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Attention is associated with postural control in those with chronic ankle instability

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ABSTRACT

Chronic ankle instability (CAI) is often debilitating and may be affected by a number of intrinsic and environmental factors. Alterations in neurocognitive function and attention may contribute to repetitive injury in those with CAI and influence postural control strategies. Thus, the purpose of this study was to determine if there was a difference in attentional functioning and static postural control among groups of Comparison, Coper and CAI participants and assess the relationship between them within each of the groups. Recruited participants performed single-limb balance trials and completed the CNS Vital Signs (CNSVS) computer-based assessment to assess their attentional function. Center of pressure (COP) velocity (COPv) and maximum range (COPr), in both the anteroposterior (AP) and mediolateral (ML) directions were calculated from force plate data. Simple attention (SA), which measures self-regulation and attention control was extracted from the CNSVS. Data from 45 participants (15 in each group, 27 = female, 18 = male) was analyzed for this study. No significant differences were observed between attention or COP variables among each of the groups. However, significant relationships were present between attention and COP variables within the CAI group. CAI participants displayed significant moderate to large correlations between SA and AP COPr ($r = -0.59$, $p = 0.010$), AP COPv ($r = -0.48$, $p = 0.038$) and ML COPr ($r = -0.47$, $p = 0.034$). The results suggest a linear relationship of stability and attention in the CAI group. Attentional self-regulation may moderate how those with CAI control postural stability. Incorporating neurocognitive training focused on attentional control may improve outcomes in those with CAI.

1. Introduction

Ankle sprains are some of the most common sports injuries. Some estimates have the frequency of occurrence at over 23,000 sprains per day in the United States with an approximate cost of $1000 per injury [1,2]. As many as 74% of those who experience an ankle sprain subsequently develop chronic ankle instability (CAI), which is characterized by a persistent dysfunction or recurrence of injury [3]. Chronic ankle instability can lead to further sprains and injury and can contribute to the development of osteoarthritis [4]. In addition, levels of physical activity may be disrupted and decreased which may impact the long-term health of individuals with CAI [5]. Thus, although many consider ankle sprains insignificant, the long-term consequences associated with CAI may exact significant physical and financial tolls.

It is currently unclear why some develop CAI while others do not, but both mechanical and neurological contributions have been suggested. After a sprain, tissue may heal with different mechanical properties, predisposing the joint to a less-than-optimal response to forces and perturbations [6]. Neurologically, it has been found that muscle spindle traffic is decreased in individuals with CAI [7]. The mechanism by which this occurs is unclear, but it is speculated that damage to mechanoreceptors within the joint may result in a lower ability to sense or respond to perturbations. Centrally mediated mechanisms, such as the organization of movement, may be disrupted and predispose an individual to repeated bouts of ankle instability [8]. However, this

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area of literature is emerging and it remains unclear why one person may develop CAI after a sprain while another may not.

Alterations in neurocognitive processing and function may also influence lower extremity injury. Recent evidence suggests those with altered neurocognitive function due to concussion may have a higher risk of lower extremity injury [9]. Similarly, individuals with a history of non-contact ACL injury have demonstrated worse reaction time, processing speed and memory compared to matched controls [10]. For the ankle specifically, dual-tasking has been used to indirectly assess attentional costs in individuals with CAI with conflicting results. One study previously found comparable time-to-boundary in those with CAI compared to controls during cognitive induced loading [11]. In contrast, another recent investigation found that those with CAI had worse postural control compared to controls with an added cognitive task suggesting a reliance on attentional control in this population [12]. However, this is not well understood because no investigations have directly measured attention in individuals with CAI.

In those with CAI, although attention has not been independently assessed, it may have a relationship to postural control which may not be present in healthy individuals. Attention is described as a limited resource, which must be distributed among all tasks a person is performing, including both motor and cognitive tasks [12]. As one process is provided more attention, another source must have access to less. Consequently, as attention is diverted to a specific task and away from others, performance may suffer. As maintaining static balance is a task requiring attention, those who have higher attentional control or self-regulation and can shift or focus their attention better, may be more efficient at maintaining their balance [13]. Therefore the purpose of this study was two-fold: 1) To identify if there was a relationship between attentional self-regulation and postural control across CAI, Coper and Comparison groups, and 2) To determine if those with CAI had altered attentional control or static postural stability compared to Comparison and Coper participants. It was hypothesized that as attentional self-regulation increased, single limb postural stability would as well and those with CAI would have decreased attentional functioning and postural control compared to Comparison and Coper participants.

2. Methods

2.1. Participants

Participants were recruited as a sample of convenience from the local university population. Participants were recruited into one of three groups; Comparison, Coper or CAI. Participants were entered into the Comparison group if they had 1) no history of lateral ankle sprain, 2) no complaints of their ankle giving way, and 3) a Cumberland Ankle Instability Tool (CAIT) score of $\geq$28, indicating good function [14]. For Copers inclusion criteria were 1) a history of a moderate to severe ankle sprain including inflammatory symptoms (pain, swelling, and/or discoloration) and disruption of desired physical activity, 2) 1 or fewer episodes of giving way at the ankle in the previous 12 months, and 3) CAIT score $\geq$28 [14,15]. Inclusion criteria for the CAI group included 1) a history of a moderate to severe ankle sprain including inflammatory symptoms (pain, swelling, and/or discoloration) and disruption of desired physical activity, 2) 2 or more episodes of giving way at the ankle in the previous 12 months, and 3) CAIT score $\leq$24, suggesting decreased ankle function [16]. In individuals who indicated bilateral instability, the limb with the lower CAIT score was utilized for testing.

All subjects were excluded with any of the following: history of lower extremity surgery or fracture; current sign or symptom of a joint sprain in the lower extremity (including pain, swelling, discoloration, or loss of range of motion or strength); any other health issue or unusual symptom (e.g., nausea, dizziness) that could affect the participant's safety or performance; pregnancy; diagnosis of a vestibular disorder; significant history of condition that impaired cognitive function such as learning disability, concussion, etc.; or if they were taking medications that affected cognitive function such as narcotics, anti-depressants, anti-anxiety agents, etc.

2.2. Procedures

Participants first arrived at the balance laboratory and completed University approved informed consent documents as well as all eligibility questionnaires. Subjects were then placed on a force platform (Neurocom, Balance Master System 8.4, Clackamas, OR, USA; 100 Hz) and asked to stand on the test limb in a quiet stance. For CAI and Coper participants the test-limb was indicated as the previously injured limb, for Comparison their dominant limb was used. Subjects performed 5 trials on their test limb for 60 s per trial. If subjects lost balance, touched the non-standing-foot down, or braced themselves on the surround, the trial was discontinued and recollected.

After the single-leg task, subjects sat in a quiet room and completed the CNS Vital Signs (CNSVS, CNS Vital Signs LLC., Morrisville, NC, USA) on a laptop computer. The CNSVS is a battery of valid and reliable computer-based neurocognitive tests designed to assess standard neuropsychological domains (e.g., memory, attention, psychomotor speed, etc.) [17]. For this study, only the domain of simple attention (SA) was calculated through data from the continuous performance test (CPT). The CPT lasts approximately 5 min and participants are presented one at a time with random letters. 200 letters are presented in total, approximately 1.5 s each. They are asked to respond to the letter "B" (40 times randomly) while ignoring all other letters, the letters continually appear regardless of response. SA is a measure of sustained attention, self-regulation and attention control; it is defined as the ability to track and respond to a single defined stimulus over lengthy periods of time while performing vigilance and response inhibition quickly and accurately to a simple task [17]. It takes into account both attentiveness and inhibition. Instructions and practice assessments were provided during the test; testing took approximately 25 min to complete.

2.3. Data and statistical analysis

A custom written MATLAB (Mathworks, Inc., Natick, MA, USA) script used the force plate's center of pressure (COP) data to calculate average velocity (COPv) of the COP sway and maximum range (COPr) of the COP in both the anteroposterior (AP) and mediolateral (ML) directions. Higher values of range indicate worse postural control whereas lower values of velocity indicated better postural control. Negative values of COPv indicate the posterior and medial directions, respectively.

Upon completion of the CNSVS a report provided age normalized, standard individual scores of various neurocognitive domains. SA is the number of correct responses minus commission (false positive) errors. Higher values indicate improved sustained attention or self-regulation.

All statistical analyses were completed in the Statistical Package for the Social Sciences^{TM} 20.0 (SPSS, Inc., Chicago, IL). An analysis of variance (ANOVA) was used to assess differences in attention and COP variables. Data were then evaluated using Pearson's Correlation Coefficients between COP and attentional variables, with separate analyses for CAI, Coper and Comparison participants, respectively. Statistical significance for all tests were set a-priori to