ($p = 0.007$) reach distances were statistically decreased while wearing ankle braces compared to the no brace conditions. In the bilateral brace condition, a small, clinically meaningful effect size was calculated that negatively affected overall anterior reach distance (ES = -0.47, CI = -0.93 to -0.01). Across all bracing conditions,
obstacle course performance time was not affected negatively by the use of inside-the-boot ankle brace \( (p = .742) \).\textsuperscript{102}

**Numbers Needed to Treat and Economics**

Currently, there are few reported studies indicating the numbers need to treat and the economic impact of using ankle braces. There have been to date only two randomized control studies looking at the efficacy of prophylactic bracing. In the RCT by Sitler et al it looked at 1,601 intramural basketball cadets at the U.S. Military Academy.\textsuperscript{103} In this research it was found that those who had a previous history of lateral ankle sprains, 18 subjects are needed to be braced in order to prevent one injury.\textsuperscript{103} Unfortunately when looking at the confidence interval of numbers needed to treat in this category, it crossed into the numbers needed to harm.\textsuperscript{103} On the other hand it would take 39 individuals treated in order to prevent one injury in the no previous injury group.\textsuperscript{103} This group did not cross into numbers needed to harm making it significantly important.\textsuperscript{103} Sitler also showed that bracing would not prevent the severity of the ankle injury just the rate of ankle sprains.\textsuperscript{103} It was stated by the authors that bracing did not reduce the range of motion at the ankle but the ankle joint awareness which would reduce the incidence.\textsuperscript{103}

In the other RCT done by Surve et al, it looked at 504 male South African soccer players.\textsuperscript{76} The results were opposite to that of the Sitler RCT. There would only need to be 5 subjects treated with an ankle brace to prevent one injury, with a confidence interval that spread from 3 to 10, making this significantly important.\textsuperscript{76} Those individuals that had no previous history of ankle sprains, it was found that it would take 57 subjects to prevent one injury.\textsuperscript{76} This group crossed into the numbers needed to harm and would not
be significantly relevant. Both of these studies used the Aircast Sports Stirrup and both studies were published in 1994. This can be seen as conflicting data, using the same bracing system as well as being done at the same time, these randomized controlled trials have shown significance in the numbers needed to treat opposite to one another. Since 1994, much advancement has been made to prophylactic braces since these two RCT’s were conducted.

Olmsted et al also looked at the numbers needed to treat and the cost-benefit analysis of taping compared to bracing. With the data from the two previous studies as well as data from Garrick and Requa, it was determined that in all three studies taping or bracing those with previous histories of ankle injuries would prevent more injuries than taping or bracing those without previous histories. It was also shown that it was more cost effective to tape an individual once but after multiple tapings it would be much more cost effective to brace than to tape. Over the course of an entire season it would be 3.05 times more expensive to tape an athlete than it would to provide them with one set of braces. In addition, a time factor is associated with taping an athlete compared to providing them with braces. If a clinician is working with a large population of athletes or subjects it takes much more time to tape those athletes.

**Military Literature**

**Injuries**

The Department of Defense employs approximately 1.3 million active duty and over 826,000 reserve service members. Physical training and activities such as sports pose as one of the greatest risks to health and force readiness for service men and women.
For the military, musculoskeletal injuries affect the DoD by increasing the number of limited duty days accrued by these men and women of the armed services. During a 1-year period, Abt et al followed U.S. Army Special Operations Forces and found that all types of physical training (57.7%), recreational activity/sports (11.5%), and tactical training (15.4%) accounted for the majority of musculoskeletal injuries sustained during that period of time. Injuries during combat only accounted for 3.8% of all injuries recorded during this 1-year period. Injury surveillance of two U.S. military units indicate that physical training exposes military service members to the greatest risk for injury. Ruscio et al in an article pertaining to injury prevention priorities, determined that sports and physical training accounted for the second leading cause of injury, behind falls, at 15.8%.

The principal reason military service members are unable to deploy is because of musculoskeletal injuries, affecting military readiness. This results in an estimated 68,000 soldiers unable to deploy due to non-combat related injuries. It is estimated that 600,000 soldiers sustain a musculoskeletal injury each year, contributing to more than 2.2 million medical encounters. Disabilities are major issues for both civilian and military populations. In the United States there are anywhere from 27 million to 49 million disabled persons. This is an even greater concern for the military because it carries with it a large financial burden for physical disabilities that result in discharge from services. In a possibly outdated statistic due to inflation and changing military medical costs, annual compensation for military disability payments are anywhere between $1.2 billion to $1.5 billion. Sprains/strains to the ankle and foot is a top ten diagnoses for disabilities cases seen by the U.S. Navy Medical Evaluation Board.
In the military, service members participating in parachuting related activities commonly sustain ankle injuries.\textsuperscript{114} 12\% to 60\% of all military parachuting ankle injuries occur at the ankle.\textsuperscript{115} During Operation Just Cause in Panama, 8\% of the 624 Army Rangers sustained ankle injuries, with 38\% of these individuals unable to continue the mission.\textsuperscript{115} Amoroso et al\textsuperscript{116} in 1998 placed 745 volunteers from the U.S. Army Airborne school into two groups, one wearing a brace and one group without a brace. The incidence of ankle sprains was 1.9\% in the unbraced group and 0.3\% in the braced group, which was shown to be statistically significant ($p=0.04$) and relative risk ratio of 6.9.\textsuperscript{116} It has been noted that the application of the parachute ankle brace (PAB) has been beneficial for reducing the risk for sustain ankle fractures and sprains.\textsuperscript{114}

During Operation Iraqi Freedom and Enduring Freedom, Hauret et al\textsuperscript{117} collected data on the frequency and causes of non-battle injury evacuations. Injuries to the lower leg and ankle accounted for 12.7\% of air-evacuated sprain or strain injuries during Operation Iraqi Freedom and was 16.9\% for Operation Enduring Freedom.\textsuperscript{117} Overall, the ankle/foot injuries were the number 4 leading cause of non-battle related injuries and accounted for 11.3\% of non-battle injuries in Iraqi and 10.7\% in Afghanistan.\textsuperscript{117} Hauret et al\textsuperscript{118} examined under-recognized injury problems among military personnel and indicated that for the 2006 calendar year, ankle and foot injuries were the third highest region for musculoskeletal injuries at 13\%.

Injuries to the ankle are one of the most commonly reported and leading causes of limited duty days in both training and combat for the military.\textsuperscript{109,117-119} It is important to note, there is a greater likelihood for ankle sprain injury in those individuals unaccustomed to military activities. Ankle injury rates are also highest in advanced units; basic
trainees, cadets, and special forces. The highest incident of injury during physical training as reported by Almeida et al. in 1999, were ankle sprains. Belmont et al. determined that ankle injuries had the highest incidence rate among all musculoskeletal injuries at 15.30 per 1,000 combat years in an ‘Army Brigade Combat Team’ over a 15 month period during Operation Iraqi Freedom. A previous epidemiological study reported that active duty services members sustain ankle sprains at 34.95 per 1,000 person years. This incidence rate is double what was presented in the study by Belmont et al., but even with the lower incidence rate, active duty ankle sprains are still over seven times more likely than what was reported in civilian populations.

From the University of Pittsburgh, the Eagle Tactical Athlete Program, developed by Sell et al., was created to study the impact of what a preventative health program may have on reducing injuries in military populations. During this first phase, 404 soldiers were recruited from the 101st Airborne, self-reported data from one year prior indicated that the highest rate of musculoskeletal injuries occurred at the ankle joint (18.2%) and ankle sprains were indicated as the most common type of injury. Nearly half of all musculoskeletal injuries were during physical training (48.5%) and was followed by running (34.3%) related injuries. Comparably with previous studies, injuries sustained during combat only accounted for 6.1%.

Sefton et al. noted that soldiers completing Army Basic Training, those soldiers with slower run times, fewer push-ups, sit-ups, and were older in age directly related to higher-incidences of acute musculoskeletal injuries such as an ankle sprain. From a two-year period, Nye et al. obtained musculoskeletal injury data from Air Force basic military trainees. This study indicated that of the 67,525 recruits to enter Basic Military Training,
12.5% sustained one or more musculoskeletal injuries. These injured trainees were 3.01 times more likely to be discharged and injured trainees who did graduate were 2.88 times more likely to graduate late.\textsuperscript{125} Over this two-year surveillance period, medical and nonmedical expenses for injuries resulted in an economic burden of more than $43.7 per year. Trainees who began with lower baseline aerobic and muscular fitness were more likely to sustain a musculoskeletal injury. Ankle sprains accounted for the fourth most common musculoskeletal injury diagnoses in Air Force trainees at 747 documented cases. In a related category, pain in joint, ankle and foot, accounted for 1240 injuries.\textsuperscript{125}

**Military Academies and Reserve Officers’ Training Corps Ankle Injuries**

Ankle sprain injuries are a significant cause for time loss and reduced force readiness at the U.S. Military Academy, Naval Academy, and Air Force Academy. An estimate of more than 300 ankle sprain treated each year at the U.S. Naval Academy.\textsuperscript{126} Unfortunately, there is no further data to specify current incidence rates for ankle sprains at United State Naval Academy. Billings\textsuperscript{127} conducted an epidemiology study of injuries and illnesses at the Air Force Academy looking specifically at the Basic Cadet Training Program. There were 1,210 cadets retrospectively analyzed for this study, with 1,619 clinical visits. Of these clinical visits, 846 (52.3%) were for injuries. Of all injuries documented, ankle sprains accounted for the highest overall volume to the Air Force Academy’s physical therapy clinic, with 11.6% of all injuries.\textsuperscript{127}

Studies have been conducted at West Point in assessing the incidence rate of ankle sprains. Over the course of one academic year at West Point, Carow et al\textsuperscript{123} in 2014 reported that of all injuries ankle sprains were the most injury (36%) during the academic year. During the Cadets initial 6 week Cadet Basic Training program, ankle
sprains were the second highest reported injury with 48 of 196 injuries, only 1 less than knee overuse injuries. Waterman et al in 2010 evaluated the incidence of ankle sprain injuries at West Point. Cadets at West Point suffered ankle sprains at rates higher than civilian and active duty populations. During the study period, 614 cadets sustained a new ankle sprain, with an overall injury rate of 58.4 per 1000 person years; additionally 75 cadets sustained multiple ankle sprains. Ankle sprain injuries largely affected the lateral ligament complex (82.7%) and time loss was recorded in 523 of the cadets. This accounted for a total of 4252 limited duty days for an average of 8.1 days per injury. It is also important to note that women had a significantly increased risk ratio for ankle sprains 1.83 (95% CI, 1.52-2.20) compared to men. A randomized ankle bracing study was conducted West Point using recreational cadet basketball players. Sitler et al collected data on 1,601 cadets over a two-year period and showed cadets with a previous history of ankle sprain had a 1.4 times greater risk for ankle sprain compared to the previously non-injured group.

Presently, there is little to no epidemiological research for injuries in Reserve Officers’ Training Corps programs. In 2015, Scott et al collected data on all cadets enrolled in an Army ROTC program. Of the 195 cadets, 165 were male and 30 were female. Forty-one cadets sustained a lower extremity injury during the study period, with an incidence rate of 60 lower extremity injuries per 100 person years. Of all injuries recorded, the highest occurrence was located at the ankle, 29.3%. Additionally, physical training had the highest rate for injuries at 39%, with field training exercises at 12% of injuries. Ankle sprain injuries are a health-care concern for the United States Armed Services. With a majority of commissioned officers graduating from ROTC programs
around the country, the lack of current epidemiological and prospective research in population is discouraging. There is currently an opportunity to develop new research opportunities within ROTC programs allowing for a better understanding their inherent differences from service academies and basic training. It is important for further research to be conducted so these injuries can be better prevented and treated once an incident occurs.
References


64. Arnold BL, Docherty CL. Low-load eversion force sense, self-reported ankle instability, and frequency of giving way. *J Athl Train.* Jul-Sep 2006;41(3):233-238.


APPENDIX C

ADDITIONAL METHODS

Figure 1. Informed Consent Form

CONSENT FOR RESEARCH
The Pennsylvania State University

Title of Project: The effects of prophylactic ankle bracing on military specific functional performance tasks in Reserve Officers’ Training Corps cadets.

Principal Investigator: Thomas M. Newman

Address: 146 Recreation Building
University Park, PA 16802

Telephone Number: 814-865-2725

Advisor: Dr. W.E. Buckley

Advisor Telephone Number: 814-865-1275

Subject’s Printed Name: ____________________________

We are asking you to be in a research study. This form gives you information about the research.

Whether or not you take part is up to you. You can choose not to take part. You can agree to take part and later change your mind. Your decision will not be held against you.

Please ask questions about anything that is unclear to you and take your time to make your choice.

1. Why is this research study being done?

   We are asking you to be in this research because in 2008 the Joint Services Physical Training Injury Prevention Work Group (JSPTIPWG) issued a recommendation stating that all military personnel involved in high-risk activities should wear semi-rigid ankle braces to reduce the rate of ankle injuries. This recommendation was based primarily on athletic data and limited data was included on strength and functional tasks military personnel are required to complete during training and combat. This study is being conducted to try and determine if the use of ankle braces cause any strength or functional performance deficits and its impact
on ankle injuries while wearing military equipment. Approximately 50 Reserve Officers’ Training Corps cadets will take part in this study at the Pennsylvania State University.

2. What will happen in this research study?

This study will require you to complete one three hour session, with two rounds of four performance measures. You will be randomly placed in one of two bracing conditions after informed consent and previous injury data is collected: (1) Bilateral Ankle Brace or (2) No Ankle Brace. You will complete a battery of four functional performance tasks and then crossover or switch bracing conditions and complete the second round. You will be wearing combat boots, combat uniform and in some cases a military back-pack with a 50 pound load.

- After consent, the following data will be collected: (1) age, (2) height, (3) weight, (4) limb length, (5) sex, (6) previous ankle injury history.
- You will be randomly assigned a bracing condition and a starting position in one of the four performance tests. You will complete the following functional performance tasks: (1) Broad Jump for distance with 3 trials, (2) Vertical leap for height with 3 trials, (3) Modified Star Excursion Balance Test with 3 trials, and (4) Functional performance course for time. All aspects of testing has the potential to be photographed for this study. Your facial features will be removed or blurred following testing the completion of the study. No one will be able to recognize individuals in photographs taken.
- The broad jump will be administered in the following manner; you will place your toes behind a strip of white tape. At your own time you will then leap as far forward as possible. Measurement will be taken from the closest heel to the tape that you leapt from. You will perform this three times and then rotate to the next performance task.
- The vertical leap test will be conducted using a Vertec. This device will have you stand below a pole with colored flags attached at the top. At your own time you will leap off of one limb and jump as high as you can. At the same time you will hit the flags to determine your jump height. This will be completed three times and then you will rotated to the next performance task.
- You will complete the modified Star Excursion Balance Test (SEBT). This will place you in the middle of a three sets of tape measures. Your dominant limb (the limb you would kick a ball with) will be placed in the center of the SEBT. The tape will look like a Y and at this time you will reach out as far as possible with your non-stance foot. You will tap with your toe and then resume your original position. This will be done three times in each direction (Anterior, Posterior and Posterior-Medial). This test will be completed with a military back-pack. It will be set at a standard weight of 20 lbs. You will then rotate to the next station after completion of this test.
- The functional performance course will have you start behind a line in a prone position or laying down on your stomach. When the tester says go, you will proceed to complete the following performance measures; (1) a 30-meter sprint from the prone position, (2) return 27-meters through a zig-zag run, (3) finish with a 10-meter casualty drag. This will be completed one time with standard military back-pack with 20 kg of load.
- With the final performance measure completed, you will switch bracing conditions and complete the four performance tasks while in the new bracing condition. At the conclusion of the second round of testing you will have completed the study with no further obligations.

3. **What are the risks and possible discomforts from being in this research study?**
   There are risks associated with performing any type of exercise. You may become sore after doing some of the tests for this study. There is also a very small chance that you could fall or hurt yourself while participating. There is also a very small risk that you may develop blisters or skin irritation with bracing, shoes and boots.

   There is a risk of loss of confidentiality if your information or your identity is obtained by someone other than the investigators, but precautions will be taken to prevent this from happening. The confidentiality of your electronic data created by you or by the researchers will be maintained to the degree permitted by the technology used. Absolute confidentiality cannot be guaranteed.

4. **What are the possible benefits from being in this research study?**
   **4a. What are the possible benefits to you?**
   There are no direct benefits for being part of this research study. The study may help us understand how healthy people normally perform on these tests and how the devices like braces, boots and military equipment affect strength and functional performance.

   **4b. What are the possible benefits to others?**
   This study may lead to potential benefits for military entities. This may include using the semi-rigid ankle brace to reduce overall rate of ankle injuries, reduction in health-care related costs and reduction in overall number of limited duty days within the armed forces.

5. **What other options are available instead of being in this research study?**
   You may decide not to participate in this research. There are no other options available to complete this study.

6. **How long will you take part in this research study?**
   If you agree to take part, it will take you about three hours to complete this research study.

7. **How will your privacy and confidentiality be protected if you decide to take part in this research study?**
   Efforts will be made to limit the use and sharing of your personal research information to people who have a need to review this information.
   - A list that matches your name with your code number will be kept in a locked file or password protected file in the office or within a protected computer of the research team.
• Your research records will be labeled with code number and will be kept within a locked or password protected file within the office of the primary investigator or within a protected computer of the research team.

• Any photos or videos that are obtained during testing will be saved digitally within the Athletic Training & Sports Medicine lab or within the Athletic Training offices. Researchers will have access to these visuals on their computers. At all times a subject’s photo or video will be encrypted by no less than one password or digital locking mechanism. All faces and identifiable markings will be pixilated before being used in any publication. These visuals will be kept for a maximum of 15 years following the completion of the study.

In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

We will do our best to keep your participation in this research study confidential to the extent permitted by law. However, it is possible that other people may find out about your participation in this research study. For example, the following people/groups may check and copy records about this research.

• The Office for Human Research Protections in the U.S. Department of Health and Human Services
• The Institutional Review Board (a committee that reviews and approves research studies) and
• The Office for Research Protections.

Some of these records could contain information that personally identifies you. Reasonable efforts will be made to keep the personal information in your research record private. However, absolute confidentiality cannot be guaranteed.

8. What are the costs of taking part in this research study?
8a. What will you have to pay for if you take part in this research study?
There is no cost to you to be a part of this study.

8b. What happens if you are injured as a result of taking part in this research study?
In the unlikely event you become injured as a result of your participation in this study, medical care is available. It is the policy of this institution to provide neither financial compensation nor free medical treatment for research-related injury. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

9. What are your rights if you take part in this research study?
Taking part in this research study is voluntary.

▪ You do not have to be in this research.
▪ If you choose to be in this research, you have the right to stop at any time.
▪ If you decide not to be in this research or if you decide to stop at a later date, there will be no penalty or loss of benefits to which you are entitled.
During the course of the research you will be provided with any new information that may affect your health, welfare or your decision to continue participating in this research.

12. If you have questions or concerns about this research study, whom should you call?
   Please call the head of the research study (principal investigator), Thomas M. Newman at 814-865-2725 or email at tmn5003@psu.edu if you:
   - Have questions, complaints or concerns about the research.
   - Believe you may have been harmed by being in the research study.

   You may also contact the Office for Research Protections at (814) 865-1775, ORProtections@psu.edu if you:
   - Have questions regarding your rights as a person in a research study.
   - Have concerns or general questions about the research.
   - You may also call this number if you cannot reach the research team or wish to talk to someone else about any concerns related to the research.

- INFORMED CONSENT TO TAKE PART IN RESEARCH

- Signature of Person Obtaining Informed Consent

Your signature below means that you have explained the research to the subject or subject representative and have answered any questions he/she has about the research.

___________________________  __________________________
Signature of person who explained this research  Date  Printed Name
(Only approved investigators for this research may explain the research and obtain informed consent.)

Signature of Person Giving Informed Consent

Before making the decision about being in this research you should have:
   - Discussed this research study with an investigator,
   - Read the information in this form, and
   - Had the opportunity to ask any questions you may have.

Your signature below means that you have received this information, have asked the questions you currently have about the research and those questions have been answered. You will receive a copy of the signed and dated form to keep for future reference.

- Signature of Subject

By signing this consent form, you indicate that you voluntarily choose to be in this research and agree to allow your information to be used and shared as described above.

___________________________  __________________________
Signature of Subject  Date  Printed Name
**Orthopedic**

*Regarding your lower extremity (feet, ankles, lower legs, knees, thighs, hips, low back and head please answer the following questions:*

### Foot & Ankle

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
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</thead>
<tbody>
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<td>Do you have a history of any broken bones?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circle one:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>If so where/when:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have a history of any torn or sprained ligament(s)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circle one:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>If so where/when:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are you currently having “giving-way”/Instability at your ankle?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circle one:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>If so when/how often:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you ever had surgery on your foot or ankle?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circle one:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>If so when/body part:</td>
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</table>

### Lower Leg & Knee

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you have a history of any broken bones?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circle one:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>If so where/when:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have a history of any torn or sprained ligament(s)?</td>
<td></td>
<td></td>
</tr>
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<td>Are you currently having “giving-way”/Instability at your knee?</td>
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<tr>
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<td>No</td>
</tr>
<tr>
<td>If so when/how often:</td>
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<tr>
<td>Have you ever had surgery on your lower leg or knee?</td>
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<td>If so when/body part:</td>
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## Thigh & Hip

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<td>Do you have a history of any broken bones?</td>
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</tr>
<tr>
<td>If so where/when:</td>
<td></td>
<td></td>
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<tr>
<td>Do you have a history of any torn or sprained ligament(s)?</td>
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<tr>
<td>If so where/when:</td>
<td></td>
<td></td>
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<tr>
<td>Have you ever had surgery on your thigh or hip?</td>
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<td>If so when/body part:</td>
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## Low Back

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<td>Circle one:</td>
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<tr>
<td>If so where/when:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have a history of any torn or sprained ligament(s)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circle one:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If so where/when:</td>
<td></td>
<td></td>
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<tr>
<td>Have you ever had surgery on your low back?</td>
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<td></td>
</tr>
<tr>
<td>Circle one:</td>
<td></td>
<td></td>
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<td>If so when/body part:</td>
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## Head Trauma & Concussion

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<td>Have you ever had a head injury or concussion?</td>
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<td>Circle one:</td>
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</tr>
<tr>
<td>If so when:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you currently have any neurological conditions?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circle one:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If so what:</td>
<td></td>
<td></td>
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<tr>
<td>Are you currently experiencing any of these symptoms due to a head injury?</td>
<td></td>
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<td>Circle one:</td>
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<td>If yes select:</td>
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Figure 3. Data Collection Sheet 1

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<thead>
<tr>
<th>Round</th>
<th>Vertical Jump</th>
<th>Horizontal Leap</th>
<th>SEBT</th>
<th>Obstacle Course</th>
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<tbody>
<tr>
<td></td>
<td>Jump 1 Jump 2 Jump 3 Leap 1 Leap 2 Leap 3 Ant Post Post-Med</td>
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Figure 4. Data Collection Sheet 2

<table>
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<tbody>
<tr>
<td><strong>Demographics</strong></td>
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<tr>
<td>Birthdate</td>
</tr>
<tr>
<td>Day</td>
</tr>
<tr>
<td><strong>Foot Wear - Size</strong></td>
</tr>
<tr>
<td>Boot</td>
</tr>
<tr>
<td>S</td>
</tr>
<tr>
<td><strong>Boot Brand</strong></td>
</tr>
<tr>
<td>Manufacture</td>
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</table>

Ankle Sprain Injury History

Have you ever worn an ankle brace?
- [ ] Yes    [ ] No

Have you ever sustained an ankle sprain?
- [ ] Yes    [ ] No

If "yes," how many sprains have you had?
- [ ] 1    [ ] 4
- [ ] 2    [ ] 5
- [ ] 3    [ ] More than 5 (specify): __________

Have you sprained one or both ankles?
- [ ] Left    [ ] Right    [ ] Both

<table>
<thead>
<tr>
<th>First Sprain</th>
<th>Second Sprain</th>
<th>Third Sprain</th>
<th>Fourth Sprain</th>
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<tbody>
<tr>
<td>Pain level</td>
<td>Pain level</td>
<td>Pain level</td>
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</tr>
<tr>
<td>mild</td>
<td>mild</td>
<td>mild</td>
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<tr>
<td>moderate</td>
<td>moderate</td>
<td>moderate</td>
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</tr>
<tr>
<td>severe</td>
<td>severe</td>
<td>severe</td>
<td>severe</td>
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<tr>
<td>Walking ability</td>
<td>Walking ability</td>
<td>Walking ability</td>
<td>Walking ability</td>
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**Figure 5. Randomization Table**

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Figure 6. Ankle Brace Sizing Instructions

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<th>Men’s Shoe Size</th>
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<td>M</td>
<td>9-11</td>
<td>10-12</td>
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<td>L</td>
<td>11-13</td>
<td>12-14</td>
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<tr>
<td>XL*</td>
<td>14 &amp; Over</td>
<td>15 &amp; Over</td>
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</tbody>
</table>

*Special Order

WARNING

McDavid Ankle Supports are designed to help reduce the frequency and severity of ankle injuries and provide extra ankle support during athletic activities. However, no ankle support can prevent all ankle injuries and no guarantee is made, either expressed or implied, that any injury will be prevented with this equipment.

McDavid Sports/Medical Products
10305 Argonne Dr.
Woodridge, IL 60517
www.mcdavidusa.com
Figure 7. Ankle Brace Application Instructions

INSTRUCTIONS

1. Apply over sock or directly to skin.
2. For greater ankle stability, use with McDaid's Double Knee Support.
3. Pull strap between the front and outside of the ankle. Tighten to secure the center of the ankle.
4. Pull strap to the side of the leg and secure with the strap. Secure strap to the outside of the ankle to secure the front of the ankle. Check comfort level.
5. Adjust as needed. Tighten and secure the strap to the outside of the ankle to secure the front of the ankle. Check comfort level.

FEATURES THAT GIVE YOU THE COMPETITIVE EDGE

1. Lightweight, nylon, stretchable, breathable material
2. Adjustable, comfortable
3. Keeps compression on the foot and ankle
4. Prevents swelling and pain
5. Allows for better range of motion

WARNING

Before using this product, please read the enclosed instruction sheet carefully. This device is for use in the treatment of ankle sprains. Do not use this product if you have a history of ankle sprain. If you have any allergy, please consult a doctor before using it. Use as directed and follow all instructions. If symptoms persist, please consult a doctor.
Figure 8. Modified Star Excursion Balance Test – Reach Directions
### APPENDIX D

### ADDITIONAL RESULTS

Table 1. Analysis of Demographic Information between ROTC Unit

<table>
<thead>
<tr>
<th>Independent Samples Test</th>
<th>Levene’s Test for Equality of Variances</th>
<th>t-Test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
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<tbody>
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<td></td>
<td>F</td>
<td>Sig.</td>
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<td><strong>Height</strong></td>
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<td>.690</td>
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<td>Equal variances not</td>
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Table 2. Paired T-Test Results for SEBT between Bracing Condition

<table>
<thead>
<tr>
<th>Pair</th>
<th>Condition Comparison</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
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</thead>
<tbody>
<tr>
<td>Pair 2</td>
<td>BracePostAve - NBracePostAve</td>
<td>-1.74687</td>
<td>6.25032</td>
<td>1.10491</td>
<td>Lower -4.00035, Upper 5.0660</td>
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<td>Pair 4</td>
<td>CompBAve - CompNBAve</td>
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<td>Lower -4.08761, Upper -8.9739</td>
<td>-3.187</td>
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<td>Pair 5</td>
<td>NormBAnt - NormUBAnt</td>
<td>-3.38125</td>
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<td>NormBPost - NormUBPost</td>
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<td>Pair 7</td>
<td>NormBPMed - NormUBPMed</td>
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Table 3. Paired T-Test Results for Functional Performance Measures between Bracing Condition

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<th>Std. Error Mean</th>
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<th>Sig. (2-tailed)</th>
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</thead>
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<td>-3.61406 to -1.07344</td>
<td>-3.763</td>
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<td>10.75603</td>
<td>1.90142</td>
<td>-9.33421 to -1.57829</td>
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<td>Pair 3 BraceOCourse-NBBraceOCourse</td>
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<td>1.45870</td>
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<td>.36971 to 1.42154</td>
<td>3.473</td>
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Table 4. Multivariate Analysis of Variance (MANOVA) Wilks’ Lambda Statistic between ROTC unit (Branch)

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<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Sig.</th>
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a. Design: Intercept + Branch
b. Exact statistic
c. Computed using alpha = .05
Table 5. MANOVA ROTC Unit Effects for Functional Performance Measures

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<tr>
<th>Source</th>
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Table 6. MANOVA ROTC Unit Effects for Star Excursion Balance Test Reach Distances

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APPENDIX E

BACK MATTER

Recommendations for Future Research

1. Do prophylactic ankle braces have negative effects on military specific functional performance measures such as ruck marches, field training exercises, and military physical fitness testing?

2. Does style or brand of military combat boot effect range of motion and dynamic balance differently due to differences in material components?

3. What are the long-term effects of ankle brace use in a military ROTC population? Do these devices reduce the rate of ankle sprains?

4. Is there a relationship between ROTC branch of service and ability to complete functional performance measures in military equipment?

5. Are there differences in dynamic balance and functional performance measures between males and females in and ROTC population while wearing prophylactic ankle braces.
Vitae

Thomas M. Newman

EDUCATION

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<th>Institution</th>
<th>Field</th>
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ACADEMIC EXPERIENCE

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NON-ACADEMIC EXPERIENCE

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<tr>
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<td>Virginia Military Institute</td>
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PROFESSIONAL CERTIFICATIONS/LICENSES

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<td>Certified Athletic Trainer</td>
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