Journal of Bodywork & Movement Therapies xxx (2018) 1–9

Contents lists available at ScienceDirect

Journal of Bodywork & Movement Therapies

journal homepage: www.elsevier.com/jbmt

Narrative Review & Case Series

The use of dry needling as a diagnostic tool and clinical treatment for cervicogenic dizziness: a narrative review & case series

James Escaloni*, Raymond Butts, James Dunning

Faculty, American Academy of Manipulative Therapy Fellowship in Orthopaedic Manual Physical Therapy, Montgomery, AL, United States

ARTICLE INFO

Article history:
Received 15 July 2017
Received in revised form
21 January 2018
Accepted 8 February 2018

ABSTRACT

Study design: Narrative Review & Case Series.

Background: No "gold standard" test presently exists to confirm a diagnosis of cervicogenic dizziness, a condition whereby the neuromusculoskeletal tissues of the cervical spine are thought to contribute to imbalance and dizziness. Clusters of tests are presently recommended to provoke signs and symptoms of the condition. In this regard, dry needling may provide a valuable diagnostic tool. Targeting the musculoskeletal structures of the upper neck with dry needling may also provide a valuable treatment tool for patients that suffer from cervicogenic dizziness. While dry needling has been used to treat various musculoskeletal conditions, it has not been specifically reported in patients with cervicogenic dizziness.

Case description: Three patients were screened for signs and symptoms related to cervicogenic dizziness in an outpatient physical therapy clinic. These patients presented with signs and symptoms often associated with (though not always) cervicogenic dizziness, including a positive flexion-rotation test, altered cervical range of motion, and tenderness with manual assessment of the upper cervical extensors. In addition, dry needling targeting the obliquus capitis inferior muscle was used diagnostically to reproduce symptoms as well as to treat the patients.

Outcomes: Two of the patients reported full resolution of their dizziness and a significant improvement in their function per standardized outcome measures. While the third patient did not report full resolution of her cervicogenic dizziness, she noted significant improvement, and dry needling was helpful in guiding further treatment. Importantly, the effect of the treatment was maintained in all three patients for at least 6 months.

Discussion: This case series with narrative review covers various testing procedures for cervicogenic dizziness and explores the use of dry needling targeting the suboccipital muscles to evaluate and treat this patient population. The physiologic changes that occur in the periphery, the spine and the brain secondary to dry needling and their potential relevance to the mechanisms driving cervicogenic dizziness are discussed in detail.

1. Introduction

The treatment of dizziness is a challenging and often frustrating endeavor for clinicians due to the complexity of the condition and the number of systems involved (Chandrasekhar, 2013; Wipperman, 2014). Interactions between the vestibular, ocular, and somatosensory system all relay afferent information to the central nervous system via a number of reflex pathways so as to maintain general balance and stability (Kristjansson and Treleaven, 2009). While disagreement between these systems can lead to appropriate alterations of reflexive posture, unresolved differences can cause symptoms of dizziness (Kristjansson and Treleaven, 2009; Treleaven, 2008a).

Notably, the cervical spine can contribute to dizziness. Bow-Hunter's syndrome (i.e. rotational vertebral artery compression) and Barré-Liéou syndrome (i.e. sympathetic vertebral plexus irritation) are disorders of cervical origin that cause dizziness (Brandt, 2001; L'Heureux-Lebeau et al., 2014; Yacovino and Hain, 2013). Moreover, some investigators have suggested that proprioceptive dysfunction in the cervical spine may be the most common finding

* Corresponding author. American Academy of Manipulative Therapy, 1036 Old Breckenridge, Ln, Montgomery, AL 36117, United States.
E-mail address: james.escaloni.pt@gmail.com (J. Escaloni).

https://doi.org/10.1016/j.jbmt.2018.02.015
1360-8592/

associated with cervicogenic dizziness (Hain, 2015). This is likely due to the role of the suboccipital muscles and upper cervical joints, which communicate important information to and from the central nervous system to alter postural stability, cervical reflexive proprioception, head & eye movement control and, ultimately, balance (Armstrong and McNair, 2008; Dutia, 1991; Fernandez-de-Las-Penas et al., 2007; Hain, 2015; Hulse, 1983; L'Heureux-Lebeau et al., 2014; McLain, 1994; Morningstar et al., 2005; Reichel and Stenner, 2013; Treleaven et al., 2011; Watson and Colebatch, 1998).

While clinicians have several tools to diagnose cervical proprioceptive dysfunction as the cause of dizziness (Al-Saif et al., 2012; Chen and Treleaven, 2013; Ellis et al., 2015; L'Heureux-Lebeau et al., 2014; Treleaven et al., 2003, 2005a), the absence of a gold standard places limits on the diagnostic accuracy and inter-examiner reliability of such a diagnosis (Hain, 2015; Huijbregts and Vidal, 2004; Li and Peng, 2015; Yacovino and Hain, 2013). Moreover, the etiology of cervicogenic dizziness is still not completely understood, and the best conservative treatment for the condition continues to be a topic of debate in the literature (Lystad et al., 2011). As such, the purpose of this paper is to explore the rationale of using dry needling as a diagnostic test and a potential treatment for cervicogenic dizziness.

2. Background

2.1. The pathophysiology of cervicogenic dizziness

In the cervical spine, the suboccipital muscles play an important role in the positioning of the head in space. These muscles can be reflexively altered by the vestibular system and are implicated in conditions such as chronic tension-type headache and dystonic torticaput (Armstrong and McNair, 2008; Fernandez-de-Las-Penas et al., 2007; Reichel and Stenner, 2013; Watson and Colebatch, 1998). Similarly, the suboccipital muscles also provide feedback to the vestibular system on the dynamic position of the head and neck. The cervical spine has an extremely well developed proprioceptive system, as evidenced by the density of gamma-muscle spindles in the deep segmental upper cervical muscles. Per Kristjansson and Treleaven, “Gamma muscle spindle system afferents are particularly important as they initiate the afferent proprioceptive feedback, while other mechanoreceptors such as the joint receptors and Golgi tendon organs fine tune the muscle spindle information, predominantly by reflex effects on the gamma motor neurons” (Kristjansson and Treleaven, 2009).

Type 1 mechanoreceptors and proprioceptors from the facet joints of the upper cervical spine deliver information to the central nervous system via the spinal nerves (Reid and Rivett, 2005). According to Borg-Stein et al., the C1-C2 dorsal roots of the spinal nerve provide afferent information to the abducens nuclei of the vestibular nerve (Borg-Stein et al., 2001). If the joints are dysfunctional, however, improper information could be sent to the vestibular nuclei, resulting in imbalance and dizziness (Cagle, 1995; Reid and Rivett, 2005).

It is perhaps also worth noting that afferent pain information from the structures of the upper cervical spine (i.e. facet joints, muscles, intervertebral discs, etc.) synapse with dorsal horns neurons, which overlap with the trigeminocervical nucleus (Li and Peng, 2015; Yacovino, 2012). The reciprocal connections between the trigeminocervical nucleus and the vestibular nuclei have been implicated in migraine headaches and vertigo (Li and Peng, 2015; Yacovino, 2012). Interestingly, the overlap of the trigeminocervical nucleus with the C1-C2 dorsal horns has also been linked to cervicogenic headaches, which are often accompanied by dizziness (Brown, 1992). This may explain why Lystad et al., found a moderate level of evidence for the use of manual therapy with or without vestibular therapy for the treatment of cervicogenic dizziness (Lystad et al., 2011; Wrisley et al., 2000). It also may account for the recent evidence supporting the use of spinal manipulation for cervicogenic headache and/or dizziness (Chaibi and Tuchin, 2011; Dunning et al., 2016; Lystad et al., 2011).

From a biomechanical perspective, the suboccipitals are considered to have a role in active motion of the head on the neck. However, the obliquus capitis inferior (OCI) appears to play a key role in proprioception of the upper cervical spine (Bexander et al., 2005). During active rotation in healthy individuals, Bexander, et al. found that there is a co-activation of the OCI bilaterally, instead of a unilateral contraction (Bexander et al., 2005). The high muscle spindle density of this muscle further suggests that the OCI plays a predominately proprioceptive role in the upper neck and is an ideal candidate for sensing joint position (Kulkarni et al., 2001). Given its role in the cervico-collic reflex, the splenius capitis, splenius cervicis, and the rectus capitis posterior major may also play a role in cervicogenic dizziness (Morningstar et al., 2005).

Bexander also found that OCI activity was altered following cervical injury such as whiplash associated disorder (WAD), leading to increased activation of neck rotatory muscles with changes in eye position (Bexander and Hodges, 2012). As such, patients that experience cervical trauma often experience impaired ocular coordination abilities and dizziness, which has been correlated with sustained cervical pain (Chen et al., 2006; Heikkilä and Wenngren, 1998; Hildingsson et al., 2009; Treleaven et al., 2006; Wrisley et al., 2000). A number of clinicians have suggested that the alteration in somatosensory function occurs secondary to direct trauma, muscle inhibition, fatty infiltration and atrophy (Chen et al., 2006; Elliott et al., 2006; Kristjansson and Treleaven, 2009; McPartland et al., 1997; Uhlig et al., 1995). Interestingly, smooth pursuit and saccade disturbances have also been related to cervical afferent dysfunction. (Eva-Maj et al., 2013; Hildingsson et al., 2009; Treleaven, 2008b). While smooth pursuit and neck disturbances can be found in patients with idiopathic neck pain and in the absence of dizziness, greater deficits in head and eye movement and postural stability have been measured in patients following a trauma to the neck (Tjell et al., 2002; Treleaven et al., 2005a,b).

Pain may also play a significant role in cervicogenic dizziness (Li and Peng, 2015). In addition to WAD, spondylosis and/or spasm at the cervical spine can be a cause of vertigo due to different “sensorial strategies in posture”. Per Li & Peng, an injection of anesthetic into the posterior neck muscles in patients with mechanical derangements has been shown to reduce pain and dizziness, suggesting that the upper neck is likely a key player in cervicogenic dizziness (Li and Peng, 2015). Notably, experimentally induced cervical pain targeting the paraspinal muscles at C2/C3 has been shown to cause significant repositioning error and decreased proprioception, leading to dizziness in some patients (Eva-Maj et al., 2013), a finding consistent with other muscle physiology studies (Chen et al., 2006; Le Pera et al., 2001; Thunberg et al., 2001).

There are several reflexes that also play an important role in upright positioning of the body and maintenance of normal balance. Of note, the cervico-collic, vestibulo-ocular, cervico-ocular, vestibulo-collic and the vestibulo-spinal reflex play an essential role in the maintenance of upright body positioning. Importantly, these reflexes can affect and/or be affected by information from the cervical spine (Brandt, 2013; Bronstein and Hood, 1986; Chambers et al., 1985; Field et al., 2008; Han and Lennerstrand, 1996; Horak and Hlavacka, 2001; Lennerstrand et al., 1996; Morningstar et al., 2005; Sjöström et al., 2003; Wapner et al., 1951). While a full discussion of these reflexes is outside the scope of this paper, the crosstalk between these reflexive systems and mechanoreceptors, proprioceptors, and nociceptors of the upper neck further suggests

Please cite this article in press as: Escaloni, J., et al., The use of dry needling as a diagnostic tool and clinical treatment for cervicogenic dizziness: a narrative review & case series, Journal of Bodywork & Movement Therapies (2018), https://doi.org/10.1016/j.jbmt.2018.02.015

that the cervical spine may play a role in dizziness.

3. Clinical tests for cervicogenic dizziness

The clinical utility of individual special tests used to diagnose cervicogenic dizziness is limited due to the lack of a gold standard test (Huijbregts and Vidal, 2004; Li and Peng, 2015; Treleaven, 2008a; Yacovino and Hain, 2013). Yacovino and Hain found that there is not a reliable clinical test or a typical time course for the condition (Yacovino and Hain, 2013). Tavanai and Hajiabolhassan reported that there is no protocol for diagnosis of cervicogenic vertigo, and diagnosis is often based on limited clinical experience (Tavanai and Hajiabolhassan, 2013). Confusing the issue further, dizziness has been found as an additional complaint in patients with Whiplash Associated Disorder (WAD) (Treleaven, 2008a; Wrisley et al., 2000). While the medical community has therefore often overlooked the patient's subjective complaints of cervicogenic dizziness (Kristjansson and Treleaven, 2009; Li and Peng, 2015; Yacovino and Hain, 2013), several individual tests (Burke et al., 2016; Ellis et al., 2015; Tjell and Rosenhall, 1998; Tjell et al., 2002; Treleaven, 2008a; Treleaven et al., 2005a; Treleaven et al., 2003), or clusters of tests (Huijbregts and Vidal, 2004; L'Heureux-Lebeau et al., 2014; Treleaven et al., 2006; Wrisley et al., 2000; Yacovino and Hain, 2013) have been suggested to be diagnostically useful when this condition is suspected.

3.1. The Smooth Pursuit Neck Torsion Test

The Smooth Pursuit Neck Torsion Test (SPNTT) examines afferent influence on eye movement control (Treleaven et al., 2005a). The test is classically performed using a light-emitting diode ramp that provides a moving sinusoid stimulus with eye movements. The stimuli are tracked via electrooculography, and the mean gain (ratio between velocity of eye movements and of the target) is calculated as a parameter to define smooth pursuits. The difference between the mean gain in a neutral position of the head and right and left torsion of the head on the body is calculated to determine the difference (Tjell and Rosenhall, 1998; Treleaven et al., 2005a). In the absence of expensive laboratory equipment, the observation of aberrant eye movements during smooth pursuit is often used to qualitatively assess oculomotor dysfunction (Della Casa et al., 2014; Treleaven, 2008a).

The SPNTT evaluates the smooth pursuit eye movement system, proprioception in the neck, the cervico-collic reflex and the cervico-ocular reflex (Tjell and Rosenhall, 1998; Tjell et al., 2002). This test has been found to possess high specificity and high sensitivity for identifying patients with WAD, particularly those with dizziness (Tjell and Rosenhall, 1998; Tjell et al., 2002). The SPNTT is also able to "differentiate between smooth pursuit abnormalities from a peripheral vestibular, brain stem or higher CNS cause from that of a cervical cause." The test has been found to be 90% sensitive and 91% specific in WAD patients with dizziness (Tjell and Rosenhall, 1998; Treleaven, 2008a; Treleaven et al., 2005a). More specifically, the SPNTT test was found to be 72% sensitive and 92% specific with a 92% positive predictive value, 71% negative predictive value and a 28.6 odds ratio for diagnosing WAD vs. non-traumatic neck pain (Tjell et al., 2002). This test has also been found to identify those with neck pain & WAD when testing smooth pursuit with predictably or unpredictably moving targets (Janssen et al., 2015).

Although the SPNTT test has adequate sensitivity and specificity for detecting WAD, there are some issues with exclusively using this test for the diagnosis of cervicogenic dizziness. First, the SPNTT is not considered a "gold standard" for this diagnosis, as "… it is unlikely that any smooth pursuit test could be of utility for diagnosing cervicogenic vertigo due to the complex nature of the multiple inputs responsible for smooth pursuit and its various susceptibilities to age, cognition, and sedation" (Hain, 2015). Second, a positive SPNTT could be caused by outstanding afferent proprioceptive or nociceptive input from the cervical region, a common clinical finding in WAD patients (Hain, 2015; Norre, 1986; Tjell and Rosenhall, 1998). This could allow for the simultaneous presence of cervicogenic dizziness and WAD, each causing separate symptoms of pain and dizziness without a test to separate the two entities. Third, the SPNTT was found to have a sensitivity and specificity of 56% and 88%, respectively, when comparing patients with BPPV and cervicogenic dizziness (L'Heureux-Lebeau et al., 2014). This type of test should have stronger differential abilities, especially when compared to a common diagnosis such as BPPV. Lastly, Tavanai and Hajiabolhassan have suggested that while this test could be helpful for the diagnosis of cervicogenic dizziness, it has not been validated (Tavanai and Hajiabolhassan, 2013). This further challenges the methodology of including this test as a stand-alone tool in the diagnosis of cervicogenic dizziness.

3.2. Joint position error test

The cervical spine Joint Position Error Test (JPET) has been suggested as a measure to assess the integrity of the cervical spine somatosensory system and has a prominent role as a test of afferent disturbance of the cervical spine (Ellis et al., 2015; L'Heureux-Lebeau et al., 2014; Treleaven et al., 2003) (See Fig. 1). A positive JPET suggests improper cervicocollic reflex inhibition, limited head-neck awareness and abnormal neck and vestibular cross-talk (Chen and Treleaven, 2013; Kristjansson and Jonsson, 2004; Kristjansson and Treleaven, 2009). However, while the JPET seems reliable (Burke et al., 2016), it is intended to determine abnormal joint proprioception and not diagnose a specific structural source of symptoms or produce familiar symptoms (Chen and Treleaven, 2013; Treleaven et al., 2003). Therefore, like the SPNTT, the JPET may be a useful screening tool, but it has limited clinical utility as a stand-alone diagnostic test for cervicogenic dizziness. Notably, Chen and Treleaven recommend using both neck torsion and Joint Position Error (JPE) to best differentiate neck dysfunction from vestibular dysfunction (Chen and Treleaven, 2013).

3.3. Altered upper cervical range of motion, movement, or control

Cervical joint mechanoreceptors have been identified as playing a role in upright posture (Armstrong and McNair, 2008; Brandt,

Fig. 1. The joint position error test.

Please cite this article in press as: Escaloni, J., et al., The use of dry needling as a diagnostic tool and clinical treatment for cervicogenic dizziness: a narrative review & case series, Journal of Bodywork & Movement Therapies (2018), https://doi.org/10.1016/j.jbmt.2018.02.015

2013; Dutia, 1991; Hulse, 1983; McLain, 1994). According to Igarashi et al., facet joint mechanoreceptors may play an even stronger role than the vestibular system in maintaining static posture (Igarashi et al., 1969). Bogduk also detailed the role of the upper cervical spine and its anatomical connections with both pain and pathology (Bogduk, 1992, 1994, 2011). According to several authors, segmental hypermobility with or without pain is a primary mechanism responsible for cervicogenic dizziness due to its presence in early spinal degenerative changes and WAD populations (Dai, 1998; Heidenreich et al., 2008; Kristjansson et al., 2003). Nevertheless, using mobility testing alone to diagnose cervicogenic dizziness is not recommended due to poor inter-tester reliability (Cleland et al., 2006; Hanney et al., 2014; Ogince et al., 2007; Piva et al., 2006; Seffinger et al., 2004; van Trijffel et al., 2005; van Trijffel et al., 2009).

In addition to high diagnostic accuracy in patients with cervicogenic headache (Ogince et al., 2007), performing rotational mobility testing of the C1-2 segment, known as the Cervical Flexion-Rotation Test (CFRT), may also have diagnostic utility in patients with cervicogenic dizziness. This test is performed with cervical rotation in full flexion, and has a high diagnostic accuracy for C1-2 rotational dysfunction in patients with cervicogenic headache with a cut-off of 32° or less and a mean of 20° (Ogince et al., 2007). The CFRT has also been found to have high sensitivity and specificity for inter-tester reliability and diagnostic validity among highly trained and novice therapists (Hall et al., 2008). Although not universally accepted, a recent Delphi study reported a high utility for using the CFRT to differentiate between cervicogenic and other causes of dizziness after a sports-related concussion (Reneker et al., 2015). Conversely, a study by Quek et al. indicated that despite postural asymmetry in patients with neck pain and a positive CFRT, differences in postural sway velocity, gait speed and neck pain intensity were negligible among patients with a positive and negative CFRT (Quek et al., 2013). The authors stated that those with a positive CFRT "seemed to have compensated for their altered somatosensory input to achieve similar functional levels" as those with a negative CFRT (Quek et al., 2013). Thus, while the cervical spine has a role in maintenance of upright posture, perhaps its mobility shouldn't be used as a stand-alone test for diagnosing cervicogenic dizziness.

Additionally, vibration testing has been suggested as a test for cervicogenic dizziness. However, while vibration testing stimulates local muscles to produce a strong afferent stimulation, it does not produce familiar symptoms of dizziness. By testing patients receiving physical therapy for neck pain and dizziness, Karlberg et al. found that vibration testing directed at the suboccipitals and gastrocnemius both produced postural sway (Karlberg et al., 1996). Moreover, suboccipital vibration resulted in postural sway following physical therapy treatment, despite significant improvement in cervical pain and dizziness. As such, Karlberg, et al. highlights the limitation of using vibration for testing for cervicogenic dizziness (Karlberg et al., 1996). Given that vibration testing may also be used to identify unilateral vestibular deficits, multiple other diagnoses are possible (Hamann and Schuster, 1999).

3.4. Signs & symptoms

In the absence of a clear gold standard test for cervicogenic dizziness, review articles and randomized control trials have relied on clusters of signs and symptoms to support the diagnosis and treatment of cervicogenic dizziness (Al-Saif et al., 2012; Bracher et al., 2000; Galm et al., 1998; Hain, 2015; Huijbregts and Vidal, 2004; Karlberg et al., 1996; L'Heureux-Lebeau et al., 2014; Reid et al., 2014a, 2015, 2014b). In a recent study, Reid et al. successfully screened 81 patients for cervicogenic dizziness that responded well to manual therapy (i.e. sustained natural apophyseal glides or passive joint mobilization) using smooth pursuit testing, vestibulo-ocular reflex testing and a thorough examination of the cervical spine (Reid et al., 2015). However, the authors failed to consider the reliability of these tests to identify patients with cervicogenic dizziness as part of the analysis. It is also perhaps worth noting that nystagmus production, neck proprioception and manual assessment of the cervical spine are the most common elements of cluster testing for cervicogenic dizziness. However, none of the tests are intended to, nor consistently reproduce, the familiar symptoms clinically (Hain, 2015; Kristjansson and Treleaven, 2009; Reid et al., 2012; Reneker et al., 2015; Vidal, 2005; Wipperman, 2014; Yacovino and Hain, 2013). Thus, in addition to the suggested clusters, a valid test that is able to reliably reproduce the signs and symptoms associated with cervicogenic dizziness is required (Al-Saif et al., 2012; Bracher et al., 2000; Galm et al., 1998; Hain, 2015; Huijbregts and Vidal, 2004; Karlberg et al., 1996; L'Heureux-Lebeau et al., 2014; Reid et al., 2014a, 2015; Reid and Rivett, 2005; Reid et al., 2014b).

4. Dry needling as a test for cervicogenic dizziness

Based on the etiology of the condition, a number of studies in the literature have recommended that the upper cervical spine be evaluated as part of a battery of tests to diagnose cervicogenic dizziness (Dai, 1998; Heidenreich et al., 2008; Kristjansson and Treleaven, 2009; Reneker et al., 2015). As such, the palpation of superficial muscles of the upper neck and the insertion of dry needles into the deep suboccipital muscles in an effort to provoke familiar symptoms may be appropriate.

Dry needling is an intervention whereby thin, monofilament needles are used to penetrate the skin and stimulate underlying neural, muscular and/or connective tissues for the management of pain and disability associated with neuromusculoskeletal conditions. (Butts et al., 2016; Casanueva et al., 2014; Dunning et al., 2014; Lewit, 1979; Neal and Longbottom, 2012; Pavkovich, 2015; Perreault et al., 2017). Dry needles may also be inserted in the vicinity of peripheral nerves and/or neurovascular bundles in order to manage a variety of related pain syndromes (Dunning et al., 2014). The optimal duration of needle insertion has not been investigated for cervicogenic dizziness; 10–20 min of needle time in-situ has been found to be optimal in the primary author's experience with this population. In general, RCTs from the acupuncture literature achieve better analgesia by adding electricity than by brief or intermittent manual stimulation alone (Langevin et al., 2015).

DN has been shown to have biomechanical (Dommerholt, 2011; Goldman et al., 2013; Langevin et al., 2001; Takano et al., 2012), chemical (Shah et al., 2008; Shah and Gilliams, 2008), and vascular effects (Loaiza et al., 2002; Lundeberg, 2013; Yao et al., 2014; Zhang et al., 2012c) at the site of insertion (Butts et al., 2016). The use of DN locally may be able to elicit a localized twitch response to clear excessive acetylcholine (ACh) from the neuromuscular junction and breaking the cycle of hypertonicity associated with myofascial trigger points (MTrPs) (Hsieh et al., 2011; Kuan et al., 2007; Shah and Gilliams, 2008). In addition, DN may lead to opioid-based reductions in pain peripherally (Su et al., 2011; Zhang et al., 2010, 2014b), via the stimulation of endogenous cannabinoids (Chen et al., 2009) and sympathetic nervous system (Binder et al., 2004; Song et al., 2014; Zhang et al., 2014a). Local needle mechanotransduction via TRPV1 receptors also facilitates ATP release and the subsequent production of adenosine, which blocks pain transmission via the inhibition of adenyl cyclase (Delmas et al., 2011; Goldman et al., 2010; Wu et al., 2014). In addition, the mechanotransduction of TRPV1 receptors has also been linked to rho-kinase based tissue remodeling (Almeida Mdos et al., 2014; Langevin et al., 2006). At the level of the spine, the stimulation of Aδ, Aβ, and C fibers via DN initiates a cascade of events, which inhibit the delivery and receipt of pain information to dorsal horn via additive effects of opioids (Besse et al., 1990; Sluka et al., 2002) (i.e. encephalin, endorphins and dynorphins) and non-opioids (Salazar-Colocho et al., 2007; Stone et al., 1999; Zhang et al., 2012b) (i.e. serotonin, norepinephrine, GABA, glycine and nociceptin/orphanin FQ). As for the changes that occur in the brain, DN with and without electric stimulation seems to result in the general reduction in the activity of the parts of the brain responsible for the affective components of pain, suggesting that the modality might have an effect on both physiologic pain and the psychosocial components of pain (Zhang et al., 2011, 2012a).

It is perhaps somewhat ironic that DN stimulates Aδ, Aβ, and C pain fibers to treat pain. The stimulation of nociceptive fibers with an acupuncture needle often results in what patients describe as a mild discomfort, a deep ache or spreading warmth. This is more commonly referred to as a "de qi" response in the literature and is often considered a crucial parameter in needling patients for pain (Kong et al., 2007; Zhou and Benharash, 2014). In cases of cervicogenic dizziness, the use of DN may initially be diagnostically relevant, as the use of DN may be able to compound the aberrant information being sent from the trigeminocervical nucleus to the vestibular nuclei (Reid and Rivett, 2005). Ultimately, however, the analgesic outcome may be able to significantly decrease pain, reduce pain inhibition in the suboccipital muscles and reset the proprioceptive system of the upper neck, improving and/or curing the cervicogenic dizziness.

Due to the prevalence of neck pain and trigger points in WAD, the use of DN has been explored in several RCTs (Boyles et al., 2015; Cagnie et al., 2015; Ettlin et al., 2008; Fernández-Pérez et al., 2012; Kietrys et al., 2013; Liu et al., 2015; Moon et al., 2014; Ong and Claydon, 2014; Tobbackx et al., 2013). In contrast, the use of DN to diagnose and treat symptoms related to cervicogenic dizziness has been infrequently investigated, though treatment of upper cervical soft tissue with needle therapy for dizziness is not without precedent. Fattori et al., inserted needles into the upper cervical muscles at acupoints BL10 and BL20 (i.e. rectus capitis posterior major and proximal obliquus capitis superior/semispinalis capitis muscle, respectively) to improve balance via posturography in patients with a history of WAD (Fattori et al., 1996). Another study by Heikkila et al. combined acupuncture with spinal manipulation in patients with dizziness of suspected cervical origin (Heikkila et al., 2000). Though thrust manipulation had the greatest effect on complaints of dizziness and range of motion, acupuncture was also useful for improving dizziness/vertigo and active head repositioning. Notably, Ghilardi, et al., reported that "cervical torsion trauma and balance disorders with cervical origin in general, such as those connected with pronounced antalgic contracture of the nape muscles due to cervical arthrosis, are the conditions which responded best to acupuncture. In fact, other groups of patients suffering from vertigo of other natures did not respond so well" (Ghilardi et al., 2014).

Clinically, needle insertion into the OCI, rectus capitis posterior major, or rectus capitis posterior minor with the patient in prone or side lying often reproduces familiar symptoms in patients with cervicogenic dizziness. After leaving the needle in situ for 10–20 min (per literature recommendations) (Dunning et al., 2014), the familiar symptoms of dizziness often resolve. Importantly, these clinical outcomes are consistent with the diagnostic criteria for cervicogenic headaches in which a 90% or greater reduction in symptoms from a diagnostic blockade is considered a positive test for the pathology (Ducros et al., 2013). Additionally, identification of local problematic muscles that reproduce symptoms associated with cervicogenic dizziness during DN is useful in determining an appropriate rehabilitation strategy. To illustrate the application of DN as a diagnostic test and treatment tool, a case series was conducted on 3 patients with cervicogenic dizziness.

5. Case descriptions

Three patients reported to an outpatient physical therapy clinic due to a primary complaint of dizziness. All subjects (3 female) ages 36, 89, and 74 were screened for conditions related to balance dysfunction, including testing for Benign Paroxysmal Positional Vertigo (BPPV), cranial nerve testing, myotome testing, dermatome testing, deep tendon reflexes, blood pressure measurements, and "red flag" symptoms. Notably, each patient reported a history of cervical pathology.

Subjectively, all patients described their dizziness as a sensation of light-headedness with certain head movements but not the sensation of intense spinning often associated with BPPV. In addition, patients did not report that changes in body position (i.e. transfers from sitting to standing after prolonged lying) provoked symptoms of dizziness, as in orthostatic hypotension. Blood pressure testing was also normal. Testing for BPPV with the Dix-Hallpike test was negative in all cases. None of the patients noted a recent history of illness suggestive of a viral source of symptoms. Moreover, cranial nerve testing did not produce signs of central nervous system pathology, and myotome/dermatome testing was unremarkable.

Further objective examination focused on the musculoskeletal system to determine the appropriateness for physical therapy management. Cervical assessment in the form of range of motion testing, mobility testing, and/or performance of the flexion-rotation test yielded abnormal findings in all three patients. Abnormal measurements included limited gross cervical ROM in one or more areas, limited mobility with upper cervical motion assessment, and limited or painful motion compared to the contralateral side in the flexion-rotation test. Additionally, palpation of the OCI muscle of the three patients produced localized pain, but not dizziness, on at least one side of the neck. It is worth noting that both the SPNTT and JPE tests were not used in these cases at the time of treatment. The utility of the tests in diagnosis were unknown to the primary author, and have since been adapted in clinical practice due to the collective evidence previously described.

6. Dry needling procedure

In an effort to more formally implicate the OCI muscle as the possible culprit of the patient's dizziness, a dry needle was directed towards the muscle in an effort to provoke the symptoms. The patients were placed in either a prone or side lying position so as to allow access to the suboccipital muscles and maintain a neutral position of the cervical spine. The area of the suboccipitals was cleansed using a 70% isopropyl alcohol pad prior to needling procedure. Seirin 0.25 mm $\times$ 30 mm needles were used.

The OCI muscle was identified via its proximal and distal attachments on the spinous process of the C2 vertebra and the transverse process of the ipsilateral C1 vertebra. The needle was inserted midway between the levels of the C1 and C2 segments approximately 2 of the patient's fingerbreadths lateral to midline with an anteriomedial (~45°) and slightly caudad angulation until a bony end-feel of the lamina of C2 was achieved (See Fig. 2). The needle was then rotated unidirectionally and/or bidirectionally in an attempt to elicit a deep ache in the region of the OCI muscle. In accordance with the relevant literature, needles were left in situ for 10 min (Dunning et al., 2014).

Please cite this article in press as: Escaloni, J., et al., The use of dry needling as a diagnostic tool and clinical treatment for cervicogenic dizziness: a narrative review & case series, Journal of Bodywork & Movement Therapies (2018), https://doi.org/10.1016/j.jbmt.2018.02.015

Fig. 2. Needle placement to target the OCI.

7. Results

DN directed at the OCI in each of the three patients produced a familiar sensation of dizziness. In addition, 2 patients had a complete resolution of dizziness complaints either immediately following treatment or by the follow-up visit 2-days later. In the 89-year old patient, the Dizziness Handicap Inventory (DHI) improved from 54 to 20, and the Berg Balance score improved from 37 points to 44 points. This was significant as the patient improved her DHI rating from Severe Handicap to Mild Handicap while meeting an MDC of 17.18 and MCID of 18 (Yorke et al., 2013). The patient also improved her Berg Balance score by a MDC of 5 points (Donoghue and Stokes, 2009). When the patient was reassessed 6-months post-treatment, she again reported a DHI score of 18, demonstrating maintenance of the treatment effect.

Similar objective improvements were reported by the 74-year old patient, whose initial measures included a Sensory Organization Performance Test time of 11 s with eyes closed (EC) on a firm surface, 8 s with EC on foam, an inability to perform a tandem stance position with either leg forward and a DHI of 40. During her follow-up visit, the patient improved her performance on the aforementioned components of the Sensory Organization Performance Test to 30 s. Interestingly, however, active and passive mobility of the cervical spine did not change. When re-evaluated 6 months post-treatment, the patient reported a DHI score of 0.

Importantly, although DN did not fully resolve the dizziness in the 36-year-old patient, the treatment was still useful. The use of DN implicated the cervical spine musculature as a possible component of the patient's dizziness, which led to appropriate treatment strategies. In addition to traditional vestibular and balance rehabilitation, the patient also received skilled manual therapy & exercise targeting the cervical spine. As a side, the 36-year old patient subjectively reported a resolution of her oscillopsia complaints and an improvement on the Dynamic Visual Acuity test following DN. Also, while her initial DHI score was 26, she reported a DHI of 4, 6-months post-treatment.

8. Recommendations

The diagnosis of cervicogenic dizziness is often considered a diagnosis of exclusion due to the absence of a gold standard and the lack of valid and reliable diagnostic tests. Many tests suggest that various systems, including the musculoskeletal structures of the neck, are involved in the dizzy patient; however, clinicians often have difficulty provoking the familiar symptoms of dizziness. Based on the literature discussed in this article regarding diagnostic testing for cervicogenic dizziness and the findings of the above case studies, dry needling may be a valuable tool for therapists who diagnose and treat dizziness. Dry needles inserted into the suboccipitals, particularly the OCI, may be used to produce familiar symptoms and should therefore be included as part of the previously described cluster testing (Al-Saif et al., 2012; L'Heureux-Lebeau et al., 2014; Reid et al., 2015) for cervicogenic dizziness. Though the cases described exclusively used the OCI muscle to produce symptoms, anecdotal experience suggests that the rectus capitis posterior major and the rectus capitis posterior minor may also need to be addressed after inserting dry needles into the OCI if there is no symptom reproduction at this muscle.

Physical therapists should continue to screen patients that report dizziness for vestibular pathology, central nervous system dysfunction and cardiovascular issues. However, clinicians should also note a history of cervical dysfunction and a subjective report of “lightheadedness” and/or “drunkenness” which seems to correlate with movements of the neck.

Objectively, clinicians should first consider mobility screening of the cervical spine with inclusion of the Cervical Flexion-Rotation test, then assess the Joint Position Error test and the Smooth Pursuit Neck Torsion Test. In addition, clinicians should attempt to insert dry needles into the suboccipital muscles in an effort to reproduce familiar symptoms. While one test likely has limited

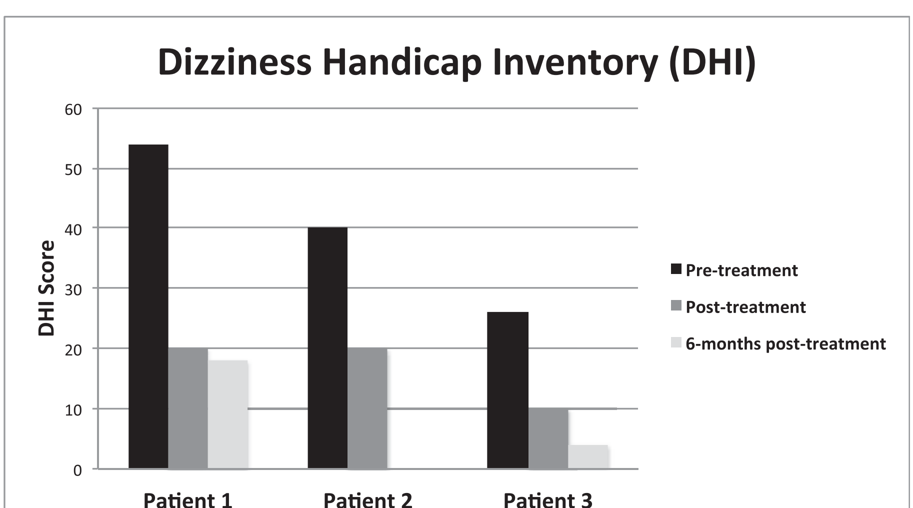

Fig. 3. Dizziness handicap inventory score for patients 1–3 at pre-treatment, post-treatment and 6-months post-treatment.

Please cite this article in press as: Escaloni, J., et al., The use of dry needling as a diagnostic tool and clinical treatment for cervicogenic dizziness: a narrative review & case series, Journal of Bodywork & Movement Therapies (2018), https://doi.org/10.1016/j.jbmt.2018.02.015

diagnostic value, clustering the tests together will likely lead to optimal diagnostic utility. Also, given that DN may be used as both a diagnostic tool and a treatment strategy, it should likely be used last to test for cervicogenic dizziness. While the optimal duration of needle insertion has not been investigated for cervicogenic dizziness, 10–20 min of needle time in-situ has been found to be optimal in the primary author's experience with this population. At a minimum, the sum of this information should be sufficient to allow the treating therapist to know if the cervical spine is either the primary source or a significant component of the patient's symptoms.

The 3 patients described in the case series received DN as a portion of a cluster of tests to help determine a diagnosis of cervicogenic dizziness. The strong, afferent stimulation that occurred from the local muscle stimulation during DN was an important test to determine if the suspected tissue was involved in the patient's dizziness. The hypertonic muscle likely resulted in increased aberrant feedback to the central nervous system, which contrasted with other upright positional afferents from the ocular and vestibular systems, adding to and/or reproducing the patient's dizziness. Ultimately, however, all 3 patients reported a significant reduction in their dizziness (see Fig. 3), suggesting that DN with mechanical stimulation may have disrupted the aberrant feedback and helped reset the proprioceptive system. Given the absence of a "gold standard", DN may, therefore, be a useful tool in the diagnosis and treatment of cervicogenic dizziness.

9. Conclusion

DN may provide a valuable tool for both diagnosing and treating cervicogenic dizziness, especially when used as part of a cluster of other special tests such as the flexion-rotation test, joint position error test and smooth pursuit neck torsion test. However, more robust studies are required to fully realize the clinical utility of DN in patients with cervicogenic dizziness.

References

Al-Saif, A., Al-Nakhli, H., Alsenany, S., 2012. Therapy examination and intervention process for patients with cervicogenic dizziness. J. Am. Sci. 8, 483–487.
Almeida Mdos, S., Guerra Fda, R., de Oliveira, L.P., Vieira, C.P., Pimentel, E.R., 2014. A hypothesis for the anti-inflammatory and mechanotransduction molecular mechanisms underlying acupuncture tendon healing. Acupunct. Med. 32, 178–182.
Armstrong, B., McNair, T., 2008. Head and neck position sense. Sports Med. 38, 101–117.
Besse, D., Lombard, M.C., Zajac, J.M., Roques, B.P., Besson, J.M., 1990. Pre- and postsynaptic distribution of mu, delta and kappa opioid receptors in the superficial layers of the cervical dorsal horn of the rat spinal cord. Brain Res. 521, 15–22.
Bexander, C.S., Hodges, P.W., 2012. Cervico-ocular coordination during neck rotation is distorted in people with whiplash-associated disorders. Exp. Brain Res. 217, 67–77.
Bexander, C.S., Mellor, R., Hodges, P.W., 2005. Effect of gaze direction on neck muscle activity during cervical rotation. Exp. Brain Res. 167, 422–432.
Binder, W., Mousa, S.A., Sitte, N., Kaiser, M., Stein, C., Schafer, M., 2004. Sympathetic activation triggers endogenous opioid release and analgesia within peripheral inflamed tissue. Eur. J. Neurosci. 20, 92–100.
Bogduk, N., 1992. The anatomical basis for cervicogenic headache. J. Manipulative Physiol. Therapeut. 15, 67–70.
Bogduk, N., 1994. The anatomical basis for spinal pain syndromes. J. Manipulative Physiol. Therapeut. 18, 603–605.
Bogduk, N., 2011. The anatomy and pathophysiology of neck pain. Phys. Med. Rehabil. Clin. North Am. 22, 367–382.
Borg-Stein, J., Rauch, S.D., Krabak, B., 2001. Evaluation and management of cervicogenic dizziness. Crit. Rev. Phys. Rehabil. Med. 13.
Boyles, R., Fowler, R., Ramsey, D., Burrows, E., 2015. Effectiveness of trigger point dry needling for multiple body regions: a systematic review. J. Man. Manip. Ther. 23, 276–293.
Bracher, E.S., Almeida, C.I., Almeida, R.R., Duprat, A.C., Bracher, C.B., 2000. A combined approach for the treatment of cervical vertigo. J. Manipulative Physiol. Therapeut. 23, 96–100.
Brandt, T., 2013. Vertigo: its Multisensory Syndromes. Springer Science & Business Media.
Brandt, T.B.A., 2001. Cervical vertigo. J. Neurol. Neurosurg. Psychiatry 71, 8–12.
Bronstein, A.M., Hood, J.D., 1986. The cervico-ocular reflex in normal subjects and patients with absent vestibular function. Brain Res. 373, 399–408.
Brown, J., 1992. Cervical Contributions to Balance: Cervical Vertigo. The Head-neck Sensory Motor System, pp. 644–647.
Burke, S., Lynch, K., Moghul, Z., Young, C., Saviola, K., Schenk, R., 2016. The reliability of the cervical relocation test on people with and without a history of neck pain. J. Man. Manip. Ther. 24, 210–214.
Butts, R., Dunning, J., Perreault, T., Maurad, F., Grubb, M., 2016. Peripheral and spinal mechanisms of pain and dry needling mediated analgesia: a clinical resource guide for health care professionals. Int. J. Phys. Med. Rehabil. 216.
Cagle, P., 1995. Cervicogenic vertigo and chiropractic. Managing a single case: a case report. J. Am. Chiropr. Assoc. 83–84.
Cagnie, B., Castelein, B., Pollie, F., Steelant, L., Verhoeyen, H., Cools, A., 2015. Evidence for the use of ischemic compression and dry needling in the management of trigger points of the upper trapezius in patients with neck pain: a systematic review. Am. J. Phys. Med. Rehabil. 94, 573–583.
Casanueva, B., Rivas, P., Rodero, B., Quintial, C., Llorca, J., Gonzalez-Gay, M.A., 2014. Short-term improvement following dry needle stimulation of tender points in fibromyalgia. Rheumatol. Int. 34, 861–866.
Chaibi, A., Tuchin, P.J., 2011. Chiropractic spinal manipulative treatment of cervicogenic dizziness using Gonstead method: a case study. J. Chiropr. Med. 10, 194–198.
Chambers, B.R., Mai, M., Barber, H.O., 1985. Bilateral vestibular loss, oscillopsia, and the cervico-ocular reflex. Otolaryngology-Head Neck Surg. 93, 403–407.
Chandrasekhar, S.S., 2013. The assessment of balance and dizziness in the TBI patient. NeuroRehabilitation 32, 445–454.
Chen, C., Lu, Y., Kallakuri, S., Patwardhan, A., Cavanaugh, J.M., 2006. Distribution of A-δ and C-fiber receptors in the cervical facet joint capsule and their response to stretch. J. Bone Jt. Surg. Am. 88, 1807–1816.
Chen, L., Zhang, J., Li, F., Qiu, Y., Wang, L., Li, Y.H., Shi, J., Pan, H.L., Li, M., 2009. Endogenous anandamide and cannabinoid receptor-2 contribute to electroacupuncture analgesia in rats. J. Pain 10, 732–739.
Chen, X., Treleaven, J., 2013. The effect of neck torsion on joint position error in subjects with chronic neck pain. Man. Ther. 18, 562–567.
Cleland, J.A., Childs, J.D., Fritz, J.M., Whitman, J.M., 2006. Interrater reliability of the history and physical examination in patients with mechanical neck pain. Arch. Phys. Med. Rehabil. 87, 1388–1395.
Dai, L., 1998. Disc degeneration and cervical instability: correlation of magnetic resonance imaging with radiography. Spine 23, 1734–1738.
Della Casa, E.H.J., Meichtry, A., Luomajoki, H., Kool, J., 2014. Head-Eye movement control tests in patients with chronic neck pain; Inter-observer reliability and discriminative validity. BMC Muscoskel. Disord. 15, 16.
Delmas, P., Hao, J., Rodat-Despoix, L., 2011. Molecular mechanisms of mechanotransduction in mammalian sensory neurons. Nat. Rev. Neurosci. 12, 139–153.
Dommerholt, J., 2011. Dry needling - peripheral and central considerations. J. Man. Manip. Ther. 19, 223–227.
Donoghue, D., Stokes, E.K., 2009. How much change is true change? The minimum detectable change of the Berg Balance Scale in elderly people. J. Rehabil. Med. 41, 343–346.
Ducros, A., Arnold, M., Dichgans, M., Houdart, E., Ferro, J., Leroux, J., Li, Y., Singhal, A., Tietjen, J., 2013. The international classification of headache disorders (beta version). Cephalalgia 33, 629–808.
Dunning, J., Butts, R., Mourad, F., Young, I., Flannagan, S., Perreault, T., 2014. Dry needling: a literature review with implications for clinical practice guidelines. Phys. Ther. Rev. 19, 252–265.
Dunning, J.R., Butts, R., Mourad, F., Young, I., Fernandez-de-las Peñas, C., Hagins, M., Stanislawski, T., Donley, J., Buck, D., Hooks, T.R., 2016. Upper cervical and upper thoracic manipulation versus mobilization and exercise in patients with cervicogenic headache: a multi-center randomized clinical trial. BMC Muscoskel. Disord. 17, 64.
Dutia, M., 1991. The muscles and joints of the neck: their specialisation and role in head movement. Prog. Neurobiol. 37, 165–178.
Elliott, J., Jull, G., Noteboom, J.T., Darnell, R., Galloway, G., Gibbon, W.W., 2006. Fatty infiltration in the cervical extensor muscles in persistent whiplash-associated disorders: a magnetic resonance imaging analysis. Spine 31, E847–E855.
Ellis, M.J., Leddy, J.J., Willer, B., 2015. Physiological, vestibulo-ocular and cervicogenic post-concussion disorders: an evidence-based classification system with directions for treatment. Brain Inj. 29, 238–248.
Ettlin, T., Schuster, C., Stoffel, R., Bruderlin, A., Kischka, U., 2008. A distinct pattern of myofascial findings in patients after whiplash injury. Arch. Phys. Med. Rehabil. 89, 1290–1293.
Eva-Maj, M., Hans, W., Per-Anders, F., Mikael, K., Måns, M., 2013. Experimentally induced deep cervical muscle pain distorts head on trunk orientation. Eur. J. Appl. Physiol. 113, 2487–2499.
Fattori, B., Borsari, C., Vannucci, G., Casani, A., Cristofani, R., Bonuccelli, L., Ghilardi, P., 1996. Acupuncture treatment for balance disorders following whiplash injury. Acupunct. Electro-Ther. Res. 21, 207–217.
Fernandez-de-Las-Penas, C., Bueno, A., Ferrando, J., Elliott, J.M., Cuadrado, M.L., Pareja, J.A., 2007. Magnetic resonance imaging study of the morphometry of cervical extensor muscles in chronic tension-type headache. Cephalalgia 27, 355–362.
Fernández-Pérez, A.M., Villaverde-Gutiérrez, C., Mora-Sánchez, A., Alonso-Blanco, C., Sterling, M., Fernández-de-las-Peñas, C., 2012. Muscle trigger points,

pressure pain threshold, and cervical range of motion in patients with high level of disability related to acute whiplash injury. J. Orthop. Sports Phys. Ther. 42, 634–641.

Field, S., Treleaven, J., Jull, G., 2008. Standing balance: a comparison between idiopathic and whiplash-induced neck pain. Man. Ther. 13, 183–191.

Galm, R., Rittmeister, M., Schmitt, E., 1998. Vertigo in patients with cervical spine dysfunction. Eur. Spine J. 7, 55–58.

Ghilardi, P.B.C., Casani, A., Bonucelli, L., Fattorri, B., 2014. Acupuncuture and Chinese medicine: equilibrium disorders. In: Whiplash Injuries Diagnosis and Treatment, second ed. Springer, pp. 373–379.

Goldman, N., Chandler-Militello, D., Langevin, H.M., Nedergaard, M., Takano, T., 2013. Purine receptor mediated actin cytoskeleton remodeling of human fibroblasts. Cell Calcium 53, 297–301.

Goldman, N., Chen, M., Fujita, T., Xu, Q., Peng, W., Liu, W., Jensen, T.K., Pei, Y., Wang, F., Han, X., Chen, J.F., Schnermann, J., Takano, T., Bekar, L., Tieu, K., Nedergaard, M., 2010. Adenosine A1 receptors mediate local anti-nociceptive effects of acupuncture. Nat. Neurosci. 13, 883–888.

Hain, T.C., 2015. Cervicogenic causes of vertigo. Curr. Opin. Neurol. 28, 69–73.

Hall, T.M., Robinson, K.W., Fujinawa, O., Akasaka, K., Pyne, E.A., 2008. Intertester reliability and diagnostic validity of the cervical flexion-rotation test. J. Manip. Physiol. Ther. 31, 293–300.

Hamann, K.-F., Schuster, E.-M., 1999. Vibration-induced nystagmus—a sign of unilateral vestibular deficit. ORL (Oto-Rhino-Laryngol.) (Basel) 61, 74–79.

Han, Y., Lennerstrand, G., 1996. Eye movements in normal subjects induced by vibratory activation of neck muscle proprioceptors. Ophthalmic Lit. 2, 114.

Hanney, W.J., George, S.Z., Kolber, M.J., Young, I., Salamh, P.A., Cleland, J.A., 2014. Inter-rater reliability of select physical examination procedures in patients with neck pain. Physiother. Theory Pract. 30, 345–352.

Heidenreich, K.D., Beaudoin, K., White, J.A., 2008. Cervicogenic dizziness as a cause of vertigo while swimming: an unusual case report. Am. J. Otolaryngol. 29, 429–431.

Heikkila, H., Johansson, M., Wenngren, B.I., 2000. Effects of acupuncture, cervical manipulation and NSAID therapy on dizziness and impaired head repositioning of suspected cervical origin: a pilot study. Man. Ther. 5, 151–157.

Heikkilä, H.V., Wenngren, B.-I., 1998. Cervicocephalic kinesthetic sensibility, active range of cervical motion, and oculomotor function in patients with whiplash injury. Arch. Phys. Med. Rehabil. 79, 1089–1094.

Hildingsson, C., Wenngren, B.-L., Toolanen, G., 2009. Eye motility dysfunction after soft-tissue injury of the cervical spine: a controlled, prospective study of 38 patients. Acta Orthop. Scand. 64, 129–132.

Horak, F., Hlavacka, F., 2001. Somatosensory loss increases vestibulospinal sensitivity. J. Neurophysiol. 86, 575–585.

Hsieh, Y.L., Chou, L.W., Joe, Y.S., Hong, C.Z., 2011. Spinal cord mechanism involving the remote effects of dry needling on the irritability of myofascial trigger spots in rabbit skeletal muscle. Arch. Phys. Med. Rehabil. 92, 1098–1105.

Huijbregts, P., Vidal, P., 2004. Dizziness in orthopaedic physical therapy practice: classification and pathophysiology. J. Man. Manip. Ther. 12, 199–214.

Hulse, M., 1983. Disequelibrium caused by a functional disturbance of the upper cervical spine, clinical aspects and differential diagnosis. Man. Med. 1, 18–23.

Igarashi, M., Alford, B.R., Watanabe, T., Maxian, P.M., 1969. Role of neck proprioceptors for the maintenance of dynamic bodily equilbrium in the squirrel monkey. Laryngoscope 79, 1713–1727.

Janssen, M., Ischebeck, B.K., de Vries, J., Kleinrensink, G.J., Frens, M.A., van der Geest, J.N., 2015. Smooth pursuit eye movement deficits in patients with whiplash and neck pain are modulated by target predictability. Spine 40, E1052–E1057.

Karlberg, M., Magnusson, M., Eva-Maj, M., Agneta, M., Moritz, U., 1996. Postural and symptomatic improvement after physiotherapy in patients with dizziness of suspected cervical origin. Arch. Phys. Med. Rehabil. 77, 874–882.

Kietrys, D.M., Palombaro, K.M., Azzaretto, E., Hubler, R., Schaller, B., Schlussel, J.M., Tucker, M., 2013. Effectiveness of dry needling for upper-quarter myofascial pain: a systematic review and meta-analysis. J. Orthop. Sports Phys. Ther. 43, 620–634.

Kong, J., Gollub, R., Huang, T., Polich, G., Napadow, V., Hui, K., Vangel, M., Rosen, B., Kaptchuk, T.J., 2007. Acupuncture de qi, from qualitative history to quantitative measurement. J. Alternative Compl. Med. 13, 1059–1070.

Kristjansson, E., Jonsson, H., 2004. Symptom characteristics in women with chronic WAD, grades I-II, and chronic insidious onset neck pain: a cross-sectional study with an 18-month follow-up. J. Whiplash Relat. Disord. 3, 3–17.

Kristjansson, E., Leivseth, G., Brinckmann, P., Frobin, W., 2003. Increased sagittal plane segmental motion in the lower cervical spine in women with chronic whiplash-associated disorders, grades I–II: a case-control study using a new measurement protocol. Spine 28, 2215–2221.

Kristjansson, E., Treleaven, J., 2009. Sensorimotor function and dizziness in neck pain: implications for assessment and management. J. Orthop. Sports Phys. Ther. 39, 364–377.

Kuan, T.S., Hong, C.Z., Chen, J.T., Chen, S.M., Chien, C.H., 2007. The spinal cord connections of the myofascial trigger spots. Eur. J. Pain 11, 624–634.

Kulkarni, V., Chandy, M., Babu, K., 2001. Quantitative study of muscle spindles in suboccipital muscles of human foetuses. Neurol. India 49, 355.

L'Heureux-Lebeau, B., Godbout, A., Berbiche, D., Saliba, I., 2014. Evaluation of paraclinical tests in the diagnosis of cervicogenic dizziness. Otol. Neurotol. 35, 1858–1865.

Langevin, H.M., Bouffard, N.A., Badger, G.J., Churchill, D.L., Howe, A.K., 2006. Subcutaneous tissue fibroblast cytoskeletal remodeling induced by acupuncture: evidence for a mechanotransduction-based mechanism. J. Cell. Physiol. 207, 767–774.

Langevin, H.M., Churchill, D.L., Cipolla, M.J., 2001. Mechanical signaling through connective tissue: a mechanism for the therapeutic effect of acupuncture. FASEB J 15, 2275–2282.

Langevin, H.M., Schnyer, R., MacPherson, H., Davis, R., Harris, R.E., Napadow, V., Wayne, P.M., Milley, R.J., Lao, L., Stener-Victorin, E., 2015. Manual and electrical needle stimulation in acupuncture research: pitfalls and challenges of heterogeneity. J. Alternative Compl. Med. 21, 113–128.

Le Pera, D., Graven-Nielsen, T., Valeriani, M., Oliviero, A., Di Lazzaro, V., Tonali, P.A., Arendt-Nielsen, L., 2001. Inhibition of motor system excitability at cortical and spinal level by tonic muscle pain. Clin. Neurophysiol. 112, 1633–1641.

Lennerstrand, G., Han, Y., Velay, J., 1996. Properties of eye movements induced by activation of neck muscle proprioceptors. Graefes Arch. Clin. Exp. Ophthalmol. 234, 703–709.

Lewit, K., 1979. The needle effect in the relief of myofascial pain. Pain 6, 83–90.

Li, Y., Peng, B., 2015. Pathogenesis, diagnosis, and treatment of cervical vertigo. Pain Physician 18, E583–E595.

Liu, L., Huang, Q.-M., Liu, Q.-G., Ye, G., Bo, C.-Z., Chen, M.-J., Li, P., 2015. Effectiveness of dry needling for myofascial trigger points associated with neck and shoulder pain: a systematic review and meta-analysis. Arch. Phys. Med. Rehabil. 96, 944–955.

Loaiza, L.A., Yamaguchi, S., Ito, M., Ohshima, N., 2002. Electro-acupuncture stimulation to muscle afferents in anesthetized rats modulates the blood flow to the knee joint through autonomic reflexes and nitric oxide. Auton. Neurosci. 97, 103–109.

Lundeberg, T., 2013. Acupuncture mechanisms in tissue healing: contribution of NO and CGRP. Acupunct. Med. 31, 7–8.

Lystad, R., Bell, G., Bonnevie-Svendsen, M., Carter, C., 2011. Manual therapy with and without vestibular rehabilitation for cervicogenic dizziness: a systematic review. Chiropr. Man. Ther. 19, 1–11.

McLain, R.F., 1994. Mechanoreceptor endings in human cervical facet joints. Spine 19, 495–501.

McPartland, J.M., Brodeur, R.R., Hallgren, R.C., 1997. Chronic neck pain, standing balance, and suboccipital muscle atrophy—a pilot study. J. Manipulative Physiol. Therapeut. 20, 24–29.

Moon, T.-W., Posadzki, P., Choi, T.-Y., Park, T.-Y., Kim, H.-J., Lee, M.S., Ernst, E., 2014. Acupuncture for treating whiplash associated disorder: a systematic review of randomised clinical trials. Evid. base Compl. Alternative Med. 2014.

Morningstar, M.W., Pettibon, B.R., Schlappi, H., Schlappi, M., Ireland, T.V., 2005. Reflex control of the spine and posture: a review of the literature from a chiropractic perspective. Chiropr. Osteopathy 13, 16.

Neal, B., Longbottom, J., 2012. Is there a role for acupuncture in tendinopathy. Acupunct. Med. 30, 346–349.

Norre, M., 1986. Cervical vertigo. Diagnostic and semiological problem with special emphasis upon "cervical nystagmus". Acta Oto-Rhino-Laryngol. Belg. 41, 436–452.

Ogince, M., Hall, T., Robinson, K., Blackmore, A., 2007. The diagnostic validity of the cervical flexion—rotation test in C1/2-related cervicogenic headache. Man. Ther. 12, 256–262.

Ong, J., Claydon, L.S., 2014. The effect of dry needling for myofascial trigger points in the neck and shoulders: a systematic review and meta-analysis. J. Bodyw. Mov. Ther. 18, 390–398.

Pavkovich, 2015. The use of dry needling for a subject with chronic lateral hip and thigh pain: a case report. Int. J. Sport Phys. Ther. 10, 246–255.

Perreault, T., Dunning, J., Butts, R., 2017. The local twitch response during trigger point dry needling: is it necessary for successful outcomes? J. Bodyw. Mov. Ther. 21, 940–947.

Piva, S.R., Erhard, R.E., Childs, J.D., Browder, D.A., 2006. Inter-tester reliability of passive intervertebral and active movements of the cervical spine. Man. Ther. 11, 321–330.

Quek, J.M., Pua, Y.H., Bryant, A.L., Clark, R.A., 2013. The influence of cervical spine flexion-rotation range-of-motion asymmetry on postural stability in older adults. Spine 38, 1648–1655.

Reichel, G., Stenner, A., 2013. The role of the obliquus capitis inferior muscle in dystonic torticaput. Toxicon 119.

Reid, S.R.D., Katekar, M., Callister, R., 2012. Efficacy of manual therapy treatments for people with cervicogenic dizziness and pain: protocol of a RCT BMC. Musculoskelet. Disord. 13.

Reid, S.A., Callister, R., Katekar, M.G., Rivett, D.A., 2014a. Effects of cervical spine manual therapy on range of motion, head repositioning, and balance in participants with cervicogenic dizziness: a randomized controlled trial. Arch. Phys. Med. Rehabil. 95, 1603–1612.

Reid, S.A., Callister, R., Snodgrass, S.J., Katekar, M.G., Rivett, D.A., 2015. Manual therapy for cervicogenic dizziness: long-term outcomes of a randomised trial. Man. Ther. 20, 148–156.

Reid, S.A., Rivett, D.A., 2005. Manual therapy treatment of cervicogenic dizziness: a systematic review. Man. Ther. 10, 4–13.

Reid, S.A., Rivett, D.A., Katekar, M.G., Callister, R., 2014b. Comparison of mulligan sustained natural apophyseal glides and maitland mobilizations for treatment of cervicogenic dizziness: a randomized controlled trial. Phys. Ther. 94, 466–476.

Reneker, J.C., Clay Moughiman, M., Cook, C.E., 2015. The diagnostic utility of clinical tests for differentiating between cervicogenic and other causes of dizziness after a sports-related concussion: an international Delphi study. J. Sci. Med.

Sport 18, 366–372.
Salazar-Colocho, P., Del Rio, J., Frechilla, D., 2007. Serotonin 5-hT1A receptor activation prevents phosphorylation of NMDA receptor NR1 subunit in cerebral ischemia. J. Physiol. Biochem. 63, 203–211.
Seffinger, M.A., Najm, W.I., Mishra, S.I., Adams, A., Dickerson, V.M., Murphy, L.S., Reinsch, S., 2004. Reliability of spinal palpation for diagnosis of back and neck pain: a systematic review of the literature. Spine 29, E413–E425.
Shah, J.P., Danoff, J.V., Desai, M.J., Parikh, S., Nakamura, L.Y., Phillips, T.M., Gerber, L.H., 2008. Biochemicals associated with pain and inflammation are elevated in sites near to and remote from active myofascial trigger points. Arch. Phys. Med. Rehabil. 89, 16–23.
Shah, J.P., Gilliams, E.A., 2008. Uncovering the biochemical milieu of myofascial trigger points using in vivo microdialysis: an application of muscle pain concepts to myofascial pain syndrome. J. Bodyw. Mov. Ther. 12, 371–384.
Sjöström, H., Allum, J.H., Carpenter, M.G., Adkin, A.L., Honegger, F., Ettlin, T., 2003. Trunk sway measures of postural stability during clinical balance tests in patients with chronic whiplash injury symptoms. Spine 28, 1725–1734.
Sluka, K.A., Rohlwing, J.J., Bussey, R.A., Eikenberry, S.A., Wilken, J.M., 2002. Chronic muscle pain induced by repeated acid Injection is reversed by spinally administered mu- and delta-, but not kappa-, opioid receptor agonists. J. Pharmacol. Exp. Therapeut. 302, 1146–1150.
Song, X.J., Luo, M.F., Jiang, J., Zhang, J.L., 2014. Effects of electroacupuncture stimulation of "Zusanli" (ST 36) on the regional vascular intercellular Adhesion Molecule-1 mRNA expression and mast cell activity in normal rats. Zhen Ci Yan Jiu 39, 461–465.
Stone, L.S., Vulchanova, L., Riedl, M.S., Wang, J., Williams, F.G., Wilcox, G.L., Elde, R., 1999. Effects of peripheral nerve injury on alpha-2A and alpha-2C adrenergic receptor immunoreactivity in the rat spinal cord. Neuroscience 93, 1399–1407.
Su, T.F., Zhang, L.H., Peng, M., Wu, C.H., Pan, W., Tian, B., Shi, J., Pan, H.L., Li, M., 2011. Cannabinoid CB2 receptors contribute to upregulation of beta-endorphin in inflamed skin tissues by electroacupuncture. Mol. Pain 7, 98.
Takano, T., Chen, X., Luo, F., Fujita, T., Ren, Z., Goldman, N., Zhao, Y., Markman, J.D., Nedergaard, M., 2012. Traditional acupuncture triggers a local increase in adenosine in human subjects. J. Pain 13, 1215–1223.
Tavanai, E., Hajiabolhassan, F., 2013. Cervicogenic vertigo: etiology, diagnosis and treatment. Bimon. Audiol. Tehran Univ. Med. Sci. 22, 1–13.
Thunberg, J., Hellström, F., Sjölander, P., Bergenheim, M., Wenngren, B.-I., Johansson, H., 2001. Influences on the fusimotor-muscle spindle system from chemosensitive nerve endings in cervical facet joints in the cat: possible implications for whiplash induced disorders. Pain 91, 15–22.
Tjell, C., Rosenhall, U., 1998. Smooth pursuit neck torsion test: a specific test for cervical dizziness. Am. J. Otol. 19, 76–81.
Tjell, C., Tenenbaum, A., Sandstrom, S., 2002. Smooth pursuit neck torsion test: a specific test for whiplash associated disorders? J. Whiplash Relat. Disord. 1, 9–24.
Tobbackx, Y., Meeus, M., Wauters, L., De Vilder, P., Roose, J., Tom Verhaeghe, J., 2013. Does acupuncture activate endogenous analgesia in chronic whiplash-associated disorders? A randomized crossover trial. Eur. J. Pain 17, 279–289.
Treleaven, J., 2008a. Sensorimotor disturbances in neck disorders affecting postural stability, head and eye movement control. Man. Ther. 13, 2–11.
Treleaven, J., 2008b. Sensorimotor disturbances in neck disorders affecting postural stability, head and eye movement control—Part 2: case studies. Man. Ther. 13, 266–275.
Treleaven, J., Clamaron-Cheers, C., Jull, G., 2011. Does the region of pain influence the presence of sensorimotor disturbances in neck pain disorders? Man. Ther. 16, 636–640.
Treleaven, J., Jull, G., LowChoy, N., 2005a. Smooth pursuit neck torsion test in whiplash-associated disorders: relationship to self-reports of neck pain and disability, dizziness and anxiety. J. Rehabil. Med. 37, 219–223.
Treleaven, J., Jull, G., Lowchoy, N., 2005b. Standing balance in persistent whiplash: a comparison between subjects with and without dizziness. J. Rehabil. Med. 37, 224–229.
Treleaven, J., Jull, G., LowChoy, N., 2006. The relationship of cervical joint position error to balance and eye movement disturbances in persistent whiplash. Man. Ther. 11, 99–106.
Treleaven, J., Jull, G., Sterling, M., 2003. Dizziness and unsteadiness following whiplash injury: characteristic features and relationship with cervical joint position error. J. Rehabil. Med. 35, 36–43.
Uhlig, Y., Weber, B.R., Grob, D., Müntener, M., 1995. Fiber composition and fiber transformations in neck muscles of patients with dysfunction of the cervical spine. J. Orthop. Res. 13, 240–249.
van Trijffel, E., Anderegg, Q., Bossuyt, P., Lucas, C., 2005. Inter-examiner reliability of passive assessment of intervertebral motion in the cervical and lumbar spine: a systematic review. Man. Ther. 10, 256–269.
van Trijffel, E., Oostendorp, R.A., Lindeboom, R., Bossuyt, P.M., Lucas, C., 2009. Perceptions and use of passive intervertebral motion assessment of the spine: a survey among physiotherapists specializing in manual therapy. Man. Ther. 14, 243–251.
Vidal, P.H.P., 2005. Dizziness in orthopaedic physical therapy practice: history and physical examination. J. Man. Manip. Ther. 13, 222–251.
Wapner, S., Werner, H., Chandler, K., 1951. Experiments on sensory-tonic field theory of perception: I. Effect of extraneous stimulation on the visual perception of verticality. J. Exp. Psychol. 42, 341.
Watson, S.R., Colebatch, J.G., 1998. Vestibulocollic reflexes evoked by short-duration galvanic stimulation in man. J. Physiol. 513 (Pt 2), 587–597.
Wipperman, J., 2014. Dizziness and vertigo. Prim Care 41, 115–131.
Wrisley, D.M., Sparto, P.J., Whitney, S.L., Furman, J.M., 2000. Cervicogenic dizziness: a review of diagnosis and treatment. J. Orthop. Sports Phys. Ther. 30, 755–766.
Wu, S.Y., Chen, W.H., Hsieh, C.L., Lin, Y.W., 2014. Abundant expression and functional participation of TRPV1 at Zusanli acupoint (ST36) in mice: mechanosensitive TRPV1 as an "acupuncture-responding channel". BMC Compl. Alternative Med. 14, 96.
Yacovino, D., 2012. Cervical vertigo: myths, facts, and scientific evidence. Neurologia.
Yacovino, D.A., Hain, T.C., 2013. Clinical characteristics of cervicogenic-related dizziness and vertigo. Semin. Neurol. 33, 244–255.
Yao, W., Yang, H., Yin, N., Ding, G., 2014. Mast cell-nerve cell interaction at acupoint: modeling mechanotransduction pathway induced by acupuncture. Int. J. Biol. Sci. 10, 511–519.
Yorke, A., Ward, I., Vora, S., Combs, S., Keller-Johnson, T., 2013. Measurement characteristics and clinical utility of the Dizziness Handicap Inventory among individuals with vestibular disorders. Arch. Phys. Med. Rehabil. 94, 2313–2314.
Zhang, J., Chen, L., Su, T., Cao, F., Meng, X., Pei, L., Shi, J., Pan, H.L., Li, M., 2010. Electroacupuncture increases CB2 receptor expression on keratinocytes and infiltrating inflammatory cells in inflamed skin tissues of rats. J. Pain 11, 1250–1258.
Zhang, R., Lao, L., Ren, K., Berman, B., 2014a. Mechanisms of acupuncture—electroacupuncture on persistent pain. J. Am. Soc. Anesthesiol. 120, 482–503.
Zhang, R., Lao, L., Ren, K., Berman, B.M., 2014b. Mechanisms of acupuncture-electroacupuncture on persistent pain. Anesthesiology 120, 482–503.
Zhang, Y., Meng, X., Li, A., Xin, J., Berman, B.M., Lao, L., Tan, M., Ren, K., Zhang, R.X., 2011. Acupuncture alleviates the affective dimension of pain in a rat model of inflammatory hyperalgesia. Neurochem. Res. 36, 2104–2110.
Zhang, Y., Meng, X., Li, A., Xin, J., Berman, B.M., Lao, L., Tan, M., Ren, K., Zhang, R.X., 2012a. Electroacupuncture alleviates affective pain in an inflammatory pain rat model. Eur. J. Pain 16, 170–181.
Zhang, Y., Zhang, R.X., Zhang, M., Shen, X.Y., Li, A., Xin, J., Ren, K., Berman, B.M., Tan, M., Lao, L., 2012b. Electroacupuncture inhibition of hyperalgesia in an inflammatory pain rat model: involvement of distinct spinal serotonin and norepinephrine receptor subtypes. Br. J. Anaesth. 109, 245–252.
Zhang, Z.J., Wang, X.M., McAlonan, G.M., 2012c. Neural acupuncture unit: a new concept for interpreting effects and mechanisms of acupuncture. Evid Base Compl. Alternative Med. 2012, 429412.
Zhou, W., Benharash, P., 2014. Significance of "Deqi" response in acupuncture treatment: myth or reality. J. Acupunct. Meridian Stud. 7, 186–189.

Please cite this article in press as: Escaloni, J., et al., The use of dry needling as a diagnostic tool and clinical treatment for cervicogenic dizziness: a narrative review & case series, Journal of Bodywork & Movement Therapies (2018), https://doi.org/10.1016/j.jbmt.2018.02.015