

The effect of a 3 minute static posture on
cervical spine position sense in
asymptomatic participants

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Abstract

Alteration to cervical spine position sense has been associated with symptomatic subjects experiencing whiplash, whiplash associated disorders (WAD) and chronic neck pain, however, there has been little investigation into cervical spine position sense in asymptomatic subjects. The aim of the current study was to investigate cervical position sense before and after a 3 minute static posture (flexion or extension) in asymptomatic subjects. This dissertation is comprised of two main sections; a literature review followed by a manuscript for a research report that has been prepared in accordance with submission requirements for *Manual Therapy*. For the main study, 32 asymptomatic subjects undertook two position sense tests; the neutral head position and target head position tests in the sagittal and transverse planes, before and after a 3 minute static posture in either flexion or extension. Absolute errors were calculated from data recorded by an orientation sensor. The effect sizes, calculated from the Wilcoxon Z values pre and post the intervention, were 'trivial' for the two position sense tests after either the flexion or extension intervention. The results indicate no substantial differences in cervical position sense before and after a 3 minute static posture, in either flexion or extension, on asymptomatic subjects.

Keywords: *Neck pain; Proprioception; Cervical pain; Neck ache*



Declaration

Name of candidate: Philip Rowe

This Research Project is submitted in partial fulfilment for the requirements for the Unitec degree of Masters of Osteopathy

Candidate's Declaration

I confirm that:

- This Research Project represents my own work;
- The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Research Ethics Committee Approval Number: 2007.756

Candidate Signature:

Date:

Student number: 1189795

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List of Abbreviations

AE	Absolute error
Ca ²⁺	Calcium
CINAHL	Cumulative Index to Nursing and Allied Health Literature
ICC	Interclass correlation coefficient
LCL	Lower confidence limit
Mdn	Median
N	Sample size
NDI	Neck Disability Index
NHP	Neutral head position
PSP	PlayStation Portable
Q-Q	Quantile-quantile
r	Effect size
s	Seconds
SD	Standard deviation
SF-MPQ	McGill short form Pain Questionnaire
SMS	Short Message Service
SPSS	Statistical Package for the Social Sciences
THP	Target head position
UCL	Upper confidence limit
WAD	Whiplash associated disorder

Preface

This research project is divided into three sections. Section 1 consists of a Literature review that will firstly examine neck pain and the risk factors of sustained postures, then discuss position sense testing and literature supporting the methods used in the current study. Section 2 is a manuscript for a research report that has been formatted in accordance to *Manual Therapy* submission requirements. Note the manuscript uses the *Manual Therapy* style of referencing as stipulated by the publisher. Section 3 of the dissertation is an appendix containing all tables and figures not included in the journal manuscript, as well as the documentation of ethics approval.

Section 1: Literature Review

Introduction

Neck pain is a common symptom and produces a high level of morbidity by affecting occupational and recreational activities. Early research has investigated trauma related neck injury prevention and management from spinal cord damage (McCoy, Piggot, Macafee, & Adair, 1984; Torg, Vegso, O'Neill, & Sennett, 1990). More recently soft tissue injuries of the cervical spine have been examined using position sense, most commonly whiplash (Heikkilä & Astrom, 1996; Loudon, Ruhl, & Field, 1997), chronic neck pain (Revel, Andre-Deshays, & Minguet, 1991; Rix & Bagust, 2001) and whiplash associated disorders (Treleaven, Jull, & Sterling, 2003). However, studies using position sense on asymptomatic subjects, pre and post an intervention are few. It is generally accepted that a forward head posture and forward flexion of the neck are two commonly sustained postures leading to neck pain. The relationship between neck pain and position sense may be a useful way of investigating the aetiology of neck pain and using proprioceptive deficits identify risk factors.

The purpose of this review is to highlight current knowledge of neck pain, sustained posture and cervical spine position sense. It includes discussion on the prevalence, incidence and aetiology of neck pain, commonly adopted sustained postures, anatomical structures involved with proprioception, position sense evaluation methods and findings from studies investigating cervical spine position sense in symptomatic and asymptomatic subjects.

Literature search

A comprehensive literature search using electronic databases including Science Direct, Ebsco, Scopus, Academic Search Premier, CINAHL and the Medline databases was undertaken to identify literature relating to neck pain, proprioception in the neck, sustained posture, ergonomics, position sense, head reposition sense/accuracy, muscle spindles, cervical muscle, vestibular system, and cervicocephalic kinesthesia. Additional studies were added by hand searching of the reference lists of original investigations and review articles.

Definition of neck pain

Pain has been defined as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” (Merskey & Bogduk, 1994). Pain is said to be subjective, which arises because each individual learns the sensation of pain through their own experiences related to injuries in earlier life. Injuries have been associated with unpleasant experiences and therefore are also emotional (Merskey & Bogduk, 1994).

“Neck pain or cervical pain is perceived as arising from an area bounded superiorly by the superior nuchal line, inferiorly by the tip of the spinous process of the first thoracic vertebrae and laterally by the lateral borders of the neck” and cervical pain has been further subdivided in upper cervical, lower cervical and suboccipital pain (Merskey & Bogduk, 1994). Neck pain may spread and be accompanied by pain in the shoulder, upper thoracic region, jaw and by an occipital headache. Clinically, it is generally accepted that subjects with neck pain but no evidence of nerve root irritation or compression may also experience referred pain to the head, ear, anterior chest, arm, face, scapulae and dorsal spine regions (Rao, 2004).

Neck pain epidemiology

Prevalence

The prevalence of neck pain has been investigated by many studies and in different time perspectives, prevalence periods including point¹ (Webb et al., 2003), a preceding week (Chopra, Saluja, Patil, & Tandale, 2002), a month (Mäkelä et al., 1991), six month (Coté, Cassidy, & Carroll, 1998), one year (Lau, Sham, & Wong, 1996) and lifetime (Brattberg, Thorslund, & Wikman, 1989). Other studies have related neck pain to the grade of intensity of the pain, and disability (Brattberg, Thorslund, & Wikman, 1989). As expected, the prevalence increases the longer the period of study. Thus, the mean prevalence estimates for adult populations show a steady increase with increased length of prevalence periods.

In a population-specific study of 1133 people in Saskatchewan Canada, 66% of adults reported experiencing neck pain at some point in their lifetimes, 54% in the most recent 6 months (Coté et al., 1998). Estimates of the prevalence of neck pain vary between studies. It has also been noted that Scandinavian countries appear to have a considerable number of investigations into neck pain prevalence. In a Swedish population, Guez, Hildingsson, Nilsson & Toolanen (2002), reported 19% of people (22% of the women and 16% of the men, odds ratio 0.66, confidence limits = 0.58–0.76) experienced continuous neck pain of more than six months duration, while a Finnish population (Mäkelä et al., 1991) of 7217 subjects reported chronic neck pain in 13.5% of females and 9.5% of

¹ Point prevalence is a measure of the proportion of people in a population who have a condition at a particular time, such as a particular date.

males. Furthermore, neck pain in a Norwegian population (Bovim, Schrader, & Sand, 1994) described an overall rate of 13.8% for greater than 6 months duration. In the United Kingdom, about 15% of hospital-based physiotherapy referrals are due to neck pain (Hackett et al., 1987). While in Canada 30% of chiropractic referrals are for neck pain (Waaen, White, & Waaen, 1994). In the Netherlands, neck pain contributes up to 2 percent of general practitioner consultations (Lamberts, Brouwer, & Groen, 1987) while neck pain in the United States accounts for almost 1% of all visits to primary care physicians (Jones et al., 2003). A study from Hong Kong (Lau, Sham, & Wong, 1996) with a sample of 300 subjects found a lifetime prevalence of 29% and a yearly occurrence 15% for males and 17% for females. Weekly prevalence estimates were investigated by two studies outside of Europe; one of 4092 subjects in India by Chopra et al., (2002) described a weekly prevalence of 3.8% for males and 8.4% for females, while the other from Mexico with a sample size of 2500 people reported weekly prevalence for males and female of 1.4% (Cardiel & Rojas-Serrano, 2002).

While there are some differences on the prevalence estimates of neck pain between studies and between different country populations, it appears neck pain is a problem in many countries and for a large number of people within these populations.

A systematic review of neck pain studies from different populations around the world by Fejer, Kyvik, & Hartvigsen (2006) considered prevalence and geography. They identified nine Scandinavian studies with a yearly prevalence of 36%, while five European studies have 26% and two Asian studies with 13%, however, the differences between the Scandinavian, European and Asian results were not found

to be significant. Fejer et al., (2006) then considered the combined men and women mean prevalence estimates over 56 studies for the different time periods was; point prevalence 7.6%, week prevalence 12.5%, month prevalence 23.3%, 6 month prevalence 29.8%, year prevalence 37.2%, lifetime prevalence 48.5% (Fejer et al., 2006). There are difficulties when comparing prevalence estimates between studies and between geographic populations; for instance in the Fejer et al., (2006) study there are disparities in the wording of the generally self-developed questionnaires, also the use of different mannequins to help visually identify the painful areas of the neck. The anatomical definition of what constitutes neck pain, typically either inclusion or exclusion of pain in the shoulder region may have some influence on the results. Finally the quality of the study's method may affect the outcome, there appeared to be considerable variation between studies regarding sample size, randomised bias, response rate, validation of neck definition and analysis of non-responders.

Neck pain has been reported to increase with age and to be more prevalent in women than men (Andersen et al., 2003; Webb et al., 2003; White & Ernst, 1999). Fejer, Kyvik, & Hartvigsen, (2006) performed a systematic review and reported 25 out of 30 (83%) studies found women had more neck pain than men.

After a comprehensive search the current review was unable to locate any statistics with specific reference to the prevalence of pain only in the neck for a New Zealand population, however, a combined neck or back pain figure was available from the 2006/07 New Zealand Health Survey. The 6 month prevalence for neck or back pain in New Zealand from 755,100 participants was 24.2% (95% Confidence Interval = 23.2–25.2), males 23.1% (21.6–24.6) and females 21.3%

(20.3–22.4) (New Zealand Ministry of Health, 2008). The New Zealand statistic is similar to estimates of the world mean 6 month neck pain prevalence 29.8% (Fejer et al., 2006). The inclusion both neck and back pain in the New Zealand results may well account for the 5.6% higher estimate than the systematic review figure of Fejer et al., (2006), this may also account for the reversal in gender prevalence.

Incidence

While numerous cross-sectional studies have assessed the prevalence of neck pain, very few cohort studies have estimated the incidence. Consequently, very little is known about the natural history of neck pain. In South Manchester, United Kingdom, Croft et al., (2001) described the cumulative annual incidence of neck pain lasting for more than 1 day as 17.9% among 7669 adults aged 18-75 years who were free from neck pain in the month prior to the survey. Côté, Cassidy, Carroll, & Kristman, (2004) measured neck pain with the Chronic Pain Questionnaire and reported the age and gender standardized annual incidence of any neck pain as being 14.6% among individuals who had been free from neck pain for the past 6 months. Furthermore, each year 0.06% (95% confidence interval 0.0-1.1) of the population develops disabling neck pain, with approximately one-third of those with neck pain experiencing a complete resolution of their condition. These findings challenge the commonly held view that neck pain is a benign disorder with a favourable prognosis. Instead it suggests that neck pain is a chronic condition characterized by episodic, persistent, recurrent or fluctuating pain and disability (Côté et al., 2004).

Both studies found a higher incidence of neck pain in women. Côté et al., (2004) suggest women are more likely than men to develop neck pain (incidence rate ratio=1.67, 95% confidence interval 1.08–2.60) and more likely to suffer from persistent neck problems and less likely to experience resolution. The Manchester study found a cumulative annual incidence of 15.3% for males and 19.7% for females, again women have an increased chance of developing neck pain with a relative risk of 1.3, 95% confidence interval 1.0-1.6 (Croft et al., 2001).

Limitations of the study by Croft et al., (2001) include that the sample population was taken from two family medical centres in South Manchester and therefore unlikely to accurately represent the adult population in the United Kingdom. This was not the case for the research by Côté et al., (2004) in Canada, where participants were randomly mailed the questionnaires, however, this study did have a lost to follow up problem. The loss to attrition appeared not to be random and included many young, unemployed and unhealthy subjects, potentially resulting in the study underestimating the incidence of new episodes of neck pain.

Aetiology

Neck pain can originate from many specific conditions and from many structures in the neck region. Conditions may include those of either an inflammatory, infectious, neoplastic, degenerative, vascular or endocrinal nature. Dysfunctions that may cause neck pain include zygapophysial joint irritation, traumatic injuries to the cervical spine and cervical disc disease such as disc herniation—which may irritate the nerve root by mechanical and biochemical stimuli (Bogduk & Teasell, 2000; Brisby, Olmarker, Larsson, Nutu, & Rydevik, 2002). Nerve fibers and endings

can be found in cervical structures including ligaments muscles, vertebrae periosteum and even deep in the annulus fibrosus and nucleus pulposus (Freemont et al., 1997) all of which offer a possible mechanism for nociception.

Posterior neck pain may, it has been suggested be the result of posture, poor ergonomics, stress and chronic muscle fatigue (Fichground, 2004). The physiology of pain associated with neck muscles is not well understood, however, neck pain patients exhibit greater activation of accessory muscles, (sternocleidomastoid, anterior scalenes, and left upper trapezius muscles) and may also show changed patterns of motor control compensating for reduced activation of painful muscles (Falla, Bilenkij, & Jul, 2004). Several possible pathophysiological mechanisms of neck pain disorders have been proposed in the literature. Visser & van Dieën (2006) suggest it appears unlikely that a single pathophysiological mechanism exists that is responsible for tissue damage and all pain sensations. Visser & van Dieën (2006) hypothesize that selective and sustained activation of type I motor units may influence the development of muscle damage due to sustained low-intensity tasks (known as the “Cinderella hypothesis”). Indeed, a study by Zennaro, Läubli, Krebs, Klipstein & Krueger, (2003), supports the Cinderella hypothesis, where long-term computer work providing low-level trapezius muscle contractions overloads low threshold motor units. Overloading of low threshold motor units may lead to selective motor unit fibres being injured leading to the development of pain. At a cellular level the overloading may lead to Ca^{2+} accumulation in the active motor units and other homeostatic disturbances due to limitations in local blood supply, also limiting metabolite removal in muscle compartment with larger numbers of active motor units. Additional mechanisms,

such as nociceptor sensitization due to intra-muscular shear forces are also assumed to play a role (Visser & van Dieën, 2006).

The aetiology of neck pain is not well understood, however, one area that has benefited from research and is now better appreciated is the zygapophysial joints. Zygapophysial or facet joints are typical synovial joints and are innervated by the medial branches of the cervical dorsal rami. Stimulation of these joints in normal volunteers causes neck pain and pain that is referred to the head, shoulder girdle, and upper limb (Bogduk & Lord, 1998). Provocative injections of contrast medium distending the joint capsule of the facet joints in pain-free volunteers produced a reproducible pattern of axial neck and shoulder pain (Dwyer, Aprill, & Bogduk, 1990). This pain could be blocked by anaesthetic injections into the facet joint (Aprill, Dwyer, & Bogduk, 1990). These studies suggest the zygapophysial joint are well innervated and when irritated are capable of producing neck and shoulder pain as well as pain that may refer to the head and upper limb.

Despite these specific structures causing neck pain, it is often clinically difficult to confidently attribute the pain to a precise origin. Commonly neck pain that is difficult to attribute is labelled soft-tissue rheumatism or muscular/mechanical/postural neck pain, or other non-specific syndromes (Ferrari & Russell, 2003). Radiographs and MRI rarely give sufficient information about the pain origin in most patients, unless the patient has a specific pathology. Boden et al., (1990) goes so far as to state that, "Age-related degenerative MRI findings often have no clinical relevance, and these changes are frequent also in pain-free individuals". Differentiating between ageing discs and pathologically degenerated discs causing symptoms is very difficult and often impossible (Guez,

2006). Radiographic changes of the cervical spine can only partially explain the neck and shoulder pain (Siivola et al., 2002).

While there may be many neck structures capable of causing neck pain it appears the precise origin is clinically more difficult to attribute and consequently is often named more generally of after a non-specific syndrome. Zygapophysial joint have been more fully studied and are capable of producing neck pain, however, the use of imaging may be less accurate at identifying precise pain causing tissues.

Risk factors

It is generally agreed that the aetiology of neck pain is multidimensional and influenced by a complex array of individual, physical and sociodemographic factors. Neck pain is also associated with factors related to general health, work situation and leisure activities. Among these various risk factors, work-related psychosocial factors appear to play a major role (Croft et al., 2001).

Psychosocial factors feature prominently in the transition of acute pain into chronic pain, and are also relevant in the development of neck and low-back pain progressing into chronic disorders (Schultz et al., 2004). Family dynamics and interactions are another psychosocial factor that appear to have a decisive influence on social learning and on behaviour development regarding acute and chronic neck pain (Bradley, McDonald-Haile, & Jaworski, 1992). Also a low educational level is associated with poor prognosis in chronic whiplash associated disorders (Sterner, Toolanen, Gerdle, & Hildingsson, 2003). Stress, distress, or anxiety as well as mood and emotions, cognitive functioning, and pain behaviour

all were found to be significant factors in the development of neck pain (Linton, 2000). Ariëns, (2001), further added to this list of psychosocial risk factors with work content, organization, interpersonal work relationships, finances, and economics. Work related psychosocial factors also showed a positive association with neck pain and included mental tiredness at the end of the day (odds ratio=2.68, 95% CI 1.81–3.78); shortage of personnel and shortages of work personnel (odds ratio=1.87, 95% CI 1.20–2.56)(Cagnie, Danneels, van Tiggelen, De Loose, & Cambier, 2007), although these personnel deficits probably reflect the consequent work overload. Studies consistently reveal that stress is associated with neck pain in both cross sectional and longitudinal studies (Leclerc et al., 1999; Viikari-Juntura et al., 2001). The beneficial and recuperative effects of regular rest breaks has been identified as a work-related psychosocial factor (Cagnie et al., 2007; Ortiz-Hernandez, Gonzalez, Martinez-Alcantara, & Mendez-Ramirez, 2003). Rest breaks reduce computer usage and therefore allow relaxation of musculature involved in sustaining a computer operating posture.

Work related physical risks factors for neck pain appear to increase prevalence of musculoskeletal pain (Bongers, Ijmker, van den Heuvel, & Blatter, 2006).

Additionally, work-related physical risk factors are associated with both acute and chronic neck pain, especially in women (Vingård & Nachemson, 2000). Ariens et al.,(2001) reported that workers that sat for more than 95% of their working day had twice the risk of neck pain compared to workers who sat infrequently. This finding is consistent with research of 420 medical secretaries with neck and shoulder pain (Kamwendo, Linton, & Moritz, 1991), and also of a study of intensive computer use of office workers (Cagnie et al., 2007). Kamwendo, Linton, & Moritz,

(1991) report a risk ratio $RR = 1.49$ for the relationship between sitting for more than 5 hours per day and self reported neck pain. Sitting for long periods of time is usually accompanied by anterior-posterior spinal curvature and increased mechanical loading on the vertebrae, ligaments and muscles (Ortiz-Hernandez et al., 2003). Static working postures and monotonous or repetitive work have been identified as risk factors for the development of neck pain (Andersen et al., 2003; Ariëns et al., 2001; Szeto, Straker, & O'Sullivan, 2005). Research into postures of office administration staff describe working in a bent or twisted posture for prolonged periods of time as the most important physical risk factor for neck pain (De Loose, Burnotte, Cagnie, Stevens, & van Tiggelen, 2008). Furthermore, holding a sustained posture for a prolonged period of time (1-2 hours) was also identified as an important physical risk factor for neck pain (Andersen et al., 2003; Ariëns et al., 2001; De Loose et al., 2008; Szeto et al., 2005). It appears that prolonged sitting and bent or twisted postures are risk factors for neck pain, however, it is static and sustained head and neck postures that are commonly adopted in the work place, which will be further investigated.

Sustained Posture

'Proper posture' is thought to involve a musculoskeletal balance with a minimum amount of stress on the body (Yip, Chiu, & Poon, 2008), this desired posture is not often exhibited by the general population (Haughie, Fiebert, & Roach, 1995). A forward head posture is commonly observed in patients with neck disorders (Chiu et al., 2002; Good et al., 2001; Haughie et al., 1995) and along with neck flexion is thought to be a risk factor for neck pain. Headaches have also been investigated regarding their association with a forward head posture, including cervicogenic, post-concussional and chronic tension-type headaches.

Forward head posture and neck mobility was reported in 25 subjects diagnosed with chronic tension-type headache and in 25 healthy subjects (Fernandez-de-las-Penas, Alonso-Blanco, Cuadrado, & Pareja, 2006a). Subjects with the chronic tension-type headaches showed a smaller craniovertebral angle² ($45.3^{\circ} \pm 7.6^{\circ}$) than the controls ($54.1^{\circ} \pm 6.6^{\circ}$), consequently presenting a greater forward head posture ($P < 0.001$), however, forward head posture and neck mobility appear not to be related to headache intensity, duration or frequency in patients suffering from chronic tension-type headaches (Fernandez-de-las-Penas, Alonso-Blanco, Cuadrado, & Pareja, 2006b). Forward head posture has also been related to other headache disorders, Watson and Trott (1993) found that patients suffering from cervicogenic headache also showed a lesser craniovertebral angle than controls ($44.5^{\circ} \pm 5.5^{\circ}$ vs. $49.1^{\circ} \pm 2.9^{\circ}$; $P < 0.001$), representing an increased forward head

² A smaller/lesser craniovertebral angle equates with a greater forward head posture.

posture. Also, Treleaven, Jull, & Atkinson, (1994) report a lesser craniovertebral angle in post-concussional headache patients ($46.7^{\circ} \pm 2.8^{\circ}$) than in control subjects ($50.7^{\circ} \pm 7.9^{\circ}$) although the difference was not significant at the 5% level. Even though forward head posture appears to be linked to the three headache types, chronic tension-type, cervicogenic and post-concussional headaches, the results are equivocal, with no consistent association being provided between an observed increased forward head posture in patients with chronic neck pain. Additionally, there may be validity issues using the craniovertebral angle method. Johnson (1998) found a weak correlation ($r = 0.39$) between surface measurement of head/neck posture and radiological measurements of the anatomical alignment of the upper cervical vertebrae and lumbar lordosis, even in subjects assessed as having an extreme forward head posture. This may have implications regarding whether it is appropriate to use a forward head posture measurement when assessing cervical pathology. There may also be a problem in focusing only on the forward position of the head when describing postural anomalies. Grimmer, (1997) contends that there is no standard for defining poor head posture and many different postural shapes can be observed, furthermore despite the intervening 11 years there still appears to be no standard for defining poor head posture. Interestingly, subjects with postural neck pain perceived 'correct posture' to be one with substantially more forward head posture than asymptomatic subjects (Edmondston et al., 2007), suggesting neck pain may lead to altered cervical proprioception and subsequent forward head posture, which is perceived by the subject, as being a 'correct posture'.

Research by Fredriksson, Alfredsson, Ahlberg, Josephson, Kilbom & Wigaeus Hjelm, (2002) and Yoo, Yi & Kim, (2006) found a forward head posture is commonly adopted through sitting and working at a computer. A Swedish study (Kamwendo, Linton, & Moritz, 1991) reported that 63% of secretaries had job related neck pain while Ong, Chia, Jeyaratnam, & Tan, (1995) noted computer users are a group at risk of musculoskeletal disorders. Szeto, Straker, & Raine (2002) carried out a field study of 16 computer using office workers comparing head and neck posture and neck discomfort. Eight asymptomatic and eight symptomatic clerical staff were observed and neck discomfort rated throughout a single working day. The results indicated increased forward head posture in the symptomatic staff; however, the study employed a small sample size, n=16, and was limited to female workers only. The researchers noted forward head posture involved a combination of upper cervical extension and lower cervical flexion. Upper cervical extensor muscles, including suboccipital muscles, are short and it has been suggested that even a small increase in extension can place these muscles in an inefficient range of their length-tension relationship (Burgess-Limerick, 2000). Consequently, this altered length-tension relationship may make the suboccipital muscles more vulnerable to the effects of fatigue. To limit the possible fatigue effect the individual may reduce upper cervical extension and increased lower cervical flexion producing a forward head posture. Burgess-Limerick, (2000) also suggest the increased forward head posture in the symptomatic subjects may be the result of a 'vicious cycle' between neck pain and increased muscle loading. Investigating the causal relationship between posture and pain has many difficulties including the ethical issues implementing random controlled trials, therefore it is only possible to examine short term or cross sectional experiments.

One experiment possibility would be to study the postures of the same subjects on different days; or to study the posture of workers before and after they experience pain; or even examine the posture and pain of subjects at the beginning and again at the end of their working day.

A further study used the craniovertebral angle to investigate head posture with pain (Yip et al., 2008). Sixty-two subjects with neck pain and 52 symptom-free subjects were measured for forward head posture and evaluated via Northwick Park Neck Pain Questionnaire and Numeric Pain Rating Scale for neck pain disability and severity. Results report the craniovertebral angle was negatively correlated with Northwick Park Neck Pain Questionnaire and NPRS ($r = -0.33$; $p = 0.009$). Results indicate subjects with a small craniovertebral angle have a greater forward head posture, and the greater the forward head posture, the greater the disability. Johnson, (1998) suggested that prolonged forward head posture may cause myofascial pain by increasing loading on non-contractile structures and producing abnormal stress to the posterior cervical structures. An earlier study (Hanten, Olson, Russell, Lucio, & Campbell, 2000), contrastingly suggests symptom free subjects had a greater forward head posture than subjects with cervical pain. However, this study did not use the craniovertebral angle to determine forward head posture, but instead, had the subject stand with scapulae touching the wall and using a ruler measured from wall to the corner of the subject's eye. This has inherent problems, including the subject's head size, eye placement, degree of thoracic kyphosis and scapulothoracic relationship which may all influence this study's measurement determining forward head posture. Also the cervical pain subjects experienced was from a wide range of conditions

including arthritis, cervical sprain, cervical strain, degenerative disc disease, temporal mandibular joint dysfunction, cervical radiculopathy and cervical herniation. Such a wide variety of conditions affecting various cervical tissues may have different influences on cervical posture and consequent forward head posture. For instance, comparing temporal mandibular joint dysfunction and cervical herniation with different pathology and affected tissues would appear to be a case of inappropriate grouping. Furthermore, the measurement by Hanten et al., (2000) for forward head posture was a linear length, this may be problematic when comparing to the experiments using the craniovertebral angle to calculate forward head posture, with a measurement of angular degrees.

Neck flexion has also been identified to provoke neck pain. A high quality Dutch study of 1334 workers from 34 companies with a follow up of 3 years found a positive relation between neck flexion and neck pain (Ariëns et al., 2001). Video recordings for neck flexion, rotation and sitting position were recorded and neck pain was assessed via a questionnaire. Results report an increased risk of neck pain was found for people working with the neck at a minimum angle of 20° of flexion for more than 70% of the working time (adjusted RR 1.63, 95% CI 0.70 to 3.82). An association between the time spent sitting working and neck pain was also noted, however, no clear relation was found between neck rotation and neck pain. Short term neck pain was also produced by maintaining extreme flexion for less than 15 minutes in healthy subjects (Harms-Ringdahl & Ekholm, 1986). Subjects sat with the lower-cervical-upper-thoracic spine in extreme flexion and neck pain assessed on a Visual Analogue Scale, the posture intending to represent some common working positions. Pain occurred within 15 minutes, increased with

time and decreased within 15 minutes after ceasing the flexion provocation position. Interestingly, this study had a small sample size, n=10, yet came to similar conclusions as the Ariëns et al.,(2001) study with 1334 sample size and a 3 year follow up. An earlier study by Grandjean & Maeda, (1980) reported similar findings, where 118 right hand keyboard operators reported increased physical impairment with increased neck flexion angles. Despite the 21 year time span between these three neck flexion studies, also the sample limited to female subjects only in the Grandjean & Maeda, (1980) study and the small sample size of the research by Harms-Ringdahl & Ekholm, (1986); all the results suggest increased neck flexion is associated with neck pain.

Sustained posture may also lead to changes in muscle group motor control strategies for neck pain subjects. A study of office workers (Szeto, Straker, & O'Sullivan, 2005) reported consistent group differences of increased myoelectric activity of neck-shoulder stabilizing muscles in symptomatic subjects compared to asymptomatic controls. Prolonged computer use, static posture and altered muscle recruitment patterns appear linked to neck pain. The researchers proposed the increased activity of symptomatic individuals may involve increased recruitment of type II muscle fibres in addition to increased type I recruitment in coping with the stressors. Type I fibres are appropriate for prolonged , low-intensity work, for instance controlling posture, however, recruitment of Type II fibres may be less suited to prolonged postural control and may lead to neck pain. Similar results to these described by Szeto et al., (2005) have also been reported by Madeleine, Lundager, Voigt, & Arendt_Nielsen, (1999) and Larsson, Bjork, Elert, & Gerdle, (2000), however, a further study reported substantially lower myoelectrical

activity in the symptomatic group (Larsson, Oberg, & Larsson, 1999), however, these researchers used symptomatic subjects with serious cervical trauma or had received disability compensations. The difficulty here is comparing subjects with mild cervical symptoms who were able to work full-time to subjects with serious cervical trauma and unable to work full-time. The studies reporting similar results had patient with similar characteristics; these were mild conditions and all were working full-time.

It is noteworthy that the increased use of hand held electronic devices (Blackberry, SMS text messaging on mobile phones, iPhone and PlayStation Portable PSP) promotes increased time in non-neutral neck flexion, while time spent working at a computer often encourages a forward head posture. Also various occupations require workers to maintain either of these two sustained postures. Due to their association with physical impairment a forward head posture and neck flexion appear to be either a cause of neck pain or a risk factor for neck pain.

Anatomical structures involved in proprioception

Position sense of the head and neck is mediated by cervical proprioceptors, visual and vestibular systems (Treleaven, 2008). The vestibular system detects rotational acceleration via the semicircular canals and linear acceleration via the saccule and utricle, this information travels via the eighth cranial nerve to the four vestibular nuclei in the medulla (Armstrong, McNair, & Taylor, 2008). The vestibular system then interprets these sensory signals and integrates this with information from visual and cervical proprioceptors. Collective inputs from cervical proprioceptors, visual and vestibular systems then determines the position of the head in space and the head relative to the body (Armstrong et al., 2008).

Blindfolding subjects excludes visual afferent information used in position sense, however, vestibular input is difficult to separate from cervical proprioception, as the vestibulocollic reflex and the cervicocollic reflex work closely together acting on the neck muscles determining the position of the head in space (Jull, Sterling, Falla, Treleaven, & O'Leary, 2008). The vestibulocollic reflex appears to respond to fast neck movements while the cervicocollic reflex seems to be more sensitive to slow neck movements (Peterson, 2004; Peterson, Goldberg, Bilotto, & Fuller, 1985). There are some data to suggest that cervical proprioceptors have a greater contribution to head repositioning to a target than vestibular afferent information (Revel et al., 1991; Taylor & McCloskey, 1988). Therefore the use of slow head movement (less than 35°/s) as suggested by Lee, Teng, Chai, & Wang (2006) and Teng, Chai, Lai, & Wang, (2007) should ensure the cervical proprioceptors are targeted in the majority.

The muscle spindles are generally accepted as being the primary cervical receptors responsible for position sense and are coupled to supplementary afferent input from the cutaneous and joint receptors (Boyd-Clark, Briggs, & Galea, 2002; Gandevia & Burke, 1992a; Kulkarni, Chandy, & Babu, 2001; Marks, 1998; Matthews, 1988). In contrast to the peripheral muscles of the limbs, very high concentrations of cervical muscle spindles with complex arrangements, including parallel, paired and tandem layout, have been identified in the central and intrinsic muscle of the feline neck (Bakker & Richmond, 1982; Richmond & Bakker, 1982) and in the human neck (Peck, Buxton, & Nitz, 1984). Muscle spindles within the neck may also be compartmentalised in series within the muscle, ensuring a response to both stretch and contraction, allowing efficient tension generation within the muscle (Dutia, 1991). High density concentrations of muscle spindles have been identified in the suboccipital muscles (Kulkarni et al., 2001), in the deeper cervical muscles (Liu, Thornell, & Pedrosa-Domellöf, 2003), in longus colli when compared to multifidus (Boyd-Clark, Briggs, & Galea, 2002) and also in the slow twitch fibres of the suboccipital muscle oblique capitis inferior (Richmond, Singh, & Corneil, 1999). Amonoo-Kuofi (1983) noted high muscle spindle densities at the upper cervical region in spinalis, semispinalis and multifidus, also in longissimus at the mid cervical and in iliocostocervicalis at the cervico-thoracic junction. The density and unique morphological features of the muscle spindles and muscle fibre composition suggests their importance for movement precision, proprioception, head position and eye-head coordination (Kulkarni et al., 2001; Liu, Thornell, & Pedrosa-Domellöf, 2003). These studies suggest the identified muscles and fibers all have functional roles as proprioceptors when contributing to cervical spine position sense.

Position sense

Position sense methods

Neck pain can be characterized in clinical terms, however, the aetiology is not so clearly understood and the association between structural pathology and cervical pain is uncertain (Boden et al., 1990; Friedenbergs & Miller, 1963; Karlsborg et al., 1997; Ronnen et al., 1996). This situation has contributed to a focus on the possible role of dysfunctional cervical proprioceptors in neck pain conditions.

There are several methods to investigate proprioception.

- i) Passive limb displacement test
- ii) Quasi-static test
- iii) Generic clinical test
- iv) Active movement angle reproduction test

A passive limb displacement test evaluates the threshold for movement sense either manually or electronically where the subject identifies the onset of motion and the direction of the joint's final position (Marks, 1998). Studies indicate that the threshold of detection for passive rotation of the head relative to the body was 1.4° angular displacement (Taylor & McCloskey, 1988). This finding is consistent with peripheral joints (Allegrucci, Whitney, Lephart, Irrgang, & Fu, 1995) and the lumbar spine (Konradsen, Ravin, & Sorensen, 1993) where subjects were able to perceive motion within 1° of movement initiation. The quasi-static position sense test usually necessitates the subject estimating the relative position or amplitude of a statically held limb using a ratio scale (Robbins, Waked, & McClaren, 1995) or a verbal ranking (Berenberg, Shefner, & Sabol, 1987). Generic clinical tests reveal

gross defects in position sense. Vision is occluded and the subject actively demonstrates position sense tests that may include finger-to-finger, finger-to-nose, finger-to-heel, heel-to-knee and finger-to-wrist movements, all carried out without specific instructions regarding speed (Marks, 1998). A further test, the most commonly used active movement angle reproduction test requires the subject to relocate a neutral head position (NHP) (Heikkilä & Astrom, 1996; Revel et al., 1991) or a target head position (THP) verbally specified (Marks, 1998), self-selected (Lee et al., 2007) or selected by the investigator (Armstrong et al., 2005; Lee et al., 2006).

Movement detection is markedly improved by muscular contraction and it has been suggested that it would be more functionally relevant to assess proprioceptive deficits during the active implementation of normal movements (Brumagne, Lysens, & Spaepen, 1999a; Gill & Callaghan, 1998; Swinkels & Dolan, 2000). Therefore, any proprioceptive discrepancies that appear in the mid-range of active movement probably characterise irregular afferent information derived from muscle receptors. These active muscles are the primary providers of proprioceptive information regarding joint position and movement (Boyd-Clark et al., 2002; Brumagne, Lysens, Swinnen, & Verschuren, 1999b; Gandevia, McCloskey, & Burke, 1992b; Kulkarni et al., 2001). While not disregarding the damage or dysfunction to ligaments and joint capsules, these tissues are however considered to provide a much larger afferent input towards end range joint position (Gandevia & Burke, 1992a). For these reasons, it appears the majority of investigations into cervical proprioceptive disturbance have used head position

sense with active movement.

Evaluation of cervical spine position sense

The dependent variable reported from the head position sense experiment is the difference between the reference point established initially (neutral head position or the target head position), and the attempted matching of this position. This is the 'position sense error' with angular units of degrees ($^{\circ}$). The dependent variable reflects the subject's accuracy at matching the reference point and consequently reveals their proprioceptive precision. Angular degrees ($^{\circ}$) are most commonly used as the unit of accuracy, however, linear measurements (cm) have also been reported (Heikkilä & Astrom, 1996). Error measurement may be analysed from four different perspectives; absolute, constant, variable and root mean square error (Lee et al., 2006; Marks, 1998). Absolute error disregards the direction of error, that is, overshoot or undershoot of the reference position, and only examining the absolute error detected during each trial (Armstrong et al., 2008). In contrast, constant error identifies the direction of error, indicating the magnitude that the reference position has been under or over estimated. Asymptomatic subjects have a magnitude of absolute and constant error generally less than 5° (Armstrong et al., 2008). Variable error refers to the subjects' consistency of responses across trials (Armstrong et al., 2008; Brumagne et al., 1999b; Marks, 1998). Root mean square error is the mathematical combination of constant and variable error, that is, the true error (Lee et al., 2006).

Position sense reliability

Christensen & Nilsson, (1999) found that asymptomatic subjects (n=38) were able to reproduce their established neutral head position in the frontal and horizontal planes with more accuracy compared to the sagittal plane. They considered the mean absolute error; standard deviation and range in their analysis of reposition sense but give no intraclass correlation coefficient (ICC) values. A study of the reliability of cervicocephalic kinaesthesia (Kristjansson, Dall'Alba, & Jull, 2001) using 20 asymptomatic volunteers reported the Revel et al.,(1991) NHP test had an ICC value of 0.44. Loudon et al.,(1997) combined NHP and THP tests and had an ICC value of 0.82. A further study of cervicocephalic kinesthesia (Pinsault et al., 2006) also supports test- retest reliability of position sense. Thirteen healthy young adults were recruited to undergo a NHP test. The test-retest reliability was determined by repeatedly measuring relocation errors to a neutral position after active movement, with trials approximately 1 hour apart. The performance score for each subject for each position sense test was the mean of the errors made during the 20 relocations (in degrees). The mean (\pm SD) rate of error of the first and second trials was $3.2 \pm 1.1^\circ$ and $2.9 \pm 0.9^\circ$, respectively. The intra class correlation coefficient was 0.81, and the standard error of measurement 0.90° . Armstrong et al.,(2005) conducted a pilot test to confirm reproducibility and reliability. These results demonstrated that recordings of repeated head and neck movements to a specific stationary target produced a high intraclass correlation coefficient (>0.96) and for repeated position-matching tasks at various angles a similarly high intraclass correlation coefficient (>0.91).

A recent study (Lee et al., 2006) investigated the test-retest reliability of both the NHP and THP tests in three cardinal planes. They found fair to excellent reliability of root mean square error (RMSE, total error) during head-to-NHP (ICC=0.45 to 0.80) and head-to-target tests (ICC=0.42 to 0.90) except in the head-to-NHP from an extended head position (ICC=0.29). They further suggested that constant error (Sterling, Jull, Vicenzino, & Kenardy, 2004) and variable error (VE) could contribute to the interpretation of whether the subject performed the reposition tests with directional bias and repositioning variability, respectively. A study to determine optimum protocol for the cervical position sense test evaluated 16 subjects on three occasions over two days (Swait, Rushton, Miall, & Newell, 2007). While many studies have been using three trials when testing cervical position sense Swait, et al., (2007) suggests six or more trials of each movement direction is used to ensure consistent estimates of proprioceptive accuracy and precision (ICC= 0.76). This study also noted head positioning following cervical extension had poorer reliability especially with three trials (ICC=0.29) but improving with 5-6 trials (ICC=0.76).

The cervical position sense test demonstrates good reliability in the evaluation of proprioception deficits and would appear to be an appropriate test to investigate the effects of sustained head postures.

Studies utilizing cervical spine position sense

Proprioceptive disturbances have been investigated using cervical spine position sense tests (Heikkilä & Astrom, 1996; Loudon, Ruhl, & Field, 1997; Revel et al., 1991; Revel et al., 1994; Rix & Bagust, 2001), otherwise known as the cervicocephalic kinesthetic sensibility test (Revel et al., 1994). These procedures examine the subject's ability to reposition the head after it has been moved away from a reference position. The reference point can be either the neutral head position or a specific target head position remote from the neutral position. Symptomatic subjects have been investigated in the majority of cervical position sense studies; these conditions include whiplash, WAD, headaches and chronic neck pain. Asymptomatic subject position sense investigations are limited and included interventions of fatigue, posture and sustained position.

Reference point relocation tests are those most widely used since being introduced in 1906 (Slinger & Horsley, 1906). One of the first experiments to quantify the alteration of neck proprioception in subjects with cervical pathology was proposed by Revel et al., (1991) using the neutral head position test. Subjects wore a helmet with an attached light beam and were instructed to find a neutral position after active movement of maximal rotation of the head to the left. Finding the NHP was repeated with the maximal rotation being to the right and again in flexion and extension. Ten trials were undertaken in each direction of motion all with the subject blindfolded. Thirty subjects with chronic cervical pain were compared to 30 healthy subjects. Their results suggest the test is able to discriminate between subjects with and without cervical pathology. Absolute errors (SD) (°) left-right rotation = 6.11° (1.59) and flexion-extension = 5.47° (1.75) for the chronic neck

pain subjects and left-right rotation = 3.50° (0.82) and flexion-extension = 3.37° (0.73) for the healthy subjects. The difference between the two groups was reported as statistically significant at $p < 0.01$. This study did consider the vestibular system and concluded cervical proprioceptive information 'overshadowed' vestibular information (Mergner, Nardi, Becker, & Deecke, 1983), the researchers also thought that if the head turned relative to the body only cervical proprioceptors are engaged (Taylor & McCloskey, 1988), however, research suggests slow movement engages primarily cervical and not vestibular proprioceptors (Peterson, 2004; Peterson, Goldberg, Bilotto, & Fuller, 1985). Revel et al., (1991) did not control for speed of head movement and consequently, may have had more than minimal vestibular involvement in their position sense testing.

Loudon, Ruhl, & Field (1997) used a variation on the Revel et al., (1991) position sense test. The subjects attempted to locate the neutral position and a target position. Subjects wore a cervical range-of-motion device on their head that was used to access joint angles. The subject's head was positioned at 30° of right rotation and then asked to return to 0° with the eyes closed. The subject reproduced the angle three times. Trials at six test position were undertaken (30° rotation left, 50° rotation left and right, 20° side bending left and right). Two groups participated in this study, 11 asymptomatic subjects and 11 subjects with a history of whiplash. Total average absolute error was 5.01° for the whiplash group and 1.75° for the asymptomatic group ($p = 0.024$). Again like Revel et al., (1991) Loudon et al., (1997) did not control for speed of subject's head movement to exclude vestibular input. Also the subjects were asked to close their eyes to exclude visual input; some visual cues would still be present even if the subject did

keep their eyes closed for the whole procedure. If the researchers really wanted to exclude this proprioceptive information an eye mask may have been more successful.

The NHP test has a number of advocates including de Hertogh et al.,(2008), Rix & Bagust, (2001) and Heikkilä & Astrom, (1996). While position sense tests using both the neutral and target position tests include studies by Armstrong et al., (2005), Teng et al., (2007) and Lee et al., (2007). The procedures are very similar between studies, however, the equipment for measuring the position angles are often different between studies. The use of a light beam in early studies (Heikkilä & Wenngren, 1998; Revel et al., to detect position errors is less capable of detecting small changes compared to more recent studies (Lee et al., 2007; Teng et al.,2007) or the 3-Space Fastrak device (Armstrong et al., 2005; Swait et al., 2007). Both the 3-Space Fastrak device and the three-dimensional motion analysis system having a measurement error of $\pm 0.2^\circ$ (Dejnabadi, Jolles, & Aminian, 2005; Maffey-Ward, Jull, & Wellington, 1996). No data for measurement error could be found for the light beam method, however the method involved the light beam shining on the target, a mobile 40cm circle with concentric rings every 1cm, the errors were calculated as centrimetric measurements which was then converted to angular degrees.

Intuitively this method appears more prone to error, most probably greater than the $\pm 0.2^\circ$ of the 3-Space Fastrak device and the three-dimensional motion analysis system methods. To combat the possible increase in error some studies had notably more trials per position, Revel et al., (1991) and Heikkilä & Astrom, (1996) undertaking 10 trials at each position, while 3 trials were reported in several

studies including Armstrong, et al., (2005), Loudon, et al., (1997) and Teng, et al., (2007).

It appears that Owens et al., (2006) is the only study to have investigated the effect of sustained posture on cervical spine position sense. These researchers used two conditioning sequences interspersed within the task: holding the head in an extended or laterally flexed position for 10 seconds; or holding a 70% maximum voluntary contraction in the same position for 10 seconds. The study established that a recent history of cervical paraspinal muscle contraction can influence head repositioning in flexion/extension, undershooting the target by 2.1° ($p < 0.001$). However, passively maintaining the head in extension or lateral flexion for 10 seconds produced no difference in head repositioning to the neutral target ($p = 0.109$). They suggest the 20° of neck extension may have been of insufficient magnitude to adequately shorten the intrafusal fibres and produce a significant reposition error. Also, 10 seconds may be of insufficient duration to affect the tissues influencing proprioceptive accuracy, the majority of receptors being in the cervical muscle spindles (Gandevia & Burke, 1992a; Marks, 1998). The experimental protocol did not appear to make any attempt to exclude vestibular proprioceptive input and isolate cervical proprioception. Also, subjects were instructed to close their eyes thereby excluding visual proprioceptive cues, again the use of an eye mask may be more effective and consistent.

Wong, Chow, Holmes, & Cheung (2006) recorded repositioning error while seated at a computer at various head on trunk flexion and extension angles, both before and after fatiguing the upper trapezius muscles. They found posture ($p < 0.001$) and fatigue ($p = 0.039$) influenced head repositioning ability in typical computer usage.

The sample size of 20 asymptomatic subjects may be relatively small in number and the measuring equipment of a 6 camera motion analysis system not a common position sense measurement method; however, the researchers did undertake a reliability study and reported comparable results to Christensen & Nilsson (1999), with absolute error values of mean (SD)= 3.00° (1.96) in the sagittal plane, 1.25° (0.82°) in the frontal plane and 1.93° (1.45) in the horizontal plane. It appears the subjects had their eyes open throughout the experiment and no reference is made of head movement speed, suggesting the inclusion of visual, vestibular and cervical proprioceptive input when assessing position sense and proprioceptive accuracy.

The majority of research using cervical spine position sense has investigated subjects with cervical pathology. The studies of Revel et al., (1991) and Loudon et al., (1997) mentioned earlier examined chronic neck pain and whiplash. Other studies investigating whiplash include Heikkilä & Astrom, (1996) reporting greater reposition errors in whiplash subjects (5.17°) compared to healthy controls (2.69°) and Heikkilä & Wenngren, (1998) report reposition errors in whiplash subjects (3.97°) and for healthy controls (2.71°). Studies on WAD subjects include Feipel, Salvia, Klein, & Rooze, (2006) stating position sense errors for WAD subjects of (3.5°) and healthy controls (2.1°) and also Sjölander, Michaelson, Jaric, & Djupsjöbacka, (2007) report position sense errors for WAD subjects of (4.1°) and for controls (2.2°). In contrast to the studies above reporting substantial differences between healthy and whiplash or WAD groups, other research has not observed these differences between groups. For WAD, studies by Armstrong et al., (2005) describe position sense deficits for WAD subjects (3.55°) and for healthy controls (3.25°) and Sterling, Jull, Vicenzino, Kenardy, & Darnell, (2003) describe

acuity in WAD subjects (2.7°) and controls (2.6°). This trend has also been noted in studies using position sense on chronic neck pain subjects. Teng et al., (2007) report errors for chronic neck pain subjects (5.1°) and for healthy controls (5.5°) while Rix & Bagust, (2001) report position sense errors for chronic neck pain subjects (3.7°) and controls (4.0°), both stating there was no substantial differences between groups. The researchers (Armstrong et al., 2005; Rix & Bagust, 2001; Sterling, Jull, Vicenzino, Kenardy, & Darnell, 2003; Teng, Chai, Lai, & Wang, 2007) suggest this lack of difference is due to the mild nature of the subjects' condition, further supported by research showing that low Neck Disability Index scores and mild functional problems are associated with minimal or no position sense errors (Marks, 1998; Treleaven et al., 2003).

Conclusion

It has been well established that neck pain is a common complaint in society today, with between 1 – 2 % of the population presenting at a primary health care provider with this symptom. Neck pain appears to be more prevalent in females and increases with age; however, the aetiology appears difficult to attribute to a precise origin, with many neck structures and conditions capable of causing pain. Risk factors for neck pain are also many and varied, broadly including individual, physical and sociodemographic factors. Psychosocial causes are considered to have a prominent role in neck pain development along with work related physical factors, particularly working postures sustained for prolonged periods of time. Two sustained postures; a forward head posture and a flexed head and neck posture, have been identified as being associated with neck pain. Such postures are commonly adopted when using computers and hand held electronic devices.

While the association between structural pathology and cervical pain is uncertain, one way to study the aetiology of neck pain is to investigate proprioceptive information and the control of head and neck movement. Cervical proprioceptive disturbances have been investigated using position sense, predominantly on subjects with cervical pathology, including whiplash, WAD and chronic neck pain. Substantial differences have been noted between these symptomatic subjects and controls, however, there has been little investigation into cervical spine position sense in asymptomatic subjects who have undertaken an intervention posture. Investigating position sense in asymptomatic subjects may inform questions regarding the aetiology of neck pain. Consequently, asymptomatic subjects were selected for this study to help determine if errors in cervical spine position sense

lead to neck pain or if neck pain leads to errors in head position sense. Therefore, the aim of the current study was to evaluate cervical spine position sense before and after a 3 minute static posture (flexion or extension) in asymptomatic subjects.

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Section 2: Manuscript

Note

This manuscript has been prepared in accordance with the Instructions for Authors for *Manual Therapy*

The effect of a 3 minute static posture on cervical spine position sense in asymptomatic participants

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Abstract

Alteration to cervical spine position sense has been associated with symptomatic subjects experiencing whiplash, whiplash associated disorders (WAD) and chronic neck pain, however, there has been little investigation into cervical spine position sense in asymptomatic subjects. The aim of the current study was to investigate cervical position sense before and after a 3 minute static posture (flexion or extension) in asymptomatic subjects. Thirty-two asymptomatic subjects undertook two position sense tests; the neutral head position and target head position tests in the sagittal and transverse planes, before and after a 3 minute static posture in either flexion or extension. Absolute errors were calculated from data recorded by an orientation sensor. The effect sizes, calculated from the Wilcoxon Z values pre and post the intervention, were 'trivial' for the two position sense tests after either the flexion or extension intervention. The results indicate no substantial differences in cervical position sense before and after a 3 minute static posture, in either flexion or extension, on asymptomatic subjects.

Keywords: Neck pain; Proprioception; Cervical pain; Neck ache.

Introduction

The prevalence of chronic neck pain is approximately 15% of females and 10% of males at any one time (Bovim, Schrader, & Sand 1994; Guez, Hildingsson, Nilsson, & Toolanen 2002; Mäkelä, Heliövaara, Sievers, Impivaara, Knecht, & Aromaa 1991) and 1-2% of all consultations to primary healthcare providers are for neck pain (Jones et al. 2003; Lamberts, Brouwer, & Groen 1987). Chronic neck pain is associated with a high level of morbidity and impacts activities of daily living, employment, recreation and decreases quality of life (Daffner et al. 2003; Hagberg & Wegman 1987; Takala, Viikari-Juntura, Moneta, Saarenmaa, & Kaivento 1992; Westgaard, Jensen, & Hansen 1993). Chronic neck pain is associated with substantial direct and indirect healthcare costs (Hoving et al. 2002; Korthals-de Bos et al. 2003).

Sustained postures have become part of a modern lifestyle. A forward head posture, with an extended neck component, is commonly adopted when sitting and working at a computer (Fredriksson et al. 2002; Yoo, Yi, & Kim 2006) and has been associated with neck pain (Ankrum & Nemeth 1995; Chiu et al. 2002; McAviney, Schulz, Bock, Harrison, & Holland 2005; Yip et al., 2008). Research on healthy subjects identified maintaining extreme neck flexion for less than 15 minutes provokes neck pain (Harms-Ringdahl & Ekholm 1986). Sustained postures are associated with slow deformation creep and may change the physico-chemical properties of spinal ligaments (Jirout 1996; Panjabi 2006), the disc annulus and the facet capsules (Panjabi 2006). Increased myoelectric activity in cervical spine muscles occurs with both flexed and extended sustained head postures (Schüldt 1988).

Cervical spine muscles are invested with receptors responsible for proprioception with the majority of receptors located in the muscle spindles (Gandevia & Burke 1992a; Marks 1998; Matthews 1988). Disturbance to proprioceptive function has been associated with joint dysfunction in the feline knee model (Ferrell, Baxendale, Carnachan, & Hart 1985), human shoulder (Lubiatowski, Romanowski, Kruczyński, Manikowski, & Jaruga 2003) and knee joints (Baker, Bennell, Stillman, Cowan, & Crossley 2002; Collier, McAuley, Szuszczewicz, & Engh 2004). Symptoms of dizziness, unsteadiness, upright posture problems and head and eye movement control deficits are also associated with altered proprioception (Grgić 2006; Heikkilä & Astrom 1996; Karlberg, Johansson, Magnusson, & Fransson 1996; Peterson, Goldberg, Bilotto, & Fuller 1985; Revel, Andre-Deshays, & Minguet 1991; Treleaven, Jull, & Sterling 2003). Additionally, it is thought that maintaining a sustained posture may compromise the integrity of joints resulting in an increase of the neutral zone (Panjabi 1992), thereby increasing spinal instability and the potential for injury (Panjabi, Oda, Crisco III, Dvorak, & Grob 1993).

Due to the unclear relationship between structural pathology and cervical pain, (Boden et al. 1990; Karlsborg et al. 1997; Ronnen et al. 1996) posture and its association with neck pain has been investigated by clinicians and scientists across several disciplines, including ergonomic, neuroscience and orthopaedics. In addition to the important psychosocial role within neck pain (Bongers, Ijmker, van den Heuvel, & Blatter 2006), one way to study the aetiology of neck pain is to investigate sensorimotor proprioceptive information and the control of head and neck movement and posture. There are several methods to investigate

proprioception; by awareness of the joint position of a body segment in passive movement, estimating the relative position or amplitude of a static limb and by active movement instigated by the participant (Marks 1998). Movement detection is markedly improved by muscular contraction and it has been suggested that assessment of proprioceptive deficits during the active implementation of normal movements are more functionally relevant (Brumagne, Lysens, & Spaepen 1999a; Gill & Callaghan 1998; Swinkels & Dolan 2000). Therefore, proprioceptive discrepancies that occur in the mid-range of active movement probably characterise irregular afferent information derived from muscle receptors. The muscle spindles within these muscles are the primary providers of proprioceptive information regarding joint position and movement (Boyd-Clark, Briggs, & Galea 2002; Brumagne, Lysens, Swinnen, & Verscheuren 1999b; Gandevia, McCloskey, & Burke 1992; Kulkarni, Chandy, & Babu 2001).

A commonly used method to measure cervical proprioception is the 'head position sense test', also known as the 'cervicocephalic kinesthetic sensibility test' (Revel et al. 1991). This test measures the subject's ability to reposition the head after it has been moved away from a reference position. Increased errors in head position sense have been strongly associated with chronic neck pain (Humphreys, Irgens, & Rix 2000; Loudon, Ruhl, & Field 1997; Revel et al. 1991; Revel, Minguet, Gergoy, Vaillant, & Manuel 1994; Sjölander, Michaelson, Jaric, & Djupsjöbacka 2008) and whiplash associated disorder (WAD) subjects when compared to asymptomatic individuals (Feipel, Salvia, Klein, & Rooze 2006; Heikkilä et al. 1996; Heikkilä & Wenngren 1998; Loudon et al. 1997; Sterling, Jull, Vicenzino, & Kenardy 2004). Treleaven et al. (2003) reported that WAD participants with dizziness had

greater joint position errors than WAD participants without dizziness. Head repositioning errors are also associated with frequency of neck pain (Lee, Wang, Yao, & Wang 2007) and with fatigue of the upper trapezius muscles in asymptomatic individuals (Wong, Chow, Holmes, & Cheung 2006). A 10 second static posture of extension or lateral flexion were both found not to change reposition sense in asymptomatic subjects (Owens, Henderson, Gudavalli, & Pickar 2006), however, a 10 second intervention may not be sufficient to alter cervical proprioception.

The majority of research into proprioceptive sensorimotor control disruption has been carried out on subjects with WAD (Armstrong, McNair, & Williams 2005; Sterling, Jull, Vicenzino, Kenardy, & Darnell 2003; Treleaven et al. 2003), whiplash (Heikkilä et al. 1998; Loudon et al. 1997), chronic neck pain (Revel et al. 1991; Rix & Bagust 2001) and cervicogenic headache (de Hertogh et al. 2008). These studies have investigated the relationship between pre-existing neck pain and the presence of position sense deficits. However, there has been little investigation into cervical position sense in asymptomatic subjects who have undertaken an intervention posture. Investigating position sense in asymptomatic subjects may inform questions regarding the aetiology of neck pain. Consequently, asymptomatic subjects were selected for this study to help determine if errors in head position sense leads to neck pain or if neck pain leads to errors in head position sense. Therefore, the aim of the current study was to evaluate cervical position sense before and after a 3 minute static posture (flexion or extension) in asymptomatic subjects.

Methods

Subjects

Subjects were recruited from a university population of volunteers who responded to poster advertisements. Inclusion criteria was an age range of 18–50 years (Demaille-Wlodyka et al. 2007; Heikkilä et al. 1996; Rix et al. 2001); a score of zero in both the McGill short form Pain Questionnaire (SF-MPQ) and the Neck Disability Index (NDI) questionnaire. Exclusion criteria were a history of head and neck surgery, known pathology of the spine, head or neck pain within the year preceding the study and evidence of vertebrobasilar insufficiency. Participants provided information about previous medical history and basic demographics.

All participants received an information sheet and signed a consent form prior to participating in the experiment. Ethical approval for this study was granted by the Unitec Research Ethics Committee.

Instrumentation

Neck range of movement was measured with a 3DM-GX1 Gyro Enhanced Orientation Sensor, (MicroStrain, Inc. Williston, VT) interfaced with a notebook computer running custom designed data acquisition and display software (LabView, National Instruments Corp. Austin, TX). The orientation sensor was attached to custom designed, size adjustable head gear and fitted snugly to the head and secured with a chin strap.

Testing procedure

Two cervical spine position sense tests were undertaken, i) repositioning to the neutral head position (NHP) and ii) repositioning to a target head position (THP). The test procedures were the same as those described by Lee, Teng, Chai, & Wang (2006) and similar to those in earlier studies investigating cervical spine reposition sense (Heikkilä et al. 1996; Loudon et al. 1997; Revel et al. 1991)

The NHP test measured the subject's ability to actively reposition their head to their self selected neutral position. The THP test measured the individual's ability to actively reposition the head to a previously demonstrated target position. The target position was 65% of the subject's maximum range of motion in flexion, extension, rotation left and rotation right, 65% of maximum range of motion was chosen so as to engage the neck muscles in a slightly lengthened position but avoiding excessive soft tissue stretch (Brumagne et al. 1999a; Lee et al. 2006).

After explaining the testing procedure the investigator blindfolded the subject with a travel eye mask and the orientation sensor was securely fixed on the head of the subject. The participants were instructed to sit upright with their feet flat on the floor, their back against the chair backrest and facing straight ahead, this position was established as their self selected 'neutral head position'. A webbing strap was used to minimize shoulder and trunk movement during the reposition test. The subject performed the maximum range of motion in flexion, extension, rotation left and rotation right and then 65% of these active maximal ranges of motion were calculated. The subject held the established neutral head position for 3 seconds and was asked to remember it, the investigator then positioned the subject's head to the first target and instructed the individual to actively hold the position for 3

seconds and remember this target. The participant was instructed to slowly move their head to the NHP, hold for 2-3 seconds, then move to their THP and hold for 2-3 seconds, returning to the NHP and THP for a second and third time. The repositioning tests were executed through four directions of cervical motion (65% of maximal flexion, extension, rotation left and rotation right), a Latin square sequence was employed to avoid any carry over between movements. The static posture intervention was then carried out, the intervention holding either 65% of the subject's maximal flexion or extension for 3 minutes. Figure 1 illustrates the testing procedure. Movement of head speed was uncontrolled during the experiment, however, speed was retrospectively averaged.

Immediately following the intervention a retest of the subject's position sense ability (finding their NHP and THP) was undertaken. The complete testing procedure was repeated on a second day with the alternate intervention (either a 3 minute static flexion or extension), with a minimum interval of 3 days between testing sessions. Sessions were scheduled at a similar time of day for each individual to minimize diurnal variation in proprioception within subjects. Data were collected from the average of a one second epoch at the neutral and target head positions, with a sampling rate of the orientation sensor being 13 readings per second. The repositioning ability of the subjects in the two tests (NHP and THP) is expressed by the mean absolute error (AE), calculated from the average of 3 attempts to locate the established neutral and target positions. During the testing the participants were instructed to move their heads slowly to reduce vestibular influence (Peterson 2004; Peterson et al. 1985). No feedback about repositioning performance was given during the testing and all tests were

administered by the same investigator. The entire procedure took approximately 15 minutes for each subject.

Testing Procedure for day 1

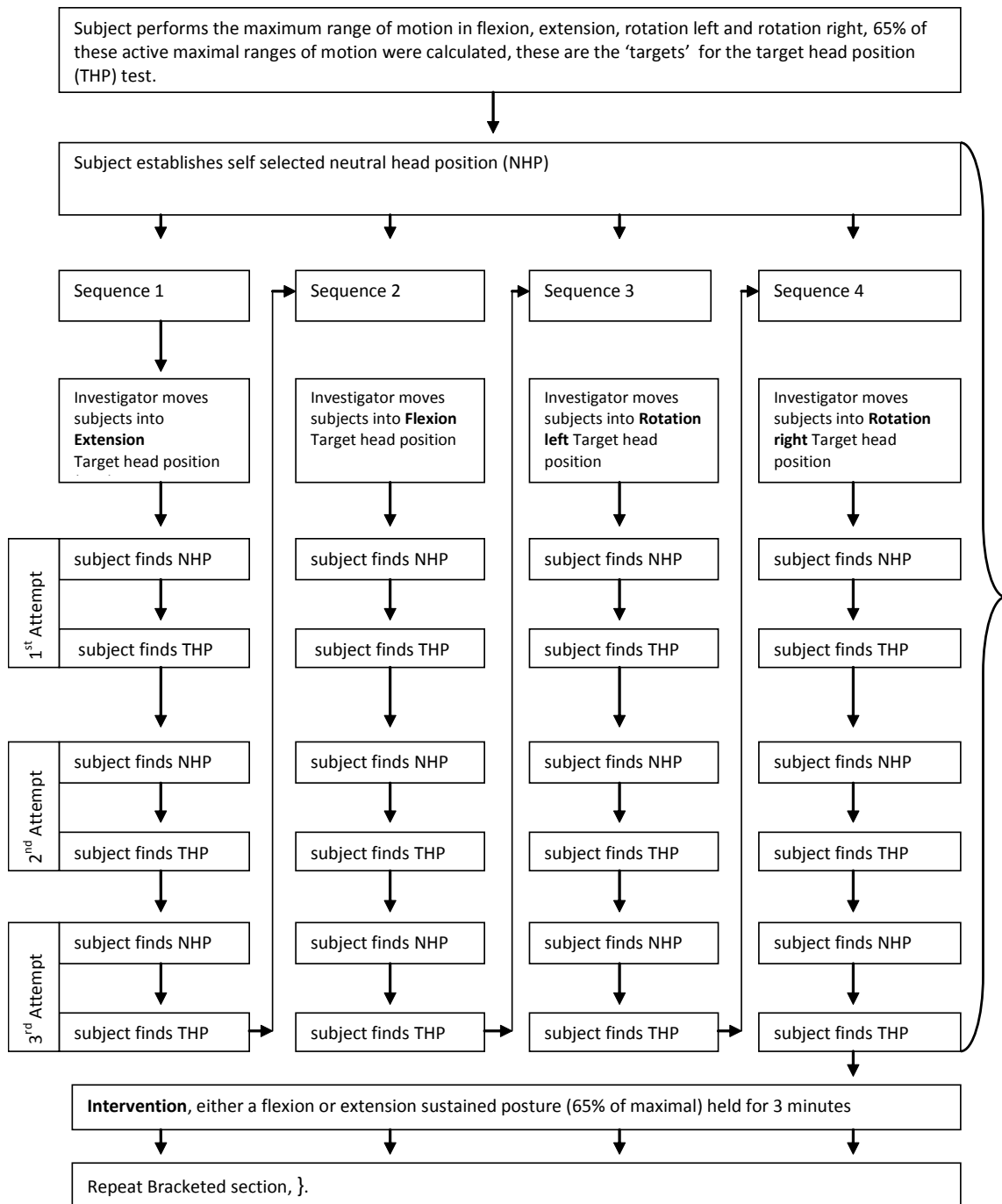


Fig 1. Testing procedure protocol for cervical spine position sense on day 1. Testing Procedure for day 2 is the same as day 1 but with the alternate intervention. NHP= Neutral head THP= Target head position

Data analysis

Normality of raw data was determined with the Shapiro-Wilk statistic and inspection of normal Q-Q plots. For non-normal position sense data Wilcoxon signed-rank tests were performed to determine the magnitude of difference between the two groups (pre and post the intervention), across the position sense tests (NHP and THP) and directions of motion (flexion, extension, rotation left and rotation right). Tests of normality and Wilcoxon signed-rank tests were performed using SPSS, v14.0 (SPSS Inc, Chicago, IL). Estimates of effect size (r) were computed from Wilcoxon Z values (Field 2005). Confidence limits and probabilities for effect size were calculated from p values as described by Hopkins (2008). Effect sizes were interpreted according to the descriptors described by Cohen (1988). Odds ratios were calculated for the frequency of 'overshooting' or 'undershooting' the reference point (Field 2005).

Results

The sample comprised 32 tertiary students including 20 females and 12 males with mean (SD) age of 28.40 years (7.67). The mean (SD) rate of head movement across all subjects was 20.83°/sec (5.32). A Shapiro-Wilk test and inspection of normal Q-Q plots both indicated non-normality data. No clear pattern of cervical reposition errors was observed irrespective of position sense tests (NHP and THP), direction of motion (extension, flexion, rotation left and rotation right) or of either intervention (flexion and extension). Table 1 summarizes the mean absolute error scores. The effect size for the neutral head position (NHP) test with the flexion and extension intervention was either 'small' or 'trivial'. Only in rotation left was there a meaningful increase in error before the intervention (Mdn= 2.16) compared to after the intervention (Mdn=3.23), $p=0.041$, $r=-0.26$. The effect size for the target head position (THP) test for both the flexion and extension interventions was either 'small' or 'trivial', except for the extension target after an extension intervention which produced a 'moderate' effect size and a decrease in reposition error before the intervention (Mdn=4.48) compared to after the intervention (Mdn=2.80), $p=0.006$, $r=-0.35$. Even though there was a moderate effect for the extension THP test after an extension intervention the confidence interval does not preclude the possibility of the true (95% likely) value being 'trivial' to 'moderate', indeed further analysis identified with 100% probability that the true value of a difference between the pre and post extension THP and rotation left NHP errors were 'trivial' (Hopkins 2008).

Overshooting in the NHP test occurred during 55.00% of trials, while overshooting in the THP occurred during 65.96% of trials (Table 2). The odds ratio indicates

during the THP test the subject is 1.59 times more likely to overshoot than undershoot the reference position compared to the NHP test. Overshooting pre the intervention was 61.39% and post the intervention was 59.57%, with resulting odds ratio of the subject being 1.08 times more likely to overshoot than undershoot pre the intervention rather than post the intervention.

Table 1

Summary of position sense tests (NHP & THP) in terms of angular degrees from 32 subjects, pre and post a sustained (3min) posture (flexion or extension) intervention.

		n=32		Neutral Head Position Test (NHP)						Target Head Position Test (THP)					
		Mean AE (SD)	Δ	P value	Effect size	UCL	LCL	Cohen descriptor	Mean AE(SD)	Δ	P value	Effect size	UCL	LCL	Cohen descriptor
		(°)	(°)		(r)				(°)	(°)		(r)			
Flexion intervention	Extension	Pre	4.51 (2.55)						4.25 (3.40)						
		Post	4.30 (3.09)	- 0.21	0.627	- 0.06	- 0.3	0.2	trivial	3.58 (2.42)	- 0.67	0.326	- 0.12	- 0.4	0.1
	Flexion	Pre	4.16 (3.38)						3.58 (2.29)						
		Post	4.65 (3.50)	0.50	0.239	- 0.15	- 0.4	0.1	small	2.80 (2.24)	- 0.78	0.054	- 0.24	- 0.5	0.0
	Rotation left	Pre	3.18 (2.65)						3.24 (2.39)						
		Post	3.80 (2.73)	0.62	0.041	- 0.26	- 0.5	0.0	small	3.08 (2.25)	0.16	0.866	- 0.02	- 0.3	0.2
Rotation right	Pre	3.97 (3.07)						4.71 (3.53)							
	Post	3.52 (2.42)	- 0.45	0.432	- 0.10	- 0.3	0.2	trivial	4.38 (2.58)	- 0.33	0.985	- 0.00	- 0.2	0.2	trivial
Extension intervention	Extension	Pre	3.64 (2.41)						5.32 (3.34)						
		Post	4.28 (2.23)	0.64	0.340	- 0.12	- 0.4	0.1	small	3.78 (3.44)	- 1.54	0.006	- 0.35	- 0.6	- 0.1
	Flexion	Pre	3.39 (2.34)						4.19 (2.81)						
		Post	3.91 (3.07)	0.52	0.701	- 0.05	- 0.3	0.2	trivial	4.17 (2.74)	- 0.02	0.985	- 0.00	- 0.2	0.2
	Rotation left	Pre	3.44 (2.41)						3.73 (2.21)						
		Post	3.81 (2.09)	0.37	0.660	- 0.06	- 0.3	0.2	trivial	3.60 (2.30)	- 0.13	0.779	- 0.04	- 0.3	0.2
	Rotation right	Pre	3.24 (1.83)						5.05 (3.56)						
		Post	3.78 (2.88)	0.54	0.933	- 0.01	- 0.3	0.3	trivial	3.66 (2.59)	- 1.39	0.050	- 0.25	- 0.5	0.0

AE= Absolute error in degrees (°) while repositioning to neutral or target position.

SD= Standard deviation.

Effect size (r) where $r = Z / \sqrt{N}$, (N=64)

Negative effect size value (r) is due to the negative Wilcoxon Z value,

Cohen descriptor (Cohen 1988) indicates correlation between pre and post the intervention reposition errors.

Extension, flexion, rotation left and rotation right indicate for the NHP test the direction the subject was coming from as they attempted to find their NHP, for the THP test they indicate the direction the target was located.

Δ = difference in degrees (°) between pre and post reposition error. Negative value indicates pre intervention value larger than post intervention value.

ULC=Upper 95% Confidence Limit; LCL=Lower 95% Confidence Limit

Table 2

Percentage (%) 'overshoots' and 'undershoots' during position sense tests

	Overshoot (%)	Undershoot (%)	Odds ratio to overshoot	Odds ratio to undershoot
NHP	55.00	45.00	0.63	1.58
THP	65.96	34.04	1.58	0.63
Pre intervention	61.39	38.61	1.08	0.93
Post intervention	59.57	40.43	0.93	1.08

NHP= Neutral head position

THP= Target head position

Odds ratio= times more likely to overshoot than undershoot reference position or undershoot than overshoot.

Discussion

The aim of this study was to evaluate neck proprioceptive sensorimotor responses before and after a 3 minute static posture intervention in asymptomatic subjects. The results indicate that holding a static posture for 3 minutes did not substantially alter position sense errors of the head.

There is a small volume of literature involving asymptomatic subjects and cervical position sense. To our knowledge, Owens et al. (2006) is the only other study of static posture using cervical spine position sense. Our findings are consistent with Owens et al. (2006) who used a 10 second static posture intervention and observed no change in subsequent cervical spine position sense. A single application of 3 minutes static postures appears to be well tolerated in terms of position sense accuracy, however, longer durations may increase stress on tissues involved in maintaining the static posture leading to position sense errors. As the majority of mechanoreceptors appear to be in the muscle spindles (Boyd-Clark et al. 2002; Gandevia et al. 1992a; Kulkarni et al. 2001) it is these structures that primarily need to be compromised to influence proprioception. However, a three minute static flexion posture did not appear to be a difficult task for any of the subjects, probably because this is a common everyday posture. Fatigue, which has been associated with position sense errors (Wong et al. 2006), does not appear to have been induced in the present study and consequently, there was no impairment of position sense. Holding 65% of maximal cervical extension was generally reported as being more difficult for subjects than the flexion task. Some mild discomfort was reported by subjects while holding the 3 minute extension intervention, however, position sense deficits were not evident. This

finding is consistent with other investigators (Armstrong et al. 2005; Feipel et al. 2006; Lee et al. 2007; Loudon et al. 1997; Revel et al. 1991) where position sense is not associated with pain intensity or duration, but only with pain frequency. The proprioceptive tissues of the subjects in the current study appear not to have been influenced sufficiently to produce a change in position sense.

There was a tendency for subjects to overshoot the reference position. Overshooting was demonstrated on 60% of trials, which is similar to Revel et al., (1991) result of 54% from a flexed position to the NHP. Additional research is needed to explain this proprioceptive discrepancy.

Position sense deficits have not been consistently linked with cervical pathology in the literature. At least three studies have reported no association between either chronic neck pain or WAD and position sense errors (Armstrong et al. 2005; Rix et al. 2001; Teng et al., 2007). These researchers attributed their findings to the mild nature of the participants' condition. This is further supported by studies that show that low NDI scores and mild functional problems are associated with minimal or no position sense errors (Marks 1998; Sterling et al. 2003; Treleaven et al. 2003). The current study's subjects were asymptomatic, had a NDI of zero and produced minimal or no position sense errors showing consistency with other studies (Armstrong et al. 2005; Marks 1998; Rix et al. 2001; Sterling et al. 2003; Teng et al. 2007; Treleaven et al. 2003).

When considering the aetiology of neck pain it appears asymptomatic subjects or those with low NDI scores or low levels of dysfunction all have minimal or no position sense errors. Subjects with WAD, whiplash, chronic neck pain and neck pain frequency all report position sense deficits, this suggests position sense

errors may be associated with neck pain also suggesting neck pain may lead to position sense errors rather than position sense leading to neck pain. However, neck pain duration and intensity does not appear to be associated with position sense error, only increased frequency of pain results in position sense errors. The relationship between neck pain and position sense is not a straight forward one, but suggests position sense may be associated with chronicity of tissue change. Infrequent pain of longer duration and greater intensity it is suggested, may have less chronic tissue change (and less position sense error), than frequent pain but of shorter duration and less intensity.

Position sense of the head and neck is mediated by cervical proprioceptors, visual and vestibular systems (Treleaven 2008), therefore, blindfolding of subjects was employed in an attempt to control against visual afferent information used in position sense. Vestibular input is difficult to separate from cervical proprioceptors, as the vestibulocollic reflex and the cervicocollic reflex work closely together acting on the neck muscles determining the position of the head in space (Jull, Sterling, Falla, Treleaven, & O'Leary 2008). However the vestibulocollic reflex appears to respond to faster neck movements than the cervicocollic reflex (Peterson 2004; Peterson et al. 1985). Additional research indicates that cervical proprioceptors make a greater contribution to head repositioning to a target than vestibular afferent information (Revel et al. 1991; Taylor & McCloskey 1988). Subjects in the current study used a slow head movement ($\approx 20^\circ/\text{s}$), during position sense testing to ensure that the majority of sensorimotor information originated from cervical proprioceptors.

A limitation of this study was the use of only three trials for each direction of motion within the position sense tests. Recently published data indicates that three trials may not be sufficient to ensure optimum evaluation of reposition ability, rather, six or more trials are suggested so as to achieve more stable estimates of accuracy (Swait, Rushton, Miall, & Newell 2007). Based on three trials the current study's estimates of position sense appears reasonably stable, standard deviations having a range from 1.83° to 3.56°.

Sample bias may also be a limitation as all the samples were from the same tertiary institution. Consequently the similar subjects are unlikely to represent the diversity of the population (Alreck & Settle 1995) and therefore the extent to which these findings may be generalised is limited. The subjects' affective disposition, mood and motivation at the time of the tests may have some influence on the results, for example if subjects were tired, excited or distracted this may compromise their concentration and be reflected in the experimental data.

Extraneous variables may have some influence on the present study (Harmon & Morgan 1999). These may include the chin strap and the thoracic strap, especially when finding the target head position, which may result in subtle 'pulling' sensations on the chin and face during movement thereby potentially assisting the subject locate the reference point. Also, it was noted that with the teeth held close together, tension in the suprahyoid and infrahyoid muscles reduces the apparent load on the cervical muscles while holding an extension posture. When the mandible is fixed the suprahyoid and infrahyoid muscles function as a unit and flex the head on the cervical column, as well as the cervical

column on the thorax (Kapandji 1982). Changes in contractile activity in the cervical muscles may influence the cervical proprioceptors and position sense accuracy. We did not control for the use of the suprahyoid and infrahyoid muscles during the extension intervention task and this may have an influence on the results.

Future studies could investigate cervical muscle fatigue in asymptomatic subjects and the influence on proprioception using position sense. As cervical position sense is influenced in the majority by mechanoreceptors in the muscle spindles, fatiguing the cervical muscles richly invested with cervical proprioceptors may induce position sense errors (Boyd-Clark et al. 2002; Kulkarni et al. 2001). An alternative study investigating cervical position sense and sustained posture, near or at end range, may also influence position sense. Cervical proprioception is thought to have supplementary input from the cutaneous and joint receptors and an end range posture may influence position sense deficits (Marks 1998; Matthews 1988). These studies may further inform questions regarding change to posture, cervical stability and the aetiology of neck pain.

Conclusion

The results of the present study indicate no differences in cervical position sense before and after a 3 minute static posture, in either flexion or extension, in asymptomatic subjects.

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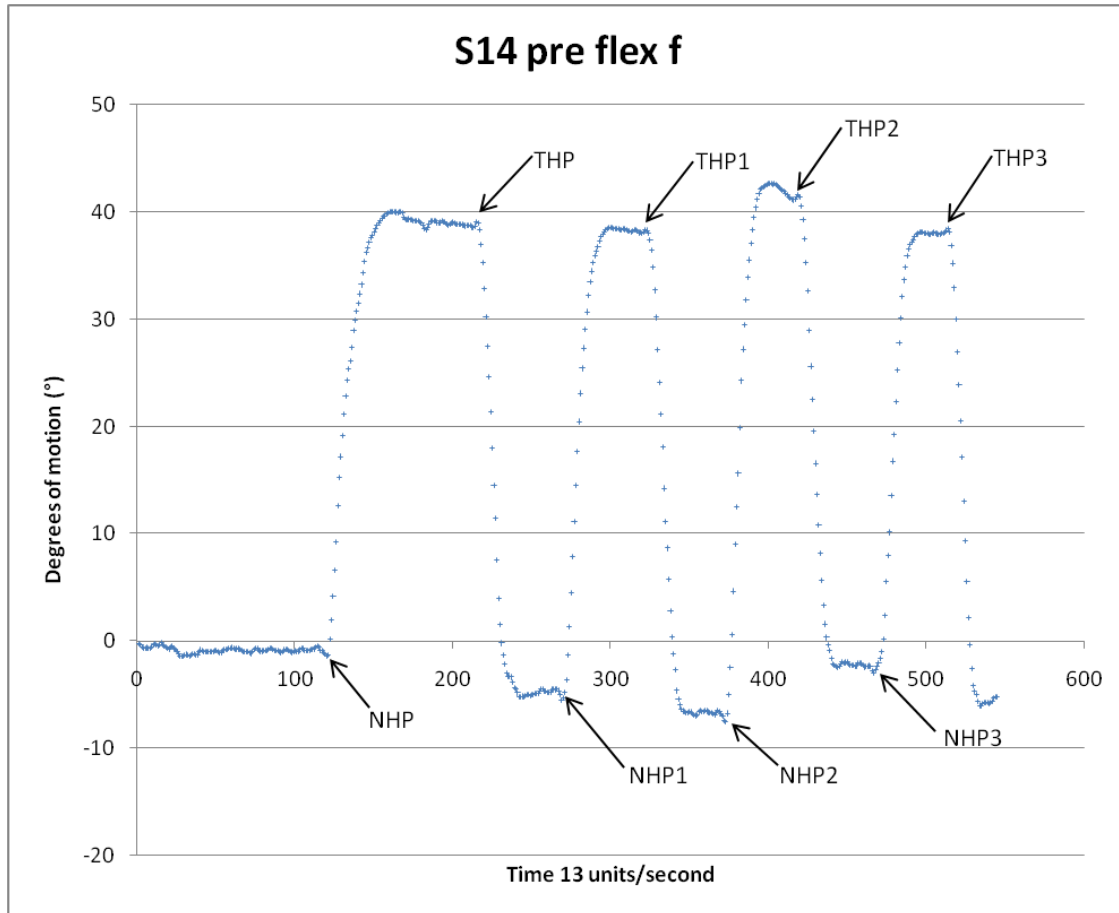
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Section 3: Appendices

Appendix A: Experimental setup in the evaluation of joint position sense using an electrogoniometer.



Appendix B: Typical data graph



S14 pre flex f = Subject 14 pre flexion intervention, with a flexion target head position

NHP= subject establishing their NHP (neutral head position)

NHP1= subject's first trial to relocate NHP, NHP2= 2nd trial, NHP3= 3rd trial

THP= subject establishing their THP (target head position)

THP1= subject's first trial to relocate THP, THP2= 2nd trial, THP3= 3rd trial

Appendix C: Confirmation letter of ethical approval for this study was granted by the Unitec Research Ethics Committee.



phone +64 9 849 4180 fax +64 9 815 2901 web www.unitec.ac.nz
address Private Bag 92025, Auckland Mail Centre, Auckland 1142, New Zealand
Mt Albert campus Carrington Rd, Mt Albert, Auckland, New Zealand
Waitakere campus Ratanui St, Henderson, Auckland, New Zealand

Phil Rowe
64 Duke St
Three Kings
Auckland 1041

October 23, 2007

Dear Phil

Your file number for this application: 2007.756

Title: The Effect of Sustained Posture on Cervical Spine Reposition Sense

Your application for ethics approval has been reviewed by the Unitec Research Ethics Committee (UREC) and has been **approved** for the following period:

Start date: 17 October 2007
Finish date: 30 June 2009

Please note that:

1. the above dates must be referred to on the information AND consent forms given to all participants
2. you must inform UREC, in advance, of any ethically-relevant deviation in the project. This may require additional approval.

This letter has been copied to the Principal Supervisor for Unitec student research projects.

You may now commence your research according to the protocols approved by UREC. We wish you every success with your project.

Yours sincerely

A handwritten signature in cursive script that reads 'Deborah Rolland'.

PP Deborah Rolland
Deputy Chair, UREC

RMOL ref#: 993

cc: Assoc Prof Andrew Stewart
Carla Sutton

Appendix D: Guidelines for submission to Manual Therapy

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- you should give a maximum of four **degrees/qualifications** for each author and the current relevant appointment
- name and address of the department or institution to which the work should be attributed
- name, address, telephone and fax numbers, and e-mail address of the author responsible for correspondence and to whom requests for offprints should be sent.

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Include three or four keywords. The purpose of these is to increase the likely accessibility of your paper to potential readers searching the literature. Therefore, ensure keywords are descriptive of the study. Refer to a recognised thesaurus of keywords (e.g. CINAHL, MEDLINE) wherever possible.

Abstracts

This should consist of **150-200 words** summarizing the content of the article.

Text

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- secondary ones should be typed in lower case (with an initial capital letter) in the left hand margin and underlined
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Lee M, Svensson NL. Effects of loading frequency on response of the spine to lumbar postero - anterior forces. *Journal of Manipulative and Physiological Therapeutics* 1993; 16(7): 439-466

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- The Case Report should conclude with a brief summary.
- Three copies of the Case Report are required.

For further details on the Case Report section please contact: Jeffrey D. Boyling, Jeffrey Boyling Associates, Broadway Chambers, Hammersmith Broadway, LONDON, W6 7AF, UK. Tel: +44 (0) 20 8748 6878 Fax: +44 (0) 20 8748 4519 E-mail:

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