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Challenging the Concussion Culture by Considering Sub-Concussive Forces and the Importance of Cumulative Impacts: a Multisystem Paradigm, Part Two

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Whiplash Associated Disorder (WAD) and in-direct concussions influence multiple systems resulting in central nervous system (CNS) sensory-mismatch that the brain may perceive as pain and so alter movement patterns. Pain and dizziness may perpetuate continued neuronal plasticity, causing motor planning reprogramming and movement compensations. It may be possible to reset the sensory-mismatch by prescribing movements or exercises aimed at normalizing the afferent information of multiple tissues and body systems. Based on the current evidence, it is theoretically conceivable that a risk profile might be developed for individual athletes. By mitigating the sensory-mismatch effects, many athletes may be assessed and screened for in-direct concussion risk in order to develop preventative exercises and movements with the specific intent of normalizing sensory input from multiple systems and reducing risk. Future research may verify and validate this theoretical construct or it may be an impetus towards further consideration and study of the multifactoral topic constituting the concussion conundrum.

Key Words: sensory-mismatch, sub-concussive, cumulative impacts, multisystem

Introduction

In the previous publication titled, A Theoretical paradigm of Central Cognitive Mechanisms Linking Concussion and Whiplash Associated Disorder: Part One (Harper, 2014) the author suggests in-direct concussions may be caused by afferent sensory bombardment overloading the brain as it attempts to match current information with previously established interpretive patterns, thereby causing sensory-mismatch. This increases the system's vulnerability to a concussive event. The implementation of multiple assessments measuring multiple body systems, including somatosensory, vestibular, and vision, may enable one to detect individuals at risk for atypical, asymptomatic, in-direct concussive impacts. The purpose of this article is to (1) examine the similarities of whiplash-associated disorder (WAD) and summative sub-concussive forces, (2) to discuss how these conditions are linked, (3) to outline multiple system metrics to assist in the identification of those at risk for suffering an in-direct concussion, and (4) to describe how exercises can target multiple systems to normalize aberrant neural input, thereby decreasing susceptibility to summative concussive trauma.

Background

It is this author's opinion that, historically, those involved with athletics have tended and continue to view concussion injuries as less serious than functionally limiting musculoskeletal injuries. As a result, players, coaches, fans, family members, and health care providers tend to minimize "bumps to the head," which are often seen as a rite of passage. This creates a concussion complaisant culture. For example, if an athlete suffers an anterior cruciate ligament (ACL) tear there are visible physical impairments preventing return to play. There would be no question that an athlete who sustained an ACL tear would be removed and not return to that athletic competition. In contrast, those who suffer concussion typically do not show outward physical damage unless cognitive deficits are overt. More often, concussion causes subtle system impairments identified through eye assessment and balance, both initial metrics of brain function.

Due to the lack of obvious clinical findings, concussion is inherently difficult to define and has been called the "silent injury" (Kirkwood et al., 2008). Multiple studies have estimated that 50-80% of concussions are not reported (Broglio & Guskiewicz, 2009; McCrea et al., 2005; McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004) and the American College of Sports Medicine (American College of Sports Medicine (ACSM), 2006) estimates that 85% of sports-related concussions are unidentified. Society tends to view concussion injury as less serious, possibly due to a limited understanding of concussion pathophysiology. Athletes, themselves, underreport concussion symptoms because they believe it is not a serious injury, they do not recognize signs and symptoms, or they think they will be withheld from competition. (Broglio & Guskiewicz, 2009; McCrea et al., 2005, 2004) Some researchers (Dematteo et al., 2010) have proposed that clinicians use the label "concussion," rather than mild traumatic brain injury (mTBI), intending to minimize patient or parental concerns about recovery and long-term sequelae. Two things are clear: (1) health care providers, athletes, parents, and coaches need to be better educated, and (2) health care providers, parents, and coaches must model safety behavior that communicates an understanding of the serious nature of concussion injuries. Unless those in authority attach as much, or more, significance to symptoms of head injury as they do for neuromusculoskeletal injuries, athlete behavior will not change. Until those agents are in place, the concussion culture of safety will not be changed.

Historically, concussion is described as metabolic starvation within the brain due to mechanical acceleration, deceleration, and shearing forces (Sahler & Greenwald, 2012). Multiple studies have used helmet telemetry to measure head impacts (Cobb et al., 2013; Rowson & Duma, 2013; Urban et al., 2013; Young, Daniel, Rowson, & Duma, 2013, 2014), but they have not been shown to reduce concussion risk (King, Brughelli, Hume, & Gissane, 2014). It is therefore the author's opinion that head impact sensors do not prevent concussion. Rather than using the data generated by the sensors to quantify cut-off scores for concussive grade impact forces, the data could be applied to assess for summative forces in order to identify those at risk for multisystem over-load in a preventative fashion. At risk athletes who remain asymptomatic after sustaining either high force or cumulative low force impacts can be removed from play to allow multisystem sideline screening. This act alone may allow sufficient time for these systems to reset or gives the brain additional time to interpret and respond to the forces just sustained. In this sense, we may prevent a concussive event due to sensory-mismatch interpretation as the complex process is interrupted. This same concept can be applied in pre-season baseline prevention assessments to identify athletes at risk for musculoskeletal or concussive injuries. Applying the afferent sensory overload construct of current research on whiplash pathophysiology to summative sub-concussive forces leaves open the possibility of prescribing preventative exercises or movements aimed at normalizing the afferent sensory input, thus diverting the sensory-mismatch conundrum.

In the author's opinion, the act of playing one game of football or ice hockey in a 2-3 hour period of time during which many inertial, high and low, acceleration-deceleration, and linear and rotational forces occur to various body regions other than the head, is comparable to being in multiple motor vehicle accidents (MVA's) within the same time period. Since multiple collisions and jostlings also occur during non-direct contact sports like soccer and basketball, in-direct forces may be received and potentially transmitted to the head. If direct and in-direct contact sports are similar to MVA forces, then one must consider the probability that athletes will likely suffer WAD.

Similarities of WAD and Sub-Concussive Forces

Current literature linking WAD and concussion is limited. Hynes and Dickey (2006) performed a prospective cohort observational study of 183 ice hockey players ages 15 to 35 during a single season. Thirteen players suffered head related injuries—seven sustained concussions and six were diagnosed with WAD—all showed symptoms of both concussion and WAD with complaints of headache followed by dizziness. The authors identify a direct relationship between neck injury from WAD and concussive symptoms, promote the importance of pre-season baseline assessments, and encourage adequate medical clearance prior to return to play (RTP) (Hynes & Dickey, 2006). This study is important because it is the only published article, to the author's knowledge, which links concussion and whiplash, emphasizes preseason baseline testing in an attempt to identify those at risk for suffering a concussion, and promotes complete evaluation of musculoskeletal structures as well as full return of cognitive function before return to activity.

With that in mind, consider the study by Schneider et al. (2013), which evaluated concussion risk based on preseason variables in male ice hockey athletes ages 13 and 14 years. Three preseason risk factors were predictive of concussion incidence including neck pain, headaches, and deficits in balance. If an athlete presented preseason with two of these three risk factors, concussion incidence during the competitive season increased by a factor of 2.4 to 3.65. These results seem to support a sensory-mismatch theory since preseason screening was able to identify individuals with signs of sensory overload and those particular athletes experienced concussions at a statistically significant increased rate; thus, the relationship is less likely to be a coincidence.

Table 1 QTF Classification Grade for WAD Clinical Presentation.
This table describes the standardized WAD classifications with respective clinical presentation for each classification. Adapted from and combines table information from Spitzer et al (1995). Spine, 20(8 Suppl),1S-73S and Sterling M. (2014). Journal of Physiotherapy, 60(1),5-12.

QTF Classification Grade	Clinical Presentation
0	No complaint about neck pain. No physical signs.
I	Neck complaint of pain, stiffness or tenderness only. No physical signs.
II	Neck complaint. Musculoskeletal signs including: • Decreased range of movement • Point tenderness
III	Neck complaint. Neurological signs including: • Decreased or absent deep tendon reflexes • Muscle weakness • Sensory deficits
IV	Neck complaint and fracture or dislocation.

WAD is usually associated with MVA and occurs when the trunk absorbs a force causing it to accelerate and, as the forces are transmitted through the cervical structures, displaces the head in one or more directions depending on the initial force vectors (Storaci et al., 2006). The energy transfer caused by an impact to the trunk, as often occurs to athletes while playing various sports, exposes the structures of the neck and head to acceleration-deceleration forces (Montfoort et al., 2006), which may easily disrupt multiple systems. In order to facilitate a common understanding of WAD (Sterling, 2014), the Quebec Task Force (QTF) developed a classification (Table) (Spitzer et al., 1995).

The QTF WAD classification has been criticized for a lack of scientific validation and simplistic clinical presentation descriptions, particularly for grade II. Despite these criticisms, it continues to be the most applied classification system for WAD (Spitzer et al., 1995; Sterling, 2014). Setting aside this debate, what is clear is that altered cervical movement patterns occur in all WAD grades. This has been demonstrated in the neck flexors during the cranio-cervical flexion test, shoulder girdle, joint position errors, and postural balance control (Helgadottir, Kristjansson, Einarsson, Karduna, & Jonsson, 2011; Jull, 2000; Revel, Andre-Deshays, & Minguet, 1991; Revel, Minguet, Gregoy, Vaillant, & Manuel, 1994; Treleaven, Jull, & Grip, 2011; Treleaven, Jull, & Lowchoy, 2005; Treleaven, Jull, & LowChoy, 2006). Furthermore, the presence of hypersensitivity has been identified in those with neck pain, suggesting a central pain processing mechanism (Coderre, Katz, Vaccarino, & Melzack, 1993; Flor, 2003; Melzack, 2001; Misra & Coombes, 2014). Those with chronic presentations of WAD also exhibit increased psychological distress and disturbances in the sensory and motor systems (Revel et al., 1991, 1994; Sterling, 2004). These multiple systems findings have been consistent in WAD literature (Bono et al., 2000; Jensen & Baron, 2003; Nederhand, Hermens, IJzerman, Turk, & Zilvold, 2003; Tjell & Rosenhall, 1998; Treleaven et al., 2011, 2005, 2006), especially with the involvement of the vestibular system and eye function (Montfoort et al., 2006; Nacci et al., 2011; Storaci et al., 2006).

Linking WAD and Summative Sub-Concussive Forces

Linking WAD to concussion is not limited to high-speed MVA. A study by Casto et al. (1997) determined that WAD soft tissue trauma and motor control deficits occurred between 8.7 to14.2 km/h (5.4 to 8.8 mph) for rear-end vehicle collisions with average acceleration of 2.7 G's while the bumper car collisions were between 8.3 to 10.6 km/h (5.2 to 6.6 mph) and average acceleration of 2.2 G's. The authors conclude that WAD from MVA occurs at velocities between 10 and 15 km/h (6 to 9 mph) and that the stresses sustained from vehicle collision and bumper car crashes were similar. Davis (1998) reviewed literature pertaining to low-speed rear-end collisions and found that neuromusculokeletal system changes and injuries were sustained at low forces. The author concluded that, although vehicle damage may not occur until 14 to 15 km/h (8.7 to 9.3 mph), WAD symptoms can occur from forces incurred from speeds of 4 km/h (2.5 mph). This is important because the literature measuring head impact forces, primarily from football helmet telemetry (Cobb et al., 2013; Rowson & Duma, 2013; Urban et al., 2013; Young et al., 2013), has designated the concussion incidence threshold force levels at a linear acceleration greater than 96 G's and rotation acceleration forces greater than 5,500 rad/s. Athletes exposed to such forces are at high risk of suffering a concussive event. These forces are much higher than those determined to be injury producing in MVAs. If concussion typically occurs from higher forces and WAD results from lower forces at low-speeds, then athletes are in fact exposed to multiple forces sufficient enough to result in WAD. This summative sensory processing disruption of multiple systems (neck muscle proprioception, vestibular, somatosensory, and ocular function) may result in symptoms of pain, movement compensation patterns, or dizziness.

Dizziness is a common symptom of WAD. Treleaven et al. (2005) linked increased dizziness in those with WAD to impaired postural control and proposed that dizziness in WAD is caused by a sensory-mismatch of abnormal cervical and normal vestibular information. This suggests abnormal cervical spine afferent input triggers altered peripheral vestibular function. Assessing balance, cervical joint position error (JPE), and smooth pursuit neck torsion can lead to the identification of deficits in postural control. Thus, dizziness, which is caused by impairments in multiple body systems, is a symptom shared by those suffering from WAD and those with concussion. Aberrant peripheral afferent sensory input may confuse the central cortical system. Confusion results from the sensory-mismatch between somatosensory, proprioceptive, vestibular, and visual systems and is expressed by the symptom of dizziness (Vidal & Huijbregts, 2005). The cerebellum is one of the primary regions interpreting afferent sensory information and initiating motor control responses. It guides movement by synthesizing visual input with cervical and eye position signals and may also regulate the gain of several vestibular reflex pathways and promote the development of new sensorimotor patterns (Manzoni, 2005). Viewed in this light, motor learning occurs through sensorimotor neuroplastic transformation resulting in either the execution of pre-determined movements (skills or performances) or an ability to learn and adapt to a new movement pattern based on a change in motor context. For example, aberrant sensory information may result in a new and altered movement pattern, which may establish new cortical movement pathways of control (Manzoni, 2005). Another example was highlighted in research by Maugans et al. (2012), demonstrating that 36% of those who suffered a concussive event displayed decreases in cerebral blood flow (CBF) for up to 30 days, without blood pressure changes, despite normalization of ImPACT scores. Thus, postural control (balance) is processed by an extensive network of neural connections between the cerebellum, the vestibular nuclei complex, the reticular activating area of the brainstem, the ocular motor nuclei, and other higher cortical brain functions (Vidal & Huijbregts, 2005).

Nacci et al. (2011) confirmed that patients with WAD or concussion can suffer from peripheral and central vestibular dysfunction and that postural control may be dramatically impaired in those with WAD, without nystagmus symptoms. Daenen et al. (2012) found that those suffering from WAD have an alteration in perception, which distorts visual feedback. They proposed this was due to altered processing of the central nervous system (CNS).

CNS processing can be influenced by pain, which causes alterations in normal movement strategies and results in new pattern adaptations of movement that are neither uniform nor predictable (Hodges & Tucker, 2011). These changes in motor control (Langevin & Sherman, 2007) restructure sensory and motor function initiating complex and comprehensive multisystem neuroplastic changes; termed central sensitization (Boal & Gillette, 2004; Coderre et al., 1993; Flor, 2003; Ji & Woolf, 2001; Langevin & Sherman, 2007). The constant barrage from multiple tissues, such as muscle spindles and mechanoreceptors, reinforces the movement compensation patterns, resulting in further damage and breakdown of innervated tissues and central sensitization; this process is known as the pain neuromatrix theory (Khalsa, 2004; Langevin & Sherman, 2007; Melzack, 1999, 2001; Moseley, 2003). This plastic ability of connective and nervous tissues is influenced by cortical centers governing motor control, thus linking these changes to movement pattern compensations (Langevin & Sherman, 2007). Similarly, altered movement patterns were identified in both those suffering from chronic neck pain and in those with WAD, indicating changes in motor control strategies (Woodhouse & Vasseljen, 2008). These findings link central processing or central sensitization with WAD, establishing a framework for continual sensory misinterpretation, and may explain how musculoskeletal pain translates into WAD clinical findings (Sterling, 2011).

Movement, motor control, and pain are processed in the brain in overlapping sensory regions of the medial wall of the cingulate cortex, particularly within the anterior midcingulate cortex (aMCC) and supplementary motor area (SMA) (Misra & Coombes, 2014). It is insignificant whether pain and neural movement patterns are activated concurrently or independently (Misra & Coombes, 2014), providing an example of the mixing of pain and motor function interpretation. One's pain experience influences one's movement choices, thereby modifying the motor pattern template. Research has even demonstrated that anticipated pain can initiate movement pattern adaptations (Coderre et al., 1993; Flor, 2003; Hodges & Tucker, 2011; Melzack, 1999, 2001). Despite the growth in understanding regarding the link between the development of motor patterns and pain processing, the full nature of the relationship is not yet been understood.

In this context of pain processing and motor re-patterning, there is the possibility of a cyclical pattern in which pain causes motor patterns perpetuating pain or altering other sensory perceptions causing other symptoms (Daenen, Nijs, Roussel, Wouters, Van Loo, et al., 2012; McCabe & Blake, 2007), such as dizziness. The CNS attempts to match the distorted information with the visual and sensory-motor inputs in patients with WAD. Thus, chronic pain may result in sensorimotor remapping, which may alter motor patterns resulting in incongruence between predicted and actual sensory feedback systems.

Abnormal eye movement is one of the first signs of brain injury. Sensory-mismatch theory is based on the functionally overlapping anatomical regions of the brain governing pain perception and movement commands. In their search for an easy and reliable screen for mTBI, Maruta et al. (2010) correlated visual tracking gaze errors to traumatic brain injury severity and cognitive deficits and found the visual errors increased proportional to the severity of the injury, supporting the use of visual tracking as a screen for mTBI. Keeping in mind that concussion is a subtype of mTBI (Harper, 2014), eye movements are currently used as a screening assessment to identify those who may be presenting with a concussion. As a metric of cognitive function through an evaluation of the motor expression of white matter integrity and neuronal processing, eye assessment may be able to identify brain injury secondary to summative low force impacts in otherwise asymptomatic athletes, according to currently accepted concussion signs and symptoms.

Alterations in cervical movement patterns within chronic WAD grades 0 to III may not be directly caused by the initial mechanism of injury. Instead, the dysfunction of the muscle pattern may be in response to pain itself (Ylinen et al., 2003). This was demonstrated with the cranio-cervical flexion test with increased neck flexor activity ($p<0.0001$) in those with chronic WAD compared to a control group (Jull, 2000). In a double blind study looking at chronic cervical pain post whiplash, researchers identified cervical zygapophyseal (facet) joint pain (95% CI, 40-68%) as the primary pain source in 54% of patients with the most commonly effected regions C2-3 and C5-6 (Barnsley, Lord, Wallis, & Bogduk, 1995). Other examples of motor control compensations in those suffering from WAD include cervical muscle weakness, possibly due to pain avoidance behavior (Prushansky, Gepstein, Gordon, & Dvir, 2005), and altered upper quarter muscular function, specifically in the serratus anterior and trapezius muscles (Helgadottir et al., 2011), which are both key players in hand-arm function.

Additional support for the sensory-mismatch hypothesis can be found by examining the current literature for WAD evidence-based treatment interventions, which favors early and active exercises rather than immobilization (McClune, Burton, & Waddell, 2002; Pho & Godges, 2004; Rosenfeld, Gunnarsson, & Borenstein, 2000; Schnabel, Ferrari, Vassiliou, & Kaluza, 2004; Ylinen et al., 2003). Cervical musculature has a proprioceptive role that can be trained, influencing cervicocephalic kinesthesia (Revel et al., 1991, 1994; Treleaven et al., 2006). Chronic neck pain alters cervical proprioceptive function and can be improved using coupled exercises involving the eye, hand, and head (Revel et al., 1994; Sarig-Bahat, 2003). Multimodal treatment interventions, stimulating multiple systems, are the primary method for treating those with chronic mechanical neck pain and WAD; reviews do not recommend any single treatment intervention to be used in isolation (Anita R. Gross et al., 2004; A. R. Gross et al., 2002).

Cervical spine proprioceptive afferent information can compensate for vestibular reflex function in peripheral vestibular damage. Deficits resulting from WAD are primarily due to altered proprioceptive input of the effected injured tissues, disrupting the vestibular spinal reflexes, and are present with or without pathological nystagmus (Nacci et al., 2011). Active myofascial trigger points, those causing spontaneous pain, in cervical spine musculature may affect the proprioception system, can be identified during physical examination, and tend to be more prominent in those suffering from WAD (Castaldo, Ge, Chiarotto, Villafane, & Arendt-Nielsen, 2014). Disruption of the oculomotor system induces dysfunction of the vestibular system and is influenced by cervical spine muscle proprioception. People with WAD grade II tend to have oculomotor dysfunctions, which, if present, indicate a need for oculomotor rehabilitation (Storaci et al., 2006). The cervico-ocular reflex (COR) works in conjunction with the vestibulo-ocular reflex (VOR) and the optokinetic reflex (OKR) to preserve stable vision during head motion. Deep neck muscles, joint capsules, primarily from C1-C3 segments, and vestibular nuclei stimulates proprioceptive afferent neural input with normal cervical head movements. If VOR and COR are not working optimally then dizziness and vertigo may be experienced and, when combined with neck pain, fatigue may result (Montfoort et al., 2006; Montfoort, Van Der Geest, Slijper, De Zeeuw, & Frens, 2008). Inability to maintain eye gaze and impaired eye co-ordination may reveal disturbances in vestibular reflex activity associated with decreased cervical range of motion and/or neck pain in those with WAD (Treleaven et al., 2011). It is an important connection to link these symptoms with WAD as they are also common in concussion.

Multisystem Risk Factors for In-Direct Concussion

Postural control, maintained by afferent information from the somatosensory, visual, and vestibular systems, is altered in those with concussion (Harper, 2014; McCabe & Blake, 2007). Balance is evaluated by the amount of sway required to maintain postural control and is impacted by impaired vision, a suppressed vestibular system, or an inefficient integration of vestibular information. Concussion causes persistent cerebral function impairments after the original injury has resolved and these affect postural control (McCrea et al., 2005; Riemann & Guskiewicz, 2000; Sosnoff, Broglio, Shin, & Ferrara, 2011). Deficiencies of balance, which have the potential to become long-term as alternative neural pathways develop via neural plastic adaptions to compensate for improper multisystem neural activity are linked to improperly integrated afferent sensory inputs (Sosnoff et al., 2011). Riemann and Guskiewicz (2000) used the Balance Error Scoring System (BESS) to detect postural stability impairment after a potential concussive event. The authors found that postural instability can be assessed using the BESS with three stances on an unstable (foam) surface as a useful tool to identify improper motor control responses up to three days after a concussive event. This study supported the importance of balance assessments, such as the BESS, in those with concussion and as an important clinical factor in return to play (RTP) decision, especially when high-tech diagnostic equipment like the NeuroCom is unavailable.

Guskiewicz et al. (2000) assessed the postural stability of collegiate athletes through baseline balance and cognitive function using the NeuroCom systems, the BESS, and five distinct neuropsychological tests including the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) and studied the progression of symptoms following a concussion, particularly among those whose concussive event involved a loss of consciousness. The researchers found a significant relationship associating postural stability impairments with concussion. However, they found no significant correlation between poor baseline balance and concussion risk. Mulligan et al. (2012) performed neurocognitive (ImPACT) and postural balance (BESS) tests on nonconcussed asymptomatic collegiate football players 48 hours post season after the last game of an 11-game schedule and compared those results with preseason baseline scores. Despite a nonconcussed status, 71% of the subjects demonstrated one or more impairments in balance, postural stability, or neurocognitive function. Balance impairment data showed statistical significance in 32% of those who had impairments. These findings suggest athletes may not recognize concussion signs and symptoms, resulting in a failure to access health care services. Talavage et al. (2014) studied high school football players who, although asymptomatic after head collisions, demonstrated changes in neurocognitive (ImPACT) and neurophysiological (functional magnetic resonance imaging) tests consistent with or exceeding those found in medically diagnosed cases. These findings corroborate those of Mulligan et al. (2012), highlighting the need for more accurate concussion diagnostics and the potential value of predictive risk baseline assessments (Talavage et al., 2014). This study is important because it suggests an alternative pathophysiology to concussion that exhibits the same symptomology. As shown by studies on WAD, multisystem impairments due to summative force impacts fulfill that criterion, causing concussion-like symptoms.

A predictive relationship has been identified between ImPACT scores and an increased risk of noncontact ACL injuries in which those who sustained ACL injuries had comparatively lower baseline ImPACT composite scores to uninjured athletes (Swanik, Covassin, Stearne, & Schatz, 2007). These findings suggest the movements during athletic events demand a higher degree of cortical information processing of motor coordination and a quicker reaction time. Anything decreasing the brain's ability to process that information is magnified in a poorly conditioned or fatigued athlete and results in a greater risk of injury. In order to determine if cognitive impairments were exclusive to head impact trauma, researchers compared the Automated Neuropsychological Assessment Metrics (ANAM) scores of athletes who were uninjured, sustained musculoskeletal injury, and those sustaining a concussion. The comparison showed a link between musculoskeletal injury and poor neurocognitive performance post-injury (Hutchison, Comper, Mainwaring, & Richards, 2011). Despite low statistical power, their findings suggest that non-head-trauma injuries may alter cognitive function, thereby indicating the probability of an alternative pathophysiological pathway to indirect neurological deficits, as might be explained by the multisystem mismatch hypotheses. Coldren et al. (2012) challenged the findings by Hutchison et al. (2011), conveying concern the data might be overemphasized by healthcare providers, who might then miss a concussion diagnosis by attributing cognitive deficits solely to musculoskeletal injuries, especially with RTP decisions. Hutchison et al. (2011) responded (Coldren et al., 2012) by reiterating that not all cognitive deficits can be traced back to a specific brain injury. This discussion highlights the complex interaction of multiple systems, especially the vestibular system, in movement deficits and concussion-like symptomology.

The King-Devick (K-D) test is being used as a sideline-screening test on those who may have suffered a concussion and might be a useful adjunct to identify those who have been exposed to significant inertial head impact forces or to those exposed to multiple summative head impacts (Kristin M. Galetta et al., 2011; M. S. Galetta et al., 2013). The K-D has been found reliable when administered by medical professionals (K. M. Galetta et al., 2011) and can be completed in less than two minutes. Its purpose is to detect impaired eye function and saccades, indicative of suboptimal brain function (Kristin M. Galetta et al., 2011; Heitger et al., 2009; Maruta, Suh, Niogi, Mukherjee, & Ghajar, 2010). Galetta et al. (2011) used the K-D as a sideline screen in collegiate athletes participating in men's and women's soccer and basketball and men's football. Ten athletes suffered a concussion demonstrating significantly higher K-D times, testing worse than their baseline scores with a median change from baseline to sideline testing of 5.9 seconds (p=0.009). Duenas et al. (2014) studied 13 male high school football players over three consecutive games. Three players suffered concussions during this short period and, following injury, had longer K-D times by 5 to 8 seconds. Early detection of concussion is vital to improved outcomes post concussion. Saccadic eye movement and working memory functions primarily occur in the dorsolateral prefrontal cortex (DLPFC), an area susceptible to concussive injury. This may explain the correlation of eye movement and memory related cognitive impairments exhibited by athletes suffering from concussion injuries (M. S. Galetta et al., 2013; White & Fielding, 2012). Leong et al. (2014) used non-medial laypersons to administer the K-D on boxers. After examination by medial professionals during and post-fight, athletes were re-assessed by the blinded non-medical testers using the K-D test. According to their data, the K-D test has test-retest reliability (ICC=0.90) with scores apparently unaffected by fatigue and can be reliably performed by non-medically trained individuals. Tjarks et al. (2013) studied 35 concussed adolescent athletes ages 12 to 19 without prior history of concussion by longitudinally comparing K-D tests with ImPACT scores. They found that during recovery from concussion the improvements in K-D scores paralleled gains in the ImPACT composite scores measuring visual processing, visual acuity, and oculomotor speed. Initial deficits are hypothesized to be a reflection of axonal damage to oculomotor neurons. Linking these two methods of assessment, K-D and ImPACT, may not only assist in the identification of those suffering from a concussive event, but, since the scores reflected severity and gradual recovery, they may be sensitive enough to track progressive brain impairment related to cumulative impacts, as well as to be utilized for RTP decisions.

Multisystem Movements Normalizing Neural Input

Recovery from concussion and RTP decisions are beyond the scope of this article, but are typically focused around graded aerobic activity (Broglio & Guskiewicz, 2009; Leddy et al., 2013; Leddy & Willer, 2013; McCrea et al., 2005; Sahler & Greenwald, 2012). Recovery and treatment interventions for WAD are also beyond the scope of this article, but ample evidence indicates that cervical spine mechanoreceptor activity should be normalized; the vestibular system should be treated with vestibular rehabilitation training (VRT), which includes eye function and normalization of ocular reflexes; muscular coordination of the deep neck flexors and upper quarter musculature should be addressed; and JPE should be addressed with hand and head movements in conjunction with eye tracking (Alsalaheen et al., 2013; Kristjansson & Treleaven, 2009; Montfoort et al., 2006; Sterling, 2014; Stewart, McQueen-Borden, Bell, Barr, & Juengling, 2012; Treleaven et al., 2005, 2006). Individuals receiving physical therapist services for concussion received unilateral vestibular hypo-function impairment treatment according to a retrospective chart review (Alsalaheen et al., 2013). Hansson et al. (2013) conducted a randomized clinical trail on those suffering from WAD with dizziness symptoms to study the effects of VRT, which included exercises aimed at stimulation of the vestibular system through eye, head, and trunk movements. Statistical significance was found, but the study had a small heterogeneous sample making the results non-generalizable. Treating the vestibular system is important because it may be a key link influencing the maintenance of sensory information mismatch, which is identified through the symptom of dizziness or vertigo. Some believe that the disruption of the body's ability to utilize and process vestibular information is the underlying cause of postural control dysfunction (Stewart et al., 2012).

Instead of focusing on one system, it may be advantageous to target multiple systems during interventional treatment, especially since multiple systems exhibit impairments. The dual-task paradigm combines activities that challenge multiple systems (Bigsby et al., 2014; Stewart et al., 2012). One method entails having an individual perform an upper extremity visuomotor coordination task while balancing on an unstable surface. Another example of dual-task exercises involves having the individual complete similar functional tasks as listed above in conjunction with a cognitive task, like verbally stating the months of the year in order backwards (Bigsby et al., 2014; Stewart et al., 2012). Such dual-task exercises can assess or train the multiple systems involved in postural control, including vestibular, visual, proprioceptive, and somatosensory systems. It may be possible for athletes to perform preventative exercises or movement patterns addressing these multiple systems to maintain optimal system function.

Conclusion

In summary, WAD and concussion share multiple symptoms, particularly subjective reports of dizziness and pain, specifically, headache. Pain and dizziness dramatically influence multiple body systems and may result in neuronal plasticity, which leads to motor planning reprogramming and movement compensations. These non-optimal movement patterns may perpetuate aberrant sensory information, which is misinterpreted as "normal" sensory input, thus creating a CNS processing conundrum. This "sensory-mismatch" of information is influenced by multiple systems. Since most concussions are not a result of large inertial impact forces, one can speculate that cumulative minor traumas to various tissues may make the CNS more susceptible to exhibiting concussion-like symptoms. It may be possible to reset the sensory-mismatch caused by summative subconcussive inertial forces by prescribing movements or exercises aimed at normalizing the afferent information of multiple tissues and body systems. Exercise prescription would depend on the primary systems involved, which can be identified by testing balance (BESS), cognitive function (ImPACT), and eye function (K-D). These same assessments, considering the results in conjunction with a prior history of concussion, prior or present musculoskeletal injuries, neck pain, or current complaints of headache (Harper, 2014), may allow for the establishment of an individual concussion risk profile. Based on the current evidence, it is theoretically conceivable the resulting risk profile might be used to prescribe preventative exercises aimed at decreasing concussion risk from in-direct impacts. By normalizing and optimizing system functions, the brain may be better able to process pain and altered sensory information thereby preventing suboptimal motor reprogramming caused by summative multisystem over-load.

Historically, the discussion of concussion has been limited to direct concussion focused on neurometabolic events which alter cerebral glucose metabolism and cerebral blood flow, leading to a temporary imbalance and metabolic famine, resulting in neuronal starvation, disrupting both cognitive and motor function (Baldwin, Fugaccia, Brown, Brown, & Scheff, 1996; Bergsneider et al., 1997, 2000; Hovda et al., 1995; Shetter & Demakas, 1979; Yamaki et al., 1998) It is important to extend this dialogue beyond the historical view of direct concussion to a multisystem threshold approach. It is the author's belief that by mitigating the sensory-mismatch effects of multiple systems many athletes and all patients across age ranges may be assessed and screened for in-direct concussion risk in order to develop preventative exercises and movements with the specific intent of normalizing sensory input from multiple systems, thereby reducing risk. Future research may verify and validate this theoretical construct or it may be an impetus for further consideration and study of the multifactoral topic that constitutes the concussion conundrum.

References

Alsalaheen, B. A., Whitney, S. L., Mucha, A., Morris, L. O., Furman, J. M., & Sparto, P. J. (2013). Exercise prescription patterns in patients treated with vestibular rehabilitation after concussion. *Physiotherapy Research International: The Journal for Researchers and Clinicians in Physical Therapy*, *18*(2), 100–108. http://doi.org/10.1002/pri.1532

American College of Sports Medicine (ACSM). (2006, June). Concussions: ACSM Issues Recommendations for Diagnosis, Treatment and Prevention. Press Release.

Baldwin, S. A., Fugaccia, I., Brown, D. R., Brown, L. V., & Scheff, S. W. (1996). Blood-brain barrier breach following cortical contusion in the rat. *Journal of Neurosurgery*, *85*(3), 476–481. http://doi.org/10.3171/jns.1996.85.3.0476

Barnsley, L., Lord, S. M., Wallis, B. J., & Bogduk, N. (1995). The prevalence of chronic cervical zygapophysial joint pain after whiplash. *Spine*, *20*(1), 20–25; discussion 26.

Bergsneider, M., Hovda, D. A., Lee, S. M., Kelly, D. F., McArthur, D. L., Vespa, P. M., … Becker, D. P. (2000). Dissociation of cerebral glucose metabolism and level of consciousness during the period of metabolic depression following human traumatic brain injury. *Journal of Neurotrauma*, *17*(5), 389–401.

Bergsneider, M., Hovda, D. A., Shalmon, E., Kelly, D. F., Vespa, P. M., Martin, N. A., … Becker, D. P. (1997). Cerebral hyperglycolysis following severe traumatic brain injury in humans: a positron emission tomography study. *Journal of Neurosurgery*, *86*(2), 241–251. http://doi.org/10.3171/jns.1997.86.2.0241

Bigsby, K., Mangine, R. E., Clark, J. F., Rauch, J. T., Bixenmann, B., Susaret, A. W., … Colosimo, A. J. (2014). Effects of postural control manipulation on visuomotor training performance: comparative data in healthy athletes. *International Journal of Sports Physical Therapy*, *9*(4), 436–446.

Boal, R. W., & Gillette, R. G. (2004). Central neuronal plasticity, low back pain and spinal manipulative therapy. *Journal of Manipulative and Physiological Therapeutics*, *27*(5), 314–326. http://doi.org/10.1016/j.jmpt.2004.04.005

Bono, G., Antonaci, F., Ghirmai, S., D'Angelo, F., Berger, M., & Nappi, G. (2000). Whiplash injuries: clinical picture and diagnostic work-up. *Clinical and Experimental Rheumatology*, *18*(2 Suppl 19), S23–28.

Broglio, S. P., & Guskiewicz, K. M. (2009). Concussion in sports: the sideline assessment. *Sports Health*, *1*(5), 361–369. http://doi.org/10.1177/1941738109343158

Castaldo, M., Ge, H.-Y., Chiarotto, A., Villafane, J. H., & Arendt-Nielsen, L. (2014). Myofascial trigger points in patients with whiplash-associated disorders and mechanical neck pain. *Pain Medicine (Malden, Mass.)*, *15*(5), 842–849. http://doi.org/10.1111/pme.12429

Castro, W. H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1997). Do "whiplash injuries" occur in low-speed rear impacts? *European Spine Journal: Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366–375.

Cobb, B. R., Urban, J. E., Davenport, E. M., Rowson, S., Duma, S. M., Maldjian, J. A., … Stitzel, J. D. (2013). Head impact exposure in youth football: elementary school ages 9-12 years and the effect of practice structure. *Annals of Biomedical Engineering*, *41*(12), 2463–2473. http://doi.org/10.1007/s10439-013-0867-6

Coderre, T. J., Katz, J., Vaccarino, A. L., & Melzack, R. (1993). Contribution of central neuroplasticity to pathological pain: review of clinical and experimental evidence. *Pain*, *52*(3), 259–285.

Coldren, R. L., Russell, M., Kelly, M. P., Parish, R. V., & Dretsch, M. (2012). Effect of musculoskeletal injury on concussion testing: letter to the editor. *The American Journal of Sports Medicine*, *40*(9), NP18–19; author reply NP19–20. http://doi.org/10.1177/0363546512457655

Daenen, L., Nijs, J., Roussel, N., Wouters, K., & Cras, P. (2012). Altered perception of distorted visual feedback occurs soon after whiplash injury: an experimental study of central nervous system processing. *Pain Physician*, *15*(5), 405–413.

Daenen, L., Nijs, J., Roussel, N., Wouters, K., Van Loo, M., & Cras, P. (2012). Sensorimotor incongruence exacerbates symptoms in patients with chronic whiplash associated disorders: an experimental study. *Rheumatology (Oxford, England)*, *51*(8), 1492–1499. http://doi.org/10.1093/rheumatology/kes050

Davis, C. G. (1998). Rear-end impacts: vehicle and occupant response. *Journal of Manipulative and Physiological Therapeutics*, *21*(9), 629–639.

Dematteo, C. A., Hanna, S. E., Mahoney, W. J., Hollenberg, R. D., Scott, L. A., Law, M. C., … Xu, L. (2010). My child doesn't have a brain injury, he only has a concussion. *Pediatrics*, *125*(2), 327–334. http://doi.org/10.1542/peds.2008-2720

Duenas, M., Whyte, G., & Jandial, R. (2014). Sideline concussion testing in high school football on Guam. *Surgical Neurology International*, *5*, 91. http://doi.org/10.4103/2152-7806.134364

Flor, H. (2003). Cortical reorganisation and chronic pain: implications for rehabilitation. *Journal of Rehabilitation Medicine*, (41 Suppl), 66–72.

Galetta, K. M., Barrett, J., Allen, M., Madda, F., Delicata, D., Tennant, A. T., … Balcer, L. J. (2011). The King-Devick test as a determinant of head trauma and concussion in boxers and MMA fighters. *Neurology*, *76*(17), 1456–1462. http://doi.org/10.1212/WNL.0b013e31821184c9

Galetta, K. M., Brandes, L. E., Maki, K., Dziemianowicz, M. S., Laudano, E., Allen, M., … Balcer, L. J. (2011). The King-Devick test and sports-related concussion: study of a rapid visual screening tool in a collegiate cohort. *Journal of the Neurological Sciences*, *309*(1-2), 34–39. http://doi.org/10.1016/j.jns.2011.07.039

Galetta, M. S., Galetta, K. M., McCrossin, J., Wilson, J. A., Moster, S., Galetta, S. L., … Master, C. L. (2013). Saccades and memory: baseline associations of the King-Devick and SCAT2 SAC tests in professional ice hockey players. *Journal of the Neurological Sciences*, *328*(1-2), 28–31. http://doi.org/10.1016/j.jns.2013.02.008

Gross, A. R., Hoving, J. L., Haines, T. A., Goldsmith, C. H., Kay, T., Aker, P., … Cervical Overview Group. (2004). A Cochrane review of manipulation and mobilization for mechanical neck disorders. *Spine*, *29*(14), 1541–1548.

Gross, A. R., Kay, T. M., Kennedy, C., Gasner, D., Hurley, L., Yardley, K., … McLaughlin, L. (2002). Clinical practice guideline on the use of manipulation or mobilization in the treatment of adults with mechanical neck disorders. *Manual Therapy*, *7*(4), 193–205.

Guskiewicz, K. M., Weaver, N. L., Padua, D. A., & Garrett, W. E., Jr. (2000). Epidemiology of concussion in collegiate and high school football players. *The American Journal of Sports Medicine*, *28*(5), 643–650.

Hansson, E. E., Persson, L., & Malmström, E. M. (2013). Influence of vestibular rehabilitation on neck pain and cervical range of motion among patients with whiplash-associated disorder: a randomized controlled trial. *Journal of Rehabilitation Medicine*, *45*(9), 906–910. http://doi.org/10.2340/16501977-1197

Harper, B. (2014). A Theoretical Paradigm of Central Cognitive Mechanisms Linking Concussion and Whiplash Associated Disorder: Part One. *Journal of Physical Therapy Practice*, *1*(1), 3–30.

Heitger, M. H., Jones, R. D., Macleod, A. D., Snell, D. L., Frampton, C. M., & Anderson, T. J. (2009). Impaired eye movements in post-concussion syndrome indicate suboptimal brain function beyond the influence of depression, malingering or intellectual ability. *Brain: A Journal of Neurology*, *132*(Pt 10), 2850–2870. http://doi.org/10.1093/brain/awp181

Helgadottir, H., Kristjansson, E., Einarsson, E., Karduna, A., & Jonsson, H. (2011). Altered activity of the serratus anterior during unilateral arm elevation in patients with cervical disorders. *Journal of Electromyography and Kinesiology: Official Journal of the International Society of Electrophysiological Kinesiology*, *21*(6), 947–953. http://doi.org/10.1016/j.jelekin.2011.07.007

Hodges, P. W., & Tucker, K. (2011). Moving differently in pain: a new theory to explain the adaptation to pain. *Pain*, *152*(3 Suppl), S90–98. http://doi.org/10.1016/j.pain.2010.10.020

Hovda, D. A., Lee, S. M., Smith, M. L., Von Stuck, S., Bergsneider, M., Kelly, D., … Mazziotta, J. (1995). The neurochemical and metabolic cascade following brain injury: moving from animal models to man. *Journal of Neurotrauma*, *12*(5), 903–906.

Hutchison, M., Comper, P., Mainwaring, L., & Richards, D. (2011). The influence of musculoskeletal injury on cognition: implications for concussion research. *The American Journal of Sports Medicine*, *39*(11), 2331–2337. http://doi.org/10.1177/0363546511413375

Hynes, L. M., & Dickey, J. P. (2006). Is there a relationship between whiplash-associated disorders and concussion in hockey? A preliminary study. *Brain Injury*, *20*(2), 179–188. http://doi.org/10.1080/02699050500443707

Jensen, T. S., & Baron, R. (2003). Translation of symptoms and signs into mechanisms in neuropathic pain. *Pain*, *102*(1-2), 1–8.

Ji, R. R., & Woolf, C. J. (2001). Neuronal plasticity and signal transduction in nociceptive neurons: implications for the initiation and maintenance of pathological pain. *Neurobiology of Disease*, *8*(1), 1–10. http://doi.org/10.1006/nbdi.2000.0360

Jull, G. A. (2000). Deep Cervical Flexor Muscle Dysfunction in Whiplash. *Journal of Musculoskeletal Pain*, *8*(1-2), 143–154. http://doi.org/10.1300/J094v08n01_12

Khalsa, P. S. (2004). Biomechanics of musculoskeletal pain: dynamics of the neuromatrix. *Journal of Electromyography and Kinesiology: Official Journal of the International Society of Electrophysiological Kinesiology*, *14*(1), 109–120. http://doi.org/10.1016/j.jelekin.2003.09.020

King, D., Brughelli, M., Hume, P., & Gissane, C. (2014). Assessment, management and knowledge of sport-related concussion: systematic review. *Sports Medicine (Auckland, N.Z.)*, *44*(4), 449–471. http://doi.org/10.1007/s40279-013-0134-x

Kirkwood, M. W., Yeates, K. O., Taylor, H. G., Randolph, C., McCrea, M., & Anderson, V. A. (2008). Management of pediatric mild traumatic brain injury: a neuropsychological review from injury through recovery. *The Clinical Neuropsychologist*, *22*(5), 769–800. http://doi.org/10.1080/13854040701543700

Kristjansson, E., & Treleaven, J. (2009). Sensorimotor func
tion and dizziness in neck pain: implications for assessment and management. *The Journal of Orthopaedic and Sports Physical Therapy*, *39*(5), 364–377. http://doi.org/10.2519/jospt.2009.2834

Langevin, H. M., & Sherman, K. J. (2007). Pathophysiological model for chronic low back pain integrating connective tissue and nervous system mechanisms. *Medical Hypotheses*, *68*(1), 74–80. http://doi.org/10.1016/j.mehy.2006.06.033

Leddy, J. J., Cox, J. L., Baker, J. G., Wack, D. S., Pendergast, D. R., Zivadinov, R., & Willer, B. (2013). Exercise treatment for postconcussion syndrome: a pilot study of changes in functional magnetic resonance imaging activation, physiology, and symptoms. *The Journal of Head Trauma Rehabilitation*, *28*(4), 241–249. http://doi.org/10.1097/HTR.0b013e31826da964

Leddy, J. J., & Willer, B. (2013). Use of graded exercise testing in concussion and return-to-activity management. *Current Sports Medicine Reports*, *12*(6), 370–376. http://doi.org/10.1249/JSR.0000000000000008

Leong, D. F., Balcer, L. J., Galetta, S. L., Liu, Z., & Master, C. L. (2014). The King-Devick test as a concussion screening tool administered by sports parents. *The Journal of Sports Medicine and Physical Fitness*, *54*(1), 70–77.

Manzoni, D. (2005). The cerebellum may implement the appropriate coupling of sensory inputs and motor responses: evidence from vestibular physiology. *Cerebellum (London, England)*, *4*(3), 178–188. http://doi.org/10.1080/14734220500193493

Maruta, J., Lee, S. W., Jacobs, E. F., & Ghajar, J. (2010). A unified science of concussion. *Annals of the New York Academy of Sciences*, *1208*, 58–66. http://doi.org/10.1111/j.1749-6632.2010.05695.x

Maruta, J., Suh, M., Niogi, S. N., Mukherjee, P., & Ghajar, J. (2010). Visual tracking synchronization as a metric for concussion screening. *The Journal of Head Trauma Rehabilitation*, *25*(4), 293–305. http://doi.org/10.1097/HTR.0b013e3181e67936

Maugans, T. A., Farley, C., Altaye, M., Leach, J., & Cecil, K. M. (2012). Pediatric sports-related concussion produces cerebral blood flow alterations. *Pediatrics*, *129*(1), 28–37. http://doi.org/10.1542/peds.2011-2083

McCabe, C. S., & Blake, D. R. (2007). Evidence for a mismatch between the brain's movement control system and sensory system as an explanation for some pain-related disorders. *Current Pain and Headache Reports*, *11*(2), 104–108.

McClune, T., Burton, A. K., & Waddell, G. (2002). Whiplash associated disorders: a review of the literature to guide patient information and advice. *Emergency Medicine Journal: EMJ*, *19*(6), 499–506.

McCrea, M., Barr, W. B., Guskiewicz, K., Randolph, C., Marshall, S. W., Cantu, R., … Kelly, J. P. (2005). Standard regression-based methods for measuring recovery after sport-related concussion. *Journal of the International Neuropsychological Society: JINS*, *11*(1), 58–69. http://doi.org/10.1017/S1355617705050083

McCrea, M., Hammeke, T., Olsen, G., Leo, P., & Guskiewicz, K. (2004). Unreported concussion in high school football players: implications for prevention. *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine*, *14*(1), 13–17.

Melzack, R. (1999). From the gate to the neuromatrix. *Pain*, *Suppl 6*, S121–126.

Melzack, R. (2001). Pain and the neuromatrix in the brain. *Journal of Dental Education*, *65*(12), 1378–1382.

Misra, G., & Coombes, S. A. (2014). Neuroimaging Evidence of Motor Control and Pain Processing in the Human Midcingulate Cortex. *Cerebral Cortex (New York, N.Y.: 1991)*. http://doi.org/10.1093/cercor/bhu001

Montfoort, I., Kelders, W. P. A., van der Geest, J. N., Schipper, I. B., Feenstra, L., de Zeeuw, C. I., & Frens, M. A. (2006). Interaction between ocular stabilization reflexes in patients with whiplash injury. *Investigative Ophthalmology & Visual Science*, *47*(7), 2881–2884. http://doi.org/10.1167/iovs.05-1561

Montfoort, I., Van Der Geest, J. N., Slijper, H. P., De Zeeuw, C. I., & Frens, M. A. (2008). Adaptation of the cervico- and vestibulo-ocular reflex in whiplash injury patients. *Journal of Neurotrauma*, *25*(6), 687–693. http://doi.org/10.1089/neu.2007.0314

Moseley, G. L. (2003). A pain neuromatrix approach to patients with chronic pain. *Manual Therapy*, *8*(3), 130–140.

Mulligan, I., Boland, M., & Payette, J. (2012). Prevalence of neurocognitive and balance deficits in collegiate aged football players without clinically diagnosed concussion. *The Journal of Orthopaedic and Sports Physical Therapy*, *42*(7), 625–632. http://doi.org/10.2519/jospt.2012.3798

Nacci, A., Ferrazzi, M., Berrettini, S., Panicucci, E., Matteucci, J., Bruschini, L., … Fattori, B. (2011). Vestibular and stabilometric findings in whiplash injury and minor head trauma. *Acta Otorhinolaryngologica Italica: Organo Ufficiale Della Società Italiana Di Otorinolaringologia E Chirurgia Cervico-Facciale*, *31*(6), 378–389.

Nederhand, M. J., Hermens, H. J., IJzerman, M. J., Turk, D. C., & Zilvold, G. (2003). Chronic neck pain disability due to an acute whiplash injury. *Pain*, *102*(1-2), 63–71.

Pho, C., & Godges, J. (2004). Management of whiplash-associated disorder addressing thoracic and cervical spine impairments: a case report. *The Journal of Orthopaedic and Sports Physical Therapy*, *34*(9), 511–519; discussion 520–523. http://doi.org/10.2519/jospt.2004.34.9.511

Prushansky, T., Gepstein, R., Gordon, C., & Dvir, Z. (2005). Cervical muscles weakness in chronic whiplash patients. *Clinical Biomechanics (Bristol, Avon)*, *20*(8), 794–798. http://doi.org/10.1016/j.clinbiomech.2005.05.003

Revel, M., Andre-Deshays, C., & Minguet, M. (1991). Cervicocephalic kinesthetic sensibility in patients with cervical pain. *Archives of Physical Medicine and Rehabilitation*, *72*(5), 288–291.

Revel, M., Minguet, M., Gregoy, P., Vaillant, J., & Manuel, J. L. (1994). Changes in cervicocephalic kinesthesia after a proprioceptive rehabilitation program in patients with neck pain: a randomized controlled study. *Archives of Physical Medicine and Rehabilitation*, *75*(8), 895–899.

Riemann, B. L., & Guskiewicz, K. M. (2000). Effects of mild head injury on postural stability as measured through clinical balance testing. *Journal of Athletic Training*, *35*(1), 19–25.

Rosenfeld, M., Gunnarsson, R., & Borenstein, P. (2000). Early intervention in whiplash-associated disorders: a comparison of two treatment protocols. *Spine*, *25*(14), 1782–1787.

Rowson, S., & Duma, S. M. (2013). Brain injury prediction: assessing the combined probability of concussion using linear and rotational head acceleration. *Annals of Biomedical Engineering*, *41*(5), 873–882. http://doi.org/10.1007/s10439-012-0731-0

Sahler, C. S., & Greenwald, B. D. (2012). Traumatic Brain Injury in Sports: A Review. *Rehabilitation Research and Practice*, *2012*. http://doi.org/10.1155/2012/659652

Sarig-Bahat, H. (2003). Evidence for exercise therapy in mechanical neck disorders. *Manual Therapy*, *8*(1), 10–20.

Schnabel, M., Ferrari, R., Vassiliou, T., & Kaluza, G. (2004). Randomised, controlled outcome study of active mobilisation compared with collar therapy for whiplash injury. *Emergency Medicine Journal: EMJ*, *21*(3), 306–310.

Schneider, K. J., Meeuwisse, W. H., Kang, J., Schneider, G. M., & Emery, C. A. (2013). Preseason reports of neck pain, dizziness, and headache as risk factors for concussion in male youth ice hockey players. *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine*, *23*(4), 267–272. http://doi.org/10.1097/JSM.0b013e318281f09f

Shetter, A. G., & Demakas, J. J. (1979). The pathophysiology of concussion: a review. *Advances in Neurology*, *22*, 5–14.

Sosnoff, J. J., Broglio, S. P., Shin, S., & Ferrara, M. S. (2011). Previous mild traumatic brain injury and postural-control dynamics. *Journal of Athletic Training*, *46*(1), 85–91. http://doi.org/10.4085/1062-6050-46.1.85

Spitzer, W. O., Skovron, M. L., Salmi, L. R., Cassidy, J. D., Duranceau, J., Suissa, S., & Zeiss, E. (1995). Scientific monograph of the Quebec Task Force on Whiplash-Associated Disorders: redefining “whiplash” and its management. *Spine*, *20*(8 Suppl), 1S–73S.

Sterling, M. (2004). A proposed new classification system for whiplash associated disorders--implications for assessment and management. *Manual Therapy*, *9*(2), 60–70. http://doi.org/10.1016/j.math.2004.01.006

Sterling, M. (2011). Whiplash-associated disorder: musculoskeletal pain and related clinical findings. *The Journal of Manual & Manipulative Therapy*, *19*(4), 194–200. http://doi.org/10.1179/106698111X13129729551949

Sterling, M. (2014). Physiotherapy management of whiplash-associated disorders (WAD). *Journal of Physiotherapy*, *60*(1), 5–12. http://doi.org/10.1016/j.jphys.2013.12.004

Stewart, G. W., McQueen-Borden, E., Bell, R. A., Barr, T., & Juengling, J. (2012). Comprehensive assessment and management of athletes with sport concussion. *International Journal of Sports Physical Therapy*, *7*(4), 433–447.

Storaci, R., Manelli, A., Schiavone, N., Mangia, L., Prigione, G., & Sangiorgi, S. (2006). Whiplash injury and oculomotor dysfunctions: clinical-posturographic correlations. *European Spine Journal: Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *15*(12),1811–1816. http://doi.org/10.1007/s00586-006-0085-0

Swanik, C. B., Covassin, T., Stearne, D. J., & Schatz, P. (2007). The relationship between neurocognitive function and noncontact anterior cruciate ligament injuries. *The American Journal of Sports Medicine*, *35*(6), 943–948. http://doi.org/10.1177/0363546507299532

Talavage, T. M., Nauman, E. A., Breedlove, E. L., Yoruk, U., Dye, A. E., Morigaki, K. E., … Leverenz, L. J. (2014). Functionally-detected cognitive impairment in high school football players without clinically-diagnosed concussion. *Journal of Neurotrauma*, *31*(4), 327–338. http://doi.org/10.1089/neu.2010.1512

Tjarks, B. J., Dorman, J. C., Valentine, V. D., Munce, T. A., Thompson, P. A., Kindt, S. L., & Bergeron, M. F. (2013). Comparison and utility of King-Devick and ImPACT® composite scores in adolescent concussion patients. *Journal of the Neurological Sciences*, *334*(1-2), 148–153. http://doi.org/10.1016/j.jns.2013.08.015

Tjell, C., & Rosenhall, U. (1998). Smooth pursuit neck torsion test: a specific test for cervical dizziness. *The American Journal of Otology*, *19*(1), 76–81.

Treleaven, J., Jull, G., & Grip, H. (2011). Head eye co-ordination and gaze stability in subjects with persistent whiplash associated disorders. *Manual Therapy*, *16*(3), 252–257. http://doi.org/10.1016/j.math.2010.11.002

Treleaven, J., Jull, G., & Lowchoy, N. (2005). Standing balance in persistent whiplash: a comparison between subjects with and without dizziness. *Journal of Rehabilitation Medicine: Official Journal of the UEMS European Board of Physical and Rehabilitation Medicine*, *37*(4), 224–229. http://doi.org/10.1080/16501970510027989

Treleaven, J., Jull, G., & LowChoy, N. (2006). The relationship of cervical joint position error to balance and eye movement disturbances in persistent whiplash. *Manual Therapy*, *11*(2), 99–106. http://doi.org/10.1016/j.math.2005.04.003

Urban, J. E., Davenport, E. M., Golman, A. J., Maldjian, J. A., Whitlow, C. T., Powers, A. K., & Stitzel, J. D. (2013). Head impact exposure in youth football: high school ages 14 to 18 years and cumulative impact analysis. *Annals of Biomedical Engineering*, *41*(12), 2474–2487. http://doi.org/10.1007/s10439-013-0861-z

Vidal, P., & Huijbregts, P. (2005). Dizziness in Orthopaedic Physical Therapy Practice: History and Physical Examination. *Journal of Manual & Manipulative Therapy*, *13*(4), 221–250. http://doi.org/10.1179/106698105790824798

White, O. B., & Fielding, J. (2012). Cognition and eye movements: assessment of cerebral dysfunction. *Journal of Neuro-Ophthalmology: The Official Journal of the North American Neuro-Ophthalmology Society*, *32*(3), 266–273. http://doi.org/10.1097/WNO.0b013e3182688230

Woodhouse, A., & Vasseljen, O. (2008). Altered motor control patterns in whiplash and chronic neck pain. *BMC Musculoskeletal Disorders*, *9*, 90. http://doi.org/10.1186/1471-2474-9-90

Yamaki, T., Murakami, N., Iwamoto, Y., Sakakibara, T., Kobori, N., Ueda, S., … Kikuchi, T. (1998). Cognitive dysfunction and histological findings in rats with chronic-stage contusion and diffuse axonal injury. *Brain Research. Brain Research Protocols*, *3*(1), 100–106.

Ylinen, J., Takala, E.-P., Nykänen, M., Häkkinen, A., Mälkiä, E., Pohjolainen, T., … Airaksinen, O. (2003). Active neck muscle training in the treatment of chronic neck pain in women: a randomized controlled trial. *JAMA*, *289*(19), 2509–2516. http://doi.org/10.1001/jama.289.19.2509

Young, T. J., Daniel, R. W., Rowson, S., & Duma, S. M. (2013). Head Impact Exposure in Youth Football: Elementary School Ages 7-8 Years and the Effect of Returning Players. *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine*. http://doi.org/10.1097/JSM.0000000000000055

Young, T. J., Daniel, R. W., Rowson, S., & Duma, S. M. (2014). Head impact exposure in youth football: elementary school ages 7-8 years and the effect of returning players. *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine*, *24*(5), 416–421. http://doi.org/10.1097/JSM.0000000000000055

Radford University Department of Physical Therapy Abstracts:

3rd Annual Waldron College Interprofessional Symposium

The abstracts below are presented as originally prepared by the authors listed below. These abstracts were peer-reviewed by the Waldron College Peer review committee. The content and accuracy of each abstract remain the responsibility of the authors. The identification codes are designated as:

Platform Presentation=**PFP** Poster Presentation=**POP**

RUDPT101-PFP

The Effect of Localized Upper Body Fatigue on Static and Dynamic Balance

Kristen Blankenship, Jaclyn Powell, Esther Kim, Jonathan Lloyd, Adrian Aron

Fatigue is one of the mechanisms with a great impact on the neuromuscular motor control. Lower extremity fatigue has been shown to alter static and dynamic balance through the effects on the lower muscles involved in balance control. Upper body exercises that lead to localized fatigue are commonly utilized in physical therapy clinics.

Purpose: The aim of this study was to determine the effects of upper body muscle fatigue on dynamic and static balance in young and old populations.

Methods: Static and dynamic balance assessments were performed on 17 males (age 36.6 ±15.6 years) before and after an upper body fatigue protocol. Static balance was assessed on the NeuroCom Equitest system using the Sensory Organization Test protocol, while dynamic balance was evaluated using the Lower Quarter Y-Balance Test normalized to leg length. Fatigue was induced through arm ergometry testing consisted of 25 watt/minute (70-80 rpm) incremental exercise protocol until exhaustion. Lactate was measured before and after the fatigue protocol in order to provide an objective measure of the participant's fatigue level.

Results: There was a significant difference between young and old groups when comparing dynamic balance performance on the right leg (92.4 ± 6.4 vs 81.2 ± 10.3, $p<0.001$). Similar results were found for the left leg (91.6 ± 6.3 vs 83.5 ± 9.6, $p<0.001$). No significant differences were found within each of the age groups when comparing pre- and post-fatigue for dynamic balance on the right leg (p=0.70) and left leg (p=0.49). Static balance performance was not different between young and old groups pre fatigue (81.2 ± 10.2 vs 82.2 ± 3.5, p=0.31) or post fatigue (79.8 ± 9.4 vs 83.3 ± 3.8, p=0.46). The same not significant trend for static balance was demonstrated within groups pre and post fatigue (p=0.38).

Conclusions: A single high intensity session of localized upper body fatigue did not significantly impact static or dynamic balance. It appears that core and upper extremity musculature is not recruited intense enough to alter the sensory and motor function. Age did not have an effect on the efficient use of strategies for postural control. These results suggest that clinicians may be able to safely implement intense upper body exercises without significantly increasing fall risk.

RUDPT102-PFP

Cardiac Variable Trends in Patients with Multiple Respiratory Conditions

Robert Weisbeck, Adrian Aron, Donald Zedalis

Background: Recent research has found the coexistence of OSA and low pulmonary function leads to a worse prognosis for patients. Both OSA and decreased pulmonary function have been recognized as independent risk factors for cardiovascular disease mainly from the impacts of increased arterial stiffness, systemic inflammation and vascular dysfunction. The purpose of this pilot study was to analyze the impact of the concomitant respiratory conditions on cardiac variables.

Methods: Subjects were recruited from consecutive patients referred for suspected sleep disordered symptoms at a local sleep medicine clinic. Patients were screened for sleep disordered breathing with gold-standard polysomnography (PSG). Cardiac function was tested using non-invasive bioimpedance technology. Pulmonary function data was collected via spirometry. From the chart review of the tested subjects, a group of 10 patients had spirometry data consistent with low pulmonary function. We used $FEV_1/FVC < 80\%$, FVC predicted < 90% and AHI > 5 to categorize the patients as having multiple respiratory conditions (MRC).

Results: Patients with MRC showed a trend toward higher systolic (138.4 ± 19.7 mmHg) and diastolic blood pressures (82.0 ± 16.7 mmHg) than patients with OSA only (SBP = 126.6 ± 15.7 mmHg; DBP = 75.5 ± 14.8 mmHg), or no OSA (SBP = 122.2 ± 12.7 mmHg; DBP = 75.6 ± 13.0 mmHg). In addition, stroke volume (SV) trended toward decreased values in MRC patients (68.5 ± 39.9 ml) compared to patients without reduced pulmonary function (93.6 ± 15.6 ml) or no sleep apnea (86.6 ± 21.4 ml).

Conclusion: Trends in this small-scale study hint that individuals with MRC may have an elevated cardiovascular risk over those with OSA only, due to increases in BP, and lower overall SV and CO. Larger scale replications of this study are needed to confirm these findings.

RUDPT103-POP

A Comparison Between Performance on Modified Star Excursion Balance Test on a Flat Surface Versus Elevated Surface

Andrew Adkins, Ashley Brooks, Amanda Cross, Helen Franck, Kristen Jagger

Purpose: Postural control and balance assessments are often used to evaluate and screen for the risk of future injury, the severity of impairments suffered after injury, and positive outcomes following injury rehabilitation. The modified Star Excursion Balance Test (mSEBT) and the Y Balance Test of the Lower Quarter (YBT-LQ™) are both lower extremity balance tests that are utilized to provide information about postural stability. Both tests require an individual to stand on one leg while reaching out maximally in three defined directions with the other leg. The mSEBT is performed on the floor and the three directions are specifically defined by taped lines. The YBT-LQ™ is performed in the same three defined reach directions on a detachable framework that can be quickly assembled and disassembled. Performance of the YBT-LQ™ requires the individual to stand on a slightly elevated (1.75in) platform. Previous research has demonstrated that the outcomes of these two tests can not be directly compared (Coughlan et al., 2012), and has questioned if the outcomes differ due to the elevated surface required for the YBT-LQ™ (Critz, et al., 2015). The current research was designed to assess whether individuals perform differently when the same balance test (mSEBT) is administered on the floor versus on the slightly elevated surface of the YBT-LQ™ framework.

Methods and Measures: This research enrolled twenty-five healthy participants between the ages of 18 and 35 in a quasi-experimental within-participants repeated measures design. Balance was assessed using the mSEBT under two conditions in randomized order – a floor surface and an elevated surface, and participants served as their own controls. On the elevated surface, each participant was instructed to place the initial test foot on the center of the stance plate in a standardized fashion. While the participant maintained his/her foot on the platform, s/he was instructed to reach as far as possible with the opposite leg and lightly touch the YBT-LQ™ frame with the toes in each of the three standardized directions (anterior, posterior-medial, and posterior-lateral). The participant was instructed to perform each motion without losing balance, moving the stance foot, or resting the reach foot on the ground. If any of these occurred, the trial was discarded and repeated. Once three successful trials were completed, the participant stood on the other foot and repeated the procedure. The same procedure was completed on both legs for the mSEBT, with the exception that trials were completed on the floor and a taped line defined each of the three standardized directions. Composite normalized reach scores were calculated using leg length and maximum reach distance in each direction for both balance tests, and were analyzed using a dependent T test to determine differences in overall performance on the floor versus the elevated surface. An independent T test was also completed to compare average reach distances, in each direction, between the two surfaces. Differences in reach distances were considered significant if the p value was less than 0.05.

Results: Results indicate that participants demonstrated significantly different reach distances when tested on the mSEBT versus the emSEBT (left lower extremity $p=0.002$ and right lower extremity $p=0.001$). Left lower extremity reach distances averaged 75.2cm on the mSEBT and 73.5cm on the emSEBT. Right lower extremity reach distances averaged 75.1cm and 72.9cm on the mSEBT and emSEBT, respectively. Although not statistically significant, researchers also found a trending difference in the anterior reach performance (bilaterally) when compared to the posterior-medial and posterior-lateral directions.

Discussion: Performance on balance tests has been shown to vary, depending on the testing mode. This research revealed that testing on an elevated platform versus on the floor resulted in significant differences in overall reach performance in the sample population. The elevated surface of the YBT-LQ™ may have influenced participants' depth perception and resulted in lower reach distances. Because balance relies on three different sensory systems – visual, proprioceptive, and vestibular – alterations within any one of these can change outcomes of a balance-related task. The two tests performed in this study relied on identical proprioceptive and vestibular input, but visual input differed, indicating that even small height differences of the testing surface can result in significantly different testing outcomes. Healthcare professionals aiming to assess balance abilities should consider the influence of the testing environment and instruments used, and weigh these factors against the convenience of utilizing one setup over another when choosing a balance screening tool.

RUDPT104-POP

Modifying Injury Risk Through Movement Intervention Protocol

Brent Harper, Steven Boswell, Cory Lail, Cameron Holshouser

Background: Identifying musculoskeletal injury risk factors in athletes is challenging. A previous injury is the most common non-modifiable risk factor predictive of future injury. The most common modifiable risk factors – asymmetrical movement patterns and musculoskeletal asymmetries – have been shown to improve with interventions. Recent research has shown that combining multiple risk factors, rather than using only one risk assessment, may improve the accuracy of injury prediction. Lower extremity non-contact injuries were predicted in 183 collegiate athletes by using the Move2Perform injury risk algorithm. The algorithm includes multiple risk factors such as: Functional Movement Screen (FMS) composite score, individual FMS score, FMS identified asymmetries, previous injury, Lower Quarter Y-Balance test (LQ-YBT) identified asymmetries and LQ-YBT composite score, Upper Quarter Y-Balance test (UQ-YBT) identified asymmetries and UQ-YBT composite scores, and demographics. Athletes had 17.6% increased likelihood for injury if they scored within the substantial risk category, indicating an increased relative risk of 3.4 times, compared with an increased likelihood of 8.9% if scores fell within the moderate category (Lehr et al. 2013).

Purpose: The purposes of this study was to compare the risk stratification of two groups using the Move2Perform injury risk algorithm and to determine the impact of interventions designed to decrease the risk of injury through mitigating asymmetrical movement patterns and normalizing multi-system integration by comparing the end of competitive season incidence of injury between a team provided with the intervention protocol and a control team without intervention.

Methods: Fifteen division one male baseball pitchers performed the FMS, LQ-YBT and UQ-YBT and the scores were entered into the Move2Perform injury risk algorithm. No intervention was provided to baseball pitchers. Seventeen female high school varsity soccer players performed the FMS and LQ-YBT and the scores were entered into the Move2Perform injury risk algorithm. The female varsity athletes performed a general warm up protocol specifically designed to promote symmetrical whole body movement patterns and to normalize multi-system integration between the ocular, vestibular, and somatic structures that result in purposeful movement patterns. This injury prevention intervention was performed before every practice and game.

Results: The Move2Perform injury risk algorithm identified those who actually suffered an injury in season. For the male baseball players 50% of those athletes categorized as substantial risk (n=2) were injured, 57.1% of those categorized as moderate risk (n=7) were injured, and 50% of those categorized as slight risk (n=6) were injured. The Move2Perform injury risk algorithm correctly identified 53% of the athletes who sustained an injury during the course of the season without intervention from substantial, moderate, and slight risk (n=8). Fifty-five percent (n=5) of the nine categorized as substantial or moderate risk were injured. None of the female soccer players (0%) categorized as substantial risk (n=4) for sustaining an injury incurred an injury during the course of the seasons, 40% (n=2) of those athletes categorized as moderate risk (n=5) were injured, and 25% (n=2) of those categorized as slight injury risk (n=8) were injured. The Move2Perform injury risk algorithm identified 23.5% of the athletes who sustained an injury during the course of the season as categorized as substantial, moderate, and slight risk (n=4). 22.2% (n=2) of the nine athletes stratified as substantial or moderate risk sustained injury.

Discussion: Due to the low number of participants in the study, the Move2Perform injury risk algorithm identified higher percentages of those at risk for substantial and moderate injury risk compared to prior reported numbers. Regardless, there was an apparent minimizing effect in actual injury rates for the athletes identified as at risk by the Move2Perform software for the female soccer athletes performing the intervention protocol. Of the 15 baseball pitchers, eight suffered injured during the season, five of which were within the substantial and moderate risk groups. Of the 17 female soccer players, four suffered injuries during the season, none of which were from the substantial risk group (n=4) and two of which were from the moderate risk group (n=5).

Reference

Lehr, M. E., Plisky, P. J., Butler, R. J., Fink, M. L., Kiesel, K. B., & Underwood, F. B. (2013). Field-expedient screening and injury risk algorithm categories as predictors of noncontact lower extremity injury. *Scandinavian Journal Of Medicine & Science In Sports*, *23*(4), e225-e232.

RUDPT105-POP

Reliability Study on Selective Functional Movement Assessment (SFMA) in Real-Time.

Daniel Harrell, Zachary Harrelson, Chelsea Hermann, Alison Phillips, Brent Harper, Adrian Aron

Purpose: Understanding the inter-rater reliability of screening and diagnostic tools is an essential factor to consider before disseminating them to the clinical environment. The Selective Functional Movement Assessment (SFMA) is a whole body musculoskeletal screening and movement diagnostic tool used to determine if altered motor control or physiological mobility dysfunction elsewhere in the body could be contributing to a person's faulty movement and/or pain. Previous research has determined the inter-rater reliability of the SFMA through analysis of participants' movement patterns on previously recorded video footage. Considering the inter-rater reliability of the SFMA has not yet been determined with real-time assessment, the generalizability of the test is still unknown. The intent of this study was to determine the inter-rater reliability of the SFMA in real-time assessment thereby emulating the clinical environment that physical therapists will encounter daily.

Methods: Two research examiners participated in a three-hour training course with a certified SFMA physical therapist to learn how to appropriately conduct the SFMA and score the results. Twenty-nine students in the Radford University Doctor of Physical Therapy Program, without pain or current injury, participated as subjects in the study. Both examiners assessed every participant individually. After providing the subject with a brief demonstration of the10 top-tier fundamental movement patterns of the SFMA, the subjects were asked to perform the same SFMA movement patterns. The examiner immediately recorded values as Functional-Non-painful, Functional-Painful, Dysfunctional-

Non-painful, or Dysfunctional-painful. Statistics were analyzed using SPSS version 21 software through intraclass correlations coefficient and Cohen's kappa coefficient.

Results: The agreement between examiners for the composite score results utilizing the intraclass correlation coefficient was found to be 0.62, demonstrating a moderate agreement. Using Cohen's kappa coefficient, examiners demonstrated the greatest inter-rater reliability (substantial) when assessing cervical flexion (0.62), left single leg stance (0.68), and squat (0.67). Reliability between examiners was moderate for right upper extremity pattern 1 (0.49), multisegmental flexion (0.43), multisegmental extension (0.45), and right single leg stance (0.46). Fair agreement was found between examiners for cervical extension (0.37), left upper extremity pattern 1 (0.33), and left upper extremity pattern 2 (0.22). Slight agreement was demonstrated for the remaining top-tier movements: left (0.17) and right (0.13) cervical rotation, right upper extremity pattern 2 (0.07), and right (0.08) and left (0.16) multi-segmental rotation, as well as the primary pattern analysis between examiners (0.14).

Discussion: The inter-rater reliability of the SFMA between two novice examiners who received three hours of education on the administration of the SFMA was determined to range from substantial to poor dependent upon which aspect of the assessment (composite score, individual categorical movement score, and/or primary pattern) was analyzed. Future research should focus on determining the minimum required training and the difference between novice and experienced clinicians in order to produce higher inter-rater reliability results.

RUDPT106-POP

Integrating Real-Time Musculoskeletal Ultrasound Education into a Doctor of Physical Therapy Curriculum

Kristen L Jagger, Cody Bailey, Harper Brent

Background: Physical therapists are leading experts in the diagnosis and treatment of movement impairments/disabilities caused by neuromusculoskeletal dysfunction. As such, knowledge of normal neuromusculoskeletal structure and function is of paramount importance, and objectifying the diagnosis and treatment of connective tissue dysfunction is critical. Utilizing existing noninvasive technology to gain a greater understanding of connective tissue's behavior during evaluation, and in response to various interventions, is of utmost importance as it will play a key role in legitimizing future clinical interventions. Real-time ultrasound (RTUS) imaging units emit pulsed sound waves to create an image of the tissues beneath the transducer head. The impedance of the tissue results in varying shades of gray on the screen of a gray-scale RTUS unit and allows the experienced user to quantify tissue thickness, density, and certain types of pathology. RTUS devices are commonly used in research and are becoming more prevalent in daily clinical practice within the field of physical therapy.

Purpose: The purpose of this study was to integrate basic RTUS education within the RU DPT program and assess the benefit as perceived by the student body. This education provided students with hands-on knowledge of current technology used within the field of physical therapy to enhance their understanding of connective tissue dysfunction.

Methods & Measures: Twenty-six Doctor of Physical Therapy students at Radford University, between the ages of 20 and 29, participated in a single education experience about the use of RTUS. Students were provided with a brief lecture regarding the history of RTUS, the mode of function of RTUS, basic terminology used, and how images are displayed. Important user scanning techniques were discussed and the session culminated with a demonstration of a SonoSite M-Turbo® RTUS device. The knee joint was chosen for demonstration to match the content being discussed in Patient Management II, the course into which the RTUS was integrated. Visualization of bony, ligamentous, tendinous, cartilaginous, and muscular connective tissues was demonstrated at rest, and real-time muscular contraction of the quadriceps was used to demonstrate the biofeedback capabilities of the technology.
Students were given a pre-test one day prior to the teaching session to assess baseline knowledge of RTUS. The same test was administered immediately after the teaching session and again one week following the session. Questions were designed to assess image recognition, terminology understanding, and the perceived benefit of RTUS in clinical practice.

Results: Results showed an increase in the percentage of correct responses on seven out of eight questions. Questions 1-3 revealed an increase in knowledge of grayscale characterization of tissue types. Questions 4-8 demonstrated an increase in correct identification of specific tissue structures within the knee joint. The sole

exception was a decrease in correct identification of a bursa. Post-test scores were higher immediately after the teaching session. One week post-test scores were higher than pre-test scores, but lower than immediate post-test scores. An open-ended question related to the perceived benefits of using RTUS in clinical practice resulted in the following findings: 18 respondents indicated an increased appreciation of the use of RTUS as a diagnostic tool and eight students commented positively regarding the use of RTUS in biofeedback.
Discussion: A single educational session successfully increased the knowledge base related to musculoskeletal RTUS in a group of 26 Doctor of Physical Therapy students. Students performed best on questions related to content that was emphasized throughout the session, while knowledge related to content that received minimal attention failed to improve. Based upon these outcomes, and the growing value of RTUS in clinical practice, it is reasonable to believe that integrating educational sessions throughout the curriculum will yield a more well-equipped entry-level physical therapist.

RUDPT107-POP

Instrument-Assisted vs. Self-Release Soft Tissue Mobilization Techniques for Individuals with Active Myofascial Trigger Points

Rebecca Harris, Erika McClaugherty, Hope Mitchell, Taylor Sutphin, Adrian Aron, Brent Harper, Alex Siyufy

Purpose: The musculoskeletal pain that many people regularly experience can often be contributed to active myofascial trigger points (MTrPs) located within the upper trapezius muscle. Treatment for the symptoms of an active MTrP can be sought at a physical therapy clinic. One form of treatment provided at many clinics is ischemic compression, which can be applied via many different methods. Two such methods are Graston Technique™ and Thera Cane™. The purpose of the current study was to assess the effectiveness of clinician-applied Graston Technique™ and self-applied Thera Cane™ on improving impairments secondary to active MTrPs in the upper trapezius. The data obtained was used to determine if the impairments caused by active MTrPs can be self-managed, limiting dependency on physical therapy treatment.
Methods: A convenience sample of eleven participants with active MTrPs were included in this study. The right upper trapezius muscle of each participant was palpated to determine the location of the MTrP and marked with a permanent marker. The independent variables measured in this study were pain pressure threshold (PPT) and cervical range of motion (CROM). PPT was measured using a pressure algometer immediately after palpation, and again seven days later. CROM was also measured on day one and day seven using a CROM device. Participants were randomly placed into one of the following interventions: Graston Technique™ or Thera Cane™. Each participant received his or her corresponding intervention on both day one and day four. The Thera Cane™ group was instructed in self-application of ischemic compression using the device and each participant was supervised during treatment application to the identified MTrP. The Graston Technique™ group received treatment to the identified MTrP from a trained member of the research group. A standard treatment protocol was followed during the application of Graston Technique™. Researchers measuring PPT and CROM were blinded to the group assignment. Independent t-tests and Mann-Whitney Tests were used to evaluate the difference in PPT and CROM measurements among each group.
Results: Of the 10 participants (9 females), there was statistical significance was found for left side-bending CROM for both groups ($p < 0.05$). There was an average change of 1.83° in left side-bending CROM for the Graston Technique™ group and an average change of 4.50° for the Thera Cane™ group.
Discussion: Active MTrPs are a common source of pain and limited CROM in the general population. Ischemic compression is a treatment often used by physical therapists as a form of soft tissue mobilization to deactivate active MTrPs in order to improve the patient's symptoms. However, ischemic compression can also be self-applied by the patient with the use of various devices. In this case, treatment to the right upper trap, utilizing either Thera Cane™ or Graston ™, yielded improvements in left side bending CROM with neither treatment showing better results than the other. The results of our study suggest that it may be possible for a patient to sufficiently self-treat his or her active MTrPs, specifically with Thera Cane™, thereby decreasing the need for clinician-applied treatment. However, this research study would benefit from the inclusion and testing of additional participants.