University of Iceland
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Cervical induced balance disturbances after motor vehicle collisions
The efficacy of two successive physical treatment approaches

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Thesis submitted for a Master of Science degree

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Jafnvægistruflanir eftir hálshnykk við bílákeyrslur
Áhrif tveggja meðferðarforma

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ÁGRIP

Aðalmarkmið rannsóknarinnar var að leiða í ljós hvort tvær tegundir meðferðarforma myndu bæta jafnvægistruflanir, sem greindar voru hjá konum með hálshnykk af gráðu I-II (n = 12). Þátttakendur voru með hreyfitruflanir í efri hálsi og viðvarandi einkenni eftir bílákeyrslur. Fyrri meðferðin var samsett af sértækri stoðkerfismeðferð og æfingum til að bæta hreyfistjórn í hálsi, en sú seinni var jafnvægismeðferð sem fylgdi í kjölfarið. Jafnvægisviðbrögð voru mæld með “dynamic posturography” í SMART Balance Master eftir hvort meðferðarform fyrir sig. Einkennalaus hópur kvenna (n = 30) var notaður til að gefa grunnviðmið í jafnvægismælingunum. Spurningalistar, þar sem konurnar með hálshnykk voru beðnar að meta ástand sitt með tilliti til svima og óstöðugleika (the Dizziness Handicap Inventory) og hálsverkja (the Neck Disability Index) voru notaðir fyrir og eftir hvort meðferðarform fyrir sig. Annað markmið rannsóknarinnar var að meta áhrif fyrri meðferðarinnar á hreyfistjórn í hálsi. Stöðu- og hreyfiskyn í hálsi, ásamt virkni djúpu hálsvöðvanna (flexora) var metið fyrir og eftir fyrra meðferðarformið.

Niðurstöðurnar leiddu í ljós að jafnvægisviðbrögð kvennanna með hálshnykk bötnuðu verulega eftir bæði meðferðarformin miðað við grunnviðmið þeirra. Niðurstöður spurningalistanna gáfu til kynna að hálsverkir minnkuðu marktækt og svima - óstöðugleika einkenni minnkuðu einnig þó að munurinn væri ekki marktækur.

Niðurstöður varðandi áhrif fyrri meðferðarinnar á hreyfistjórn, leiddu í ljós bætt innskyn í hálsi, bæði hvað varðar stöðuskyn, sem var mælt með NHP prófi, og hreyfiskyn, sem var mælt með “Flugu” prófi. Þriðja prófið, CCFT, sem var notað til að meta starfsemi djúpra hálsvöðva (flexora), sýndi bætta starfsemi í vöðvunum eftir meðferðina, en munurinn var ekki marktækur.

Niðurstöður þessarar rannsóknar gefa til kynna að margþætt meðferðarform fyrir einstaklinga með viðvarandi einkenni eftir hálshnykk og með jafnvægistruflanir, sé líklegt til að hafa áhrif á truflanir í tauga-vöðvastjórn hjá þessum hópi. Margþætt meðferðarform gæti komið í veg fyrir viðvarandi einkenni hjá einstaklingum með hálshnykk. Mikilvægt er að endurtaka þessa tilraun í slempivalsrannsókn með stærra þýði.

ABSTRACT

The primary aim of this active intervention study was to reveal whether balance disturbances detected in women with whiplash-associated disorders (WAD) of grades I-II, (n=12), had improved after two successive treatment interventions. The participants had dysfunction in the upper cervical structures and chronic symptoms after motor vehicle collisions (MVCs). The interventions consisted of a combined manual therapy and motor control approach followed by a balance exercise program. Balance performance was measured by dynamic posturography in a SMART Balance Master before and after each of the two successive treatment interventions. An asymptomatic group of women (n=30) served to give data for baseline comparison in the balance measurements. Questionnaires, that served to evaluate self-reported complaints of dizziness and unsteadiness (the Dizziness Handicap Inventory) and of neck pain and disability (the Neck Disability Index) were applied before and after each of the two treatment interventions. The secondary aim of the study was to measure the treatment effects of the combined manual therapy and motor control approach in improving specific neuromuscular dysfunctions in the neck.

The results showed that the participants' balance performances improved significantly after both treatment interventions compared to the their baseline performances. The questionnaires revealed that neck pain and disability improved significantly; the scores of the Dizziness Handicap Inventory (DHI) revealed improvement after the treatment interventions, but the difference was not significant. The former treatment intervention revealed significantly improved cervicocephalic kinesthesia by the tests of relocation to neutral head posture (NHP) and the movement test "FLY". The outcome of the third test, the cranio-cervical flexion test (CCFT), revealed tendency towards improved recruitment of the deep neck flexor muscles, but the difference was not significant.

The results of this study indicate that multimodal physical treatment approach for patients with chronic WAD and cervical induced balance disturbances, is likely to address deficits in neuromuscular control and sensorimotor function present in this patient group. A multimodal treatment approach may help to prevent development and maintenance of chronic symptoms in patients with whiplash injuries. The results of this study must wait replication of a randomized clinical trial in a bigger cohort.

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LIST OF ABBREVIATIONS

CCFT	cranio-cervical flexion test
CNS	central nervous system
COR	cervico-ocular reflex
DHI	Dizziness Handicap Inventory
EMG	electromyography
GTOs	Golgi tendon organs
LUH	Landspitali University Hospital
MRI	magnetic resoning imaging
MVC	motor vehicle collision
NDI	Neck Disability Index
NHP	neutral head posture
QTF	Québec Tast Force
ROM	range of motion
SBM	SMART Balance Master
SCM	sternocleidomastoid
SOT	Sensory Organization Test
VOR	vestibular-ocular reflex
VSR	vestibulospinal reflex
WAD	whiplash-associated disorders

1 INTRODUCTION

Several cervical structures are injured during a whiplash injury caused by a low speed motor vehicle collision (MVC). Included in these structures are among others, muscles, ligaments, facet joints, joint capsules and nerves. Neck pain is a common complaint following whiplash injury (Barnsley et al. 1994; Sterling et al. 2002), along with neck stiffness, headache, shoulder and arm pain. Symptoms like dizziness, visual disturbances, paraesthesia and difficulties in concentration and memory loss also belong to the plethora of symptoms in whiplash associated disorders (WAD) (Barnsley et al. 1994). No treatment has been optimized to prevent the chronic course in WAD, as the underlying mechanisms are still poorly understood (Spitzer et al. 1995; Rö et al. 2000). Until recently it has not been possible through clinical examination to objectively verify the complaints of patients with chronic WAD, or to detect musculoskeletal impairments in the neck. The latest advances made in the development of objective assessment methods for neck pain patients (Jull 2000; Kristjansson et al. 2003; Kristjansson et al. 2004; Sterling 2004) are a prerequisite for the development of efficient treatment strategies for patients suffering after MVCs. Identification of structural pathology has proved to be difficult in most patients diagnosed with WAD (Rö et al. 2000). Recent advances in magnetic resonance imaging (MRI) have, however, made it possible to identify structural abnormalities in the soft tissue of the upper cervical spine (Krakenes et al. 2002; Kaale et al. 2005).

The recent diagnostic methods developed for neck pain patients now make it possible to start studying the efficacy of various treatment modalities. The present study was designed to ascertain whether a specific treatment approach would benefit a subgroup of patients with chronic WAD, a subgroup verified in this study to have balance disturbances of suspected upper cervical somatosensory origin.

1.1 Whiplash-associated disorders (WAD)

Classification of patients with whiplash injuries into five grades based on a combination of signs and symptoms (Table 1) was published by the Québec Task Force (QTF) in 1995. The aim of this classification was to facilitate comparison between studies. The QTF introduced and defined the term "Whiplash-Associated Disorders" (WAD), as a convenient term because the symtoms are not always confined to the neck:

> *"Whiplash is an acceleration-deceleration mechanism of energy transfer to the neck. It may result from rear-end or side-impact motor vehicle collisions, but can also occur during diving or other mishaps. The impact may result in bony or soft-tissue injuries (whiplash injuries), which in turn may lead to a variety of clinical manifestations (Whiplash-Associated Disorders)" (Spitzer et al. 1995).*

Table 1 QTF classification of WAD

Grade	Clinical presentation
0	No complaint about the neck No physical sign(s)
I	Neck complaint of pain, stiffness, or tenderness only No physical sign(s)
II	Neck complaint and musculoskeletal sign(s)*
III	Neck complaint and neurological sign(s)**
IV	Neck complaint and fracture or dislocation

* Include decreased range of motion and point tenderness.
** Include decreased or absent tendon reflexes, weakness and sensory deficits.
Deafness, dizziness, tinnitus, headache, memory loss, dysphagia and temporomandibular joint pain are among symptoms and disorders that can be manifest in all grades.

QTF classification of patients' symptoms into groups has a limited utility in the therapeutic management of patients with WAD, grades I-II. More than 80% of the WAD patients, whose symptoms persist for longer than 6 months, correspond to grades I-II (Spitzer et al. 1995; Rö et al. 2000). The general range of motion (ROM) and point tenderness parameters as the only physical measures (Table 1), are poor diagnostic tools to guide therapeutic interventions. Neck pain, decreased ROM and point tenderness are all symptoms that are non-specific and common in the general population. Thus, these symptoms are of little value when distinguishing WAD from other similar disorders (Kristjansson and Jonson 2004). Identification of different subgroups of WAD patients, according to the underlying biological mechanisms and the level of physical impairment is important for the development of physical treatment strategies. It is recommended that WAD patients should firstly be classified according to whether their symptom's origin is from the upper or lower cervical structures (Kristjansson 2004).

This classification has been a common clinical practice in the treatment of other neck pain patients for a long time but is seldom mentioned in research on patients with WAD. This may indicate that the complaints of patients with chronic WAD have been underestimated or misrepresented (Kristjansson 2004).
The distinction between the upper and lower cervical spine has been well established both biomechanically and neurophysiologically (Bogduk and Mercer 2000). The upper neck region is an important sensory organ due to a dense network of mechanoreceptors located in the upper cervical joints and musculature. They provide the central nervous system (CNS) with information which, combined with vestibular and visual information is used in postural control (Karlberg 1995; Brandt 1996; Gdowski and McCrea 2000; Shumway-Cook 2001). Injury to the upper cervical joints and musculature may disturb afferent proprioceptive input, which can lead to imbalance or unsteadiness and the subjective feeling of dizziness (Hildingsson et al. 1989; Rubin et al. 1995; Hagstrom and Carlsson 1996; Karlberg et al. 1996; Mallinson 1996).

1.2 The Postural Control system

Human postural control is dependent on coordinated information from visual, vestibular, and proprioceptive receptor organs within the locomotor system (Johansson and Magnusson 1991). This information is processed and integrated at different levels within the CNS to avoid mismatch in the efferent activity created for optimal performance of movements (Karlberg et al. 1996). Postural control involves controlling the body's position in space for the dual purpose of stability and orientation and therefore its ability to maintain an appropriate relationship between the body segments and the environment for different tasks (Shumway-Cook 2001). No sensory system alone provides all of the necessary information for sensing motion of the whole body, each sensory system contributes different and necessary information (Herdman SJ 2000).

1.2.1 The vestibular system

The vestibular system is one of the phylogenetically oldest functions that in all species is especially developed to detect gravity and body motion, which is a prerequisite to maintain posture and locomotion on land, sea or in the air (Herdman SJ 2000). Trunk, limb and eye muscle reflexes are developed to meet these requirements. Specialized hair cells in the semicircular canals and in the utriculus and sacculus provide information about angular and linear acceleration of the head and the position of the head with respect to gravity. The CNS processes these signals and combines them with other sensory information to estimate head and body orientation and movement. The postural control output of the central vestibular system goes to the ocular muscles and to the spinal cord to serve the two important reflexes, the vestibulo-ocular reflex (VOR) and the vestibulospinal reflex (VSR) (Herdman SJ 2000). The VOR generates eye movements, to enable clear vision while the head is in motion, and the VSR generates muscular tonus in the antigravity muscles in order to maintain head and postural stability, thereby preventing falls (Markham 1987; Herdman SJ 2000; Shumway-Cook 2001).

1.2.2 The visual system

The visual inputs to postural control report information regarding the position and motion of the head with respect to surrounding objects and helps to direct gaze through the VOR. Visual inputs are an important source for postural control but not absolutely necessary, since most of us can keep our balance when we close our eyes or enter a dark room (Shumway-Cook 2001). The visual postural system consists of three different eye movements: the smooth-pursuit, the saccadic and the optokinetic (Tjell and Rosenhall 1998). They are mediated by the VOR i.e. it stabilizes images on the retina under different conditions (Tjell and Rosenhall 1998). The cervico-ocular reflex (COR) consists of eye movements driven by the mechanoreceptors in the upper cervical joints and muscles. Interacting with the powerful VOR, the weaker COR enables positioning and movements of the head in relation to the rest of the body, as well as keeping clear vision during movements (Cohen 1961; McLain 1994; Herdman SJ 2000). In dysfunctional conditions such as increased muscle tension in the neck or bilateral vestibular destruction, the COR seems to take over the function of the VOR in eye-head coordination (Hildingsson et al. 1989; Karlberg 1995; Rosenhall et al. 1996; Tjell and Rosenhall 1998; Tjell 2002).

1.2.3 The somatosensory system

The somatosensory system provides information about the position and motion of the body with respect to its support surface and the configuration of body segments, as well as speed and force of movements (Herdman SJ 2000). Efficient interaction between the afferent input from the neck and from the rest of the locomotor system, as well as from the vestibular and visual systems is essential for postural stability. Afferents from the deep muscles in upper cervical spine are known to have effects on postural reflexes, which help maintain postural control during the perturbations encountered in everyday activities (Cohen 1961).

1.2.3.1 The role of the upper neck in the postural control system

During evolution of the cervical spine, neuromuscular changes developed in order to meet the needs of spatial orientation and movement, as vertebrates evolved from the sea as chordates and crawled on to land, where they would come to survive in an upright position. This was at first accomplished through the development of movement between the head and the rest of the body, allowing the nodding movement necessary for eating, occurring at the atlanto-occipital joint. To adequately scan the environment for danger in the horizontal plane, development of the dens axis enveloped by the ring of atlas proceeded (Wolff 1998). The first two cervical vertebrae are therefore unique in shape and motion as their joints contribute nearly one third of the flexion-extension movement and more than half of the axial rotation of the cervical spine. Further development took place at the C2/C3 segment which facilitated coupled movements in the transverse and the frontal planes to both the opposite and the same side. The upper cervical spine behaves like a spherical joint, enabling us to efficiently scan the environment by the sensory organs in the head (Richmond and Vidal 1988; Dutia 1991). The differences in construction in the lower cervical spine from that of the upper cervical spine make them capable of moving independently of each other, and compliment each other for more efficient function of the cervical spine as a whole (Kristjansson and Jonsson 2002).
The mobility of the cervical spine, supporting the head with its important sensory organs, allows scanning and orientation of the environment in three-dimentional space (Dutia 1991; Bogduk and Mercer 2000). The mobility however, comes at the expense of decreased mechanical stability, which is enhanced by the proprioceptive system of the neck (Dutia 1991; McLain 1994). The development and special arrangement of the deep segmental musculature is unique for the upper neck, because of its high density of mechanoreceptors (Kulkarni et al. 2001). These deep neck muscles differ from other muscles in the configuration and arrangement of the muscle spindles and in that they have a substantial number of other receptors, such as Golgi tendon organs (GTOs) (Richmond and Abrahams 1979; Kulkarni et al. 2001). The abundant network of mechanoreceptors in the upper cervical region supplies the CNS with proprioceptive information on the orientation

of the head in respect to the rest of the body (Neuhuber 1998). Great demands are placed on the central nervous system in providing postural stability and motor control in the presence of the mobile cervical spine (Dutia 1991). The activity of the muscles throughout the trunk and extremities is affected by neurophysiological events that occur at the cervical level. Therefore, proper function of the neck, and especially the upper cervical structures, is essential for effective interaction with the environment (Markham 1987; Dutia 1991). There is strong experimental evidence, supporting the important role of neck afferent activity in maintenance of posture, in oculomotor control and in the perception of balance (Brown JJ 1992). On this basis alone, it is not surprising that disturbance of balance may be associated with injury or pathology of the cervical joints and muscles (Brown JJ 1992). Individuals who have neck injuries from trauma may have multiple-system deficits, including movement disorders that affect postural control (Brown 1990).

1.3 Investigations of cervical induced balance disturbances

The role of the cervical structures as a sensory organ and its importance in the control of balance and posture in animals has been known since the 19th century. Magendie discovered cervical ataxia in the guinea pig before 1838, and more animal studies on the subject followed in the mid 19th century (de Jong and Bles 1986). Magnus and de Kleijn among others studied extensively the cervical influences on posture and tonic postural neck reflexes in the early 20th century (Magnus and DeKleijn 1912; Magnus 1926). In 1955 Ryan and Cope (Ryan and Cope 1955) introduced the term “cervical vertigo” to describe symptoms of vertigo experienced by patients suffering from neck disorders. They suggested disturbed neck proprioception to be the cause of the symptoms, as the vertigo in the cases they described was supposedly caused by interference with the tonic neck reflexes. They thought that damage to the end organs high in the cervical region could produce vertigo. The finding of numerous spindles in human deep neck muscles by Voss 1958 and Cooper and Daniel 1963, prompted further experiments in cats that confirmed a large mechanoreceptor field in the deep upper neck muscles (Richmond and Abrahams 1979; Richmond and Bakker 1982; de Jong and Bles 1986). Vertigo, ataxia, nystagmus and gait disturbances were produced in experimental animals by interference with upper cervical sensory supply, by damaging or anesthetizing neck muscles or by cutting upper cervical dorsal roots (Cohen 1961; de Jong et al. 1977). Dizziness and ataxia have been seen in humans following damage or anesthesia of neck muscles presumably due to a blockage of afferent activity arising in cervical joint and muscle receptors (de Jong et al. 1977; de Jong and Bles 1986). Despite considerable research activity into this area there is a lack of clinical research that highlights the multifactorial consequences of upper cervical neck pain and dysfunctions in humans.

1.3.1 Clinical research of cervical induced balance disturbances

The relationship between chronic neck pain of insidious origin, disturbed neck proprioception (Revel et al. 1991), the subjective feeling of dizziness and disturbed balance performance has been documented (Karlberg et al. 1996; McPartland et al. 1997; Michaelson et al. 2003). Quantitative studies which highlight the significance of disorders of the upper cervical structures as a cause of vertigo or dizziness are few. An association between dysfunction in the segments between occiput and C3 and symptoms of dizziness has been confirmed (Galm R et al. 1998). The relationship between dysfunction in the upper cervical structures and chronic neck pain, disturbed balance performance and sub-occipital muscle atrophy has also been indicated in two pilot studies (Hallgren et al. 1994; McPartland et al. 1997). Cervical dizziness, in the form of ataxia and unsteadiness of gait in patients with cervicogenic headache is also reported (Dieterich et al. 1993).

There is growing evidence suggesting that some patients with persistent WAD may have cervical induced balance disturbances. The generalized influences of this impairment include balance and visual disturbances leading to symptoms such as unsteadiness, dizziness and blurred vision. Altered eye movement control in chronic whiplash patients owing probably to proprioceptive dysfunction in the neck (Hildingsson et al. 1989), has been detected by the smooth pursuit neck torsion test (SPNT) (Gimse et al. 1996; Tjell 2002; Treleaven et al. 2005), as well as altered standing balance performance (Rubin et al. 1995; Kogler et al. 2000; Sjöström et al. 2003; Madeleine et al. 2004; Treleaven et al. 2005). However, none of these aforementioned studies discriminated between the upper and lower cervical structures as a cause of the patient’s complaints.

1.4 Measurements of impairment in the cervical part of the postural control system

Precise neuromuscular control of the mobile upper cervical spine is critical for efficient utilization of the sense of balance due to the neurophysiologic link between the upper cervical structures and the sensory system of postural control (see section 1.2.3.1). Two clinical tests have recently been developed to monitor changes in neuromuscular control of the neck. The first test is an indirect measurement of recruitment of the deep neck flexors, called the cranio-cervical flexion test (CCFT); the second test calculates the accuracy of neck movements (the Fly). Both these tests and an earlier developed test that measures the subject's awareness of the neutral head posture (NHP) were used in this study as means of determining neuromuscular control of the neck. It is still difficult to measure balance disturbances of cervical origin as no clinical test has yet been validated. A diagnosis of cervical induced dizziness is therefore a diagnosis of exclusion of other possible causes. Questionnaires and functional tests have been useful in screening patients with suspected cervical dizziness. These tests, as well as posturography, were used to measure whether cervical induced balance disturbances could be ascertained in the chronic WAD group in this study.

1.4.1 Cranio-cervical flexion test (CCFT)

The cranio-cervical flexion test (CCFT) (Jull et al. 1999; Jull 2000) is a low-load test to target the deep cervical muscles, the longus capitis and longus colli muscles. The test was designed to assess the tonic holding and endurance capacity of the deep cervical flexors. The test is based on anatomical grounds, i.e. cranio-cervical flexion or a head nodding movement is the action of the longus capitus and colli muscles and not the action of other superficial neck flexors such as the sternocleidomastoid (SCM) and the anterior scalene muscles, which flex the neck but not the head. The test is also based on the hypothesis of an altered neuromotor strategy in the neck flexor synergy with neck pain (Jull et al. 1999). Research has reported that neck pain patients of whiplash and insidious origin (Jull et al. 2004), and patient with diagnosed cervicogenic headache (Jull et al. 1999) have a significantly poorer performance on CCFT test than asymptomatic individuals.

1.4.2 Tests of cervicocephalic kinesthesia

Cervicocephalic kinesthesia is an appropriate term in clinical measurements for altered cervical proprioceptive function (McCloskey 1978). Kinesthesia has been defined as a sensation which detects and discriminates between the relative weight of body parts, joint positions and movements, including direction, amplitude and speed (Newton 1982). This sensation is the result of the cumulative neural input to the CNS coming from the extensive muscular and articular proprioceptive system (Wyke 1979; Taylor and McCloskey

1988; Revel et al. 1991; McLain 1994). Thus, the term includes all the qualities that are supposed to be a result of proprioception (McCloskey 1978) and can be tested actively in a clinical setting. Revel et al. introduced a method which measures the ability of the subject, while blindfolded, to relocate the head to a neutral position, after active cervical movements (Revel et al. 1991). The test has been used to measure position sense of the neck. Recently, a new test was developed which measures the accuracy of the subject's head and neck movements on a moment-to-moment basis. The test, called "The Fly", is considered to be capable of measuring the movement sense of the neck (Kristjansson et al. 2004).

Cervicocephalic kinesthesia has been documented to be significantly poorer in patients with chronic neck pain of insidious onset compared with asymptomatic individuals (Revel et al. 1991; Humphreys and Irgens 2002; Michaelson et al. 2003). These results are in contrast with a study conducted by Rix et al., where non-traumatic neck pain patients showed little evidence of impaired cervicocephalic kinesthesia (Rix and Bagust 2001). Several studies provide evidence of deficits in cervicocephalic kinesthesia in whiplash patients in comparison with asymptomatic individuals, both reduced position sense (Heikkila and Astrom 1996; Loudon et al. 1997; Heikkila and Wenngren 1998; Sterling et al. 2003; Treleaven et al. 2003) and movement sense (Kristjansson et al. 2004), and also when comparing chronic neck pain patients of whiplash origin and insidious onset origin (Kristjansson et al. 2003).

1.4.3 Posturography

Posturography is a balance function test that augments the information provided by the traditional vestibular function and Romberg tests (Nashner and Peters 1990; El-Kashlan et al. 1998; Allum et al. 2001; Allum et al. 2001; Allum et al. 2002). In posturography, whether it is static or dynamic, the body sway associated with postural control is estimated through forces exerted by the subject's feet on the support surface (Karlberg 1995). Nashner and co-workers designed a posturography method called the Sensory Organization Test (SOT), which focuses on the sensory component of postural control (Shumway-Cook 2001). The SOT evaluates the subject's ability to make effective use of visual, vestibular and somatosensory inputs separately and to suppress sensory information that is inaccurate. The six conditions tested on the platform posturography are successively more difficult and represent the SOT test (Figure1). The SOT seems to be sensitive and accurate in defining balance disturbances, but it is not specific to any particular lesion (Nashner and Peters 1990). It has been shown to reveal specific patterns of abnormal balance and appears to be capable of distinguishing between different patient groups, e.g. distinguishing cervical dysfunction from that of vestibular neuritis (Rubin et al. 1995; Karlberg et al. 1996).

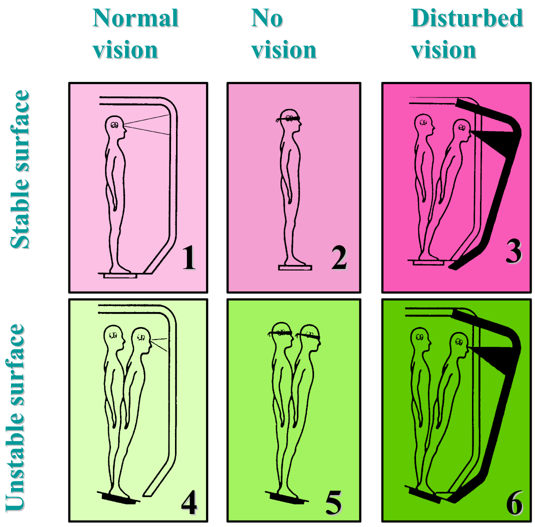


Figure 1 The six sensory conditions on the SOT. With kind permission from Neurocom/Austurbakki.

1.4.3.1 Posturography and cervical induced balance disturbances

A simultaneous vibratory stimulus has been given to the cervical extensor muscles during posturography in order to challenge the cervical part of the somatosensory system. The vibrating stimuli signals that the muscles are lengthening and the patient gets an illusory feeling that the head and neck are moving forward (Karlberg et al. 1996; Koskimies et al. 1997). Other investigators have used different cervical spine positions when performing posturography tests and the extended position was found to be the most sensitive one for detecting a cervicogenic balance disorder (Kogler et al. 2000). The question remains whether other stimuli are more appropriate for challenging cervical proprioceptive function. Vibration most likely stimulates the superficial muscles more than the deep segmental ones and cervical extension stimulates the utricle otoliths (Kristjansson 2004). In a recent study (Gestsdottir 2005), an effort was made to quantify balance disturbances in two groups of women with upper cervical dysfunction, in the early and in the late stages of WAD. This was done by challenging the cervical proprioceptive function through slow rotation movement of the neck, but it failed to distinguish between the groups.

1.5 New treatment approach built on motor control theories

No treatment regime exists for patients having balance disturbances of suspected cervical origin after MVCs. New advances in physical therapy indicate that motor control theories (Shumway-Cook 2001), which address neuromuscular deficits in a more specific way, must be implemented for patients with complicated musculoskeletal problems (Richardson et al. 1999). Motor control has been defined as the ability to regulate or direct the mechanisms essential to movement (Shumway-Cook 2001). Coordination of movements is a core term in motor control and can be defined as the sensorimotor processes which organize and activate large and small muscles with the right amount of force in the most efficient sequence. Coordination is therefore the way one organizes one's degree of freedom in coordinative structures to only a few free parameters (movements). How the free parameters are manipulated is synonymous with motor control and the manipulation of the free parameters also reflects the progression in a rehabilitation strategy which is built on motor control principles (Newell 1985; Spirduso 1995). Neuromuscular training can largely be viewed as motor learning, where the patient has to regain coordinated movements or learn new coordinated movement patterns (Shumway-Cook 2001). Motor learning is more than just a motor process, it rather involves learning new strategies for sensing as well as producing movements. It can be described as the search for a solution of a task that emerges from an interaction of the individual with the task and the environment (Shumway-Cook 2001). Recovery of a function lost through injury is reacquired by motor learning, defined as a relatively permanent change. In order to achieve recovery, repetition and practice in performing the task is necessary. Complicated voluntary movements require extensive practice, but once these are learned they can be accomplished automatically and unconsciously, or with low degree of attention (Shumway-Cook 2001). Habituation is one form of learning and is defined as a decrease in responsiveness that occurs as a result of repeated exposure to a stimulus, and it is used to treat dizziness in patients with certain type of vestibular dysfunction (Shumway-Cook 2001). Prolonged pain and disrupted afferent input from injury, when repair and regeneration is delayed such that chronic pain may ensue, may result in neuroplastic changes in the peripheral and central neural tissues (Sessle 2000). As the nervous system is capable of reorganization following central as well as peripheral lesions, its neuroplasticity can also be facilitated by therapeutic input i.e. retraining (Shumway-Cook 2001). This knowledge when implemented as a theoretical background for a new treatment approach may have the potential to compensate for the effects of a whiplash injury. It is hypothesized in this thesis that specific balance approach must be conducted in addition to local and regional treatment for the neck.

1.5.1 Specific balance exercises

Balance retraining incorporates exercises to improve gaze- and postural stability, consisting of both static and dynamic balancing tasks. Vestibular rehabilitation is well known and widely used. The goal of the exercise approach being to facilitate central nervous system compensation for disorder within the vestibular system (Horak 1992; Krebs et al. 1993; Shepard et al. 1993; Shumway-Cook 1997; Hain et al. 1999; Rine et al. 1999; Murray et al. 2001). The treatment approach is designed along the line of adaptation and of habituation. Adaptation, refers to the long-term changes that occur in the response of the vestibular system to input. Habituation is an exercise approach based on the concept that repeated exposure to provocative stimulus will result in a reduction in the pathological response to that treatment (Herdman SJ 2000). This knowledge was used in this study for establishing a new treatment protocol for improving balance disturbances of cervical origin. It included training of eye-head coordination and balance, as well as a combination of exercises aimed at training specific motor tasks. Repetition, intervals and increasing challenge were incorporated into the program to facilitate active learning (Tjernstrom et al. 2002). The treatment strategies were also intended to expose the patient to external perturbations in order to improve the reflex mediated neuromuscular responses of the cervical muscles.

The research that forms the basis for this thesis is the treatment part of the earlier mentioned study by Gestsdottir (Gestsdottir 2005). In this thesis a specific treatment intervention for women with chronic WAD and pain and disability from upper cervical structures is tested. The chronic WAD group in the Gestsdottir study participated also in the present study. The efficacy of two successive treatment interventions on improved balance performance was tested.

2 AIMS

The primary aim of this active intervention study was to reveal whether balance disturbances detected in women with chronic WAD of grades I-II had improved after each of the two successive treatment interventions. The secondary aim was to measure the treatment effects of a combined manual therapy and motor control approach in improving specific neuromuscular dysfunctions in the neck. The hypothesis tested in this thesis was that patients with chronic WAD will respond to combined manual therapy and motor control approach for the neck by partial improvement of balance performances. It was further hypothesized that a specific treatment approach based on modified vestibular rehabilitation must be accomplished for adequate improvement of their balance performances.

3 MATERIAL AND METHODS

A pre-test/post-test study design of active interventions on one group of subjects was used to observe the effect of treatment. The balance outcome measure at baseline was compared to an asymptomatic control group.

3.1 Participants

Forty-two women divided into two study groups participated in the study. A group with chronic WAD patients (n=12), and a control group including asymptomatic women (n=30). Samples of convenience were used in both groups. The asymptomatic group was recruited from hospital staff and students, while subjects in the chronic WAD group were recruited through contacts with physical therapists in Reykjavik. Participants were screened according to inclusion and exclusion criteria (Table 2). Table 3 shows that participants in both groups were of similar age, height and weight.

Table 2 Inclusion and exclusion criteria

Inclusion	Exclusion
1 Women	1 Pregnancy
2 Age 18-55	2 Medication with side effects on postural control
3 WAD of grades I or II after a MVC	3 Diseases that can influence postural control, e.g.neurologic, rheumatologic, or vestibular diseases
4 Moderate-severe neck pain and/or headache, at least regularly	4 Headache, neck pain, dizziness or unsteadiness in the past six months prior to MVC
5 Painful dysfunction in the upper cervical spine	5 Psychological disorders e.g. depression or anxiety, in the past six months prior to MVC
6 Suspected balance disturbances	6 Low back pain or pain in lower extremities

The inclusion criteria applied to the chronic WAD group, while the exclusion criteria applied to both study groups.

3.2 Screening procedures

The screening procedures (Figure 2) were performed at an outpatient physical therapy clinic in Reykjavik and the Landspitali-University Hospital (LUH). The screening procedures consisted of three parts: a telephone interview, physical examination by a physical therapist, and an otoneurological evaluation by a specialist in otolaryngology.

Table 3 Participants demographics - Mean age, height and weight (SD in parenthesis)

	Asymptomatic group (n=30)	**Chronic WAD group (n=12)**
Age	34.7 (9.3)	33.0 (11.0)
Height	168.8 (5.4)	165.6 (6.3)
Weight	69.4 (10.3)	73.2 (21.0)

No significant difference between groups at the 0.05 level.

3.2.1 Telephone interview

In the telephone interview the subjects were asked about the collision event and present symptoms. They had to suffer from moderate to severe headache and/or neck pain, at least regularly, to be eligible for the study. Information about age, medication and general health status was collected from all participants.

3.2.2 Examination by a physical therapist

The subjects who fulfilled the inclusion criteria in the telephone interview were enrolled to visit a physical therapist specialized in manual therapy for further screening. The clinical examination verified whether the subjects had painful dysfunction in the upper cervical region and whether balance disturbances were suspected using clinical tests (Romberg, Romberg on foam, tandem walking).

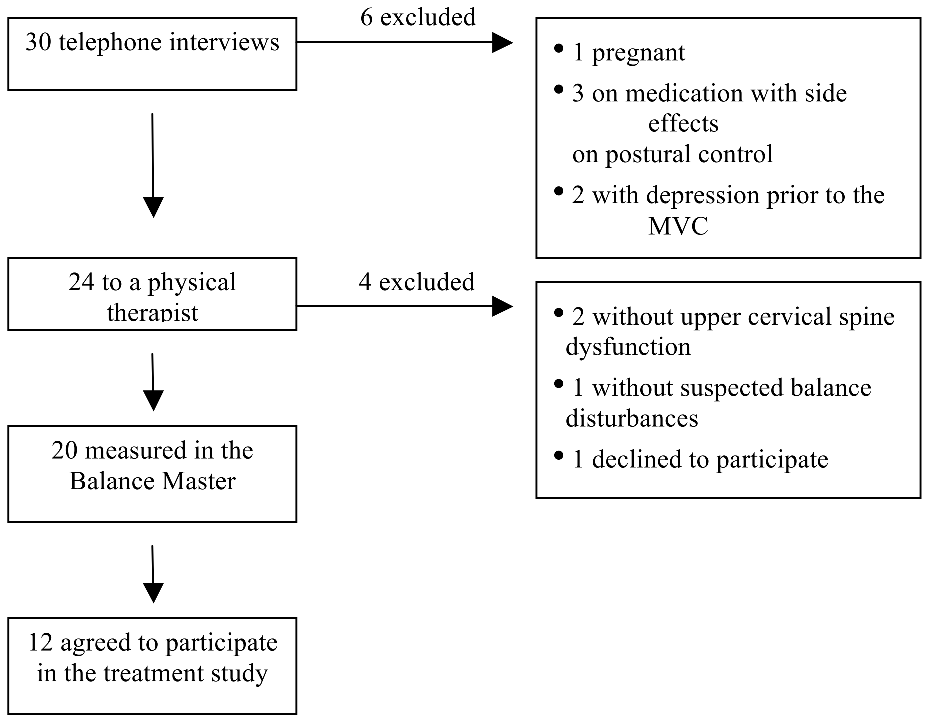


Figure 2 **The screening procedure for the chronic WAD group**.

3.2.3 Evaluation by a specialist in otolaryngology

A specialist in otolaryngology examined seven out of 12 chronic WAD patients to rule out vestibular dysfunction. A smooth pursuit eye movement test and caloric test were performed. The remaining five patients were judged not likely to have vestibular dysfunction as nothing in their medical history and physical examination indicated such a dysfunction.

All participants who fulfilled the inclusion criteria (Table 2) and were willing to participate on a voluntary basis gave informed consent after they had received information about the study set-up and test procedures. Ethical clearance was obtained from the Icelandic Medical Ethics Committee.

3.3 Instrumentation and measurements

Two questionnaires, the SMART Balance Master, the CCFT, NHP and the Fly were used to measure the outcome in this study.

3.3.1 Questionnaires

The Neck Disability Index (NDI) is a ten-item questionnaire designed to measure activity limitations due to neck pain, particularly pain caused by whiplash injuries. The items include evaluation of seven functional activities (personal care, lifting, reading, work, driving, sleeping and recreational activities), as well as pain intensity, headache and concentration. There are six potential responses for each item, describing an increasing degree of disability (score 0-5). The total outcome ranges from no disability (0) to total disability (100) by adding together the scores for each item, multiplied by two. The interpretation intervals for the total scoring of the NDI are as follows: 0-8 = no disability; 10-30 = mild; 32-48 = moderate; 50-68 = severe; above 68 = complete (Vernon and Mior 1991; Hoving et al. 2003).

The Dizziness Handicap Inventory (DHI) is a 25-item measure developed to evaluate self-perceived disabling effects of dizziness or unsteadiness. The total outcome consists of three subscales, each measuring different aspects of disability, i.e. functional (e.g. travel capacities), emotional (e.g. stress on relationships with family or friends) and physical (e.g. increased problems in moving the head quickly). There are three possible answers to each question: no (0 points); sometimes (2 points); and yes (4 points). The outcome measure for the DHI, range from no disability (0) to total disability (100) by adding the scores for every item (Jacobson and Newman 1990).

The reliability and validity of the English versions of these questionnaires have been tried out and accepted (Jacobson and Newman 1990; Jacobson et al. 1991; Vernon and Mior 1991; Hoving et al. 2003). The English versions have been translated into Icelandic and back into English. The two questionnaires are provided in Appendix I, both the English and Icelandic versions.

3.3.2 Dynamic Posturography

Balance measurements were performed on a SMART Balance Master (NeuroCom International Inc.). The conventional SOT portion (Figure 1) of the equipment was used as the main output measurement. Each condition on the SOT was measured three times during 20-second trials to manifest if subjects improved or adapted with repeated trials (Nashner and Peters 1990). Force transducers located in the force platform registered the forces actuated by the feet on the platform and thereby allowing estimation of the body sway. Signals from the force transducers were registered by a computer and the data were quantified into an equilibrium score for each trial. The equilibrium score represents the magnitude of sway based on the assumption that an asymptomatic individual can exhibit 12.5° of anteroposterior sway without falling. The score is determined by comparing an angular difference between the individual's calculated center of gravity (COG) maximal displacement during a trial and the individual's theoretical maximum. A composite score is calculated for the whole test series (SOT 1-6). The equilibrium score and composite score, i.e. the outcome measures, range from 0-100, with 100 indicating perfect stability (no sway) and 0 representing a fall (subject takes a step or uses hands for support) (Nashner and Peters 1990; NeuroCom system operator´s manual: SMART Balance Master 2000).

The SOT 1-6, was performed such that conditions 4-6 were measured before conditions 1-3. Conditions 4-6 are known to be more difficult (Nashner and Peters 1990), as more challenge is put on the vestibular, visual and somatosensory systems for postural control. This was done because the participants in this study were the same as used in another masters study by Gudrun Gestsdottir (Gestsdottir 2005). This sequence of measurement was required in her study procedure, as to more easily facilitate comparison between conditions and thus increase reliability. In the present study this sequence of the SOT conditions was used throughout all the balance measurements. The duration of the SOT 1-6 was 15-20 minutes.

3.3.3 Cranio-cervical flexion test (CCFT)

The subjects were positioned in supine lying and an air filled pressure sensor (Stabiliser. The Pressure Biofeedback Unit. Chattanooga Group Inc.) was placed suboccipitally between the testing surface and the back of the neck and inflated to a baseline pressure of 20 mmHg. This baseline pressure is sufficient to fill the space between the back of the neck and the testing surface. The head nodding action of cranio-cervical flexion was taught and practiced before testing. A contraction of the deep upper cervical flexors causes a subtle flattening of the cervical lordosis (Mayoux-Benhamou et al. 1994), which is registered as an increase in pressure in the sensor. The test was performed in five progressive stages of cranio-cervical flexion movement. Performance was guided by feedback from the pressure sensor with each of the five stages corresponding to a 2 mmHg increase of pressure, from 22 mmHg to a maximum of 30 mmHg. The researcher instructed the subject to perform the CCFT to target 22 mmHg and hold the position steady. Each target pressure was held for 10 seconds, with a 10 seconds rest between each task. The pressure sensor was connected to a pressure transducer (RS component) and electrical signals from the pressure transducer were amplified and relayed to a visual feedback device and to an Amlab data acquisition system*. The visual feedback device consisted of an electronic voltmeter, marked in 2 mmHg increments from 20 to 30 mmHg, and calibrated to display the pressure in the pressure bag, based on the pressure transducer output. Sampling frequency for pressure measurements was 1000 Hz. The mean pressure that each subject achieved over the 10 s holding time of the five test levels was calculated to determine whether subjects had reached each prescribed level of the test. The differences between the mean pressure achieved (actual pressure) and the nominated target pressure for each stage were calculated. Surface EMG was used over the right and left sternocleidomastoid (SCM) muscles to measure myoelectric activity of the superficial flexors during the test. Electrodes were positioned along the lower one third of the muscle bellies of the SCM muscles (Falla et al. 2002).

* Associated Measurements Pty Ltd., Australia.

3.3.4 Cervicocephalic kinesthetic tests

A 3-Space Fastrak system® was used in the tests (Polhamus Navigation Science Division, Kaiser Aerospace, Vermont). The Fastrak is a non-invasive electromagnetic measuring instrument, which tracks the positions of sensors in three-dimensions relative to a source. One sensor is placed on the forehead and another over the spinous process of C7 when testing the relocation or on the back of the head in the movement test. An inner ring from a helmet was used to ensure the same placement of the head sensors during all movements. The electromagnetic source (transmitter) was placed in a box attached to the back of a wooden chair. The Fastrak was connected to an IBM compatible PC and continually recorded the positions of the sensors relative to the source during the entire test sequences (Kristjansson 2004).

3.3.4.1 Test for relocation to NHP

The test replicates that of Revel et al. (Revel et al. 1991). The starting position was sitting with the head in the neutral head position (NHP). The subjects were blindfolded and asked to perform full active cervical rotation to the left and to the right within comfortable limits and then to return to the NHP and indicate when they considered they had relocated the starting position as accurately as possible. This point was recorded by activation of the electronic marker switch. Between each test movement, the subject's head was manually adjusted back to the original starting position, guided by the real time display on the computer screen. Three trials of relocation were performed to the left and then to the right.

3.3.4.2 The Fly

A software program, "the Fly®" which formatted and processed the data for analysis was used. In this program, the difference between the locations of the forehead sensors relative to the sensors on the back of the head, both vertically and horizontally, was calculated, and this data were used to indicate on the computer monitor the movement of the head. This 2-dimensional movement data were then processed by "the Fly" and projected into a square (bounding box) on the monitor. Two cursors are visible in this square: a blue one tracing unpredictable movement patterns (derived from "the Fly") and a black one indicating the movement of the head (derived from the Fastrak system). It is impossible to predict the movement because only the cursors are visible on the screen. The software program makes it possible to record the absolute distance (radius) between the 2 cursors continuously during the entire test sequence and to store this information along with information about how each pattern is generated. The duration of each movement pattern and the velocity of "the Fly" can be adjusted. The subjects were sitting and in advance of the test the intention and nature of the task required of them was explained. To familiarize them with the test, one movement pattern (not one of the test patterns) was performed once by all the participants and was not used for measurements. Three movement patterns, A, B, and C, were used for the measurements (Figure 3). Subjects were required to repeat each movement pattern 3 times, with a 10 seconds interval between each trial. The duration of each trial was 30, 20, and 40 seconds for movement patterns A, B, and C, respectively. The test was performed in random order across patterns and trials. The randomization was done in Microsoft Excel.

The Fly: Movement patterns A-B-C

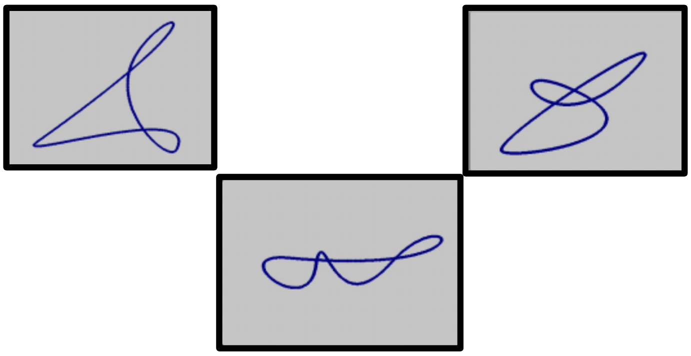


Figure 3 **Movement patterns A-B-C traced by the Fly which the subjects were required to follow by moving their head.**

3.4 The intervention

The first intervention A) consisted of manual therapy and a motor control treatment but the second intervention B) was a specific balance exercise program.

<u>A) Manual therapy and motor control treatment for the neck</u>

The manual therapy (MT) examination and treatment was in accordance with the Nordic System of Manual Therapy (Kaltenborn 2003). The main aim of the manual therapy treatment was to normalize the range of motion and lessen the pain when moving the neck. A pragmatic treatment approach directed at the symptomatic segments which exhibited hypomobility was used as well as muscle stretching and soft tissue mobilisation (Evjenth and Hamberg 1984). The motor control treatment consisted of three parts: retraining of the deep neck flexors according to Jull 2000 (Jull 2000); treatment to enhance better awareness of one's head posture according to a modified Feldenkrais approach (Olafsdottir and Helgadottir 2001) and a recently developed treatment which required the subjects to follow predicted paths, with different degrees of difficulty, by moving their heads. The subjects had a laser light fastened to their forehead which enabled them to follow the paths which were drawn on paper (A3) and placed 180 cm in front of them. The aim was to improve the accuracy of the subjects' cervical movements as measured by "the Fly".

B) Exercise program for cervical induced balance disturbances

A combination of eye-head coordination, balance, and task dependent exercises was used.

a) Oculomotor exercises standing on an unstable surface (foam).
   i. Eye movements with head stationary, the subjects moved the eyes between two black dots on the wall, 1 m. apart.
   ii. The subjects' eyes followed a target moving side to side and up and down, head stationary.

b) Eye-head coordination exercises standing on an unstable surface (foam).
   i. The subjects practiced leading with the eyes first to the target and then the head, ensuring the eyes were kept focused on the target. Direction of movements was to the left and right sides.
   ii. The subjects fixed their gaze on a black dot on the wall, 1 m away, and moved their head to the sides in rotation and upwards and downwards.
   iii. The subjects rotated the eyes and the head to the opposite side in both the left and right directions.

c) Walking on uneven and on narrow surfaces (tandem), progression into performing various tasks while walking, such as throwing and catching a ball and eye-head coordination exercises, e.g. following a stationary or moving object while walking.

d) Standing balance exercises; standing feet-apart, feet together and tandem, on an uneven surface, foam, balance board and trampoline. The subjects practiced their standing balance with their eyes open and closed, while performing various perturbations, e.g. arm movements and exercises with a ball. Eye-head coordination exercises were also incorporated in these situations.

e) One of the latest sessions was performed outdoors practicing walking on uneven surfaces, like sand and stones, as well as uphill and downhill. Different tasks were performed while walking, e.g. moving the head as in following flying birds, following birds or moving persons with the eyes only, the head stationary.

f) Instructions for home exercises every day were given in accordance with the above.

3.5 The study procedure

In the chronic WAD group, data from the questionnaires, the CCFT, NHP, FLY and the SMART Balance Master were recorded before and after the first treatment intervention and data from the questionnaires and the SMART Balance Master were recorded after the second treatment intervention. In the asymptomatic group, data from the SMART Balance Master were recorded once.

The balance measurements were performed at the LUH Landakot, and the collection of background information and other measurements were performed at an outpatient physical therapy clinic. Both treatment interventions were performed at the same out-patient clinic by two manipulative physical therapists. The examination procedure was explained in a standardized manner to all the participants. They were asked not to consume any alcoholic beverages or painkillers 24 hours before testing, but were allowed to take prescribed medication as usual. All measurements were performed within the same week. The duration of the first treatment intervention was six weeks, 2-3 times a week depending on the outcome of the physical examination. The second treatment intervention consisted of 10 sessions, twice a week.

3.6 Data management and analysis

The outcome measure was: the composite score for the whole SOT test sequence and the scores of the two questionnaires. The composite score before and between each of the two successive treatment interventions was compared by the Friedman test and a paired comparison of the score was performed using the dependent-samples *t* test. The same tests were used to compare the scores of the two questionnaires. For each participant the mean of three trials in his equilibrium score was calculated and used in comparing each test condition. Where comparison of equilibrium scores and composite scores was made between the asymptomatic group and the chronic WAD group, the independent-samples *t* test was used. The mean scores of the CCFT, NHP, and the Fly tests were compared before and after the first treatment intervention, using the dependent-samples *t* test. If the parametric test was not appropriate for comparison the non-parametric Wilcoxon signed-ranks test was used. Number of subjects, means and SD were used for description of the data as well as box plots. The significance level for all tests was set at 0.05.

The Statistical Package SPSS 13.0 was used for data analysis.

4 RESULTS

Twenty women met the inclusion criteria, but only twelve of them agreed to participate in the study (Fig.2) and they present the chronic WAD group. Seven of the twelve women underwent otoneurological evaluation with negative results. The five remaining women had no signs in their medical history or physical examination that indicated an otoneurological dysfunction. Asymptomatic women (n=30) served to give baseline data for the balance measurements. Demographics for the asymptomatic and the chronic WAD groups are presented in Appendix II and the collision-related variables for the chronic WAD group are presented in Appendix III.

4.1 Questionnaires

Table 4 shows the mean scores (SD) of the NDI questionnaire, for neck pain and disability, and the p-values for the dependent-samples *t* test. A significant difference was revealed when the NDI questionnaire mean scores were compared before and after the first treatment intervention, $t(11) = 2.842$; $p = 0.016$. A significant difference was also revealed when comparing the mean scores before treatment and after both treatment interventions, $t(11) = 3.335$; $p = 0.006$. The difference in mean scores was not significant between the two successive treatment interventions $t(11) = 1.443$; $p = 0.177$. The Friedman test for repeated measures revealed a significant difference, p=0.004, in comparison with the mean scores of the NDI questionnaire at baseline and after the two successive treatment interventions. Table 5 shows the mean scores (SD) of the DHI questionnaire, for self-perceived disability from dizziness or unsteadiness. No significant differences were revealed when the DHI scores were compared across treatments.

Table 4 Total score of the NDI (SD) of the chronic WAD group (n=12) after each of the successive treatment interventions.

	Mean	(SD)		P-value		
	Baseline	**Treatm.A**	**Treatm.B**	**Baseline/ Treatm.A**	**Baseline/ Treatm.B**	**Treatm.A/ Treatm.B**
Total score	41.7(13.5)	33.3(13.3)	28.0(13.4)	0.016*	0.006*	0.177

*Significant at the 0.05 level by dependent-samples *t* tests.
Treatment A = manual therapy in combination with regional motor control approach
Treatment B = specific balance exercise program.

Table 5 Total score of the DHI (SD) of the chronic WAD group (n=12) after each of the successive treatment interventions.

	Mean	(SD)		P-value		
	Baseline	**Treatm.A**	**Treatm.B**	**Baseline/ Treatm.A**	**Baseline/ Treatm.B**	**Treatm.A/ Treatm.B**
Total score	38.5(19.8)	40.2(21.9)	33.0(18.7)	0.608	0.304	0.177

No significant differences at the 0.05 level were found by dependent-samples *t* tests.
Treatment A = manual therapy in combination with regional motor control approach
Treatment B = specific balance exercise program.

4.2 SOT-1-6

Table 6 and Figure 4 show the analysis of the composite score in the SBM at baseline and after each of the two successive treatment interventions (A and B). Table 7 displays the mean composite scores and the mean equilibrium scores for each condition at baseline and after each of the two treatment interventions. Comparison between baseline and each of the two treatment interventions as well as between the two treatment interventions are also shown in Table 7. The dependent-samples *t* test revealed a significant difference in the composite score of the chronic WAD group after the first treatment intervention, $t(11) = -4.08$; $p = 0.002$, and also between the two successive treatment interventions, $t(11) = -4.01$; $p=0.002$. The total improvement in the composite score of this group of patients after both treatment interventions was significant, $t(11) = -5.15$; $p < 0.001$. Table 8 shows the descriptive statistics of the composite scores of the chronic WAD group after the two successive treatment interventions in comparison with the baseline composite scores of the asymptomatic group, a group with subchronic WAD symptoms and the chronic WAD group itself.

Table 6 Descriptive statistics of the mean (SD) composite scores of the chronic WAD group (n=12) in the SBM, before and after each of the successive treatment interventions.

		Percentiles		
	Mean (SD)	**25^{th}**	**50^{th} (Median)**	**75^{th}**
Baseline	51.0 (20.2)*	35.7	49.5	71.7
Treatment A	64.5 (15.6)*	61.0	68.0	75.2
Treatment B	72.4 (14.8)*	70.7	76.0	83.2

*Significant difference by Friedman Test, *p*< 0.001
Treatment A = manual therapy in combination with regional motor control approach
Treatment B = specific balance exercise program.

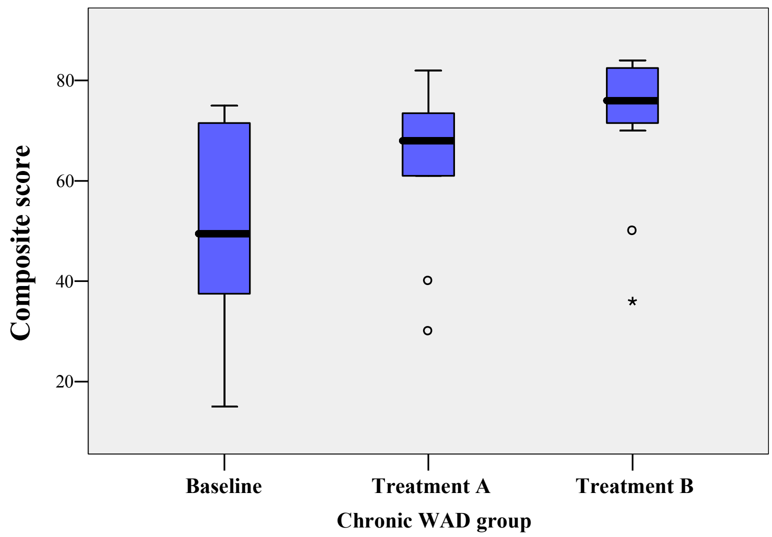


Figure 4 The boxplot of the composite scores of the chronic WAD group (n=12) at baseline and after each of the two successive treatment interventions (A and B).

Table 7 Mean composite score (CS) and mean equilibrium scores of the asymptomatic group (n=30) and chronic WAD group (n=12) for every condition (cond.) on the SOT (SD in parenthesis).

	Asympto-matic (n=30)	**Chronic Mean** Baseline	**WAD (SD)** Treatm.A	**(n=12)** Treatm.B	Baseline/ Treatm.A	**P-value** Baseline/ Treatm.B	Treatm.A/ Treatm.B
Cond.1	94.9(1.6)	86.9(5.9)	88.9(4.9)	92.2(3.2)	0.320	0.018*	0.049*
Cond.2	92.2(2.1)	73.9(21.0)	85.4(10.0)	88.2(4.9)	0.087	0.033*	0.288
Cond.3	95.3(1.2)	71.9(23.4)	88.4(6.3)	91.5(3.8)	0.017*	0.012*	0.064
Cond.4	86.1(8.2)	40.9(31.4)	58.0(25.5)	69.6(23.9)	0.050*	0.008*	0.021*
Cond.5	68.2(8.6)	35.7(25.5)	48.2(23.2)	58.5(21.9)	0.060	0.006*	0.014*
Cond.6	76.7(10.2)	34.6(22.8)	47.6(22.7)	58.4(23.2)	0.001*	<0.001*	0.038*
CS	**83.4(4.9)**	**51.0(20.2)**	**64.5(15.6)**	**72.4(14.8)**	**0.002***	**<0.001***	**0.002***

*Significant at the 0.05 level by dependent-samples *t*-test.
Treatment A = manual therapy in combination with regional motor control approach
Treatment B = specific balance exercise program.

Table 8 A three group comparison of the mean composite scores (CS) on the SOT in the SBM (SD).

Intervention	**Asymptomatic group (n=30)**	**SubchronicWAD group** (n=12)**	**ChronicWAD group (n=12)**	**p-value**
Baseline	83.4 (4.9)	66.3 (13.1)	51.0 (20.2)	<0.001*
Treatment A	-	-	64.5 (15.6)	
Treatment B	-	-	72.4 (14.8)	

*Significant at the 0.05 level by one way ANOVA
Treatment A = manual therapy in combination with regional motor control approach
Treatment B = specific balance exercise program.
**Subchronic WAD group: From Gestsdottir study (Gestsdottir 2005) – with kind permission.

4.3 Regional treatment

4.3.1 The cranio-cervical flexion test (CCFT)

The differences between the target pressure and the actual pressure (mean value) achieved for each stage of the CCFT before and after the recruitment treatment of the deep neck flexor muscles are presented in Figure 5. Within each stage, the mean shortfalls in pressure before and after treatment were not significantly different (Figure 5).

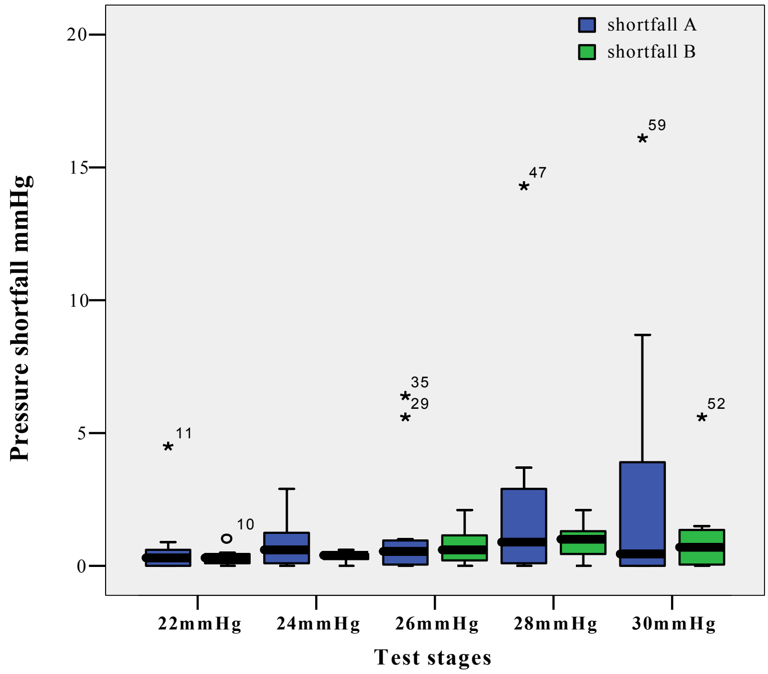
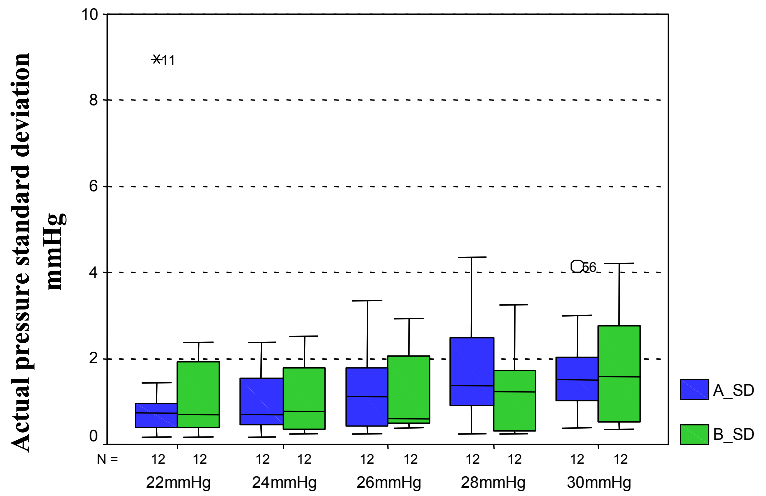


Figure 5 The boxplot for the shortfalls in pressure from the target pressure for each stage of CCFT before and after treatment of the deep neck flexor muscles in the chronic WAD group. (A = before treatment; B = after treatment).

Figure 6 shows that the analysis of the standard deviations (SDs) of the pressure measurements in the CCFT revealed a trend towards increased difficulty of the patients to keep the actual pressure steady at the later pressure stages.



Test stages

Figure 6 **The boxplot of the standard deviations of the actual pressure for each stage of the CCFT before (A) and after (B) treatment of the deep neck flexor muscles in the chronic WAD group.**

Figure 7 shows the analysis of the actual pressure values the patients were able to withhold during the CCFT. A significant difference in performance before and after treatment of the deep neck flexor muscles was revealed in all stages except at the first stage (22 mmHg).

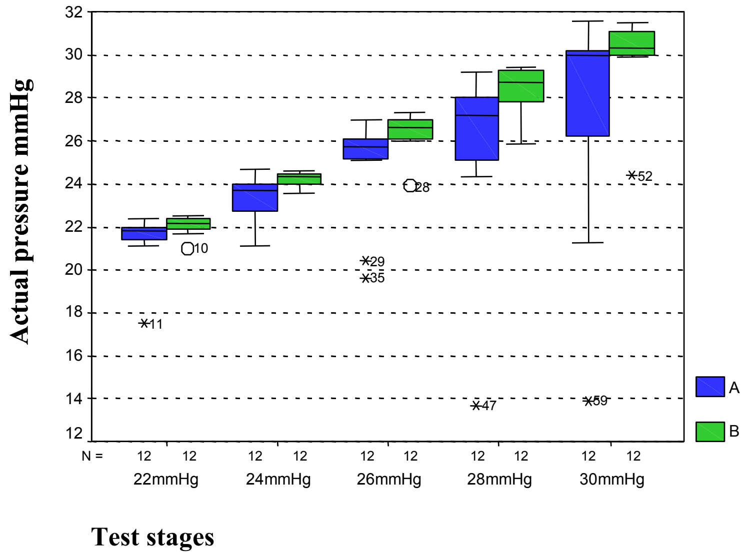


Figure 7 **The boxplot of the actual pressure for each stage of the CCFT before (A) and after (B) treatment of the deep neck flexors in the chronic WAD group. The broken lines show the target pressure values, and the boxplot reveals the actual pressure values.**

The EMG measurements failed to reveal a significant difference before and after the treatment of the deep neck flexors muscles (Figure 8).

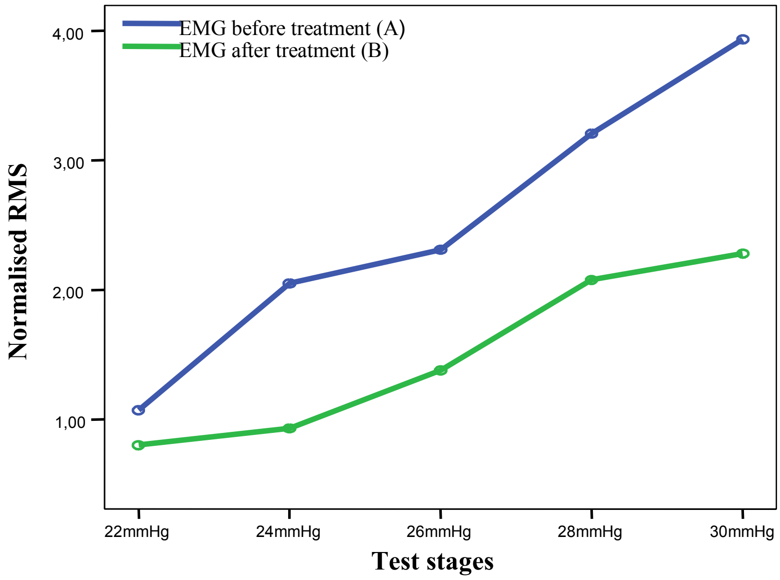


Figure 8 **The means for normalized RMS values for SCM in each stage of the CCFT before and after treatment of the deep neck flexor muscles in the chronic WAD group.**

4.3.2 Relocation to NHP

The descriptive statistics of the relocation test to NHP for the chronic WAD group before and after treatment are summarized in Table 9. A significant difference (*p* =0.034) was revealed in the mean absolute error of relocation to NHP. The descriptive statistics of the relocation test to NHP for each individual subject in the chronic WAD group are presented in Appendix IV.

Table 9 Relocation error to NHP (absolute mean ±SD) following axial rotation before and after treatment in the chronic WAD group (n = 12). Logarithm transformation of the absolute (Abs.) error is shown in the right columns.

Test	Abs.err A Mean(±SD)	Abs.err B Mean(±SD)	p	Log A Mean(±SD)	Log B Mean(±SD)	p
NHP	3.16° (1.50)	2.31° (1.31)	0.028*	1.03°(0.50)	0.70° (0.54)	0.034*

* Significant at the 0.05 level by Wilcoxon.

4.3.3 The Fly

Table 10 presents the error magnitude for each of the three movement patterns for the chronic WAD group before and after the treatment with "the Fly". The data reveal a significant difference in the error magnitude in each of the three movement patterns (A-B-C) and also in the three movement patterns combined (ABC). The descriptive statistics of "the Fly" for each individual subject in the chronic WAD group are presented in Appendix V. The plot of the 3 repeated measurements in all movement patterns of the "Fly", are also shown in Appendix V.

Table 10 Error Magnitude of the Fly for each movement pattern (A,B,C) and combined (ABC) (Mean ±SD) before (A) and after (B) treatment in chronic WAD group (n=12)

Movement Pattern	A Error Magnitude (mm) Mean (SD)	B Error Magnitude (mm) Mean (SD)	p
A	9.64 (3.31)	7.71 (1.12)	0.035*
B	7.75 (1.77)	6.51 (1.02)	0.015*
C	9.06 (3.59)	7.14 (1.55)	0.023*
ABC	8.82 (2.77)	7.12 (1.18)	0.017*

*significant at the 0.05 level by the dependent-samples *t* test.

5 DISCUSSION

Both treatment interventions improved the balance performances significantly in the chronic WAD group in this study when compared to the baseline balance performances (Table 6 & Table 7). The first treatment intervention was a combined manual therapy and motor control approach for the neck and the second intervention was a specific balance exercise program. The results of this study indicate that specific treatment interventions for chronic WAD patients can improve their balance performances. Each treatment method used in the regional motor control approach also revealed significant improvement in most tests. To the author's knowledge this is the first study that addresses both regional treatment for the neck and a specific balance exercise program to improve balance disturbances of cervical origin in a selected group of patients. The participants were selected according to whether they had symptoms and signs of upper cervical dysfunctions and balance disturbances detected by clinical tests.

The following discussion relates to the effects of each measure used in this study to monitor changes in the subjective and objective status of the patients before and after the two successive treatment interventions.

5.1 Questionnaires

The results of the questionnaires indicate considerable disability during activities of daily living related to neck pain and dizziness (Tables 4 and 5). The Neck Disability Index (NDI) is a self reporting instrument for the assessment of daily living, of sufferers of disabling neck pain. Scores higher than 30 on the NDI are considered to be moderate to severe. The results show a considerable improvement of the self reported pain and disability after the two treatment interventions reflected by a statistically significant difference in the NDI scores (Table 4). The reported disability of the chronic WAD group in this study is in agreement with other studies on WAD patients (Sterling et al. 2003; Sterling et al. 2003; Sterling et al. 2003). A recent study using NDI and MRI showed that self-reported complaints among WAD patients grade II could be linked with structural abnormalities in ligaments and membranes in the upper cervical spine (Kaale et al. 2005).

The Dizziness Handicap Inventory (DHI) did not demonstrate statistically significant difference in the perceived dizziness among the patients in this present study. However, some improvement in total scores of the DHI was noticed, after both treatment interventions, but the standard deviations show that the distribution of scores was too wide (Table 5). Prior studies have indicated a significant correlation between the DHI and the SOT posturography scores, and recommended it as an outcome measure for documenting treatment benefits in rehabilitation of various balance disturbances (Jacobson et al. 1991; Robertson and Ireland 1995). The results of this present study indicate that the DHI questionnaire is not specific enough to detect complaints of dizziness of cervical origin although it may detect a perceived handicap of dizziness from other causes. Some efforts have been made towards the development of a questionnaire that can detect disability as a consequence of cervical induced dizziness (Treleaven et. al 2003).

5.2 Balance treatment

Addressing both the regional and whole body impairment in rehabilitation is of importance for the treatment outcome of various disorders (Shumway-Cook 2001). The improvement in balance performance in the chronic WAD group, after both treatment interventions was significant. Moreover, the difference in outcome between the two successive treatment interventions was also significant and is of great clinical importance. This is particularly the case in WAD as the neck, especially the upper cervical structures, is a very delicate sensory organ due to its direct neurophysiological connections to vital organs and functions in the head (McCough et al. 1951; Dutia 1991; Hulse 1998; Neuhuber 1998), as the introductory review presents.

The equilibrium scores for the asymptomatic group and the chronic WAD group before the treatment interventions (baseline) (Table 7) reveal how well the asymptomatic group performed in the more difficult conditions 4-6, compared to the chronic WAD group. Despite good improvement after the interventions the chronic WAD group did not reach the equilibrium scores of the asymptomatic group (Table 7). Likely explanations are the unremitting condition in the WAD group and the effect of dysfunctional central pain modulation, which is prevalent in chronic conditions (Lidbeck 2002). Unresolved balance disturbances in WAD patients may be an important contributing factor for transition from acute to chronic stages. In long-standing chronic cases, neurophysiological modulation in the CNS can occur due to its plasticity (Sessle 2000), which could explain why many chronic neck patients have difficulties with improving from conventional approaches. In theory, once the CNS has adapted to the altered somatosensory inputs, the symptoms of cervical dizziness would abate even though the underlying dysfunction remains (Clendaniel 2000). Evidence of sensory changes in chronic WAD, likely reflect disturbances in central neurobiological processing of pain, and could also be an explanation for the persistence of the chronic symptoms (Koelbaek-Johansen et al. 1999; Sterling et al. 2003; Banic et al. 2004). The modulation of the CNS has to be addressed when a successful treatment approach for chronic WAD patients is designed. The concept on which vestibular rehabilitation is based can be a useful addition to manual therapy and motor control treatment of the neck as this present study demonstrates. This knowledge highlights the importance of screening patients for balance disturbances early on after the MVCs. A balance screening procedure is also necessary for patients who have no subjective complaints of dizziness or balance disturbances, as clinical experience indicates that this impairment may be masked in milder cases by unrelenting hyperactivity in the postural muscles (Kristjansson 2004).

Comparisons between studies performed to reveal balance disturbances of cervical origin are difficult as different posturography methods have been used. A recent masters thesis assessed the baseline balance measurements presented in this present study (Gestsdottir 2005). The results of this prior masters thesis (Table 8) showed a significant difference in balance performance on the SBM, between asymptomatic controls, subchronic and chronic WAD groups (Gestsdottir 2005).

Treatment intervention studies for patients with WAD are sparse but some guidelines have been published (Gwendolijne et al. 2002; Sterling 2004). The treatment studies that have been published recommend active in preference to passive intervention (Provinciali et al. 1996; Borchgrevink et al. 1998; Rosenfeld et al. 2003). The present study used both passive and active interventions. The regional treatment of the neck in this study, a combination of manual therapy and motor control approaches, improved the balance performances significantly (Table 6 and 7). The balance exercise approach, employed for the first time in this study to improve balance performances, consisted of combined eye-head coordination exercises, balance exercises, and task dependent exercises. The positive results of this treatment regime indicate that it should be used as a part of a multimodal intervention program for patients with balance disturbances of cervical origin.

5.3 Regional treatment

The active motor control treatment was considered an important part of the treatment for the neck in this study, as the passive manual therapy treatment could not address all the impairments that are present after whiplash-type distortion injuries. There are few studies on treatment strategies aimed at improving neuromuscular control of the neck (Kristjansson 2004). Physical therapy, cervical injection of local anesthetics at tender points and immobilization of the neck with a collar have all been suggested as treatment forms for cervicogenic dizziness (de Jong and Bles 1986; Brown 1992). A few studies have been conducted that show positive results from local manual therapy and physical therapy approaches for improving dizziness of suspected cervical origin in patients with insidious onset neck pain (Karlberg et al. 1996). Manipulation of the upper cervical joints seems to improve the feeling of dizziness to a certain degree (Galm R et al. 1998; Hülse and Hölzl 2000). Manipulation, decreasing muscle tension, and an exercise program for improving coordination of motor patterns seem to benefit cervicogenic dizziness as well as the use of electrotherapy for pain relief (Bracher et al. 2000; Hülse and Hölzl 2000). The positive results are explained by the reduction in pain and the normalization of tissue compliance ensuring adequate stimulation of the mechanoreceptors in the tissue (Kristjansson 2004). However, in more difficult cases, as in patients with chronic WAD, the joint stability may be compromised by permanent changes in tissue compliance or direct damage to the mechanoreceptors and the axons connected to them, because they have lower tensile strength than the surrounding collagen fibers (O´Conner et al. 1992; McLain 1994). Chemical changes, brought about by ischemic or inflammatory events, may affect the sensitivity of the receptors (Johansson et al. 1993; Thunberg et al. 2001) as well as reflex joint inhibition of the muscle spindles (McGrea 1986; Windhorst and Kokkoroyiannis 1992; Thunberg et al. 2001). Altered joint biomechanics, irrespective of the reasons, also causes different mechanoreceptors to fire too late or too early, too little or too much (Cole et al. 1996; Sjölander et al. 2002). Patients who are affected by these conditions are unlikely to respond to conventional physical therapy or manual therapy alone. The consequent faulty recruitment muscle patterns result in the underestimation or overestimation of the situation, making the soft tissue liable to repeated microtrauma or "self injury" (Bojsen-Møller 1991; Gardner-Morse et al. 1995). This may cause uncertainty for the injured person and increased muscular guarding (Bojsen-Møller 1991; Bojsen-Møller 1998), which may be a major factor in maintenance, recurrence or progression of local and referred symptoms (Glencross and Thornton 1981; Deusinger 1984; Laskowski et al. 1997; Lephart et al. 1997; Suter and

Hertzog 2000). Identifying and resolving disordered motor control deficits are therefore considered an important key in diminishing the unceasing chronic symptoms in WAD patients.

5.3.1 Recruitment of the deep neck flexors

The results of CCFT in our study did not reveal a significant difference before and after treatment (Figure 5). A certain tendency towards improvement could be observed in the actual pressure achieved during each incremental stage of the test in Figure 7. Interestingly, before treatment the scores of the chronic WAD group tended to be under the target pressure values, while after the treatment their scores tended to be above it. Accordingly the patients were more successful in staying closer to the target values after the treatment, which might indicate better recruitment of the deep neck flexors (Figure 7). The deviations of the actual pressure reached at each stage demonstrated the inability of the patients to keep the actual pressure steady especially at later two stages of the test (Figure 6). The pressure unit used for the test in this study was extremely sensitive, which could explain the difficulty the patients had in holding the precise target pressure. The EMG measurements failed to reveal a significant difference before and after treatment, but less activity in the SCM muscles in each stage of the CCFT test after treatment was revealed (Figure 8). This could suggest that these muscles were recruited to further stabilize the neck, as the contractile demand of the longus capitis and colli muscles increased in the inner ranges of cranio-cervical flexion. Lower values of the SCM after treatment indicate improved control and recruitment of the deep neck flexors and less need for the superficial muscle activity. Altered patterns of co-ordination has been inferred to be present between the deep and superficial flexor muscles in individuals with neck pain of insidious (Cholewicki et al 1997) and whiplash origin, and that both groups have more difficulty in achieving the last stage of the test (30 mmHg) (Jull et al. 2004). The CCFT test has been used to determine effectiveness of manual therapy and a low-load exercise program, both alone and combined, for cervicogenic headache patients with positive results for the exercise program (Jull et al. 2002).

5.4 Cervicocephalic kinesthesia

This is the first intervention study that addresses both sub-modalities of proprioception. The modified Feldenkrais approach was used to improve the static component of position sense, and “the Fly” was used to improve the dynamic component of movement sense. This dual modality kinesthetic treatment revealed significant differences for each modality (Table 9, Table 10). It can be reasoned that the improved cervicocephalic kinesthetic sensibility contributed considerably to the documented improvement in balance performances (Table 6 & Table 7) and self-reported neck pain and disability (Table 4).

5.4.1 Position sense: Awareness of one's neutral head posture

The relocation test to NHP showed a significant difference before and after treatment (Table 9). This is the second study that uses this modified Feldenkrais approach to improve awareness of one's neutral head posture. The first trial was also conducted on patients with chronic WAD and showed a significant improvement in targeting the NHP after a 4-week training period (Olafsdottir and Helgadottir 2001; Kristjansson 2004). Revel et al. (1994) conducted a randomized control trial on chronic neck pain patients; the treatment intervention tested was mainly eye-neck coordination exercises and training of movement awareness. Head repositioning accuracy together with neck pain and disability significantly improved in the treatment group after an 8-week period (Revel et al. 1994). Similar results were shown in a study conducted by Humphreys et al. in 2002 after a 4-week treatment period (Humphreys and Irgens 2002). Manipulation has also been reported to improve the accuracy for repositioning of the head as well as a reduction of reported dizziness in patients with complaints of dizziness of suspected cervical origin (Heikkila et al. 2000).

5.4.2 Movement sense: Accuracy of neck movements

This is the first study that uses "the Fly" as an outcome measure when regarding the effect of treatment. A significant difference was revealed in the accuracy of performing the test before and after the treatment (Table 10). The test by "the Fly" has been shown to be reliable and capable of discriminating between chronic WAD patients and asymptomatic subjects (Kristjansson et al. 2004). There was a significant difference between each of the three trials for all movement patterns, before and after the intervention, except in the third trial (Appendix V). A likely cause is a very high score of one of the participants in the third trial before treatment, leading to a high standard deviation. The chronic WAD group in the present study did not reach the same performance in the test after the intervention as the asymptomatic group in Kristjansson study (Kristjansson et al. 2004), but

they showed the same tendency as in better performance with repeated successive trials (Appendix V). This could be an indication of improved firing of the mechanoreceptors in the neck, learning effects or adaptation in the neuromuscular control system (Gandevia and Burke 1992).
A discrepancy existed between the treatment and the test in this study as the patients followed predicted paths in the treatment but the test required the patients to follow unpredictable paths. This discrepancy will be improved before the next treatment trial as more movement patterns with different difficulties will then be generated. It will then be possible to use “the Fly” for treatment purpose with progressive difficulties to improve the accuracy of neck movements.

Limitations

This study revealed improved function of the neck, but care must be taken in the interpretation of the results because of the study design. The main limitation of this study is that there was no control group. The sample size was also relatively small and the participants were a sample of convenience. This study was also conducted on patients who were already suffering from chronic pain and it did not seek to establish any firm causal relationship between the MVCs and the symptoms present at the time of the study.

The main aim of the manual therapy treatment was to normalize range of motion (ROM) and lessen pain. The ROM parameter was used in this study to measure the effect of the manual therapy treatment but unfortunately these data are missing as it was not possible to process them for analysis.

The study was designed so that the balance exercise program became the second intervention based on the hypothesis tested. It is recommended that when using these treatment interventions in clinical practice the methods should be intertwined. The balance exercise program, which was supposed to challenge the cervical part of the somatosensory system may have increased the tension in the neck muscles resulting in temporary increased pain. Increased muscle tension may have had a negative effect on postural control (Branström et al 2001). Manual therapy treatment used simultaneously would presumably have relieved those symptoms and further improved the function of the neck. A follow-up protocol could answer a most wanted question about the preservation of the effect of treatment.

The SOT testing procedure started with condition 4 instead of condition 1. This was done because the subjects in this study were participants in a preceding study (Gestsdottir 2005), where this test order was required. Condition 4-6 represent moving support surface while misleading information are given with normal, no or disturbed vision. Starting with a more difficult condition might have had some impact on the balance performance and limit the comparison to conventional SOT outcomes in other studies.

6 CONCLUSIONS

This study used multimodal pragmatic intervention programs to treat patients with chronic WAD and cervical induced balance disturbances. The positive results of the study highlight the importance of scrutinizing the treatment effects prospectively in a randomized controlled trial. The main clinical message to learn from this study is that the physical treatment has to be directed towards defined subgroups within the broad group of WAD patients with grade I-II.

For the purpose to diminish the risk of WAD becoming chronic the management must also be aimed at addressing deficits in neuromuscular control and sensorimotor function, which will most likely be accomplished by a multimodal physical treatment approach.

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Appendix I

Neck Disability Index Questionnaire (NDI)

Please Read: This questionnaire is designed to enable us to understand how much your neck pain has affected your ability to manage everyday activities. Please answer each Section by circling the **ONE CHOICE** that most applies to you. We realize that you may feel that more than one statement may relate to you, but please **just circle the one choice which closely describes your problem right now.**

Section 1--Pain Intensity

- I have no pain at the moment
- The pain is mild at the moment
- The pain comes and goes and is moderate
- The pain is moderate and does not vary much
- The pain is severe but comes and goes
- The pain is severe and does not vary much

Section 2--Personal Care (Washing, Dressing etc.)

- I can look after myself without causing extra pain
- I can look after myself normally but it causes extra pain
- It is painful to look after myself and I am slow and careful
- I need some help, but manage most of my personal care
- I need help every day in most aspects of self-care
- I do not get dressed, I wash with difficulty and stay in bed

Section 3--Lifting

- I can lift heavy weights without extra pain
- I can lift heavy weights, but it causes extra pain
- Pain prevents me from lifting heavy weights off the floor but I can if they are conveniently positioned, for example on a table
- Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned
- I can lift very light weights
- I cannot lift or carry anything at all

Section 4--Reading

- I can read as much as I want to with no pain in my neck
- I can read as much as I want with slight pain in my neck
- I can read as much as I want with moderate pain in my neck
- I cannot read as much as I want because of moderate pain in my neck
- I cannot read as much as I want because of severe pain in my neck
- I cannot read at all

Section 5--Headache

- I have no headaches at all
- I have slight headaches which come infrequently
- I have moderate headaches which come infrequently

- I have moderate headaches which come frequently
- I have severe headaches which come frequently
- I have headaches almost all the time

Section 6--Concentration
- I can concentrate fully when I want to with no difficulty
- I can concentrate fully when I want to with slight difficulty
- I have a fair degree of difficulty in concentrating when I want to
- I have a lot of difficulty in concentrating when I want to
- I have a great deal of difficulty in concentrating when I want to
- I cannot concentrate at all

Section 7--Work
- I can do as much work as I want to
- I can only do my usual work, but no more
- I can do most of my usual work, but no more
- I cannot do my usual work
- I can hardly do any work at all
- I cannot do any work at all

Section 8--Driving
- I can drive my car without neck pain
- I can drive my car as long as I want with slight pain in my neck
- I can drive my car as long as I want with moderate pain in my neck
- I cannot drive my car as long as I want because of moderate pain in my neck
- I can hardly drive my car at all because of severe pain in my neck
- I cannot drive my car at all

Section 9--Sleeping
- I have no trouble sleeping
- My sleep is slightly disturbed (less than 1 hour sleepless)
- My sleep is mildly disturbed (1-2 hours sleepless)
- My sleep is moderately disturbed (2-3 hours sleepless)
- My sleep is greatly disturbed (3-5 hours sleepless)
- My sleep is completely disturbed (5-7 hours sleepless)

Section 10--Recreation
- I am able to engage in all my recreational acitvities with no pain at all
- I am able to engage in all my recreational activities with some pain in my neck
- I am able to engage in most, but not all recreational activities because of pain in my neck
- I am able to engage in a few of my usual recreational activities because of pain in my neck
- I can hardly do any recreational activities because of pain in my neck
- I cannot do any recreational activities at all

Neck Disability Index (NDI)

Þessi spurningalisti er hannaður til þess að gefa upplýsingar um það hvernig hálsverkir hafa áhrif á daglegt líf þitt. Vinsamlegast svaraðu öllum spurningum sem eiga við. Þú merkir aðeins við það svar sem lýsir vandamáli þínu best.

1. Verkur

- o Ég hef enga verki sem stendur
- o Verkurinn er vægur sem stendur
- o Verkurinn er nokkur sem stendur
- o Verkurinn er þó nokkur sem stendur
- o Verkurinn er mjög mikill sem stendur
- o Verkurinn gæti ekki verið verri sem stendur

2. Hirðing eigin líkama (þvottur, klæðnaður o.fl.)

- o Ég sinni eigin þörfum eðlilega án þess að verkir versni
- o Ég sinni eigin þörfum eðlilega en það eykur verkinn
- o Verkirnir versna það mikið er ég sinni eigin þörfum að ég verð að fara mér hægt og varlega
- o Ég sinni að mestu eigin þörfum en þarf þó svolitla aðstoð við það
- o Ég þarf aðstoð að mestu leyti til að sinna eigin þörfum
- o Ég get ekki klæðst eða þvegið mér án það mikilla óþæginda að ég er mikinn hluta dagsins í rúminu

3. Burður

- o Ég get lyft upp þungum hlut án þess að verkir aukist
- o Ég get lyft þungum hlut en verkirnir aukast við það
- o Vegna verkja get ég ekki tekið upp þunga hluti af gólfinu en get lyft þeim upp ef þeir eru vel staðsettir, t.d. á borði
- o Vegna verkja get ég ekki lyft þungum hlutum en get lyft léttum og meðalþungum hlutum ef þeir eru staðsettir þægilega
- o Ég get eingöngu lyft mjög léttum hlutum
- o Ég get hvorki lyft upp hlutum né borið þá

4. Lestur

- o Ég get lesið að vild án verkja í hálsi
- o Ég get lesið að vild en finn fyrir verkjum í hálsi
- o Ég get lesið að vild en finn fyrir þó nokkrum verkjum í hálsi
- o Ég get ekki lesið að vild vegna verkja í hálsi
- o Ég get varla lesið vegna mikils sársauka í hálsi
- o Ég get ekki lesið neitt vegna verkja

5. Höfuðverkir

- o Ég fæ enga höfuðverki
- o Ég fæ milda höfuðverki sem koma sjaldan
- o Ég fæ mikla höfuðverki sem koma sjaldan

- Ég fæ milda höfuðverki sem koma oft
- Ég fæ mikla höfuðverki sem koma oft
- Ég er nánast alltaf með höfuðverk

6. Einbeiting
- Ég get einbeitt mér að fullu þegar ég vil, án erfiðleika
- Ég get einbeitt mér að fullu þegar ég vil, með nokkrum erfiðleikum
- Ég á í smá vandræðum með að einbeita mér þegar ég vil
- Ég á í þó nokkrum vandræðum með að einbeita mér þegar ég vil
- Ég á í miklum vandræðum með að einbeita mér þegar ég vil
- Ég get alls ekki einbeitt mér

7. Vinna
- Ég get unnið vinnu mína án þess að verkir versni
- Ég get unnið vinnu mína en verkir versna við það
- Ég get unnið hálfa vinnu þrátt fyrir verkina
- Ég get unnið 2-4 klst. þrátt fyrir verkina
- Ég get unnið minna en 2 klst. vegna verkjanna
- Ég get ekkert stundað vinnu vegna verkjanna

8. Akstur
- Ég get ekið bifreið án þess að verkir versni
- Ég get ekið bifreið en verkir versna við það
- Ég get ekið bifreið í meira en 4 klst. þrátt fyrir verki
- Ég get ekið bifreið í 2-4 klst. þrátt fyrir verki
- Ég get ekið bifreið í minna en 2 klst. vegna verkja
- Ég get ekki ekið bifreið vegna verkja

9. Svefn
- Ég á í engum vandræðum með svefn
- Svefninum er nær ekkert raskað (minna en 1 klst. á nóttu)
- Svefninum er lítið raskað (1-2 klst. á nóttu)
- Svefninum er þó nokkuð raskað (2-3 klst. á nóttu)
- Svefninum er mikið raskað (3-5 klst. á nóttu)
- Ég ligg andvaka á nóttunni

10. Félagslíf
- Ég lifi eðlilegu félagslífi án þess að verkir aukist
- Ég lifi eðlilegu félagslífi en verkirnir aukast við það
- Verkirnir koma í veg fyrir mikla hreyfingu, t.d. dans, en að öðru leyti lifi ég eðlilegu félagslífi
- Verkirnir hafa talsverð áhrif á félagslíf mitt og ég fer minna út en áður
- Verkirnir hafa verulega áhrif á félagslíf mitt og ég fer mun minna út en áður
- Verkirnir koma alveg í veg fyrir allt félagslíf

The Dizziness Handicap Inventory (DHI)

The purpose of this scale is to identify difficulties that you may be experiencing because of your dizziness or unsteadiness. Please answer "yes", "no" or "sometimes" to each question. Answer each question as it pertains to your dizziness or unsteadiness problems only.

1. Does looking up increase your problem?
   □ no □ sometimes □ yes

2. Because of your problem, do you feel frustrated?
   □ no □ sometimes □ yes

3. Because of your problem, do you restrict your travel for business or recreation?
   □ no □ sometimes □ yes

4. Does walking down the aisle of a supermarket increase your problem?
   □ no □ sometimes □ yes

5. Because of your problem, do you have difficulty getting into or out of bed?
   □ no □ sometimes □ yes

6. Does your problem significantly restrict your participation in social activities such as going out to dinner, going to movies, dancing or to parties?
   □ no □ sometimes □ yes

7. Because of your problem, do you have difficulty reading?
   □ no □ sometimes □ yes

8. Does performing more ambitious activities like sports, dancing, household chores such as sweeping or putting dishes away increase your problem?
   □ no □ sometimes □ yes

9. Because of your problem, are you afraid to leave your home without having someone accompany you?
   □ no □ sometimes □ yes

10. Because of your problem, have you been embarrassed in front of others?
   □ no □ sometimes □ yes

11. Do quick movements of your head increase your problem?
   □ no □ sometimes □ yes

12. Because of your problem, do you avoid heights?
□ no □ sometimes □ yes

13. Does turning over in bed increase your problem?
□ no □ sometimes □ yes

14. Because of your problem, is it difficult for you to do strenuous housework or yard work?
□ no □ sometimes □ yes

15. Because of your problem, are you afraid people may think you are intoxicated?
□ no □ sometimes □ yes

16. Because of your problem, is it difficult for you to go for a walk by yourself?
□ no □ sometimes □ yes

17. Does walking down a sidewalk increase your problem?
□ no □ sometimes □ yes

18. Because of your problem, is it difficult for you to concentrate?
□ no □ sometimes □ yes

19. Because of your problem, is it difficult for you to walk around your house in the dark?
□ no □ sometimes □ yes

20. Because of your problem, are you afraid to stay home alone?
□ no □ sometimes □ yes

21. Because of your problem, do you feel handicapped?
□ no □ sometimes □ yes

22. Has your problem placed stress on your relationships with members of your family or friends?
□ no □ sometimes □ yes

23. Because of your problem, are you depressed?
□ no □ sometimes □ yes

24. Does your problem interfere with your job or household responsibilities?
□ no □ sometimes □ yes

25. Does bending over increase your problem?
□ no □ sometimes □ yes

Spurningalisti um svima – óstöðugleika
(The Dizziness Handicap Inventory)

Einkennin sem spurt er um í eftirfarandi spurningalista eru einkum um svima og/eða óstöðugleikatilfinningu. Svaraðu öllum spurningunum eftir bestu getu.

1. Þegar þú horfir upp fyrir þig veldur það svima/jafnvægisleysi?
   □ nei □ stundum □ já

2. Valda einkenni þín þér gremju?
   □ nei □ stundum □ já

3. Eru einkenni þín þess valdandi að þú forðist ferðalög hvort sem er vegna vinnu eða í tómstundum?
   □ nei □ stundum □ já

4. Eykur það einkenni þín að ganga milli hilluraða í stórmörkuðum?
   □ nei □ stundum □ já

5. Valda einkenni þín þér erfiðleikum við að fara í og úr rúmi?
   □ nei □ stundum □ já

6. Hindra einkenni þín þig í að taka þátt í félagslegum viðburðum, eins og fara út að borða, í bíó, út að dansa, eða í veislur?
   □ nei □ stundum □ já

7. Áttu erfitt með að lesa vegna einkenna þinna?
   □ nei □ stundum □ já

8. Valda flóknari athafnir eins og íþróttir, dans eða dagleg heimilisverk (t.d.sópa gólf og þurrka diska og setja uppí skáp) auknum einkennum?
   □ nei □ stundum □ já

9. Ertu hrædd/ur við að fara út án fylgdar vegna einkenna þinna?
   □ nei □ stundum □ já

10. Hefur þú orðið vandræðaleg/ur fyrir framan aðra vegna einkenna þinna?
    □ nei □ stundum □ já

11. Ef þú hreyfir höfuðið snöggt eykur það einkenni þín?
    □ nei □ stundum □ já

12. Ertu lofthrædd/ur vegna einkenna þinna?
    □ nei □ stundum □ já

13. Eykur það einkenni þín að snúa þér í rúmi?
    □ nei □ stundum □ já

14. Auka erfið heimilisverk eða garðvinna einkenni þín?
□ nei □ stundum □ já

15. Valda einkenni þín því að þú ert hrædd/ur um að fólk haldi að þú sért undir áhrifum lyfja/alkóhóls?
□ nei □ stundum □ já

16. Áttu erfitt með að fara ein/n í gönguferð vegna einkenna þinna?
□ nei □ stundum □ já

17. Eykur það einkenni þín að ganga eftir gangstétt?
□ nei □ stundum □ já

18. Áttu erfitt með að einbeita þér vegna einkenna þinna?
□ nei □ stundum □ já

19. Áttu erfitt með að ganga í myrkri á heimili þínu vegna einkenna þinna?
□ nei □ stundum □ já

20. Ertu hrædd/ur við að vera ein/n heima vegna einkenna þinna?
□ nei □ stundum □ já

21. Finnst þér einkenni þín valda þér fötlun af einhverju tagi?
□ nei □ stundum □ já

22. Hafa einkenni þín truflað eða valdið álagi á samband þitt við fjölskyldumeðlimi eða vini?
□ nei □ stundum □ já

23. Finnur þú fyrir þunglyndi vegna einkenna þinna?
□ nei □ stundum □ já

24. Trufla einkenni þín skyldur þínar í vinnu og á heimili?
□ nei □ stundum □ já

25. Eykur það einkenni þín að beygja þig fram?
□ nei □ stundum □ já

Appendix II

Subject demographics. Count (%) for each variable.

	Asymptomatic group (n= 30)	Chronic WAD group (n=12)
Education		
- elementary school	1 (3.3%)	-
- high school	7 (23.3%)	5 (41.7%)
- university	20 (66.7%)	4 (33.3%)
- other	2 (6.7%)	3 (25.0%)
Work		
- full time	25 (83.3%)	6 (50.0%)
- part time	4 (13.3%)	5 (41.7%)
- not working	1 (3.3%)	1 (8.3%)
Working part time or not working because of WAD	-	5 (41.7%)
Medication	-	4 (33.3%)
Compensation closure	-	12 (100%)
Treatment	-	12 (100%)

Appendix III

Collision-related variables. Count (%) for each variable.

	Chronic WAD group (n = 12)
Site of collision	
- rear	9 (75.0%)
- front	2 (16.7%)
- other	1 (8.3%)
Driver	7 (58.3%)
Passenger	5 (41.7%)
With seat belt	12 (100%)

The mean duration from injury for the chronic WAD group (n=12) was 3 years, the standard deviation was 2.53 (range 1.0-8.5 years).

Appendix IV.

The descriptive statistics of the relocation test to NHP of each individual subject in the chronic WAD group (mean ±SD).

	A			B		
Sub-	**Mean**	**(SD)**	**Abs.errorA**	**Mean**	**(SD)**	**Abs.errorB**
ject	From left	From right	Mean(SD)	From left	From right	Mean(SD)
1	2.43°(1.87)	1.30°(0.26)	1.86°(1.35)	1.17°(0.45)	2.08°(1.36)	1.63°(1.03)
2	5.50°(1.85)	4.43°(1.52)	4.96°(1.62)	1.46°(0.77)	2.00°(1.12)	1.73°(0.91)
3	1.33°(1.49)	4.46°(3.39)	2.90°(2.90)	2.43°(2.27)	1.99°(1.74)	2.21°(1.82)
4	1.96°(0.47)	5.03°(1.64)	3.50°(1.99)	2.65°(2.44)	1.59°(1.33)	2.12° (1.85)
5	3.03° (1.25)	3.33°(1.85)	3.18° (1.42)	1.48°(1.02)	1.27°(0.80)	1.37° (0.83)
6	4.43° (3.05)	6.26°(0.70)	5.34° (2.22)	4.40° 3.06)	6.30°(0.70)	5.35° (2.24)
7	1.50° (0.90)	5.83°(1.81)	3.67° (2.69)	1.33°(0.85)	5.46°(1.82)	3.40° (2.59)
8	1.96° (1.56)	1.70°(1.48)	1.84° (1.36)	1.24°(0.92)	0.27°(0.23)	0.74° (0.82)
9	2.00° (0.60)	2.86°(2.05)	2.43° (1.43)	1.74°(0.81)	1.97°(1.21)	1.86° (0.93)
10	2.32° (1.93)	0.17°(0.27)	1.24° (1.70)	1.97°(1.85)	0.23°(0.32)	1.10° (1.52)
11	4.16° (1.36)	6.97°(5.71)	5.57° (4.01)	2.63°(1.93)	2.09°(1.35)	2.36° (1.52)
12	0.96° (0.53)	1.89°(2.40)	1.43° (1.63)	2.56°(0.23)	5.37°(2.06)	3.96° (2.02)

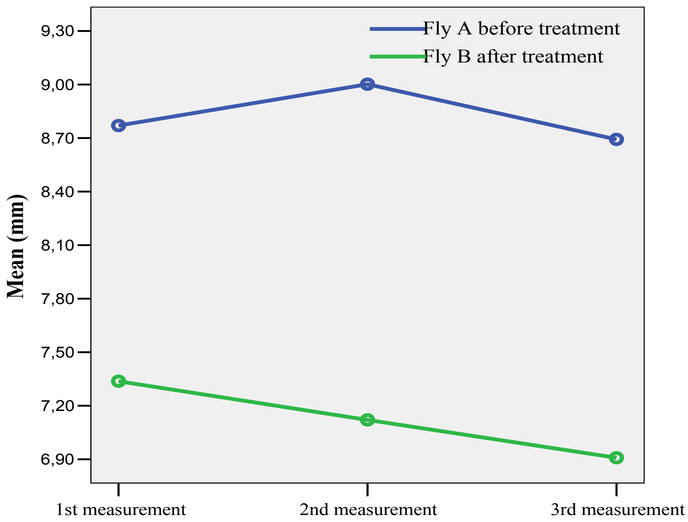
Mean(SD) A = before treatment
Abs.error A = Absolut error before treatment.
Mean (SD) B = after treatment
Abs.error B = Absolut error after treatment.

Appendix V

The descriptive statistics of the error magnitude (Mean ±SD) for each movement pattern (A,B,C) in the "Fly" test, of each individual subject in the chronic WAD group.

	Before	**treatment**		**After**	**treatment**	
Sub-ject	Pattern A Mean(SD)	Pattern B Mean(SD)	Pattern C Mean(SD)	Pattern A Mean(SD)	Pattern B Mean(SD)	Pattern C Mean(SD)
1	10.68(3.44)	6.92(0.17)	7.68(0.43)	8.34(0.82)	6.92(0.33)	8.12(0.48)
2	10.50(2.49)	9.09(1.93)	9.80(2.19)	8.52(0.46)	7.26(0.55)	7.71(0.67)
3	7.95(0.61)	7.24(0.31)	7.46(0.88)	6.42(0.19)	5.22(0.43)	5.54(0.51)
4	19.61(2.81)	11.48(1.50)	19.65(3.75)	9.58(0.57)	8.39(1.91)	11.12(2.98)
5	6.95(0.59)	5.23(0.41)	5.52(0.12)	6.76(0.15)	5.62(1.08)	6.23(0.34)
6	7.56(1.21)	5.56(0.25)	8.08(0.69)	9.07(0.90)	7.32(0.85)	8.08(0.74)
7	9.14(0.84)	9.96(2.05)	10.12(0.46)	7.19(0.77)	6.99(0.56)	6.45(0.19)
8	8.23(1.06)	7.99(0.28)	7.59(0.50)	8.92(1.45)	7.21(0.82)	7.48(0.10)
9	8.42(0.63)	6.74(0.76)	6.94(0.42)	6.61(0.27)	6.43(0.52)	6.40(0.16)
10	8.62(1.37)	6.88(0.89)	7.87(0.99)	6.42(0.20)	5.22(0.46)	5.57(0.51)
11	9.09(0.57)	7.91(2.36)	8.01(0.64)	7.21(0.67)	5.16(0.35)	5.86(0.34)
12	9.05(1.35)	8.02(0.64)	10.02(0.50)	7.45(0.36)	6.44(0.58)	7.16(1.01)

Note: Values are in mm.



A plot of the 3 repeated measurements in all movement patterns of the "Fly" for the chronic WAD group. A significant difference was revealed by dependent-samples t test between each of the three measurements before and after treatment, except in the third measurement.