

School of Physiotherapy

**The clinical utility and validity of the cervical flexion-rotation test in
the diagnosis and management of cervicogenic headache**

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Doctor of Philosophy
of
Curtin University of Technology**

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Toby Hall

Date: 16th August 2010

Abstract

Headache is a common complaint with increasing prevalence in the third decade. Because it is so common, headache gives rise to substantial financial costs to society. In addition headache burdens both the health care system and the family.

Headache is a symptom arising from a range of different disorders. Consequently, classification of headache is important, as a successful outcome is only likely if intervention is targeted to the underlying cause. For example cervicogenic headache (CGH) appears to be uniquely amenable to physical intervention.

Differential diagnosis of migraine and CGH is a common clinical challenge made difficult by symptom overlap and the presence of multiple headache forms (MHF). Consequently incorrect headache diagnosis is common. In individuals with headache symptom overlap, classification of CGH is based on physical examination. Cervical movement impairment is reported to be an important factor in CGH diagnosis. The flexion-rotation test (FRT) is an easily applied form of movement analysis, the aim of which is to identify C1/2 segment movement impairment.

The general aim of this doctoral research was to analyze the clinical effectiveness of the FRT in CGH diagnosis. The FRT was evaluated in a series of six studies, which will be presented in sequence and grouped in Parts A, B, and C.

Part A consisted of two studies. The first was designed to investigate the long-term stability and reliability of FRT measurements over time. Twenty-five subjects, 15 with CGH, were assessed using the FRT on 4 occasions spread over two-weeks. For subjects with CGH there was no significant change in FRT range of motion over days. Reliability was excellent and minimal detectable change was at most seven degrees.

The second study in Part A was designed to investigate the diagnostic accuracy of the FRT. Sixty subjects with headache (20 with CGH, 20 with migraine and 20 with MHF) were evaluated using the FRT. The results demonstrate significantly greater deficits in range of motion in CGH. Based on the FRT, an experienced examiner was able to make the correct diagnosis of CGH 85% of the time. The cut-off value for a positive FRT was 30°.

Part B consisted of two further studies designed to determine the validity of the FRT as a test of cervical movement impairment at, and pain arising from, the C1/2 segment. The aim of the first study was to measure rotation from the occiput to the C4 vertebra with the neck in neutral position and in flexion using Magnetic Resonance Imaging. Nineteen asymptomatic subjects were evaluated. There was a significant difference in the pattern of cervical segmental rotation between axial rotation and the FRT. At the C0/1 segment, there was negligible range recorded in either position. In contrast, the most mobile segment was C1/2, providing the majority of rotation during the FRT.

The aim of the second study, in Part B, was to investigate the impact of lower cervical joint pain on the FRT. Twenty-four subjects were evaluated, 12 with CGH and 12 with lower cervical joint pain. A single examiner conducted the FRT. Subjects with lower cervical joint pain were evaluated using the FRT prior to therapeutic cervical spine block procedure and were excluded if they did not gain complete pain relief following that procedure. Range of rotation during the FRT was significantly less in the CGH group. Sensitivity and specificity for CGH diagnosis was 75% and 92% respectively. The cut-off value for a positive FRT was 32°.

Part C consisted of two final studies designed to determine the clinical utility of the FRT in CGH evaluation. The aim of the first study was to investigate the reliability of manual examination and the frequency that segments above the C4 vertebra were the dominant source of symptoms in CGH. Eighty subjects were evaluated, 60 with CGH, and 20 who were asymptomatic. Two examiners evaluated each subject with standard manual examination procedures. Each examiner independently rated each segment for pain and dysfunction. The C1/2 segment was found to be the most commonly agreed dominant source of symptoms, with positive findings at this level in 63% of cases. Other segments were less frequently dominant.

The aim of the second study in Part C, was to investigate the association between the presence and severity of CGH symptoms and the impairment in range of motion measured during the FRT. Ninety-two subjects were evaluated, 72 with CGH and an additional 20 asymptomatic subjects. A single experienced examiner conducted the FRT. Range of motion was significantly reduced by 6° in the presence of headache at the time of testing. Furthermore, half the variance in FRT range of motion was explained by an index of headache severity, or component parts.

This series of studies has highlighted the central role that the FRT should play in the diagnosis of CGH. CGH principally arises from dysfunction of the C1/2 segment, although usually more than one segment is involved. Determining dysfunction at the C1/2 segment can be reliably achieved by using the FRT as well as manual examination procedures. The FRT, in contrast to manual examination, is an easily applied clinical test that is reliable, when used by experienced or inexperienced examiners. Measurement and interpretation of the FRT is stable over time. Range recorded during the FRT is related to the severity of headache symptoms. The presence of pain arising from segments other than C1/2 does not influence interpretation of the FRT. Finally, the similarity of headache characteristics but difference in cervical spine range of motion deficits (specifically the FRT) between those with migraine and those with CGH highlights the importance of the FRT in headache evaluation.

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List of Publications

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Hall T, Briffa K, Hopper D, Robinson K (2010): Long-term stability and minimal detectable change of the cervical flexion rotation test. *Journal of Orthopaedic & Sports Physical Therapy* 40(4):225-229

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Hall T (2009): Are all headaches just a pain from the neck. 1st International
Conference on the Mulligan Concept. Chicago, USA

List of Abbreviations

CGH	Cervicogenic headache
CI	Confidence interval
CROM	Cervical range of motion device
FRT	Flexion-rotation test
ICC	Intraclass correlation coefficient
ICD-10	International Classification of Diseases
ICHD	International Classification of Headache Disorders
IHS	International Headache Society
MHF	Multiple headache form
MDC	Minimal detectable change
MRI	Magnetic resonance imaging
OR	Odds ratio
ROM	Range of motion
SD	Standard deviation
SEM	Standard error of measurement
TCN	Trigemincervical nucleus
TTH	Tension-type headache

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Chapter 1: Introduction

1.1 INTRODUCTION

Headache can be defined as pain in the head that can arise from many disorders or may be a disorder in itself. In broad terms headaches may be classified as primary, where there is no other causative factor, or secondary where the headache occurs in close temporal relationship to another disorder to which it is attributed. Primary headache disorders include migraine, tension-type headache (TTH), cluster headache, trigeminal autonomic cephalalgias and other primary headache. Secondary headache disorders are numerous and include headache associated with head trauma, vascular disorders and headache or facial pain associated with disorder of cranium, neck, eyes, ears, nose, sinuses, teeth, mouth or other facial or cranial structures. Included within the secondary headache category is cervicogenic headache (CGH) arising from a disorder of the neck. Further elaboration of the forms of primary and secondary headache will be presented later in this review.

Headache is the most prevalent pain condition, ranked within the top ten causes of disability, affecting the majority of the global population and present at all stages of life (World Health Organization 2001). It is also one of the top five causes of disability in women (World Health Organization 2001).

The lifetime prevalence of headache for all ages is reported as 66% and current one-year prevalence is 47% (Stovner and Hagen 2006). A prevalence rate of 47% indicates that headache represents a major health problem. One-year prevalence rates are the more useful indicator as they provide a better understanding of disease burden. People who suffer from headache are more likely to remember headache frequency in the previous year than they are over a lifetime. One-year prevalence is higher in females (52%) and lower in males (37%) (Stovner and Hagen 2006) peaking in the second and third decade of life. It then slowly declines with increasing age, such that by the eighth decade headache prevalence is half that of earlier years (Radtke and Neuhauser 2009).

Headache prevalence rates are not consistent across continents. For example one-year prevalence in Australia is 50% but only 21% in Africa (Stovner et al 2007). Possibly, headache burden varies considerably between different parts of the world, owing to differences in genetic background, climatic and socioeconomic conditions,

life-style, other disease spectrum and general health (Stovner et al 2007). For example a recent survey in Germany revealed that a higher level of education was associated with a higher prevalence of headache (Radtke and Neuhauser 2009). In addition in the United States, the lowest prevalence of migraine was observed among Asian-Americans, intermediate estimates were reported in African-Americans, and the highest prevalence estimates were observed among Caucasian-Americans, before and after adjusting for demographic covariates (Stewart et al 1992). An alternative explanation for the low prevalence rates in some countries may be that headache is a minor concern in comparison to other health and life issues and may simply be under-reported.

1.2 THESIS RATIONALE

It is clear that headache diagnosis and classification is important when it comes to providing effective management. This is particularly important when using physical treatment for headache. Only CGH appears to respond to physical intervention (Bronfort et al 2004).

The difficulty of diagnosing CGH lies in the commonality of symptoms with other headache forms such as migraine. People who suffer from CGH or migraine complain of symptoms in the head and neck, and even associated symptoms of nausea, photophobia, or phonophobia. Although the prevalence of these features is more common in migraine, they still occur in patients with CGH. Hence the International Headache Society (IHS) classification system does not readily distinguish migraine from CGH, and an incorrect diagnosis may occur. An additional complication in headache diagnosis is that it is common to find individuals with headache who have multiple headache forms (MHF), rather than a single headache disorder. This may account for the mixture of headache symptoms in many individuals with headache.

The flexion-rotation test (FRT) is a clinical test of movement impairment, purportedly biased to assess dysfunction at the C1/2 motion segment (Stratton and Bryan 1994; Hall et al 2008). This test appears to show early promise in CGH evaluation. For example diagnostic accuracy has been demonstrated in highly selected homogenous groups of patients with migraine with aura, CGH or healthy

controls (Ogince et al 2007; Hall et al 2008). In addition the FRT has high levels of inter-tester and intra-tester reliability on a test and re-test basis (Hall and Robinson 2004; Ogince et al 2007; Hall et al 2008). Furthermore there is preliminary evidence that the FRT may be useful in determining treatment success (Hall et al 2007). However, further studies are required to develop these preliminary investigations. Hence, the purpose of this thesis is to examine the FRT as a diagnostic tool in the evaluation of CGH.

This thesis will consist of a series of six studies, which will be presented in sequence. Each study will address different components of the overall thesis objective, which is to determine the diagnostic utility of the FRT in CGH evaluation. These studies are grouped into three components:

- 1.** Part A will consist of two studies designed to determine the long-term stability, minimal detectable change, and diagnostic accuracy of the FRT in CGH evaluation.
- 2.** Part B will consist of two further studies designed to determine the validity of the FRT as a test of cervical movement impairment at, and pain arising from, the C1/2 segment.
- 3.** Part C will consist of two final studies designed to determine the clinical utility of the FRT in CGH evaluation

Prior to the commencement of these doctoral studies, ethical approval was sought for the studies conducted in Australia and granted by the Human Research Ethics Committee of Curtin University of Technology (see Appendix 10.1). Likewise ethical approval was sought for the study conducted in Japan and granted by the Japanese Society of Physical Therapy Science, prior to that study's commencement (see Appendix 10.1).

The purpose of the following chapter is to provide an overview of the relevant background literature in relation to the burden, classification, differential diagnosis and management of headache. Particular emphasis is given to migraine and CGH, due to their similarity. Similarity in terms of symptoms, but wide disparity in terms

of underlying pathomechanisms and response to physical treatment. The information contained in this chapter reinforces the importance of identifying accurate, valid and reliable clinical tools of CGH diagnosis, such as the FRT.

Chapter 2: Literature Review

2.1 BURDEN AND DISABILITY OF HEADACHE

The term 'burden' may cover all types of disease impact, but often it is a designation of impact in non-economic terms. Estimates of the burden of headache have been largely underestimated (Harpole et al 2005) and traditionally headache disorders have been seen as trivial and undeserving of medical care (Martelletti et al 2007). To counteract this a global campaign was launched to identify and reduce the burden of headache (Steiner 2004). In support of this campaign it has been stated that headache disorders are a major clinical problem and should be a public health priority. This is because of their high prevalence, spread across genders and ages, duration (most are life-long conditions) and their imposition of disability and restricted participation upon those affected by them (Martelletti et al 2007).

Some indication of the burden of headache was identified by a telephone survey of a representative sample of the general population in Germany (Radtke and Neuhauser 2009). In this survey of 7341 people, 60% of respondents reported headache, 60% of whom suffered from severe headache. Radtke & Neuhauser (2009) indicated that almost one-quarter of people in their survey with headache had frequent attacks (more than 20 days in the previous year). Furthermore 3% of the total sample reported chronic headaches, defined as more than 10 days in the past 4 weeks. For the purpose of the study, disability because of headaches was defined as the inability to perform usual activities at work and in everyday life during at least one day in the previous year and was reported by 16% of all headache sufferers. Women suffered more often from severe and frequent headaches. As a consequence of their headache, women reported disability more often, and rated their health worse than men (Radtke and Neuhauser 2009).

A number of headache sub-types cause substantially greater disability and a significant burden both to the individual and society as a whole (Stovner et al 2007). It has been estimated that TTH carries a higher burden than migraine due to the high prevalence, frequency and headache duration compared with other types of headache (Stovner et al 2007). Taking the total headache burden to be the sum of the burdens of migraine and of TTH, TTH was found to contribute 58% and migraine 42% (Stovner et al 2007). Furthermore, since headache in general was found to affect as

many as 50% of Europeans, this estimate, if true, would make headache a much more costly disorder than migraine alone (Stovner and Andree 2008).

Migraine is a highly prevalent as well as a painful and costly disease (Smith et al 2010). Using 1994 data, the estimated economic burden of migraine in the United States of America was \$14 billion per annum, with \$1 billion in direct medical care (Hu et al 1999). A further \$13 billion was accounted for by indirect costs related to lost productivity (Hu et al 1999; Oksanen et al 2006). A more recent assessment revealed direct medical costs were substantially higher at \$11 billion per annum in 2004 (Hawkins et al 2008). Similarly in Australia the direct and indirect financial costs of migraine have been estimated to be approximately half a billion dollars per annum (Schweitzer 1999).

Part of the economic cost of headache is due to loss of productivity caused by absenteeism during acute headache attack. To quantify absenteeism from work a telephone survey was conducted on a random sample of the population (n=4007) aged from 16-65 in England. It was estimated that of a working population of 30 million people, 100,000 are absent on any given day due to migraine. Over a year this would account for 25 million days of missed work or school in the United Kingdom alone (Steiner et al 2003).

In addition to work absenteeism, part of the economic cost of headache arises from lost work productivity. Again most of the research has investigated migraine, where working with a headache is suggested to result in a 35% loss of self-reported work productivity (Berg and Stovner 2004). However, Pransky (2005) reported that objectively measured working efficiency reduced by only 8% in contrast to self-reported working ability, which reduced by 20% (Pransky et al 2005). Based on findings such as these, it has been suggested that workers find creative ways to cope with the pain, and maintain standards of their work efficiency, even in the presence of severe headache (Stovner and Hagen 2006).

As well as the financial cost to society, headache burdens the health care system. An estimate of this burden was determined from data collected by the National Hospital Ambulatory Medical Care Survey of Physicians working in outpatient clinics in the United States in 1997 (Schweitzer 1999). According to this analysis headache was the fourth most common cause of an emergency room visit. Based on the same survey from 1990-1998 the medical management of migraine in

the United States of America has been estimated to involve 5-9 million visits per year to primary care physicians (Gibbs et al 2003). As a consequence, headache surely impedes access to medical practitioners for people suffering from other conditions (Smith et al 2010).

Headache also burdens the family, significantly disrupting family life, with impact on spouses, children, and friends. To investigate this Stang et al (2004) analyzed two large databases consisting of 4.3 million people in the United States of America. They compared families with and without a family member suffering from migraine. Total health care costs, work absence days, short-term disability, and workman's compensation days all were higher among families with migraine than those without. As headache affects women more often than men and is most prevalent in the child rearing years, a substantial impact on family life might be expected. An on-line survey of 866 people with headache revealed that 90% of participants postponed household chores because of headaches, 30% canceled family and social activities during headache attack, and two-thirds feared letting others down because of their headaches (MacGregor et al 2004). Furthermore individuals with headache missed more days from family or leisure activities than from work or school (mean 4.2 versus 2.4 days).

Lipton et al (2003) examined the influence of headache on family life both from the perspective of the person with migraine and from the perspective of their partner. A validated computer-assisted telephone interview identified 1142 people with migraine from a population sample of 8383 in England, and the United States of America. People who suffer from migraine, along with their partners, were interviewed about the impact of migraine on their participation in social, family and leisure activities and on family relationships. It was reported that at least 50% believed that they were more likely to argue with their partners or children as a result of their headache. In addition 52-73% reported other adverse consequences for their relationships with family members, and at work. A third of participants believed that their relationships would be improved if it were not for their headaches. When partners were questioned, 29% felt that arguments were more common because of headaches and 20-60% reported other negative effects on relationships at home (Lipton et al 2003).

Table 2.1- Distribution of perceived impact of headache on sub-modalities of function, relationships and emotions (Diener 2001)

Sub-modality	Specific impact	Percent yes	Percent no
Impacting on function	Forced to take time off work	47	53
	Loss of productivity	89	11
	Unable to do household chores	34	66
	Restricted in sport	32	68
Impacting on relationships	To spouse or close friend	86	14
	To dependents	42	58
	To colleagues	79	21
Impacting on emotions	Depression	35	65
	Isolation	33	67
	Anxiety	75	25
	Suicidal thoughts	12	88
	Anger	48	52

Although other types of headache are less prevalent than either TTH or migraine they still cause considerable disability.

Diener (2001) conducted a quantitative retrospective study of 450 patients' perceptions of the impact of their CGH. High scores were reported for severe functional disability, for considerable emotional handicap and for negative impact on close relationships. Decreased productivity was reported by 89% of the population studied. Subjects expressed emotions of anxiety, anger and helplessness. Table 1 shows the distribution of perceived impact on sub-modalities of function, relationships and emotions. Consequently CGH was considered to have severe impact on the health-related quality of life of individuals in this study.

To compare differences in functional health status between healthy controls and people with CGH, migraine and TTH van Suijlekom (2003) used the medical outcomes study short form general health survey, which has eight generic health

domains. This is considered to be a valid and reliable tool to measure health related quality of life (Stewart et al 1988). Significant differences were found between healthy controls and people with CGH. In contrast there were no differences between people with TTH, migraine, and CGH for all domains except physical functioning. Physical functioning was significantly worse in people with CGH. The conclusion drawn from this study was that people with CGH have a quality of life burden that is substantial and is at least comparable to that of people with migraine and TTH.

In addition to the financial and social consequences, headache causes psychological distress. Tenhunen et al (2005) found reduced quality of life in people who suffered from headaches on a daily basis. Using qualitative analysis they identified that beliefs and perceptions about loss of control were the central experiences mediating the impact of headache on the individual's quality of life. Loss of control included cognitive, behavioural, emotional, as well as interpersonal aspects. Such information may potentially be of value in the development of interventions to enhance the quality of life in those affected.

Population-based studies involving more than 11,000 participants have shown that headache is under diagnosed and under managed (Harpole et al 2005; Lipton et al 2001; Radtke and Neuhauser 2009). For example approximately 50 percent of persons with severe headache classified as migraine under IHS guidelines have never consulted a physician about their headaches (Lipton et al 2001). Similarly a recent German survey (Radtke and Neuhauser 2009) revealed that even when suffering from frequent headaches and considerable disability, less than half of those people with migraine sought professional care. Hence it would appear that many people are not receiving optimal management that should be available to them and the direct costs of managing headache are probably underestimated. On the contrary, given the evidence for effective treatment of headache, (to be presented subsequently), it is clear that many people with headache could benefit from consulting a health care practitioner and gaining access to specific treatment relevant to their headache condition. Such access could perhaps, substantially reduce the burden of headache to the individual and society as a whole.

2.2 CLASSIFICATION OF HEADACHE

Examination and subsequent classification of headache is important to ensure that correct treatment is administered (Dodick 2010). The International Headache Society (IHS) in 1988 provided the first International Classification of Headache Disorders (ICHD-1) with specific definitions of the various headache types (Classification Committee of the International Headache Society 1988). This classification was later incorporated into the International Classification of Diseases (ICD-10) (International Headache Society 1997). The ICHD-1 was revised in 2004 (ICHD-2) (Classification Committee of the International Headache Society 2004), but only minor changes were made with respect to the definitions of the most prevalent headache types.

Classification of headache according to the ICD-10 is hierarchical (Classification Committee of the International Headache Society 2004). The level of detail regarding diagnosis is dependent on the requirements of the researcher or clinician. As outlined in Chapter 1, headaches may be classified as primary or secondary.

Within these categories further sub-classification can be made. For example migraine is classified as with and without aura (ICHD 1.1 and 1.2). Further subdivisions are possible such as typical aura with migraine headache (ICHD 1.2.1) and typical aura with non-migraine headache (ICHD 1.2.2) with 4 other sub-types (ICHD 1.2.3-1.2.6). CGH is coded ICHD 11.2.1 (Classification Committee of the International Headache Society 2004).

Severely affected individuals may receive more than one diagnosis and have MHF. For example a single person may have both migraine without aura and medication overuse headache. Such diagnoses are listed in order of importance for the individual. Investigations of large cohorts of people with chronic headache reveal a substantial proportion with MHF (Paffenrath and Kaube 1990; Fishbain et al 2001; Amiri et al 2007). In a survey of the whole population of the town of Vaga in Norway 41 of 75 people were found to have a single headache form (CGH), while the remaining 34 had MHF (Sjaastad and Bakketeig 2007). The presence of MHF undoubtedly increases the difficulty of identifying the form of headache for each individual person who presents for assessment of his or her headaches.

Despite the IHS classification system, in one survey approximately 40% of those people with migraine who consulted a physician did not subsequently self-report this diagnosis of migraine to other clinicians, suggesting problems with diagnosis, communication, or both (Edmeads et al 1993). Even when headaches are properly diagnosed, they may not always be correctly classified according to subtype. Data from the Landmark Study (Tepper et al 2004) in which participants used longitudinal diaries to record events, indicate that one in four people, with IHS defined migraine were not diagnosed with migraine by their primary care physicians.

2.3 RELIABILITY OF HEADACHE CLASSIFICATION

Despite the fact that it is more than 20 years since the IHS provided ICHD-1 (Classification Committee of the International Headache Society 1988) there have been very few studies examining the reliability of the IHS classification system. In addition, to our knowledge, no study has investigated the reliability of the most recent modification of the IHS headache classification system in general clinical practice.

One study has investigated the reliability of the IHS classification system in a hospital emergency department (Friedman et al 2007). Among the 480 subjects assessed, 25% had a secondary headache disorder, 64% had a primary headache disorder, 10% had a coexisting primary and secondary headache, and for 20% of subjects, neither a primary nor a secondary headache could be diagnosed. Of 309 subjects with a primary headache, 60% had migraine, 11% had TTH, 1% had trigeminal autonomic cephalalgia, and 26% had an unclassifiable primary headache. However, a specific ICHD headache diagnosis could not be assigned to 36% of subjects examined. The emergency medicine investigators had a high level of inter-observer agreement on the major sub-categories of primary headaches (agreement 91%, kappa=0.86). In addition, there was a high level of inter-observer agreement on the overall categorization of secondary headaches (agreement 94%, kappa=0.86), but no attempt was made to examine reliability of further sub-categorization.

In a small pilot study van Suijlekom et al (1999) investigated the inter-observer reliability in distinguishing CGH from migraine without aura and TTH. Physicians from different areas of medical specialty examined 24 people with

headache using a semi-structured interview. Diagnosis for migraine and TTH was carried out in accordance with the IHS criteria and the criteria for CGH from Sjaastad et al (1998). Kappa statistics ranged upwards from 0.83 for physicians experienced in headache classification. Agreement was lower in those physicians without such experience. The conclusions drawn from this study were that reliability of classification of migraine, TTH and CGH were similar when using either IHS or Sjaastad et al (1998) classification criteria.

Granella et al (1994) assessed inter-observer reliability of an earlier version of the IHS classification protocol for the diagnosis of primary headaches. In this study 103 consecutive people with headache were assessed. Each person was given a structured interview recorded on videotape. Four experienced clinicians then reviewed the interviews separately and made a diagnosis of headache according to IHS criteria at the single digit level. The Kappa value was 0.74 indicating substantial agreement.

In summary, headache is a common condition affecting both men and women at all stages of life. Estimates of the burden of headache have been underestimated which has led to a call for more research into all aspects of headache. Despite the high prevalence of headache and considerable cost burden many people with headache do not seek medical care and do not receive a diagnosis. Consequently individuals who suffer from headache may not receive the most effective treatment. The following section considers the classification of headache, which is important for headache diagnosis and subsequent management.

2.4 PRIMARY HEADACHE - MIGRAINE

2.4.1 Classification of migraine

There are two sub-categories of migraine broadly differentiated by the presence of an aura that warns of a headache attack. An aura is defined as a reversible neurological event that usually lasts for 60 minutes after which the headache commences. Symptoms of migraine aura can be visual, sensory, language, or motor in nature (Kirchmann 2006). A visual aura is the most common, occurring in 99% of 163 cases of migraine with aura reviewed by Russell and Olesen (1996). A visual aura is a disturbance of vision consisting usually of flashes of light or dazzling

zigzag lines. Some patients complain of blurred vision, as though they were looking through thick or smoked glass. Sensory features of an aura occur in 31% of cases (Russell and Olesen 1996) and consist of a feeling of pins-and-needles experienced in the hand and arm as well as in the nose-mouth area on the same side as the headache. Symptoms spread up the arm and then extend to involve the face, lips and tongue. Motor symptoms are rare, occurring in only 6% of cases reviewed Russell and Olesen (1996). When present the condition is categorized as familial hemiplegic migraine (Classification Committee of the International Headache Society 2004).

Premonitory or non-headache symptoms prior to the onset of headache need to be distinguished from an aura. Such symptoms include concentration problems, depression, food craving, physical hyperactivity, irritability, nausea, phonophobia, fatigue, sleep problems, stressed feeling, stiff neck and yawning (Schoonman, 2006). The prevalence of premonitory symptoms in migraine has been reported to occur in as many as 87% of a sample of 461 sufferers of migraine (Schoonman et al 2006) and as few as 12% (Rasmussen and Olesen 1992).

Migraine without aura is more common and more disabling than migraine with aura because of a higher attack frequency (Classification Committee of the International Headache Society 2004). Estimates of one-year prevalence in the German adult general population, of equal gender mix, is 3.6% for migraine with aura and 10.6% for migraine without aura (Radtke and Neuhauser 2009). Higher prevalence occurs in females. In contrast, a recent survey of 27,840 white female health professionals aged over 45 revealed 18.4% reported migraine; 39.7% of which were categorized as migraine with aura (Schurks et al 2010). The difference in prevalence rates may be explained by differences in subjects in the two cohorts in these studies. In the German study the sample was taken from the general population, where as in the second study the sample consisted of middle-aged female health professionals.

The IHS (Classification Committee of the International Headache Society 2004) defines the diagnostic criteria for migraine with and without aura. The IHS criteria are shown in Table 2.

Table 2.2 International Headache Society classification criteria for Migraine
(Classification Committee of the International Headache Society 2004)

	Migraine without aura	Migraine with aura
A	At least 5 attacks each fulfilling items B, C, and D	At least 2 attacks each fulfilling B, C, and D
B	Headache attacks lasting 4-72 hours	Aura consisting of at least one of the following, but no motor weakness: <ul style="list-style-type: none"> (i) Fully reversible visual symptoms including positive features and/or negative features (ii) Fully reversible sensory symptoms including positive features (ie, pins and needles) and/or negative features (ie, numbness). (iii) Fully reversible dysphasic speech disturbance.
C	Headache with at least two of the following characteristics: <ul style="list-style-type: none"> (i) Unilateral location (ii) Pulsating quality (iii) Moderate or severe intensity (iv) Aggravation by or causing avoidance of routine physical activity 	At least 2 of the following: <ul style="list-style-type: none"> (i) Homonymous visual symptoms and/or unilateral sensory symptoms. (ii) At least one aura symptom developing gradually over ≥ 5 and/or different aura symptoms occurring in succession over ≥ 5 minutes. (iii) Each symptoms lasting ≥ 5 and ≤ 60 minutes
D	During headache at least one of the following: <ul style="list-style-type: none"> (i) Nausea and/or vomiting (ii) Photophobia and phonophobia 	Headache (fulfilling criteria B, C, and D for migraine without aura) begins during the aura or follows aura within 60 minutes
E	Not attributed to another disorder	Not attributed to another disorder

Despite these criteria the diagnosis of migraine can be difficult and many patients receive an incorrect diagnosis (Pfaffenrath and Kaube 1990; Moeller et al 2008). This may be explained by the complex nature of the symptoms or the presence of a number of different headache forms in the same patient. One study revealed that 33% of patients with CGH also met the IHS criteria for migraine (Vincent and Luna 1999).

2.4.2 Cervical movement impairment in headache

Neck pain and neck stiffness are common accompaniments of migraine (Schoonman et al 2006; Calhoun et al 2010). In addition there is a frequent association between headache and upper body musculoskeletal symptoms (Hagen et al 2002). Between 1995 and 1997 Hagen et al (2002), invited all 92,566 adults in Nord-Trondelag County in Norway to participate in a health survey. A total of 51,050 (55%) people responded to questions concerning headache and musculoskeletal symptoms. Both migraine and non-migrainous headache were strongly associated with musculoskeletal symptoms. The prevalence of chronic headache (headache >14 days/month) was more than four times higher (OR = 4.6; 95% CI 4.0-5.3) in the group of individuals with musculoskeletal symptoms than in those without. Individuals with neck pain were more likely to suffer from headache when compared with those with musculoskeletal symptoms in other areas.

Due to the high presence of neck pain in migraine, it is understandable the presence of cervical musculoskeletal dysfunction in people with this headache form has been examined. A recent systematic review sought to evaluate the strength of the evidence for the role of cervical musculoskeletal dysfunction in migraine (Robertson and Morris 2008). In this review, electronic database searches up to April 2006 were performed, and 17 studies selected for review. Two independent reviewers using a customized checklist assessed the methodological quality of the included studies. The review found that inter-subject differences were inadequately reported and controlled. This resulted in grouping of participants with varying pathologies and symptoms. Furthermore, a diverse range of assessment procedures was used by the reviewed studies, which made comparison of their findings difficult. Despite these methodological flaws, this systematic review of the literature found that there is

currently no convincing evidence to confirm the presence of musculoskeletal impairment in migraine.

Since this review a number of additional studies have investigated the presence of cervical movement impairment in different headache forms. In the studies published since 2006 there appears to be some disagreement as to the presence of cervical movement impairment in migraine. One study reported impairment (Bevilaqua-Grossi et al 2009) while others found no impairment (Oksanen et al 2006; Amiri et al 2007; Jull et al 2007). In each study cervical range of motion was assessed in a consistent manner, using the same measurement device. The discrepancy in study findings may be explained by the differences in subjects within the different study cohorts. Amiri et al (2007) investigated 108 community-based volunteers with two or more concurrent frequent intermittent headache forms. Jull et al (2007) investigated 73 community-based volunteers, with migraine, TTH, and CGH. Oksanen et al (2006) investigated children in the community, with headache identified by a questionnaire. In that study 59 children had migraine, 65 had TTH, and 59 were asymptomatic controls.

In contrast, in the only study to find cervical movement impairment in migraine (Bevilaqua-Grossi et al 2009), female subjects only were selected from a headache clinic. Each group comprised 15 subjects of either transformed migraine, migraine without aura, or asymptomatic controls. People with transformed migraine had movement impairment in more directions of their cervical spine range of motion than people with migraine without aura. For individuals with migraine without aura, only cervical right rotation was significantly different from asymptomatic controls. However, no differences were found in cervical range of motion between transformed migraine and migraine without aura. These differences are not consistent with other reports (Oksanen et al 2006; Amiri et al 2007; Jull et al 2007). This difference may be accounted for by the small sample size, single female gender, and difference in subject recruitment in the study by Beviaqua-Grossi et al (Bevilaqua-Grossi et al 2009).

If cervical movement impairment was a function of headache frequency, it would be expected that a greater reduction in cervical range of motion would be found in people with transformed migraine relative to those who had migraine without aura, but this is not the case (Bevilaqua-Grossi et al 2009). However the

study authors suggested that their study sample was not sufficiently large to expose such a difference.

A single factor of cervical musculoskeletal function may not be sufficient to distinguish people with different headache forms. Jull et al (2007) examined a range of different markers of cervical musculoskeletal function in 73 community-based volunteers, of whom 22 had migraine, 33 had TTH, and 18 had CGH. Range of movement, manual examination of cervical segments, cervical flexor and extensor strength, the cranio-cervical flexion test, cross-sectional area of selected extensor muscles at C2 and cervical kinaesthetic sense were measured by a blinded examiner. There was no evidence that the cervical musculoskeletal impairments were present in the migraine and TTH groups. Findings indicated that a combination of factors were best able to identify CGH with 100% sensitivity and 94% specificity. The combination of factors included cervical movement impairment in the cardinal planes, in association with evidence on manual examination of upper cervical joint dysfunction and impairment identified by the craniocervical flexion test. While Jull et al's (2007) report is very useful, further examination of different aspects of cervical movement impairment in migraine, particularly in patients with associated neck pain, are required to consolidate this information.

2.4.3 Mechanisms of migraine

The pathophysiological mechanisms underlying migraine remain poorly understood. Previously migraine was thought to be primarily a vascular disorder, or due to cortical spreading depression (spreading wave of depolarization of the brain). Recent reviews point to abnormality of brain function as the primary cause of pain leading to a chain of events in the periphery (Buzzi and Moskowitz 2005; Olesen 2006; Goadsby et al 2009). Altered brain function consists of dysfunction or dysmodulation of sensory networks with the dominant disturbance affecting abnormal processing of essentially normal neural traffic (Goadsby et al 2009). Pain of migraine has been likened to neuropathic pain, but in migraine there is no nerve injury per se (Dodick and Silberstein 2006). In simple terms migraine pain can be thought of as an altered perception of normality, such that normal sensory input is misinterpreted as pain (Gantenbein and Sandor 2006).

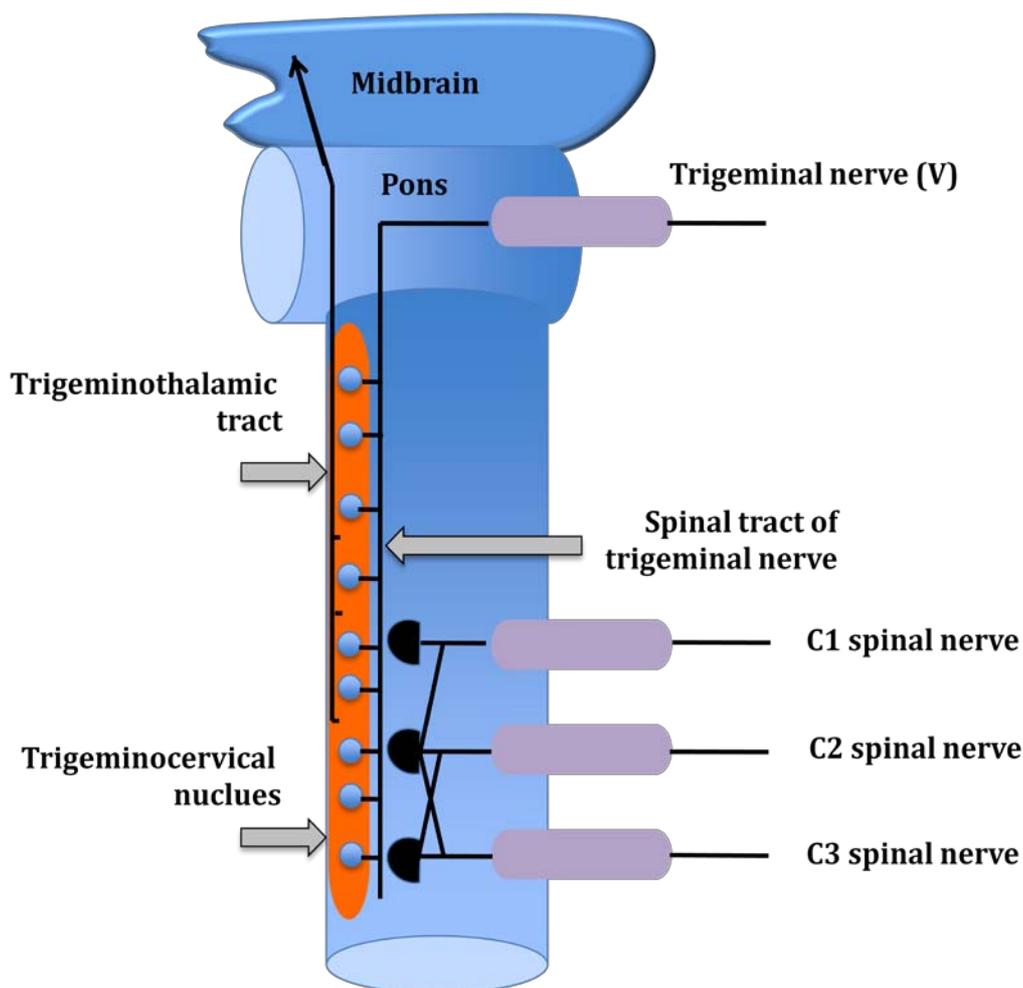


Figure 2.1: Anatomy of the Trigemincervical nucleus (adapted from Bogduk and Govind (2009))

The neuroanatomical substrate for migraine and other headache forms is the trigemincervical nucleus (TCN), which lies in the upper cervical cord and brainstem (Figure 1) (Niere 2009). Migraine pain is experienced in the head and neck in the region innervated by the cutaneous afferents of the trigeminal and C1 to C3 nerves, all of which have input into the TCN (Robertson and Morris 2008). In this nucleus, trigeminal and cervical nociceptive afferents converge onto common second-order neurons in the trigeminal nerve spinal tract (Bogduk and Govind 2009).

The migraine pain process is likely to be a combination of direct factors, i.e. activation of the trigeminal nociceptors supplying pain-producing intra- and

extracranial structures (dura mater, mucosal membranes of the sinuses, conjunctiva, eyelid and intracranial vessels among others), in concert with a reduction in the normal functioning of the centrally mediated endogenous pain control pathways that normally gate that pain (Goadsby et al 1991). Thus there are both central and peripheral mechanisms involved.

Central sensitization of the TCN and peripheral sensitization of the trigeminal and cervical afferents is postulated as the essence of the pathophysiology of migraine and other headache forms (Dodick and Silberstein 2006; Niere 2009).

The peripheral component of migraine involves the release of chemicals that increase nociceptor drive to an already sensitized TCN. Moskowitz (1990) suggests that the pain of migraine may be a form of sterile neurogenic inflammation. This may, in part, be explained by the release of a number of neurochemicals including substance P and calcitonin gene related peptide together with the formation of nitric oxide from sensory afferent terminals of the trigeminal nerve (Olesen 2008). Release of these chemicals causes intracranial plasma extravasation and other vascular changes (Goadsby et al 2009) inducing peripheral sensitization.

Lending support for vascular dysfunction contributing to the peripheral component of migraine are studies showing that distension of the intracranial vessels causes referred pain in the ophthalmic division of the trigeminal nerve (Martins et al 1993; Nichols et al 1993). However in people with migraine, dilation of blood vessels does not coincide with pain (Tegeler et al 1996). So it is probable that blood vessel dilation is a consequence of vasoactive peptides release associated with pain rather than the cause of pain itself (May et al 2001). Trigeminal nerve induced neurogenic inflammation may also explain the associated features of migraine, which include conjunctival injection, tearing and rhinorrhoea (Buzzi and Moskowitz 2005). Such associated autonomic like symptoms occur in up to 45% of those with more severe migraine (Urban and Gebhart 1999).

Central modulation of the sensitization of the TCN is very complex and not clearly understood but may potentially involve a number of different higher centers including the cortex, thalamus and hypothalamus. These centers modulate the TCN and thereby influence the transmission of pain through descending inhibition acting through the nucleus raphe magnus (Lambert et al 2008) and ventrolateral periaqueductal grey (Goadsby et al 2009).

Lambert et al (2008) suggests that the nucleus raphe magnus is modulated by cortical mechanisms and experimental stimulation of this region of the brain causes marked inhibition of the TCN. In addition the inhibitory effects of the nucleus raphe magnus can be prevented by cortical spreading depression waves (the basis for the aura), further suggesting an indirect modulation of the TCN by cortical activation via the cortico- nucleus raphe magnus -trigeminal neuraxis.

As postulated by Goadsby et al (2009), the ventrolateral periaqueductal grey appears to have influence on the TCN as experimental stimulation of neurons emanating from this region inhibits activity in the TCN. Similarly electrical or chemical stimulation of the hypothalamus causes inhibition of the TCN and thereby reduces nociceptive traffic through this nucleus. Thus the pathway for hypothalamus induced inhibition of the TCN is via the ventrolateral periaqueductal grey

2.4.4 Management of Migraine

Current management of migraine includes abortive medication, prophylactic drug therapy, non-pharmacological interventions (including physical treatment), and management of symptomatic medication overuse (Mueller 2007).

A variety of different medication classes are used to abort headache including non-steroidal anti-inflammatory drugs used early in headache initiation and triptans or ergotamines for worsening headache (Hershey, 2010). Prophylactic medications are usually prescribed for people with more than four headache attacks per month. Medication is taken daily to reduce headache frequency, decrease headache intensity, and/or allow for improved abortive management of migraine (Mueller 2007). Drugs that have been used for prevention of migraine include anti-depressants, anti-hypertensives, anti-histamines or anti-serotonergics, and anti-epileptics (Mueller 2007). Despite published guidelines for the pharmacological management of migraine a sizable proportion of people who suffer from migraine use medications that are not first-line (Bigal et al 2009).

Behavioural management includes cognitive behavioral therapy and bio-behavioral training (ie, biofeedback, relaxation training, and stress management). Behavioral approaches to migraine management in conjunction with drug management show promise (Buse and Andrasik 2009). However, the availability of

programs to bring these approaches to people with migraine is limited, and their efficacy is not well established. Informing people about realistic treatment expectations, possible delayed efficacy of medications, and avoidance of headache triggers, may also be helpful in headache management (Mueller 2007).

Physical treatments for migraine include massage therapy, physiotherapy, osteopathy and chiropractic among others (Biondi 2005). The reason people seek physical treatment for their headache is that they commonly experience neck pain either before or during a headache attack (Calhoun et al 2010). Hence they have a belief that their neck is the source of the head pain and treatment to the neck might alleviate it. Unfortunately quality studies are lacking to support the use of physical treatment for migraine (Biondi 2005). This finding was broadly supported by a Cochrane review of non-invasive physical treatments for chronic/recurrent primary headache (Bronfort et al 2004). That review concluded that the evidence associated with spinal manipulation indicates that it has only a short-term effect, similar to that of a commonly used, effective drug amitriptyline, but that study was of low-level methodological quality (Nelson et al 1998). In view of this, one published guideline did not recommend the use of manual therapy for the treatment of migraine (Scottish Intercollegiate Guideline Network 2008).

Other possible treatment options with weaker evidence for effectiveness are electrotherapy modalities. For TTH, there is evidence that adding spinal manipulation to massage is not effective. The lack of evidence for manual therapies for TTH was also reported in a more recent review (Fernandez-de-Las-Penas et al 2006). Hence it appears that physical treatment is not effective in the long-term management of patients with either migraine or TTH.

The preceding section has described the incidence, pathophysiology, classification and management of primary headache disorders with an emphasis on migraine. From this information it can be concluded that primary headache such as migraine and TTH are not relieved by physical modalities. In the following section, secondary headache will be presented. In contrast to primary headache, there is evidence that physical treatment is effective for some forms of secondary headache such as CGH. This makes differentiation of CGH from primary headache very important, as it enables targeted intervention, which is likely to be more effective. For example in one small case series of people with headache originally diagnosed as

migraine, all of whom were un-responsive to treatment for migraine, all subjects gained long-term relief following treatment designed for CGH (Yi et al 2005). In that case series migraine was mistakenly diagnosed for CGH. As migraine and CGH share many clinical features (including the presence of neck pain and possibly cervical movement impairment) more research is required to investigate other means of differentiating between them.

2.5 SECONDARY HEADACHE

Secondary headache is defined by the IHS (Classification Committee of the International Headache Society 2004) as headache that occurs in close temporal relationship to another disorder to which it is attributed. In addition, headache is greatly reduced or resolves after successful treatment or spontaneous remission of the causative disorder.

According to the IHS (Classification Committee of the International Headache Society 2004) the major categories of secondary headache include:

- “1. Headache attributed to head and neck trauma
2. Headache attributed to cranial or cervical vascular disorder
3. Headache attributed to non-vascular intracranial disorder
4. Headache attributed to a substance or its withdrawal
5. Headache attributed to infection
6. Headache attributed to disturbance of homeostasis
7. Headache or facial pain attributed to disorder of the cranium, neck, eyes, ears, nose, sinuses, teeth, mouth or other facial or cranial structures
8. Headache attributed to psychiatric disorder”

p. 7

In addition to these 8 major secondary categories and 4 major primary categories, further sub-division is possible. For example CGH is coded as ICHD 11.2.1, and is a sub-category of headache attributed to disorder of the neck. This category also contains ICHD 11.2.2 (headache attributed to retropharyngeal tendonitis) and ICHD 11.2.3 (headache attributed to craniocervical dystonia).

The IHS lists more than 180 different forms of secondary headache (Classification Committee of the International Headache Society 2004), although more are described but not recognized or not listed by the IHS. Due to the large number of secondary headache forms, a detailed description of the prevalence,

pathophysiology, and clinical identification of each of these headache forms is beyond the scope of this thesis.

As the headache symptoms of secondary headache are associated with many and varied disorders and pathophysiology, the underlying pain mechanisms are also likely to be many and varied. The principal mechanism underlying headache symptoms in the majority of secondary headache disorders is based on a concept of convergence. Nociceptive afferents converge onto common second-order neurons in the brainstem and upper part of the spinal cord, together with trigeminal nerve afferents (Bogduk and Govind 2009). This leads to a loss of somato-sensory spatial sensitivity. Hence afferent input from a secondary headache disorder (such as infection of the sinuses) leads to symptoms of headache. This concept is described in more detail in a subsequent section on CGH.

It is important to recognize that, in contrast to primary headache, secondary headache arises from a wide variety of different specific disorders. Indeed, as part of the IHS classification criteria for secondary headache (Classification Committee of the International Headache Society 2004) the disorder must greatly reduce after successful treatment of the specific causative disorder.

Thus in effect the diagnosis is made after the patient has recovered. These criteria have been recently questioned and a new set of criteria proposed (Olesen et al 2009) that do not include section D of the IHS classification (Headache is greatly reduced or resolves within 3 months). These criteria are shown in Table 3.

The reasoning upon which this change in headache classification is founded, is the need to emphasize the importance of diagnosis. Basically, it should be possible for medical practitioners to diagnose the patient at the time they present, rather than after treatment has been successful (Olesen et al 2009). The original classification was designed more for the purpose of classification to facilitate scientific discussion rather than for clinical practice. An incorrect initial diagnosis is likely to lead to treatment failure, as the underlying condition will not be adequately addressed.

The incidence, pathophysiology, clinical evaluation, diagnosis and management of CGH will be extensively reviewed in Chapter 3.

Table 2.3 Criteria for classification of secondary headache (Olesen et al 2009)

	Secondary headache
A	Headache of any type, fulfilling criteria C and D
B	Another disorder scientifically documented to be able to cause headache has been diagnosed
C	Evidence of causation shown by at least two of the following: <ol style="list-style-type: none"> 1. Headache has occurred in temporal relation to the onset of the presumed causative disorder 2. Headache has occurred or has significantly worsened in temporal relation to worsening of the presumed causative disorder 3. Headache has improved in temporal relation to improvement of the presumed causative disorder 4. Headache has characteristics typical of the causative disorder³ 5. Other evidence exists of causation
D	The headache is not better accounted for by another headache diagnosis

Physical treatment has been shown to be effective for the long-term management of some but not all headache forms. Bronfort et al (2004) conducted a systematic review of randomized- and quasi-randomized controlled trials of non-invasive physical treatments used to treat different forms of chronic or recurrent headache. These authors searched a range of databases from their inception to 2002. Two independent reviewers abstracted trial information and scored trials for methodological quality. Outcome data were standardized into percentage point and effect size scores wherever possible. Subsequently these data were analyzed to determine the strength of the evidence of effectiveness using pre specified rules.

Twenty-two studies with a total of 2628 people (age 12 to 78 years) met the inclusion criteria. Five types of headache were studied: migraine, TTH, CGH, a mix of migraine and TTH, and post-traumatic headache. Ten studies had methodological quality scores of 50/100 or more, but many methodological limitations were identified. The conclusions from this review were that for the prophylactic treatment of CGH, there is evidence that physical treatment is effective. In contrast, as

previously presented, the physical treatment of people with migraine and TTH could not be supported.

Based in the information available in the literature, it is apparent that successful treatment using physical intervention is dependent on ensuring that only people with CGH receive this form of intervention. For example headache attributed to disorder of the sinuses is unlikely to respond to manual therapy of the cervical spine. Likewise headache associated with substance abuse is also unlikely to respond to such form of treatment. It is therefore apparent that accurate differential diagnosis is essential to ensure that appropriate treatment can be provided.

2.6 SUMMARY OF CHAPTER 2

Headache is common complaint with increasing prevalence in the third decade. Although men and women report headache, women suffer more often from severe and frequent headaches. Due to its commonality, headache gives rise to substantial direct and indirect financial costs to society, causing absenteeism and loss of work productivity. As well as the financial costs, headache burdens the health care system and is one of the most common reasons for an outpatient medical consultation. In addition headache burdens the family, disrupting family life, with adverse consequences for relationships with partners, children and friends.

Classification of headache is important for management and is based on guidelines published by the IHS. Headaches may be classified as either primary where there is no other causative factor, or secondary where the headache occurs in close temporal relationship to another disorder to which it is attributed. Primary headache includes migraine without aura, many symptoms of which are similar to CGH, which is a secondary headache form. Consequently classification of headache on IHS guidelines is difficult and misdiagnosis is common. Although the IHS criteria have been in place for over 20 years there has been little in the way of research to identify the reliability and validity of the classification system.

Evaluation of functional health status for people across different headache sub-types reveals similar levels of disruption of quality of life in a range of different

domains. However, people with CGH have substantially greater loss of physical function than people with migraine or TTH.

The pathophysiological mechanisms underlying primary headache remain poorly understood but are believed to involve abnormal brain function together with sensitization of trigeminal nociceptors supplying pain-producing intra- and extracranial structures. This is in contrast to the mechanisms underlying secondary headache, including CGH. Convergence of cervical nociceptive afferents onto common second-order neurons in the trigeminal nerve spinal tract is the underlying basis of CGH.

Due to the presence of neck pain, people who suffer from primary headache, including migraine, frequently seek physical treatment to the neck. The belief is that treatment will relieve their headache. However, unlike CGH, the available evidence does not support the use of physical treatment for the management of primary headache. In view of this, guidelines for managing headache do not recommend the use of physical treatment for the treatment of migraine. Hence the importance of distinguishing subjects with CGH from subjects with migraine.

As CGH and migraine share many clinical features (including the presence of neck pain and possibly cervical movement impairment) more research is required to investigate other means of differentiating between them. Accurate diagnosis depends on a range of factors, which are presented in the following paper. Information related to the management of CGH will be presented subsequently to conclude this review.

Chapter 3: Cervicogenic headache

3.1 CLINICAL EVALUATION OF CERVICOGENIC HEADACHE

The clinical evaluation and diagnosis of CGH are examined in detail in the following paper.

Hall TM, Briffa K, Hopper D. Clinical evaluation of cervicogenic headache. *Journal of Manual and Manipulative Therapy* 2008; 16(2): 73-80

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Clinical Evaluation of Cervicogenic Headache: A Clinical Perspective

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Headache is the most prevalent pain disorder, affecting 66% of the global population¹, and thereby it represents a major health problem, disturbing both quality of life and work productivity^{2,3}. It was reported in 1999 that in the US alone, migraine headache cost American employers about \$US13 billion per year because of missed workdays and impaired work function⁴.

The International Headache Society (IHS)⁵ has classified headaches as primary, where there is no other causative factor, or secondary, where the headache occurs in close temporal relationship to another disorder to which it is attributed. A list of 14 different headache forms have been documented by the IHS⁵. Further sub-classification is possible; for example,

migraine can be sub-classified as migraine with or without aura, and again even further sub-classified. Since each form of headache has a different pathological basis and incorrect differential diagnosis will often lead to treatment failure, it is critical to correctly diagnosis the type of headache. This is of particular importance for manual therapy interventions as they are unlikely to be effective for the majority of headache forms. It should also be noted that different forms of headache may co-exist⁶, further presenting a challenge for differential diagnosis.

The most common form of headache is tension-type headache with a global prevalence of 38%¹, whereas migraine has a prevalence of 10%¹, chronic daily

headache 3%¹, and CGH 2.5–4.1%^{7,8}. Prevalence alone, however, does not provide a complete picture of the disability associated with different forms of headache, as it does not include factors such as the frequency of attacks and intensity of symptoms. Although the prevalence of CGH is considerably lower than tension-type headache and migraine, patients with CGH have a substantial quality-of-life burden, comparable to patients with migraine and tension-type headache⁹.

The pathophysiological mechanisms underlying many of the classifications of headache are not well understood. In terms of research evaluation, migraine has received the most attention, and it is believed to involve abnormal brain function¹⁰, but the pathophysiology is still not clearly defined¹¹.

CGH arises primarily from musculoskeletal dysfunction in the upper three cervical segments¹². The pathway by which pain originating in the neck can be referred to the head is the trigeminocervical nucleus (Figure 1), which descends in the spinal cord to the level of C3/4, and is in anatomical and functional continuity with the dorsal gray columns of these spinal segments¹³. Hence, input via sensory afferents principally from any of the upper three cervical nerve roots may mistakenly be perceived as pain in the head¹², a concept known as convergence.

Manual therapists have for some time treated the cervical spine in efforts

ABSTRACT: Headache is a common complaint that affects the majority of the population at some point in their lives. The underlying pathological bases for headache symptoms are many, diverse, and often difficult to distinguish. Classification of headache is principally based on the evaluation of headache symptoms as well as clinical testing. Although manual therapy has been advocated to treat a variety of different forms of headache, the current evidence only supports treatment for cervicogenic headache (CGH). This form of headache can be identified from migraine and other headache forms by a comprehensive musculoskeletal examination. Examination and subsequent diagnosis is essential not only to identify patients with headache where manual therapy is appropriate but also to form a basis for selection of the most appropriate treatment for the identified condition. The purpose of this paper is to outline, in clinical terms, the classification of headache, so that the clinician can readily identify those patients with headache suited to manual therapy.

KEYWORDS: Diagnosis, Headache Disorders, Physical Examination, Post-Traumatic Headache.

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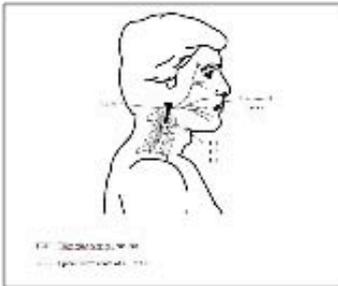


FIGURE 1. Diagrammatic representation of the anatomical basis for convergence of sensory input from the upper 3 cervical nerve roots with the trigeminal nerve in the trigeminocervical nucleus.

to relieve headache²⁴, but it is only recently that researchers have evaluated the effectiveness of such intervention for specific headache disorders. For example, Jull et al¹⁵, in a randomized controlled trial of high methodological quality, showed that manual therapy was an effective form of management for CGH. Furthermore, Bronfort et al¹⁶ reviewed the evidence for non-invasive physical treatments for five types of headache including "migraine," "tension-type," "CGH," a mix of "migraine and tension-type," and "post-traumatic" headache. They found evidence that both neck exercise (low-intensity endurance training) and spinal manipulation were effective in the short-term and long-term for CGH. In contrast, their review did not support the use of manual therapy for the long-term management of migraine or other headache forms. Similar reviews came to the same conclusions for the treatment of migraine and tension-type headache^{17,18}. In one review, it was proposed that since the aetiology of tension-type headache, CGH, and migraine are different, manual therapy approaches should be different¹⁸, but this has not been investigated. When reviewing these data, the reader must take into consideration the relative paucity and low-level of evidence available¹⁹. There is an ongoing need for high-quality randomized controlled trials investigating the effectiveness of manual therapies for headache management before it will be possible to form firm conclusions.

Nonetheless, currently available evidence suggests that manual therapy is ineffective for some forms of headache. It follows that correct classification of the headache disorder is very important so that appropriate treatment can be given, and it could be argued that manual therapists have an ethical obligation to make an accurate diagnosis so resources are not wasted on physical treatment when patients would be better directed to more appropriate therapy.

One of the common diagnostic challenges in headache evaluation is to distinguish CGH from other headache forms^{20,21}. Indeed, studies have shown that an incorrect headache diagnosis may occur in more than 50% of cases²². Diagnosis is essentially based on the presenting symptoms, together with the clinical physical examination findings²³. Similarities of signs and symptoms among the many types of headache²⁴ undoubtedly contribute to the challenge of differentiating between some headache forms, whereas those forms with unique characteristics are more readily identified.

Examination

Subjective Examination

It is of primary concern to exclude serious or life-threatening pathology such as cranial tumors, meningitis, giant cell arteritis, sub-arachnoid hemorrhage, carotid artery, or vertebral artery dissection, among others. Although these are relatively rare²⁵, the clinician should be vigilant for historical features or "red flags" suggestive of such disorders. "Red flags" include (1) sudden onset of a new severe headache; (2) a worsening pattern of a pre-existing headache in the absence of obvious predisposing factors; (3) headache associated with fever, neck stiffness, skin rash, and with a history of cancer, HIV, or other systemic illness; (4) headache associated with focal neurologic signs other than typical aura; (5) moderate or severe headache triggered by cough, exertion, or bearing down; and (6) new onset of a headache during or following pregnancy²⁶. Patients with one or more red flags should be referred

for an immediate medical consultation and further investigation.

Some headaches are easy to differentiate from CGH due to their distinctive subjective characteristics. For example, cluster headaches, paroxysmal hemicranias, and other trigeminal autonomic cephalalgias typically present with very severe unilateral but short-lasting headache. According to the IHS⁵, headache duration may be as short as 2 minutes with a frequency of 5 per day for paroxysmal hemicrania. Typically, the pain is associated with autonomic features of eye tearing, nasal stuffiness, facial sweating, and ptosis. Taken as a whole, these characteristics are not consistent with CGH and patients presenting with such symptoms should seek medical consultation, as they are unlikely to respond to manual therapy.

Migraine with aura also has distinctive symptoms²⁷, such as flickering lights or spots in the field of vision, numbness, or pins and needles, all of which are fully reversible, lasting less than 60 minutes. Typical characteristics of migraine without aura include pain of unilateral location, pulsating quality, moderate or severe intensity, lasting a fixed time period of 24–72 hours, aggravated by routine physical activity such as stair-climbing, and associated with nausea, photophobia, or phonophobia⁵.

Characteristics of chronic tension-type headache include headache lasting from 30 minutes to 7 days, of pressing or tightening quality, mild to moderate intensity, bilateral location, and no aggravation by physical activity. In addition, there should be no associated features of nausea, vomiting, photophobia, or phonophobia⁵.

The profile of sufferers of CGH varies according to the population under review. Hospital-based studies reveal an 85–88% female preponderance^{8,28}; in contrast, a large-scale community-based study revealed a 71% male preponderance⁹. This difference was explained by the reluctance of males to seek treatment. Mean age at onset has been reported as 33–43 years, and a mean duration of symptoms of 7–17 years^{7,8}. Chronicity appears to develop through increasing frequency of short-lasting

headache attacks, rather than continuous unrelenting pain.

Characteristics of CGH according to the Cervicogenic Headache International Study Group^{23,29} are shown in Table 1. Unfortunately, a number of headache characteristics are shared between the common headache forms and CGH, except for the presence of non-throbbing pain that usually starts in the neck, with episodes of varying duration²³.

Vincent and Luna³¹ examined the validity of Sjaastad et al's 1990 diagnostic criteria in patients with CGH, tension-type headache, and migraine. Patients with CGH met significantly more criteria than those with tension-type headache or migraine. However, 30% of patients with CGH met the IHS criteria for migraine, whereas only 3% of patients with CGH met the criteria for tension-type headache; the remaining 66% of patients could not be classified according to IHS criteria as having either migraine or tension-type headache. Antonaci et al³⁴ reported that at least five items of Sjaastad et al's 1990 diagnostic criteria must be present in order to establish a diagnosis of CGH. Furthermore, Vincent³¹ has shown that if seven or more of these criteria were present, then cervicogenic headache could be distinguished from migraine and tension-type headache with a high level of sensitivity and a moderate level of specificity. Moreover, if pain is first experienced in the neck and then spreads to the frontal region and is unilateral, the chance of correctly identifying patients as CGH increases significantly. While unilaterality is a strong diagnostic indicator of CGH, in clinical practice bilateral symptoms do not preclude CGH³², as there is a strong case for a "unilaterality of two sides"³².

A recent community-based study revealed differences in headache profile between sufferers of relatively "pure" CGH and "pure" migraine^{43,44}. Migraine sufferers are more likely to be female, and more frequently report nausea, photophobia, phonophobia, and throbbing pain. In addition, headache onset is in the anterior head and is infrequently brought on by mechanical provocative activity (sustained or awkward neck po-

sitioning) and exacerbated by a change in spatial orientation (standing from lying, or forward bending to upright)³⁴.

While efforts have been made to try to isolate patients with "pure" CGH from other headache forms, it is apparent that there is a significant proportion of headache sufferers who cannot be categorized into such a group as they have mixed features of CGH, migraine, tension-type headache, or other headache forms. Indeed Fishbain et al⁶ in their study of pain clinic patients presenting with headache found that 84% had neck pain. The most common predictor of headache onset across diagnostic groups was severe headache beginning in the neck, and 44% had more than one headache form. This suggests that there are patients with either concurrent headache diagnoses³⁵ or perhaps there is a continuum across different headache forms.

Taken as a whole, the information from the subjective examination should point towards the possible involvement of the cervical spine in headache pathogenesis and that further physical examination is required to confirm the diagnosis. A summary of the subjective criteria is shown in Table 2.

Physical Examination

Although up to 70% of individuals with frequent intermittent headache report accompanying neck pain^{36,37}, less than 18% are thought to be symptoms of neck pathology³⁸. One explanation for this may be the convergence of afferent information from the sensitized trigeminal afferents with the upper three cervical nerves in the trigeminocervical nucleus³⁹. In this way, pain arising in the head/face is being perceived as pain in the neck. Consequently, physical examination of the neck is a critical component of differential diagnosis^{23,35,40-42}. Physical examination criteria include clinical, laboratory, and/or imaging evidence of a disorder within the cervical spine or soft tissues of the neck known to be a valid cause of headache. In the absence of this, there should be evidence that the headache can be attributed to the neck disorder based on clinical signs

that implicate a source of pain in the neck, or abolition of headache following diagnostic blockade (pain-relieving injection) of a cervical structure or its nerve supply⁶. Essentially, any structure that is innervated by the upper three cervical nerves is a potential source of headache. Hence, the clinical examination must potentially encompass the articular, neural, and myofascial structures shown in Figure 1.

Articular System

The CGH international study group considers restricted range of motion of the neck to be one of the major diagnostic criteria for CGH²⁹. Some^{40,42,43} but not all^{44,45} studies have reported diminished cervical ROM in subjects with CGH with limitation of active movement in the sagittal plane, in particular extension, as the major loss. Other studies, however, have not found any limitations^{44,45}.

As previously stated, CGH arises primarily from musculoskeletal dysfunction in the upper three cervical segments¹². Manual examination has high sensitivity and specificity to detect the presence or absence of cervical joint dysfunction in neck pain and headache patients⁴⁶⁻⁴⁸. Moreover, Zito et al⁴² determined that the presence of upper cervical joint dysfunction measured by manual examination, in comparison to measures of posture, range of motion, cervical kinaesthesia, and craniocervical muscle function⁴⁹, most clearly identified CGH sufferers. The term *manual examination* incorporates tests of passive physiological intervertebral motion, as well as passive accessory intervertebral motion, such as posteroanterior pressures. Motion restriction and symptom responses indicate the most painful dysfunctional cervical motion segment⁴⁶⁻⁴⁸. However, these tests require a high degree of skill on the part of the therapist, and their reliability has been questioned⁵⁰. It has been suggested though that this may be a reflection of poor research methods rather than being an unreliable test⁵⁰. More recently, Jull et al⁴⁶ and Amiri et al³⁵ have condensed the manual examination proce-

TABLE 1. CGH: Cervicogenic Headache International Study Group diagnostic criteria²³.

Major criteria	
I. Symptoms and signs of neck involvement	
a) Precipitation of comparable symptoms by:	
1) neck movement and/or sustained, awkward head positioning, and/or	
2) external pressure over the upper cervical or occipital region	
b) Restriction of range of motion in the neck	
c) Ipsilateral neck, shoulder or arm pain	
II. Confirmatory evidence by diagnostic anaesthetic block	
III. Unilaterality of the head pain, without sideshift	
Head pain characteristics	
IV. Moderate-severe, non-throbbing pain, usually starting in the neck	
Episodes of varying duration, or fluctuating, continuous pain	
Other characteristics of some importance	
V. Only marginal or lack of effect of indomethacin	
Only marginal or lack of effect of ergotamine and sumatriptan	
Female gender	
Not infrequent history of head or indirect neck trauma, usually of more than medium severity	
Other features of lesser importance	
VI. Various attack-related phenomena, only occasionally present, and/or moderately expressed when present:	
a) nausea	
b) phono- and photophobia	
c) dizziness,	
d) ipsilateral "blurred vision"	
e) difficulties swallowing	
f) ipsilateral oedema, mostly in the periocular area	

ture to include only passive accessory intervertebral motion assessed using posteroanterior pressure. Identification of a pain response, rather than joint hyper- or hypomobility, simplifies the identification of cervical dysfunction, thereby reducing the skill required. However, this information on its own is not sufficient to provide adequate sensitivity and specificity to identify CGH;

other forms of assessment are required⁴⁶.

The cervical flexion-rotation test (FRT) is an objective method of determining upper cervical joint dysfunction that is showing promise in the identification of patients with CGH. The FRT (Figure 2) is a simplified form of manual examination developed to identify C1/2 dysfunction³¹. In this test procedure, the

cervical spine is fully flexed and should allow unrestricted motion at C1/2, which has a unique ability to rotate in any cervical posture. As movement at other cervical segments would be constrained by this end-range position, movement is isolated to the C1/2 segment.

Range of rotation in end-range flexion is normally 40–44° to each side^{45,52}. In contrast, subjects with C1/2 dysfunction have significantly less rotation^{20,45,53,54}. When administered by highly trained manual therapists, the FRT has high sensitivity (91%) and specificity (90%) in differentiating subjects with CGH from asymptomatic controls or subjects with migraine with aura²⁰. Data from the same study demonstrated that a range limited to 32° or less may be considered positive.

Subjects in that study were selected according to strict criteria to ensure that the comparative groups were discrete and that there was no cervical involvement in the migraine or control groups. Hence the reliability, sensitivity, and specificity determined in this study may be higher than levels occurring in a clinical environment where patients are likely to be more heterogeneous. However, similar values (diagnostic accuracy = 89%; kappa = 0.85, positive cut-off value = 33°) have been reported when the FRT was evaluated in a more heterogeneous sample including subjects with CGH arising from levels other than C1/2⁵⁵. This study also demonstrated that inexperienced examiners could use the FRT test. Although inexperienced examiners recorded larger ranges of motion for the FRT, the sensitivity (>83%), specificity (>83%), and agreement (kappa >0.67) were still within acceptable values.

Another advantage of the FRT is that it is independent of other physiological and lifestyle factors⁵⁶. In a cross-sectional study, whole cervical cardinal plane active movement, sleeping posture, age, gender, hand-dominant recreation, or occupation (activity involving repetitive use of one side of the body) were correlated with FRT mobility. Multiple linear regression analysis demonstrated that 59% of the variance in the FRT (ROM) was explained by the pres-

TABLE 2. Summary of subjective diagnostic criteria contrasting migraine and CGH^{8,34}.

	Migraine	CGH
Gender ratio	1.69 female/male	0.71 female/male
Age at onset	18 years	33 years
Headache onset	Anterior head	Posterior head/neck
Pain area	50% unilateral	Predominately unilateral
Nausea	Frequent	Infrequent
Photo/phonophobia	Very frequent	Infrequent
Throbbing pain	Frequent	Infrequent
Pain increases when bending forward	Very frequent	Infrequent
Migraine medication	Usually helpful	Not helpful
Sustained/awkward neck position provokes pain	Rare	Universal

**FIGURE 2.** The cervical flexion-rotation test.

ence of pain and cervical lateral flexion measures. Consequently, the test has utility regardless of the age, gender, or lifestyle of the patient.

Muscle System

Muscle dysfunction has also been identified as an important feature of CGH^{8,42,57,58}. It has been suggested that dysfunction may include loss of postural alignment and neuromuscular control as well as muscle weakness, endurance, and extensibility⁵⁹. A reflection of the importance of the muscle system to CGH is shown by the long-term improvement in headache symptoms as a result of exercise designed to retrain the muscle system in patients with CGH¹⁵.

Posture is an indirect measure of the functional status of the neuromuscular system. While one early study found an association between forward head posture and CGH³⁴, which has been cited in the literature, this associa-

tion has not been substantiated by more recent studies, and postural change is not a unique feature to sufferers of CGH^{42,44,60}.

Impairments in muscle strength and endurance of the deep neck flexors appear to be one of the defining features of CGH^{42,57,58}. Similar impairments were not present in migraine or tension-type headache⁶¹. The craniocervical flexion test indirectly measures deep neck flexor function⁶¹, and it has been shown to have good reliability⁵⁷. This test is performed in crook-lying, and it requires the patient to perform upper cervical flexion in five stages of increasing range, holding each position for up to 10 seconds. The range of upper cervical spine flexion has been shown using electromyography to be directly related to the activation of the deep neck flexors⁶² in asymptomatic controls. While it is not possible to directly palpate the deep neck flexors, it is possible to palpate the superficial flexors muscles, which should be minimally active during this test. One of the key features that clinically identifies deep neck flexor dysfunction is increased superficial flexor muscle during the craniocervical flexion test⁶³, in an attempt to gain range of motion.

There are a number of reports of muscle tightness^{42,57,60,63} and trigger points⁶⁴ associated with CGH. Various muscles have been implicated, including upper trapezius, sternocleidomastoid, scalenes, levator scapulae, pectoralis major and minor, and short sub-occipital extensors. In one study, muscle tightness was found in 35% of CGH subjects

compared to only 17% in migraine and 16% for tension-type headache subjects⁴²; in that study, no one muscle predominated. An earlier study found muscle tightness predominated in the upper trapezius muscle⁵⁷.

Sensorimotor disturbance has been implicated in neck disorders. Clinical measures of sensorimotor disturbance include cervical joint position sense, postural stability, and oculomotor control; these have been described elsewhere⁶⁵. Dizziness, neck pain, and headache are a common feature of sensorimotor disturbance of the cervical spine⁶⁶. However, joint position sense or cervical kinaesthesia has been shown to be no different in subjects with either migraine, CGH, or tension-type headache⁶⁶.

Neural System

The IHS⁵ recognizes a variety of neural disorders that can cause headache. These can be broadly classified under disorders of the neck and cranial neuralgias and include, among others, occipital neuralgia, neck-tongue syndrome, post-herpetic neuralgia, and trigeminal neuralgia. Classification of neuropathic pain, based on aetiology such as occipital neuralgia, has inherent problems as pathology of a nerve does not always cause pain^{67,68}. In contrast, it has been proposed that neuropathic pain be classified according to a dominance of patho-mechanisms⁶⁸. Neural tissue-related pain disorders have been classified⁷⁰ as either 1) peripheral nerve sensitization exhibiting

increased nerve trunk mechano-sensitivity; 2) denervation with neurological deficit; or 3) central sensitization showing positive features (paraesthesia, allodynia, dysaesthesia, hyperalgesia and stimulus independent pain). In the upper cervical spine, denervation disorders are relatively rare compared to the lower cervical region. In part this is due to the difference in gross anatomy, with no disc and the relatively small nerve root/spinal nerve, with comparatively more free space in the intervertebral foramen, in the upper cervical region.

In our clinical experience, the most prevalent neural disorders causing headache present with peripheral nerve sensitization but normal neurological function. Peripheral nerve sensitization can be assessed according to the principles described by Elvey and Hall⁷¹. There should be evidence of pain provocation and limitation of movement during neural tissue provocation tests, which elongate the upper cervical neural structures. In addition, there should be evidence of pain on palpation of the same tissues. An important test in this respect is upper cervical flexion, which elongates the neuromeningeal tissues in the high cervical region⁷². To distinguish pain responses of peripherally sensitized neural tissue from adjacent joints and muscles, it is important to repeat the test with the arms positioned in abduction, or the lower limbs in straight-leg-raise, to increase the mechanical provocation of, and thereby implicate, the neural tissue.

Although there is some evidence of altered responses to neural tissue provocation tests in subjects with CGH when compared to migraine⁷³, the presence of increased neural tissue mechano-sensitivity in patients with CGH is relatively rare, with the reported incidence between 7 and 10%⁴². Nevertheless, it is important to identify these patients as they usually respond inadequately to joint mobilization or motor control retraining.

Headache patients with a dominance of peripheral nerve sensitization usually present with a very typical pattern. They tend to adopt an antalgic poker chin posture. Active upper cervical flexion is diminished in range, and in

long sitting this movement is more provocative. Similar restriction is demonstrated passively in supine as previously discussed. Finally, palpation of nerve trunks arising from the upper cervical spine is also provocative, for example, the greater occipital nerve, lesser occipital nerve, or third occipital nerve.

In this article, we have outlined various aspects of examination that will assist clinicians in identifying headache patients with disorders that are likely to respond to manual therapy intervention. While the individual items of assessment may be of importance, the time-honored approach is to consider the whole examination rather than individual components. This has been supported by a recent study that sought to identify which aspects of the physical examination distinguished subjects with CGH from migraine and tension-type headache. Analysis revealed that collectively, restricted neck movement, in association with evidence on manual examination of upper cervical joint dysfunction and impairment in the deep neck flexors identified by the craniocervical flexion test, had 100% sensitivity and 94% specificity to identify CGH⁴⁶. While these three features have been shown to be important in identifying CGH, another study has shown no clear pattern of predictors from variables in subjects' demographics and headache history, which might identify those who achieve a significant reduction in headache following manual therapy intervention⁷⁴.

Conclusion

Headache is a very common complaint, arising from a variety of different causes, not all of which are amenable to manual therapy intervention. The key to identifying appropriate patients is to interpret information from all aspects of the examination including the subjective history. This article has outlined the now considerable evidence underpinning the identification of patients with CGH.

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3.2 MANAGEMENT OF CERVICOGENIC HEADACHE

Although there have been many treatments suggested for CGH, few have been tested and even fewer have been proven successful (Bogduk and Govind 2009). Treatment varies from pharmacological management to invasive procedures such as joint arthrodesis, cervical fusion, radiofrequency neurotomy and steroid injections into facet joints. All of the invasive, procedures are costly, with many showing limited evidence of success (Bogduk and Govind 2009).

In contrast, physical treatment is non-invasive and there is at least moderate evidence of success based on a number of different systematic reviews of the literature (Bronfort et al 2004; Gross et al 2004; Fernandez-de-Las-Penas et al 2005; Bronfort et al 2010). Physical treatments include manipulation, mobilization, exercise, massage, electrotherapy modalities, and acupuncture among others. In the most recent systematic review Bronfort et al (2010) examined the scientific evidence regarding the effectiveness of manual treatment (not including exercise) for the management of a variety of musculoskeletal and non-musculoskeletal conditions including CGH. In this review only randomized controlled trials and evidence-based clinical guidelines were included and were identified by database searches. All publications were formally quality-assessed by two reviewers using a scale assessing the risk of bias recommended for use in Cochrane systematic reviews. This review found moderate quality evidence that spinal manipulation is more effective than placebo manipulation, friction massage, and no treatment. In addition there was moderate quality evidence that self-mobilizing natural apophyseal glides are more effective than placebo but inconclusive evidence in an unclear direction for the use of mobilization.

Since this systematic review, additional studies have shown that physical treatment is effective for the prophylactic management of CGH (Haas et al 2010a; Haas et al 2010b). In the study by Haas et al (Haas et al 2010a) 80 participants were randomized to receive spinal manipulation or a control. Improvements in CGH in the prior four weeks were dichotomized into a binary outcome at two thresholds: 30% representing minimal clinically important change and 50% representing clinical success. Groups were compared at 12 and 24-week follow-up using binomial regression to compute the adjusted risk difference between groups and number

needed to treat after adjusting for baseline differences between groups. For headache pain, clinically important improvement (30% or 50%) was more likely for spinal manipulation. The conclusion from this study was that spinal manipulation demonstrated a benefit in terms of a clinically important improvement of CGH.

A novel form of physical management for CGH, described by Mulligan (2006), was investigated in a randomized controlled trial (Hall et al 2007). Thirty-two subjects with CGH and a limitation of passive upper cervical range of motion were randomized into a specific novel exercise or placebo group. After an initial instruction and practice visit in the clinic, interventions consisted of exercises applied independently by the subject twice daily at home on a continual basis. Headache symptoms were determined by a headache index over time, assessed by questionnaire pre-intervention, at 4 weeks post-intervention, and at 12-months post-intervention. Headache index scores were significantly less in the physical intervention group at 4 weeks and 12-months when compared to the placebo group with an overall reduction of 54% for the individuals in the physical intervention group.

Success of physical treatment in the management of CGH relies in the first instance on an accurate differential diagnosis of a cervical musculoskeletal origin to the headache (Jull 1997). Physical treatment consists of preventative intervention together with intervention designed to relieve symptoms. Preventative intervention is aimed at addressing the underlying cause and should be expected to have a significant impact on headache characteristics including frequency, intensity and duration (Biondi 2005).

Headache is a complex problem, involving multiple dimensions or aspects. Consequently, Andrasik et al (2005) have suggested that outcome of treatment for headache should be assessed using a range of different measurement tools. These tools should include headache diaries, headache symptom questionnaires, headache functional disability questionnaires as well as indices measuring headache burden and severity. In addition, because headache improvement can occur in a variety of ways, researchers are advised to include in their assessment of outcome different parameters evaluating all aspects of headache. These parameters include primary and secondary measures of headache. Primary measures of headache include attack frequency or headache days per month. Secondary measures of headache include

headache indices, headache duration, and peak headache severity. Additional parameters include secondary measures of disability and quality of life and secondary non-headache measures including medication consumption, psychiatric symptoms, stress and coping, and treatment satisfaction.

Simply measuring headache frequency, intensity and duration as an outcome measure may be problematic as people tend to either underestimate or overestimate their symptoms depending on how they feel at the time they are asked (Wittrock and Foraker 2001). These memory biases mean that global, retrospective measures of headache can be heavily influenced by current pain experience and expectations (Andrasik et al 2005). Hence evaluating a range of headache parameters unrelated to pain intensity, frequency and duration are likely to give a clearer, bias free estimate of change.

As cervical movement impairment defines CGH, it would seem reasonable to infer that reduction in impairment deficits should occur as CGH symptoms improve. It has been suggested that the FRT can be used as an outcome measure when managing individuals with CGH (Hall et al 2007). It is apparent that the FRT is a reliable measure of cervical movement impairment on a test-retest basis, but the stability of the measurement over time has not been tested. In addition the magnitude of error, or minimal detectable change (MDC), associated with the test is unknown. A final consideration, when using the FRT as an outcome measure, is the influence of pain at the time of testing on test interpretation and range of motion. All are important criteria when using the FRT to evaluate CGH over time.

Typically symptoms of CGH are episodic in nature, spanning days or weeks between headache attacks. Management of CGH frequently requires long periods between evaluation sessions, to determine changes in headache symptoms. If the FRT is to serve as a useful measure of impairment in CGH evaluation, and to evaluate treatment outcome, then measurement of mobility recorded during the FRT must be demonstrated to be stable over time, with minimal error, in individuals with CGH.

An additional consideration for the use of the FRT as an outcome measure is whether range of motion recorded during the test is related to the severity of headache symptoms. Findings from two studies (Hall and Robinson 2004; Ogince et al 2007) investigating this relationship are inconsistent. This inconsistency may

relate to the small sample size or homogenous nature of the samples in both studies. Knowledge of this relationship is important from a diagnostic point of view as well as for the use of the test as a treatment outcome measure. Further studies are required to determine the relationship between headache symptoms and range of motion deficits identified by the FRT.

3.3 SUMMARY OF CHAPTER 3

CGH is a sub-category of secondary headache with an estimated prevalence of 4.1% in the general population. Despite the low prevalence, people with CGH have a substantial quality of life burden comparable to migraine and TTH.

Diagnostic criteria for CGH have been established but many of the subjective features of CGH are common with other headache forms, in particular migraine. Indeed studies have shown that an incorrect diagnosis may occur in 50% of cases. In addition more than one headache form may co-exist in any patient with headache. Hence CGH diagnosis relies heavily on physical examination. While there is some evidence of cervical musculoskeletal dysfunction in headache disorders other than CGH, it has been shown that collectively, restricted neck movement, in association with evidence on manual examination of upper cervical joint dysfunction and impairment in the deep neck flexors identified by the craniocervical flexion test, had 100% sensitivity and 94% specificity to identify individuals with CGH from those with migraine or TTH.

The FRT is one form of manual examination purported to identify symptoms arising from and dysfunction at the C1/2 segment, but the validity of this test has not been established. Test and re-test reliability as well as values for normal range of movement and range for subjects with CGH have been established. However long-term stability and MDC of the FRT has not been tested. Such information is important when using the FRT over prolonged time periods, as is commonly the case when treating patients with CGH. In addition the diagnostic accuracy of the FRT has been established in homogenous, carefully selected populations where comparison groups were either migraine with aura or asymptomatic controls. However, no studies have investigated the diagnostic accuracy of the FRT in heterogenous groups.

For example, no study has investigated the diagnostic accuracy of the FRT in identifying CGH from migraine without aura or those with MHF.

The presence of pain at the time of testing may influence range of motion recorded during the FRT. This may influence the diagnostic accuracy of the FRT in CGH diagnosis. In addition this may influence the examiners interpretation of range of motion data when the FRT is used as an outcome measure following an intervention for headache. No studies have investigated whether the presence of pain influence examiner interpretation of the FRT.

There is also uncertainty about the relationship between headache symptoms and impairment measured by the FRT. One report found a strong correlation between an index of headache severity and range recorded during the FRT but another study did not. Further studies are required to investigate this.

One final consideration regarding the diagnostic accuracy of the FRT is the frequency with which the C1/2 segment is the cause of CGH. The FRT is a more valuable clinical test if there is a high frequency of involvement of the C1/2 segment in CGH. The lower the frequency of involvement, then the lower the diagnostic accuracy of the test. Previously the author conducted a survey investigating the frequency with which the C1/2 segment is the cause of CGH, but the study was of low methodological quality (Hall et al 2003). In that study, the C1/2 segment was the most common symptomatic cervical segment. Further studies are required to investigate this.

The studies undertaken to examine the issues identified related to the value of the FRT in establishing a diagnosis of CGH and its management will be presented in the following chapter.

The Studies

Part A – Study 1 and 2

- Reliability and diagnostic accuracy of the flexion-rotation test

Part B – Study 3 and 4

- Validity of the flexion-rotation test

Part C – Study 5 and 6

- Clinical utility of the flexion-rotation test

Chapter 4: Part A

Study 1 and 2

- Reliability and diagnostic accuracy of the flexion-rotation test

4.1 RESEARCH QUESTIONS

From the literature review it is apparent that the FRT is a reliable measure of cervical movement impairment but the stability of the measurement over time has not been tested. In addition the magnitude of error, or MDC, associated with the test is unknown. Both are important criteria, particularly when using the FRT to evaluate CGH, symptoms of which are episodic in nature, spanning days or weeks between headache attacks. Management of CGH frequently requires long periods between evaluation sessions, to determine changes in headache symptoms. If the FRT is to serve as a useful measure of impairment in CGH evaluation, and to evaluate treatment outcome, then measurement of FRT mobility must be demonstrated to be stable over time, with minimal error, in individuals with CGH.

Hence the following research questions were developed for Study 1:

1. Does range of motion recorded during the FRT and examiner interpretation of the test finding vary over days or weeks
2. What is the error (standard error of measurement and MDC) involved in repeated measurement of the FRT over days or weeks?

4.2 STUDY 1 OBJECTIVES

The objectives of this study were to identify the long-term stability of the FRT measurements, to investigate the long-term reliability of test interpretation and to establish the MDC.

As the FRT has been shown to have excellent sensitivity, specificity and examiner agreement in the diagnosis of CGH in highly controlled studies further studies were developed to evaluate the diagnostic accuracy of the FRT in “real world” clinical situations. In clinical practice people who suffer from headache frequently present with a range of different headache forms, sometimes with MHF in an individual person. The diagnostic challenge is to differentiate migraine from CGH, and to identify the presence of CGH in individuals with MHF. Hence there is a need to identify the diagnostic accuracy of the FRT in heterogeneous samples of people with CGH, migraine and MHF.

Hence the following research questions were developed for Study 2:

1. What is the diagnostic accuracy of the FRT in differentiating people with CGH from migraine without aura and those with MHF
2. Does range of motion values for the FRT differ in people with migraine, MHF and CGH?

4.3 STUDY 2 OBJECTIVES

The objectives of this study were to identify the diagnostic accuracy of the FRT in CGH evaluation. An additional aim was to compare the findings of the FRT between subjects with CGH, migraine without aura, and MHF.

4.4 METHODOLOGY FOR STUDY 1 & 2

4.4.1 Study design Study 1

A repeated measures longitudinal design was used to investigate the stability of FRT measurements over time (days and weeks), to investigate the long-term reliability of test interpretation (weeks), and to establish the MDC in subjects with CGH.

4.4.2 Study design Study 2

A single blind comparative measurement study design was used to determine whether range recorded and examiner interpretation of the FRT differs between subjects with MHF and those with Migraine and CGH

4.4.3 Sample size calculation

Sample size estimate for both studies were based on data collected from previous studies (Ogince et al 2007; Hall et al 2008).

4.4.3.1 Study 1

A priori power analysis determined that a sample size of 15 subjects with CGH was required to obtain a statistical power of 0.80. This was based on 4 repeated measurements, with a predetermined coefficient of reliability of 0.9 and a calculated

effect size of 0.3 (Eliasziw et al 1994; Faul et al 2007). Ten asymptomatic subjects were included to reduce examiner bias but were not included in the analysis.

4.4.3.2 Study 2

Based on a single measurement of the FRT, with a standard deviation of 11 degrees for range of motion, and a calculated effect size of 0.4 (Eliasziw et al 1994; Faul et al 2007), *a priori* power analysis determined that a total sample size of 60 subjects (20 in each group, consisting of Migraine, CGH, or MHF) was required to obtain a statistical power of 0.80 with alpha set at 0.05.

4.4.4 Subjects

Recruitment for subjects in both studies was as follows: Subjects with CGH and migraine without aura were recruited in a manner of convenience through advertisements placed in local newspapers and through the University website. Asymptomatic subjects were volunteers recruited from Curtin University students.

4.4.4.1 Inclusion criteria

CGH - Subjects were selected based on criteria developed by the IHS (Classification Committee of the International Headache Society 2004) and Sjaastad (1998). These included a primary complaint of side dominant headache without side shift, headache preceded by neck pain, and headache precipitated or aggravated by neck movement or posture. Additionally headache frequency needed to be at least once per week and episodic headaches needed to have been present for more than the previous 3 months.

Migraine - Subjects were selected according to the IHS diagnostic criteria for migraine without aura (Classification Committee of the International Headache Society 2004). These criteria are at least five headache attacks, each lasting 4-72 hours, which have at least two of the following characteristics: unilateral location; pulsating quality; moderate or severe intensity; aggravation by or causing avoidance of routine physical activity. In

addition one of the following is present during headache: nausea and/or vomiting; photophobia and phonophobia. Finally the headache may not be attributed to another disorder.

MHF - Subjects were selected according to the IHS diagnostic criteria (Classification Committee of the International Headache Society 2004), where an individual with headache could be categorized as having more than one form of headache.

Asymptomatic - In Study 1, asymptomatic subjects without neck pain or CGH were matched for age to the subjects with CGH.

4.4.4.2 Exclusion criteria

Subjects were excluded in either Study 1 or 2 if they had inability to communicate, inability to tolerate the FRT, if they were receiving physical treatment for their neck (for example physiotherapy or chiropractic), and if they did not provide informed consent

CGH – Subjects with CGH were excluded if they had continuous headache for more than 48 hours and headache was not of cervical origin.

Migraine – Subjects with migraine were excluded if the headache could be attributed to another headache form.

Asymptomatic – Subjects were excluded if they had significant history of neck pain or headache (once per month or more).

All participants were given a written information sheet explaining the procedure prior to testing and gave written consent. The Human Research Ethics Committee of Curtin University of Technology granted approval for this study. Subject information sheets, consent forms, and ethical approval documentation are presented in the appendix section (Chapter 10).

4.4.5 Variables

4.4.5.1 Study 1

Independent variables

- Two groups - CGH and asymptomatic
- Time (days)

Dependent variables

- Range of rotation to the left and the right (degrees) recorded during the FRT measured by a modified cervical range of motion device (CROM)
- Examiner interpretation of the FRT (positive or negative)

4.4.5.2 Study 2

Independent variables

- Groups – CGH, migraine and MHF

Dependent variables

- Range of rotation to the left and the right (degrees) recorded during the FRT, measured by a CROM device
- Examiner interpretation of the FRT (positive or negative)
- Subject and headache characteristics including gender, age, history of headache, dominant side of headache, anti-migraine medication helps, forward bend increases headache, presence of photophobia or phonophobia, nausea, neck movement or positions provoke headache, neck symptoms precede headache, and headache of pulsating quality.

Reliability of measures

Previous studies conducted by the author have shown excellent inter-tester

and intra-tester reliability of FRT measurements, when the test is followed by an immediate re-test, for both asymptomatic subjects, and subjects with CGH (Hall and Robinson 2004; Ogince et al 2007). The examiners in these previous studies were also used for the current study.

4.5 STUDY 1

Study 1 is encapsulated in the following publication.

Hall T, Briffa K, Hopper D, Robinson K. 2010 Long-term stability and minimal detectable change of the cervical flexion-rotation test. *Journal of Orthopaedic and Sports Physical Therapy*. 40(4):225-229.

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[RESEARCH REPORT]

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Long-Term Stability and Minimal Detectable Change of the Cervical Flexion-Rotation Test

One of the common diagnostic challenges in headache evaluation is to distinguish cervicogenic headache (CGH) from migraine.¹⁵ In fact, studies have shown that an incorrect headache diagnosis may occur in more than 50% of cases.²³ Because migraine and CGH have very different underlying pathological mechanisms, incorrect diagnosis will most likely lead to treatment failure; hence, accurate diagnosis is essential, so that treatment can be directed appropriately.

Reported guidelines for headache diagnosis are based on the presenting symptoms, together with the clinical physical examination findings.²⁴ Zito et al²⁰ deter-



mined that the presence of upper cervical joint dysfunction, measured by manual examination,²⁶ most clearly identified individuals with CGH. Manual examina-

tion has high sensitivity and specificity to detect the presence or absence of cervical joint dysfunction in patients with neck pain and headache.^{14,25,25} However, these tests require a high level of clinical skill on the part of the therapist, and the reliability of these tests has been questioned.²⁸

The C1-C2 motion segment accounts for 50% of the rotation in the cervical spine.⁹ Thus accurate and reliable examination of C1-C2 impairment is important in assessment of cervical spine disorders, particularly those involving the upper cervical region, such as CGH.²⁹ Indeed, pain arising from an impairment of the C1-C2 motion segment is a frequent finding in individuals with CGH.^{3,4,9}

The flexion-rotation test (FRT), in contrast to other forms of manual examination, is an easily applied clinical test purportedly biased to assess dysfunction at the C1-C2 motion segment.^{12,30} The neck is passively held in end range flexion and rotated to the left and right. The presence of either pain or resistance to the movement may be the limiting factor. Average FRT range of motion in healthy individuals is 44°. Ogince et al¹⁰ reported that the test is positive if the amount of motion is less than 32°. They also demonstrated that highly trained manual therapists using the FRT have high sensitivity

• **STUDY DESIGN:** Reliability of clinical measurements over time.

• **OBJECTIVES:** To determine the long-term stability and minimal detectable change (MDC) of the flexion-rotation test (FRT) measurements over days in subjects with cervicogenic headache (CGH).

• **BACKGROUND:** The FRT is used by physical therapists to assist in identifying upper cervical movement impairment, as well as to gauge treatment effectiveness. Test-retest reliability for the FRT has been reported, but the stability of range-of-motion measures taken during the FRT over time and the MDC have not been investigated.

• **METHODS:** Fifteen subjects with CGH were evaluated on headache-free days using the FRT by a blinded examiner at baseline, 2, 4, and 14 days later. An additional 10 asymptomatic subjects were included for blinding purposes. On each occasion, the examiner measured range of motion and deter-

mined whether the FRT was positive or negative.

• **RESULTS:** For subjects with CGH, there was no significant change in FRT range of motion over days ($P > .05$). Intraclass correlation coefficients for intratester reliability were 0.95 (95% CI: 0.90 to 0.98) and 0.97 (95% CI: 0.94 to 0.99) for right and left rotation, respectively. MDC₉₅ was 4.7° for right rotation and 7° for left rotation. Examiner interpretation of the FRT was consistent over time, with $\kappa = 0.92$.

• **CONCLUSIONS:** This study provides evidence that FRT measurements are stable over time, and the MDC₉₅ indicates that a change in FRT range of motion of at least 7° is required to be confident that a change has occurred due to an intervention rather than measurement error. *J Orthop Sports Phys Ther* 2010;40(4):225-229. doi:10.2519/jospt.2010.3100

• **KEY WORDS:** cervicogenic headache, neck, psychometrics, ROM, spine

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[RESEARCH REPORT]

(91%) and specificity (90%) in identifying individuals with CGH. In clinical practice, the test is deemed positive if there is a 10° reduction in the visually estimated range on either side, and this method of test interpretation has been shown to be valid and reliable when compared with goniometry.¹²

A number of researchers have investigated the FRT.^{10-12,20,27} These studies have provided encouraging evidence of the importance of the FRT in evaluation of CGH. Although excellent intertester and intratester reliability of FRT measurements has been demonstrated when the test is followed by an immediate retest for both asymptomatic subjects and subjects with CGH,^{30,30} the minimal detectable change (MDC) for the test has not been reported. In addition, the stability of the FRT over time (day-to-day or week-to-week) has not been studied. Long-term stability is an important criterion for a test of CGH, which is episodic in nature and often requires long periods between evaluation and treatment sessions.³⁵ If the FRT is to serve as a useful measure of impairment in CGH evaluation and to evaluate treatment outcome, then measurement of FRT mobility must be demonstrated to be stable over time in individuals with CGH. The purpose of this study was to investigate the long-term stability of the FRT measurements, to investigate the long-term reliability of test interpretation, and to establish the MDC. The principal hypothesis was that examiner interpretation of the FRT and FRT mobility would be stable over time, with minimal variation between days in individuals with CGH.

METHODS

A REPEATED-MEASURES LONGITUDINAL design was used to investigate the stability of FRT measurements over time (days and weeks), to investigate the long-term reliability of test interpretation (weeks), and to establish the MDC in subjects with CGH. The Curtin University Human Research Ethics Committee

granted approval for this study. Subjects gave written informed consent prior to the study and were able to withdraw from the study at any time.

Subjects

Sample size estimate was based on data collected from previous studies.^{12,30} An a priori power analysis determined that a sample size of 15 subjects with CGH was required to obtain a statistical power of 0.80. This was based on 4 repeated measurements, with a predetermined coefficient of reliability of 0.9 and a calculated effect size of 0.3.³⁷ Subjects were recruited in a manner of convenience through advertisements placed in local newspapers and through the University website. To reduce examiner bias for measurement of range of movement and examiner interpretation of the FRT, an additional 10 asymptomatic subjects were included who had no significant history of neck pain or CGH and were of similar age to the subjects with CGH. The inclusion of asymptomatic subjects was also designed to mimic the clinical situation, in which patients present for headache evaluation who may or may not have a contributing cervical spine disorder. For subsequent analysis of stability of FRT measurements over time, only the 15 subjects with CGH were included. For analysis of long-term reliability of test interpretation, all 25 subjects were included.

Inclusion criteria for subjects with CGH were based on criteria developed by the International Headache Society (IHS)¹ and Sjaastad.²⁸ These included a primary complaint of side-dominant headache without side shift, headache preceded by neck pain, and headache precipitated or aggravated by neck movement or posture. Additionally, headache frequency needed to be at least once per week and episodic headaches needed to have been present for more than the previous 3 months. Exclusion criteria were continuous headache more than 48 hours, headache not of cervical origin, inability to communicate, inability to tolerate the

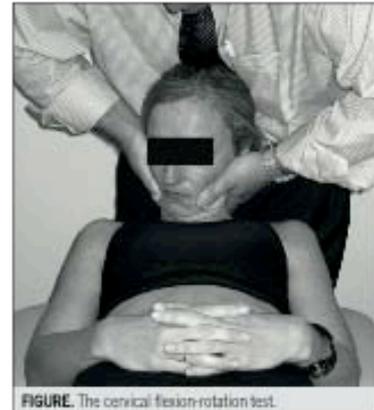


FIGURE. The cervical flexion-rotation test.

FRT, receiving physical treatment (for example physiotherapy or chiropractic), and lack of informed consent. Accordingly, 15 subjects (mean age, 33 years; age range, 24-49 years; SD, 6.3) with chronic CGH were recruited. The mean history of headache occurrence was 5 years (range, 3-7; SD, 0.7), and for 9 of 15 subjects the right side was the dominant side of headache.

Procedures

A separate researcher screened for eligibility, based on the inclusion and exclusion criteria, by an interview. Prior to any measurements, the subjects with CGH completed a headache questionnaire to obtain an index of headache severity (0-100, with 100 being maximum severity).¹⁹ This index is based on a composite score of headache intensity, duration, and frequency, with equal weight given to each element. Test-retest measures of 20 subjects with CGH over 24 hours showed high levels of reliability, with an ICC_{3,3} of 0.92.¹⁹ Average headache severity was 58/100 (range, 45-75; SD, 9.1).

A single examiner with 15 years of clinical experience using the FRT, who was blind to the subject's clinical presentation, assessed all subjects. An experienced examiner was utilized, as the purpose of this study was to investigate the long-term stability of the FRT rather than intertester reliability. Previous

TABLE 1		
DESCRIPTIVE AND INTRARATER RELIABILITY STATISTICS FOR RANGE RECORDED DURING FRT FOR SUBJECTS WITH CGH (N = 15)*		
	FRT Right	FRT Left
Baseline	32.6 ± 11.5	34.1 ± 13.3
Day 2	33.2 ± 10.6	33.7 ± 12.0
Day 4	33.8 ± 12.2	32.7 ± 11.9
Day 14	32.3 ± 10.8	33.3 ± 11.4
ICC _{3,1} (95% CI)	0.95 (0.90-0.98)	0.97 (0.94-0.99)

Abbreviations: CGH, cervicogenic headache; CI, confidence interval; FRT, flexion-rotation test; ICC, intraclass correlation coefficient; SD, standard deviation.
* Values are mean ± SD except where otherwise indicated.

TABLE 2			
BASELINE MEASURES AND MINIMAL DETECTABLE CHANGE FOR THE FRT FOR SUBJECTS WITH CGH (N = 15)			
	Baseline Mean (SD)	SEM	MDC _{95%}
FRT right	32.6 (11.5)	2.0	4.7
FRT left	34.1 (13.3)	3.0	7.0

Abbreviations: CGH, cervicogenic headache; FRT, flexion-rotation test; MDC, minimal detectable change; SD, standard deviation; SEM, standard error of measurement.

research indicates reasonable levels of reliability, even for completely naive examiners.¹²

With the subject relaxed in a supine position and the cervical spine passively maximally flexed, the head was passively rotated left and right (FIGURE, ONLINE VIDEO). Range of motion in rotation was determined either by the subject reporting onset of pain or by firm resistance encountered by the therapist, whichever came first. At this point, the examiner made a visual estimate of the rotation range of motion and was required to state whether the FRT was positive or negative and which side was positive. A positive test was defined as an estimated range that was reduced by more than 10° from the anticipated normal range of 44°. The examiner then repeated the procedure and objectively measured mobility during the FRT using a cervical range-of-motion device (CROM). The CROM consists of a floating compass (Plastimo Airguide Inc, Buffalo Grove, IL) attached to the apex of the head by Velcro straps.^{19,20} Range of motion was recorded

for left and right rotation rather than range towards the side of restriction or range towards the side of headache. The reason for this was to allow comparison with previous reports, as well as to allow for subjects limited in range towards the opposite side of dominant headache and for subjects with a bilateral restriction in range of motion.

Subjects were tested at baseline and at 2 days, 4 days, and 2 weeks later, unless they were experiencing headache symptoms at the planned time. Where a delay was necessary due to headache, the symptom-free test was conducted as soon as possible after the headache had resolved. Subjects were requested to refrain from seeking treatment for their neck during the study period.

Statistical Analysis

Statistical analysis was performed using SPSS, Version 17.0. (SPSS Inc, Chicago, IL). Alpha was set at .05 for each analysis. A random-effects, repeated-measures analysis of variance (ANOVA) was used to determine changes in FRT mobility

over time (4 occasions) for the 15 subjects with CGH. Single-measure ICC_{3,1} and 95% confidence intervals (CIs) were generated for the range recorded during the FRT on these occasions for these 15 subjects. Subsequently, reliability coefficients were calculated for subjects with CGH, and these were used to generate the standard error of measurement (SEM) using the following formula to indicate the range of scores that could be expected upon retesting in this population²¹: SEM = SD √(1 - reliability coefficient).

The MDC at the 90% CI was calculated using the formula below to indicate the minimal change between 2 measurements required for the change to be considered a real change: MDC = 1.65 × SEM × √2.

Kappa statistics were used to determine the reliability of the examiner interpretation of the FRT (positive or negative) from the first to last measurement occasion. All subjects were included for this analysis.

RESULTS

DESCRIPTIVE STATISTICS AND INTRARATER reliability coefficients for subjects with CGH are shown in TABLE 1. All underlying assumptions for the repeated-measures ANOVA were met. In subjects with CGH, there were no significant differences in range of motion recorded during the FRT over headache-free days to the left (F_{3,32} = 1.2, P = .12) or to the right (F_{3,32} = 2.5, P = .06). In subjects with CGH the maximum mean difference between days in range recorded during the FRT was 1.5° (95% CI: -0.8 to 3.9) to the right and 1.4° (95% CI: -0.6 to 3.4) to the left.

Intrarater reliability coefficients were high for positive/negative interpretation of the FRT over days for the combined sample (α = 0.92; 95% CI: 0.77 to 1.00; P < .001).

Descriptive statistics, SEM, and MDC for subjects with CGH for left and right rotation during the FRT are shown in TABLE 2.

[RESEARCH REPORT]

DISCUSSION

IDEALLY, FOR ANY TEST OF PHYSICAL impairment to be useful in clinical examination, it must be accurate and reliable on repeated-measurement occasions over a relevant period.¹⁶ The results of this study suggest that, in subjects with CGH, repeated measurements taken of the FRT over a 2-week period on headache-free days are stable. In addition, intratester reliability of the measurements is excellent and the interpretation of the test (positive or negative) shows almost perfect agreement between repeated trials, based on the Landis and Koch scale.¹⁷ This provides further support for the use of the FRT in the evaluation of individuals with CGH.

The data for range of motion measured during the FRT are similar to those reported in previous studies using the CROM device in subjects with CGH.^{10,12,20} In addition, previous studies have reported similarly high ICC values for intratherapist reliability of range of motion measured during the FRT¹⁰ on a test and immediate retest basis. This is the first study to demonstrate long-term stability of range of motion measured during the FRT over several days. Long-term stability of range-of-motion measures is important for the evaluation of CGH disorders, which are chronic and episodic in nature.¹⁵ Typically, treatment sessions for these patients will be spaced out to allow for the episodic nature of headaches. It is important to recognize that on all occasions subjects were tested on headache-free days. The presence of headache at the time of testing may influence range of motion during the FRT and subsequent test interpretation, although the extent and nature of this influence requires further investigation.

We found no significant difference in range of motion of the FRT over a 2-week period in subjects with CGH, demonstrating lack of systematic bias in the measurements. This perhaps explains the high level of intraexaminer reliabil-

ity for test interpretation. Sterling et al²⁰ also investigated long-term reliability of cervical range-of-movement measures. They measured active range of motion, in both symptomatic and asymptomatic subjects, and found consistency of measurement over a 1-week period. SEMs were small, ranging from 2° to 7°, though slightly higher than studies that had tested cervical range of motion over a short interval.^{6,21,22}

Although reliability coefficients are important as indicators of the strength of any relation between 2 variables, they do not provide information about the evaluative properties of measurement procedures. In contrast, the SEM and MDC provide information about the magnitude of the error associated with a test and enable a clinician to distinguish real change that occurs as a result of an intervention.^{6,8}

In our study, we found SEMs of 2° and 3° for right and left rotation, respectively. This is in agreement with previous studies of the FRT,¹⁰ but at the lower end of the range shown for studies of active cervical range of motion.^{6,21,22} It has been reported that measures of cervical range of motion can vary in excess of 5° for the same segment in the same individual, if they are studied by the same technique on separate occasions.⁵ The difference in fluctuation of measurement for active range of motion compared to the FRT can be explained by a difference in the test application. The FRT is performed passively, to constrain movement to the C1-C2 motion segment and limit movement at all other cervical motion segments.⁹ In contrast, active movements are much more variable, with movement possibly occurring in a different manner each time measurements are taken.⁵ Hence, movement during the FRT test may be more consistent over time.

In our study, the MDC₉₀ for right rotation was 4.7° and 7.0° for left rotation in subjects with CGH. This indicates that a change in FRT range of motion of at least 7° is required to be 90%

confident that a change has occurred rather than measurement error. The smaller value for right rotation may relate to the greater proportion of subjects with right-side-dominant headache in our sample, but this requires further investigation.

Caution should be taken when interpreting the MDC, as a statistically meaningful change does not attest to the clinical importance of the change. It has previously been reported that a reduction in range of motion greater than 10° identifies a positive FRT. Hence, the minimum clinically important change that is important to a patient might be 10°, with the MDC₉₀ reported in this study enabling error-free identification of this threshold. Furthermore, Hall et al¹¹ reported a 15° change in FRT range of motion after 1 treatment aimed at improving impairment identified by the FRT. This gain in range is much greater than the MDC₉₀ identified in our study, indicating that the test should be sufficiently sensitive and precise to monitor change in individual patients.

There are a number of limitations of this study that may affect the interpretation and generalizability of these results either in clinical practice or research settings. First, only 1 very experienced tester was used. Previous research demonstrates that completely naïve examiners with minimal training can identify a positive FRT¹²; hence, examiner experience is not a major factor in the FRT application or interpretation. Second, although blind to the subject group allocation, the tester may have recalled previous measurements and test reporting. In an attempt to prevent this, subjects were assessed in groups to reduce the likelihood of the examiner recalling exact range of motion data between sessions. Third, no account was made for the effect of repeated movement on range of motion. Repeated testing, theoretically, may influence range; but this has not been found to occur with the FRT¹⁰ and was minimized by only testing the movement twice on each occasion.

CONCLUSIONS

RANGE-OF-MOTION MEASURES TAKEN during the FRT are stable over a 2-week period in subjects with CGH, and examiner interpretation of the FRT is highly reliable. Moreover, interpretation of the MDC_{95} indicates that a change in mobility of greater than 7° following an intervention can be confidently interpreted as real change rather than measurement error. ●

KEY POINTS

FINDINGS: The FRT is a stable and repeatable method of cervical spine examination. There is low measurement error, and examiner interpretation of the test is reliable when used by an experienced clinician over days. The MDC_{95} is 7° .
IMPLICATIONS: The FRT is a clinically reliable tool for measurement of upper cervical range of motion in evaluation of CGH.

CAUTION: All measurements were carried out by a single experienced examiner.

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4.6 STUDY 2

Study 2 is encapsulated in the following publication.

Hall T, Briffa K, Hopper D, and Robinson K. 2010 Comparative analysis and diagnostic accuracy of the cervical flexion rotation test. *Journal of Headache and Pain*. DOI 10.1007/s10194-010-0222-3

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Comparative analysis and diagnostic accuracy of the cervical flexion–rotation test

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Abstract The aim of this study was to compare the findings of the cervical flexion–rotation test (FRT) between subjects with probable cervicogenic headache (CGH), migraine without aura (Migraine), and multiple headache forms (MHF). An additional aim was to identify the diagnostic accuracy of the FRT in CGH evaluation. Sixty subjects were evaluated: 20 with CGH, 20 with Migraine, and 20 with MHF. Subject and headache symptoms were evaluated by questionnaire. A single-blind examiner conducted the FRT, reporting the test state (positive or negative) before measuring range of motion using a goniometer. The average range of unilateral rotation to the most restricted side was 25°, 42° and 35° for groups CGH, Migraine and MHF, respectively. The difference between groups was significant ($P < 0.001$). Range of rotation was significantly reduced in the CGH group when compared to groups Migraine ($P < 0.001$) and MHF ($P = 0.001$), with an additional smaller significant difference between groups Migraine and MHF ($P = 0.039$). A receiver operating curve revealed that an experienced examiner using the FRT was able to make the correct diagnosis 85% of the time ($P < 0.001$), with a positive cut-off value of 30°. Multivariate regression analysis revealed that 44% of the variance in FRT range of motion was explained by the presence of two variables: neck movement or positions provoke headache, and neck symptoms precede headache, but not by other factors associated with migraine. These findings provide further evidence supporting the clinical utility of the FRT in CGH evaluation.

Keywords Cervicogenic headache · Migraine · Neck · Sensitivity and specificity · Range of motion

Introduction

Headache is among the most prevalent of pain disorders, affecting the majority of the population [1], disturbing both quality of life and work productivity [2, 3].

Migraine is one of the common primary headaches [4], the underlying mechanisms of which are poorly understood but are believed to involve abnormal brain function [5] including functional cortical hyperexcitability arising from among other things, reduced inhibition from the cortex [6]. In contrast cervicogenic headache (CGH) is a subgroup of secondary headache, stemming from a disorder of the cervical spine [7]. The mechanisms underlying CGH [8] are based on the concept of convergence of afferent information from musculo-skeletal structures in the upper three cervical segments with trigeminal afferents in the trigeminocervical nucleus (TCN). Hence input via sensory afferents from any of the upper cervical nerve roots is mistakenly perceived as pain in the head.

Differentiating different headache forms is principally based on the history and presenting symptoms, together with the clinical physical examination [9]. For example, migraine without aura is the most common sub-type of migraine, lasting a fixed time period of 24–72 h. Diagnostic characteristics include unilateral location, pulsating quality, moderate to severe intensity, aggravated by activity, and associated with nausea, photophobia or phonophobia [10]. However, a number of these features are also associated with CGH [11] as is the presence of neck pain [12]. As a result, one of the common diagnostic challenges in headache evaluation is to distinguish CGH from migraine [13]. Indeed studies have shown that an incorrect headache diagnosis may occur in more than 50% of

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cases [14]. Since migraine and CGH have very different underlying pathological mechanisms, it is very important to correctly classify the headache disorder so that treatment can be directed appropriately. For example, physiotherapy has been found to be effective for CGH [15, 16] but not for migraine [17].

Up to 74% of individuals with frequent intermittent headache and migraine report accompanying neck pain [12, 13, 18], but this does not necessarily indicate dysfunction in the cervical spine. Associated neck symptoms during headache may simply suggest spread and referral of pain via trigemino-cervical interaction, resulting in hyperalgesia and allodynia [12]. Consequently, physical examination of the neck is a critical component of CGH diagnosis [19], particularly where subjective characteristics are not clearly indicative of any one headache form or where multiple headache forms (MHF) co-exist. As CGH predominantly arises from musculoskeletal dysfunction in the upper three cervical segments [8], physical examination of the upper cervical spine is particularly important. Recently it has been shown that collectively, cervical movement impairment, in association with palpable upper cervical joint dysfunction and impairment in craniocervical muscle control, has 100% sensitivity and 94% specificity to identify CGH from migraine [20].

The flexion-rotation test (FRT) has shown promise as a valid and reliable test of upper cervical movement impairment associated with CGH [21–24]. Movement during this test occurs predominantly at C1/2, as a result of maximally flexing the cervical spine, pre-emptively constraining movement at all other levels [25]. We have previously demonstrated that the FRT has high levels of accuracy in CGH diagnosis [24], but the comparison group in that study were asymptomatic controls and a relatively “pure” form of migraine with aura, which is easily defined. To date no studies have investigated whether the FRT is reduced in mobility in subjects with Migraine or in subjects with subjective features suggesting MHF. If subjects with CGH have significantly greater impairment on the FRT than subjects with Migraine or with MHF, then this further validates the utility of the FRT in CGH evaluation.

The main purpose of this study was to compare FRT mobility between three groups: Migraine, CGH, and MHF. Secondary purposes were to examine the diagnostic accuracy of the FRT in CGH diagnosis and to determine the most significant predictors of range of motion during the FRT. This knowledge has the potential to improve the clinical utility of the FRT.

Methods

A single-blind comparative measurement study design was used to determine whether range recorded during the FRT

and examiner interpretation of the FRT differs between subjects with MHF and those with Migraine and CGH. The Curtin University Human Research Ethics Committee granted approval for this study, which was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. Subjects gave written informed consent prior to the study commencement and were able to withdraw from the study at any time.

Subjects

Sample size estimate was based on data collected from previous studies [24, 26]. Based on a single measurement of the FRT, with a standard deviation of 11° for range of motion, and a calculated effect size of 0.4 [27, 28], a priori power analysis determined that a total sample size of 60 subjects (20 in each group) was required to obtain a statistical power of 0.80 with alpha set at 0.05.

Subjects were recruited in a manner of convenience through advertisements placed in local newspapers and through Curtin University website. Volunteers were screened for eligibility into three groups: Migraine, CGH or MHF. For all subjects headache frequency was required to be at least once per week for more than the previous 3 months. Migraine was defined according to the IHS diagnostic criteria [10], CGH was defined according to the criteria proposed by Sjaastad [11] and further evaluated by Antonaci [29], with the exception of diagnostic anaesthetic blocks. These criteria were intermittent, side dominant headache of moderate intensity, without side shift. The headache was required to be preceded by ipsilateral neck pain and precipitated or aggravated by neck movement or posture, thereby fulfilling 5 of 7 criteria outlined by Antonaci [29] as indicative of “probable” CGH. Subjects in either the migraine or CGH group were excluded if they also met the IHS criteria for other headache forms. Subjects who reported two or more distinct forms of headache were defined as MHF. In all three groups subjects were excluded if they were unable to tolerate the FRT (none were excluded in this way) or if they had received physical treatment to their neck from a physiotherapist or other health professional in the previous 4 weeks. In addition, to account for the potential for a concurrent cervical spine disorder in the Migraine group, subjects were excluded if they had interictal episodes of neck pain or a known cervical spine disorder.

Respondents to advertisements ($n = 115$) were screened by either telephone or face-to-face interview with 55 rejected, according to the inclusion and exclusion criteria. Accordingly 20 subjects with Migraine (12 female, mean age 30 years, range 18–59, SD 6.5), 20 subjects with CGH (11 female, mean age 35 years, range 18–61, SD 10.9) and

Table 1 Characteristics of the subjects in groups Migraine, CGH and MHF

Variable	Headache group		
	CGH (<i>n</i> = 20)	Migraine (<i>n</i> = 20)	MHF (<i>n</i> = 20)
History of headache (years)			
Mean (SD)	4.8 (2.8)	9.1 (4.8)	5.7 (3.9)
Range	0.5–11.0	4.0–20.0	0.5–14
Index of headache severity (/100)			
Mean (SD)	56.3 (10.8)	54.1 (14.1)	47.9 (11.4)
Range	35.0–81.0	31.3–81.6	31.3–71.0
Dominant side of headache			
Left	8	4	5
Right	12	7	11
Bilateral	0	9	4
Positive flexion–rotation test	14	5	8
Pulsating headache	4	12	7
Photophobia	5	16	8
Phonophobia	4	15	9
Nausea	5	16	9
Neck positions/movement provoke headache	20	3	8
Neck symptoms precede headache	17	4	10
Anti-migraine medication helps	1	13	5
Forward bend increases headache	6	13	9
Exertion increases headache	6	16	14

Migraine migraine without aura, *CGH* cervicogenic headache, *MHF* multiple headache forms

20 subjects with MHF (15 female, mean age 33 years, range 20–63, SD 9.4) were recruited. Headache symptoms and other characteristics are shown in Table 1.

Procedures

Entry-level eligibility was based on inclusion and exclusion criteria and assessed by a separate researcher, an experienced specialist musculoskeletal physiotherapist. Subsequently all subjects completed a questionnaire to obtain an index of headache severity (0–100, with 100 being maximum severity) [30]. This index is based on a composite score of headache frequency, duration, and intensity with equal weight given to each element. Previously this index has been shown to have high levels of reliability with $ICC_{(2,1)}$ of 0.92 [30]. Additional demographic details, including subject and headache characteristics were also assessed by questionnaire. These characteristics included: dominant side of headache, headache of pulsating quality, nausea, photophobia or phonophobia, anti-migraine medication helps, forward trunk bend increases pain, neck movement or positions provoke headache, headache aggravated by exertion, and neck symptoms precede headache.

One specialist musculoskeletal physiotherapist experienced in using the FRT, who was unaware of the subject's clinical presentation, assessed all subjects. An experienced examiner was utilized, as the purpose of this study was not to investigate reliability but to investigate differences in impairment of range of motion during the FRT in subjects with different headache forms. We have previously established high levels of intra-rater reliability for range of motion measured by an experienced examiner. Intra-class correlation coefficients were reported as 0.95 (95% CI 0.90–0.98) [23]. Furthermore, examiner interpretation of the FRT has been shown to be consistent over time with Kappa of 0.92 [23].

The FRT consisted of pre-positioning the cervical spine in maximal end range flexion followed by passive rotation of the head to the left and the right, with the subject relaxed in supine. End of range was determined either by firm resistance encountered by the therapist or the subject reporting the onset of pain, whichever came first. The intention was to measure range of motion irrespective of cause of limitation, in the least provocative manner, to prevent potential exacerbation of symptoms. The examiner made a visual estimate of the range of rotation to determine whether the FRT was positive or negative, and then reported the test state and the positive direction if any.

A positive test was defined where the visually estimated range was reduced by more than 10° from the anticipated normal range of 44° [21, 24]. Subsequently the FRT procedure was repeated and mobility determined by using a cervical range of motion device (CROM). The CROM is a floating compass [Plastimo Airguide Inc (Compasses), 1110 Lake Cook Road, Buffalo Grove, Illinois, 60089] attached to the apex of the head by Velcro straps [21, 24].

All subjects were tested on one occasion on a headache-free day to negate the influence of headache at the time of testing [23]. All 11 subjects complained of headache on the day of testing and were required to return on a symptom-free day.

Statistical analysis

Statistical analysis was carried out using SPSS V17.0 (SPSS Inc., 444 N. Michigan Avenue, Chicago, Illinois, 60611). Alpha was set at 0.05 for each analysis. One-way ANOVA and planned orthogonal comparisons were used to determine differences in FRT mobility between groups. The sensitivity and specificity of the FRT were analysed using cross tabulation and were determined with a receiver operating characteristic (ROC) curve. To calculate the sensitivity and specificity the subjects with Migraine and MHF were combined and then compared to the subjects with CGH. The frequencies used to calculate sensitivity and specificity are given in Table 1. The dichotomous variables used to determine the sensitivity and specificity were the therapist's assessment of whether the FRT was positive (10° visually estimated limitation of range) and whether the subject had CGH or not. The ROC curve was created using the FRT range of motion values. Finally, forward stepwise multiple linear regression analysis (forward stepwise; P to enter <0.05 , P to remove >0.1) was used to determine the relationship between subject and headache characteristics and range of motion during the FRT.

Findings

Subject recruitment occurred from January to December 2008. All 60 subjects completed this study. The demographic and headache characteristics of the study sample are presented in Table 1.

All underlying assumptions for repeated measure ANOVA were met. The range of rotation to the most restricted side was significantly lower in the CGH group when compared to the Migraine and MHF groups [$P \leq 0.001$; mean (SD) range 25.2° (11.1), 41.8° (5.1) and 35.1° (8.0), respectively] (Fig. 1). There was also a

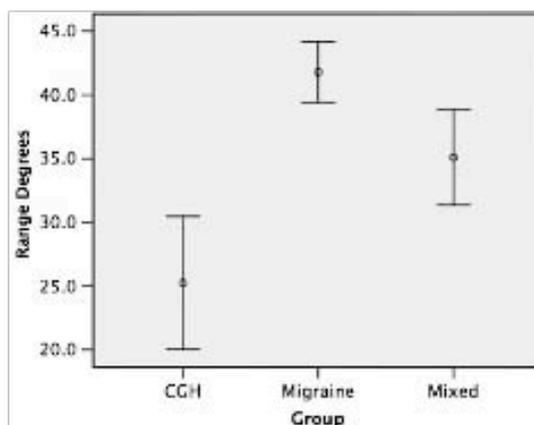


Fig. 1 The mean range of motion and 95% confidence interval of unilateral cervical rotation in maximal flexion to the most restricted side for each subject group

significant but smaller difference in range between the Migraine and MHF groups ($P = 0.039$) (Fig. 1).

The examiner interpreted the FRT as positive in 70% of subjects (14/20) from the CGH group and 30% of subjects (12/40) from the combined groups Migraine and MHF. Consequently for CGH diagnosis the FRT had sensitivity of 0.7 (95% CI 0.46–0.87), specificity of 0.7 (95% CI 0.53–0.83), positive predictive value of 0.54 (95% CI 0.34–0.74), negative predictive value of 0.82 (95% CI 0.65–0.93), positive likelihood ratio of 2.33 (95% CI 1.34–4.06) and negative likelihood ratio of 0.43 (95% CI 0.21–0.85). Examination of sensitivity and specificity data plotted on a ROC curve (Fig. 2) revealed that an experienced clinician should be able to correctly differentiate a patient with CGH from one from the Migraine or MHF groups 85% of the time ($P < 0.001$). Additionally, coordinates on the ROC curve indicated that, in this sample, the test value that provides the highest sensitivity and the lowest 1-specificity was 30° . In other words range of 30° , measured using a compass goniometer, represents the cut-off score for a positive test.

When variables “neck movement or positions provoke headache” and “neck symptoms precede headache” and other variables (gender, age, history of headache, dominant side of headache, anti-migraine medication helps, forward bend increases headache, presence of photophobia or phonophobia, nausea or headache of pulsating quality) were entered into forward stepwise multiple linear regression analysis with range of motion towards the most restricted side during the FRT as the dependent variable, “neck movement or positions provoke headache” and “neck symptoms precede headache” were the most significant predictors of range of motion (Table 2). These

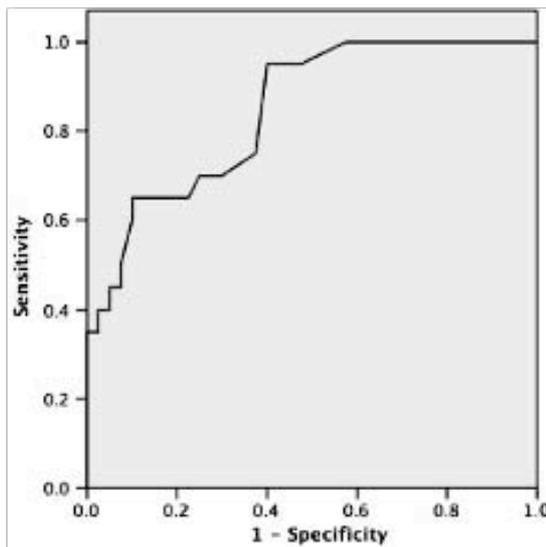


Fig. 2 The diagnostic accuracy of the cervical flexion-rotation test. The area under the curve is 0.85 ($P < 0.001$, CI 0.75, 0.95)

Table 2 Forward stepwise multiple linear regression analysis with β , standard error, P , and adjusted R^2 values presented: predictive variables for range of motion towards the most restricted side during the flexion-rotation test (FRT) ($n = 60$)

Variable	Coefficient (β)	Standard error	P
Constant	10.17	3.64	<0.001
Neck positions/movement provoke headache	10.83	2.55	<0.001
Neck symptoms precede headache	5.51	2.54	0.04

Adjusted $R^2 = 0.44$, R^2 change for "Neck positions/movement provoke headache" = 0.41, R^2 change for "Neck symptoms precede headache" = 0.04. Variables entered forward stepwise

variables accounted for 44% of the variance in FRT range of motion [$F(2,59) = 24.5$, $P < 0.001$], with neck movement or positions provoke headache as the most significant predictor accounting for 41% of the variance. Once these two variables had been entered into the model, none of the remaining independent variables made sufficient additional contribution to the model to meet the entry criterion.

Discussion

This is the first reported study to compare FRT range of motion deficits in subjects with CGH, Migraine and MHF. We found a clinically significant difference in range of motion between the different headache groups. Range was most restricted in subjects with CGH (25°), significantly

greater impairment than either group's Migraine (42°) or MHF (35°). Similarly, subjects with MHF had significantly lesser range than those subjects with Migraine. The data for range of motion measured during the FRT are similar to those reported in previous studies using the CROM device in subjects with CGH [26, 31]. Mean range of rotation towards the most restricted side was 25° in the current study and 22° and 26° in previous reports [26, 31]. In the present study an asymptomatic group was not included, but compared to previous studies range recorded in the Migraine group was marginally less than the reported normal range of 44°–45° to each side [21, 32].

Our results for mean range of motion for subjects with Migraine concur with a previous report of mean range of 39° for subjects with migraine with aura [24]. It would appear that the presence of an aura has minimal effect on range of motion during the FRT. As range of motion for subjects with Migraine was also consistent with asymptomatic controls this might indicate that, in general terms, cervical movement dysfunction is not a pre-requisite for migraine either with or without aura. This observation is consistent with a previous study investigating active range of motion. Subjects with Migraine had range consistent with asymptomatic controls, which was significantly greater than range in subjects with CGH [19, 33]. In another study of episodic migraine, only range of right rotation was significantly reduced by 8° when compared to healthy controls [34]. Interestingly in cases of unilateral pain, limitation was not associated with the symptomatic side of migraine [34], which is different from CGH where the limitation of movement is predominantly to the symptomatic side, particularly when evaluated by the FRT. Further evidence of a lack of cervical movement impairment in Migraine was demonstrated by a recent systematic review, although the reviewers were critical of the methodological quality of many of the reviewed studies [35].

Migraine headache is experienced in the regions innervated by the cutaneous afferents of the trigeminal and C2 and C3 nerves, all of which have input into the TCN [35]. Sensitization of the TCN is postulated as central to the pathophysiology of CGH, migraine and other headache forms and may explain why some patients with headache complain of neck pain [12], and demonstrate limitation of cervical range of motion, in the absence of cervical musculoskeletal disease [36]. Furthermore sensitization of the TCN may also increase neck muscle tone through increased motor efferent activity, with consequent effect of limiting range of motion of the neck [37]. If TCN sensitization were the cause of headache then limitation in range is unlikely to be related to a specific side or level of cervical motion segment dysfunction, and the FRT is unlikely to be significantly restricted. We found only 5/20 subjects with migraine with a positive FRT, indicating a lack of

segmental joint restriction in the majority of migraine sufferers. Consistent with this and as previously stated no association was found between the side of migraine headache and direction of movement limitation [34]. Thus for a patient with headache, associated neck pain and minor limitation of cervical range of motion does not necessarily indicate a cervical contributing factor. Further physical examination tests are required in that patient to confirm the presence of CGH. It is the combination of limitation of cervical movement together with evidence of deep neck flexor dysfunction and pain on palpation of the upper cervical spine that confirms the presence of CGH with a high degree of certainty [20].

Previously it has been shown that the FRT has good diagnostic accuracy to identify subjects with CGH from subjects with migraine with aura and asymptomatic controls [24, 26]. In the study by Ogince et al. [24] subjects with CGH were compared with control subjects, whereas in this study the comparison was with subjects with Migraine or MHF. This difference in comparison groups would also explain the slightly lower cut-off value in the present study when compared with earlier studies (30° against 32°) [26]. This has implications for clinical practice where diagnosis of CGH might rely on a number of features including presenting symptoms as well as physical examination [22]. In patients who have subjective features that do not fit into a specific headache category (or who have evidence of MHF) then the physical examination might be more important and a lower cut-off score is necessary on the FRT to be confident of a diagnosis of CGH. In patients with relatively pure form of CGH, clearly defined by the presenting symptoms, then a higher cut-off score might be adequate.

It is important to recognise that the FRT is a relatively isolated test of movement impairment of the C1/2 motion segment [25], and may not adequately test other motion segments or indeed other upper cervical structures potentially contributing to a patient's CGH. This might explain the negative test finding in 6/20 subjects with CGH, where cervical motion segments or structures other than C1/2 may have been the cause of headache. Hence it is important not to rule out the potential for CGH in patients negative on the FRT.

We found that variables forward bend increases headache, anti-migraine medication helps, photophobia, phonophobia, nausea, pulsating headache, exertion increases headache, history of headache, gender, and age were not associated with range of motion towards the restricted side during the FRT. The only factors associated with range of motion were neck movement or positions provoke headache, and neck symptoms precede headache. The variable neck position or movement provoke headache accounts for 41% of the variance (adjusted $R^2 = 0.41$). The inclusion of

the variable neck pain precedes headache results in an additional 4% of the variance ($R^2 = 0.4$). This result is not surprising when considering these two associated factors are determinants of CGH and that apart from age, gender and history of headache, the non-associated factors are common complaints of migraine, but rarely reported by subjects with CGH [38]. Previously we have also shown that three headache features (headache severity, frequency and duration), either separately or combined into an index [30], also influence range of motion during the FRT in subjects with CGH [31]. In addition we have shown that the presence of pain at the time of testing also influences range of motion [23]. Hence the FRT appears to be associated with a number of different factors including the presence and severity of headache as well as the factors suggesting cervical spine dysfunction.

The interpretation and generalization of these results needs to be cautioned by a number of potential limitations. Firstly, one experienced examiner tested all subjects. Secondly a diagnosis of "probable" CGH was only possible as diagnostic injection block procedures were not available, hence some subjects may have been misclassified. Finally 14/20 subjects with CGH were positive on the FRT, which may indicate that subjects were misclassified as CGH or did not have headache arising from C1/2.

Conclusions

Range of motion towards the most restricted side during the FRT is significantly reduced in subjects with CGH when compared to subjects with Migraine or MHF. Furthermore, the FRT has good sensitivity and specificity in the diagnosis of CGH and the cut-off value for a positive test is range of motion less than 30° for differentiation between these headache groups. Subjective features characteristic of Migraine are not associated with FRT range of motion but features consistent with CGH are. These findings provide further evidence supporting the clinical utility of the FRT.

Conflict of interest None.

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4.7 SUMMARY OF FINDINGS FROM PART A

The preceding two studies have provided new information regarding the FRT and its use in CGH diagnosis. Study 1, demonstrated that range of motion measures taken during the FRT are stable over a 2-week period in subjects with CGH and examiner interpretation of the FRT is highly reliable over the same time period. Moreover the MDC that is required to be confident that a real change has occurred to the FRT range of motion deficit, rather than measurement error was identified.

In Study 2, range of motion deficits during the FRT were significantly larger in subjects with CGH when compared with subjects with migraine or MHF. Furthermore the FRT showed good sensitivity and specificity in the diagnosis of CGH. Collectively the findings from Study 1 and 2 provide further evidence supporting the diagnostic utility and long term-stability of the FRT.

Chapter 5: Part B

Study 3 and 4

- Validity of the flexion-rotation test

5.1 RESEARCH QUESTIONS

From the preceding studies it can be seen that the FRT has the ability to identify individuals with CGH. However it is not clear why range of motion recorded during the FRT is reduced in people with CGH. Previously it has been suggested that the FRT is selective to the upper cervical spine, specifically the C1/2 motion segment (Stratton and Bryan 1994; Dvorak 1998). However the validity of this assumption has not been tested. Specifically no studies have measured segmental movement in the cervical spine during the FRT.

Hence the following research questions were developed for Study 3:

- 1) What is the range of rotation, at each cervical motion segment, during the FRT and during axial rotation?
- 2) What proportion of total cervical rotation occurs at C1/2, during the FRT?
- 3) What proportion of rotation at motion segments above C4 occurs at C1/2?

5.2 STUDY 3 OBJECTIVES

The objective of this study was to investigate the validity of the FRT by measuring and comparing total and segmental rotation from the occiput to the C4 vertebra with the neck in neutral position and in flexion position, using magnetic resonance imaging (MRI).

An alternative means of identifying the validity of the FRT as a selective measure of C1/2 movement is to measure how pain arising from cervical motion segments other than C1/2 influences range of motion recorded during the test. If the biomechanical theory regarding the relative isolation of the FRT to the C1/2 segment is correct, then pain arising from or dysfunction of motion segments other than C1/2 should have little influence on range of motion recorded during the FRT. If the FRT were to be influenced by the presence of lower cervical facet pain then the validity, sensitivity and specificity of the FRT would be diminished.

Hence the following research questions were developed for Study 4:

1. Is range of motion recorded during the FRT and examiner interpretation of the test influenced by the presence of lower cervical facet joint pain?

2. What is the diagnostic accuracy of the FRT in identifying subjects with CGH from those with lower cervical facet joint pain?

5.3 STUDY 4 OBJECTIVES

The objectives of this study were to investigate the impact of lower cervical facet pain on range of motion recorded during, and examiner interpretation of the FRT.

5.4 METHODOLOGY FOR STUDY 3

5.4.1 Study design Study 3

A cross-sectional measurement study design was used to investigate the validity of the FRT as a test of predominantly C1/2 motion. A comparison was made between total and segmental rotation from the occiput to the C4 vertebra with the neck in neutral position and in flexion position, using MRI.

5.4.2 Subjects

Subjects were volunteers recruited from staff at Sapporo Medical University, Sapporo, Japan.

5.4.2.1 Inclusion criteria

Subjects were included if they were less than 145cm tall (to enable positioning in the MRI unit), without any history of significant cervical spine or shoulder girdle disorders.

5.4.2.2 Exclusion criteria

Subjects were excluded if they could not achieve end range flexion in the MRI unit (22 subjects were excluded in this way). Additionally subjects were excluded if they had any evidence on MRI of musculoskeletal disorders of the cervical spine. Two orthopedic surgeons experienced in MRI evaluations, inspected all MRI images for abnormalities on the sagittal T2-weighted images and the axial

T2*-weighted images. Four subjects were found to have potential evidence of musculoskeletal disorders (non-symptomatic disc bulging) and were thus excluded.

All participants were given a written information sheet explaining the procedure prior to testing and gave written consent. Approval for this study was granted by the Society of Physical Therapy Science in Japan.

5.4.3 Variables

Independent variables

- Cervical position - neutral and end range flexion.

Dependent variables

- Segmental rotation angles combined to the left and the right (Occiput-C1, C1-C2, C2-C3, C3-C4 and combined segments below C4).
- Angle of cervical flexion.

Reliability of measures

To determine intra-observer variation of the measurement of the segmental rotation angles and the angles of neck flexion in both conditions (flexion and end range flexion), one investigator measured the images twice on two separate occasions. On the second occasion, the examiner was blind to the results of the first measurement session. To study inter-observer variation, two different examiners, blind to each other's assessment, measured the same series.

5.5 METHODOLOGY FOR STUDY 4

5.5.1 Study design Study 4

A single blind between group design was used to investigate whether lower cervical joint pain, confirmed by facet joint block, influences FRT mobility and examiner interpretation of the test.

5.5.2 Sample size calculation

Sample size estimate was based on data collected from a previous report (Ogince et al 2007) and pilot data. *A priori* power analysis determined that a total sample size of 24 subjects (12 in each group) was required to obtain a statistical power of 0.80 with alpha set at 0.05. This was based on a single measurement of the FRT, together with a known mean value of 27° (SD = 11) for the FRT in subjects with CGH, with a mean value of 41° (SD = 5.1) for the lower cervical facet joint pain group.

5.5.3 Subjects

Recruitment for subjects was as follows: Subjects with CGH were recruited in a manner of convenience through advertisements placed in local newspapers and through the University website. Subjects awaiting lower cervical facet joint block were recruited from private physiotherapy clinics.

5.5.3.1 Inclusion criteria

CGH - Inclusion criteria for this group were based on criteria developed by the IHS (Classification Committee of the International Headache Society 2004) and Sjaastad (1998), with the exception of diagnostic anaesthetic blocks. These criteria include side dominant headache without side shift, headache preceded by neck pain, headache precipitated or aggravated by neck movement or posture and associated neck, shoulder or arm symptoms. Additionally, headache frequency was at least once per week and episodic headache occurred for more than the previous 3 months.

Lower cervical facet joint block – Inclusion criteria for this group included episodic or continuous neck pain for more for than 3 months and complete, even if temporary, pain relief from therapeutic cervical facet joint intervention at cervical segments other than at C1/2. Intervention consisted of cervical facet intraarticular injections, or cervical medial branch block or cervical radiofrequency neurotomy.

5.5.3.2 Exclusion criteria

CGH – Subjects were excluded if their headaches were not of cervical origin (Classification Committee of the International Headache Society 2004) and if they were unable to tolerate the FRT.

Lower cervical facet joint block – Subjects were excluded if they had CGH, arm symptoms, and inability to tolerate the FRT procedure. Subjects thus selected were believed to have neck pain arising from lower cervical motion segments.

All participants were given a written information sheet explaining the procedure prior to testing and gave written consent. The Human Research Ethics Committee of Curtin University of Technology granted approval for this study. Subject information sheets, consent forms, and ethical approval documentation are presented in the appendix section (Chapter 10).

5.5.4 Variables

Independent variables

- Two groups – CGH and lower cervical facet joint pain

Dependent variables

- Range of rotation to the left and the right (degrees) recorded during the FRT measured by a modified cervical range of motion device (CROM)
- Examiner interpretation of the FRT (positive or negative side recorded)

Reliability of measures

Previous studies conducted by the author have shown excellent inter-tester and intra-tester reliability of FRT measurements, when the test is followed by an immediate re-test, for both asymptomatic subjects, and subjects with CGH (Hall and

Robinson 2004; Ogince et al 2007). The examiner used in these studies was also used for the current study.

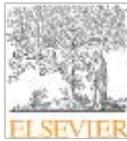
5.6 STUDY 3

Study 3 is encapsulated in the following publication.

Takasaki H, Hall T, Oshiro S, Kenoko S, Ikemoto Y, & Jull G. 2010. Normal kinematics of the upper cervical spine during the Flexion-Rotation Test – in vivo measurements using Magnetic Resonance Imaging. *Manual Therapy*

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Original article

Normal kinematics of the upper cervical spine during the Flexion–Rotation Test – In vivo measurements using magnetic resonance imaging

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ABSTRACT

The Flexion–Rotation Test (FRT) is proposed to assess mobility primarily at C1–C2. However, there is no in vivo measurement investigating the validity of the FRT. The purpose of this study was 1) to examine measurement reliability of segmental upper cervical movements using magnetic resonance imaging and 2) to investigate the content validity of the FRT. Nineteen asymptomatic female subjects (mean age: 22.2 years) were evaluated with a 0.2-T horizontally open MRI unit. The segmental rotation angles from Occiput–C1 to C3–C4 and the C4 vertebra were assessed with the head maximally rotated to both the right and the left in two conditions – neck in neutral and in flexion. Good reliability of the method of measurement was suggested by error considerations. A repeated measure ANOVA revealed an interaction between the two different neck starting positions and segment levels ($P < 0.0001$). Post-hoc analysis revealed that there were significant reductions in the flexed position ($P < 0.0001$) except for at Occiput–C1. While there was only a 16.3% reduction in rotation range at C1–C2, the reduction was 68.1% at C2–C3, 61.4% at C3–C4, and 76.9% at segments below C4, respectively, supporting the content validity of the FRT as a clinical measure of atlanto-axial mobility.

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1. Introduction

Restriction of range of motion appears to be a generic feature of neck pain disorders, and it is routinely assessed in the clinical evaluation of patients (Dall'Alba et al., 2001; Woodhouse and Vasseljen, 2008). Clinical examination of primary plane movements provides overall information about movement of the spinal segments collectively, but some tests reportedly are biased toward a certain cervical segment (Edwards, 1992; Dvorak et al., 2008).

The Flexion–Rotation Test (FRT) described by Dvorak (1998) is commonly used as an assessment of mobility in the upper cervical region. The cervical spine is placed in end-range flexion, in an attempt to block rotation of all vertebrae below C2. It is postulated that rotation in end-range cervical flexion occurs predominantly at

the atlanto-axial joint (C1–C2) (Hall and Robinson, 2004; Ogince et al., 2007; Dvorak et al., 2008; Hall et al., 2008b). Proponents of this test report its relative ease of use with minimal practitioner skill required (Hall et al., 2008b), which is in contrast to other passive segmental mobility tests (Jull et al., 1988, 1997). Normal range of motion is approximately 45° to both sides (Hall and Robinson, 2004; Hall et al., 2008b). Range of motion less than 33° to one side is rated as abnormal (Ogince et al., 2007; Hall et al., 2008b). In addition, range of motion recorded during the FRT is stable over time (Hall et al., 2010). Hence, the FRT has been used clinically in cervicogenic headache diagnosis and as a treatment outcome measure after physical therapy interventions to the upper cervical spine (Hall et al., 2007, 2008a). However, to date there has been no in vivo study to measure cervical segmental movements during the FRT to confirm the validity of the FRT.

The purpose of this study was two-fold. The first purpose was to examine measurement reliability of segmental rotation angles derived from Magnetic Resonance Imaging (MRI) data by considering errors. The second was to investigate the content validity of the FRT as a test of predominantly C1–C2 motion. This was achieved

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by measuring and comparing segmental rotation from Occiput-C1 to C3-C4 and rotation of the C4 vertebra, which indicates total rotation of segments distal to C4, with the neck in neutral position and in flexion position.

2. Materials and methods

2.1. Participants

Subjects were volunteers recruited from advertising in the Sapporo Medical University. Forty-five asymptomatic subjects who were less than 145 cm tall, without any history of significant cervical spine or shoulder girdle disorders were included. Twenty-two subjects were immediately excluded as they could not achieve end-range cervical flexion in the narrow space within the MRI unit. To identify potential cervical spine disorders, all remaining volunteer subjects were screened by sagittal T2-weighted and axial T2*-weighted MRI of the neck and by a routine physical examination of range of motion of the neck and upper limbs. Two orthopedic surgeons experienced in MRI evaluations, inspected all MRI images for abnormalities on the sagittal T2-weighted images (FSE, FOV: 250, TR/TE: 2570/140 msec, Thickness: 5.0 mm, Interval: 6.0 mm, Scan time 5:39) and the axial T2*-weighted images (GE, FOV: 200, TR/TE: 900/20 msec, Thickness: 5.0 mm, Interval: 5.0 mm, Scan time 5:24). Four subjects were found to have potential evidence of musculoskeletal disorders (non-symptomatic disc bulging) and were thus excluded. As a result, 19 females of the original 45 volunteer subjects completed the study. The mean height of the 19 subjects was 141.2 cm (range, 136–145 cm) and mean age 22.2 years (range, 19–27 years).

All subjects were informed of the study design and the procedures to be used and all provided informed consent prior to data collection. Data collection was conducted in the Shinoro Orthopedic, Sapporo, Japan. Approval for this study was granted by the Society of Physical Therapy Science.

2.2. Measurement method

2.2.1. Equipment

MRI of the cervical spine was performed with a 0.2-T horizontally open unit (AIRISmate, HITACHI Inc., Sapporo, Japan). The participants were placed in the supine position on a custom-made positioning device that was designed and constructed to fit into the MRI unit and attach to the examination table. It was located beneath the flexible receiver surface coil (MR-JCL-72 separate type, HITACHI Inc. Sapporo, Japan) and used to guide the movements of neck rotation from neck in neutral position and end-range flexion position. Both shoulders and chest were fixed firmly by belts (Fig. 1).

2.2.2. Data acquisition method

The range of vertebral rotation was assessed at each level from the occiput to the C4 vertebra under two conditions: head rotation with the neck in neutral position (lying without a pillow) and in a flexed position. The angle of the spinal column in the sagittal plane in the neutral and flexed positions was measured and calculated from the angle of bisection of the lines drawn parallel to the inferior end-plates of the C2 and C7 vertebra. This measurement has previously been shown to be reliable (Takasaki et al., 2009a). It was described as positive if it rotated anteriorly relative to the line described by C7, from sagittal T1-weighted images (GE, FOV: 250, TR/TE: 90/12 msec, thickness: 5.0 mm, interval: 9.0 mm, scan time 0:35). The sagittal T1-weighted image was captured before the measurements of head rotation in each neck position.



Fig. 1. The Flexion–Rotation Test.

For each measurement of the vertebral rotations (neutral and in flexion), an examiner passively maintained the end-range head rotated position during scanning. The order of testing (neck in neutral or in flexion) was randomized between subjects.

2.2.3. Measurement angles

Segmental rotation angles (Occiput-C1, C1-C2, C2-C3 and C3-C4) were calculated from the vertebral rotation angles as follows. Firstly, each vertebral rotation from the occiput to C4 vertebra was measured from axial T1-weighted images (GE, FOV: 260, TR/TE: 450/15 msec, Thickness: 2.5 mm, Interval: 2.5 mm, Scan time 2:56). Rotation of the occiput was measured by drawing a line from the midpoint of the foramen magnum to the nasal septum on the T1-weighted axial image (Fig. 2) and defining the rotation value between that line and sagittal plane (vertical image frame). The rotations of C1 and C2 were defined using a line drawn through the lateral masses of the atlas dividing C1 symmetrically into anterior and posterior parts (Fig. 3), and a line drawn parallel to the posterior border of the body of C2 (Fig. 4). The rotation values of the

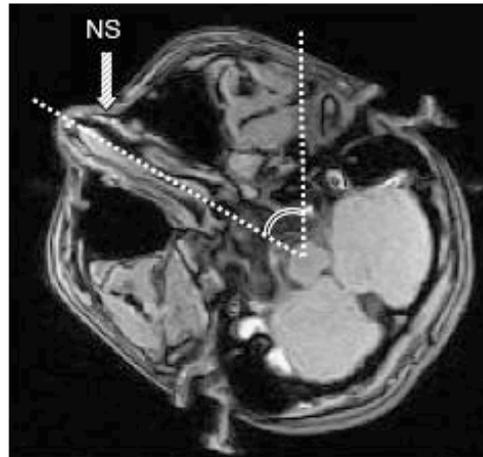


Fig. 2. Rotation of the occiput. Landmarks for determining rotation were the midpoint of the foramen magnum and the nasal septum (NS).

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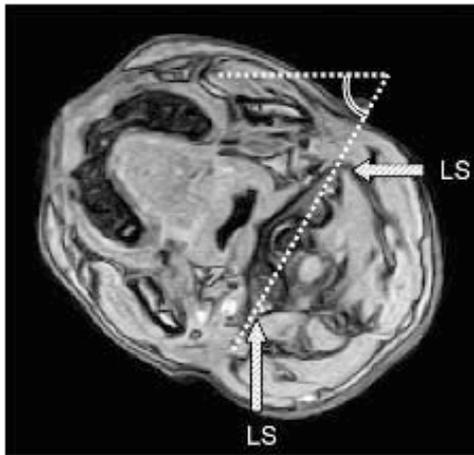


Fig. 3. Rotation of C1. Landmarks for determining rotation were the lateral masses (LS) of the atlas.

C1 and C2 vertebrae were defined between those lines and coronal plane (horizontal image frame). The angles of the C3 and C4 vertebrae were defined using a line drawn from the midpoint of each spinous process to the center of each vertebral body (Fig. 5). The sagittal plane (vertical image frame) was used as a reference. Secondly, segmental rotation angles were calculated by subtracting the rotation values of the lower vertebrae from those of the upper vertebrae. Each measurement was taken on two occasions and for analysis and presentation of results, the averaged values of two measurements were used. In addition, the angles of rotation to the left and right at each segment were summed.

To examine inter- and intra-observer variation of the measurement of the segmental rotations and the C4 vertebral rotation, two examiners experienced in the measurement of MRI data were included. The two different examiners, blind to each other's assessment, measured the same series to study inter-observer variation. To investigate intra-observer variation, one of the two

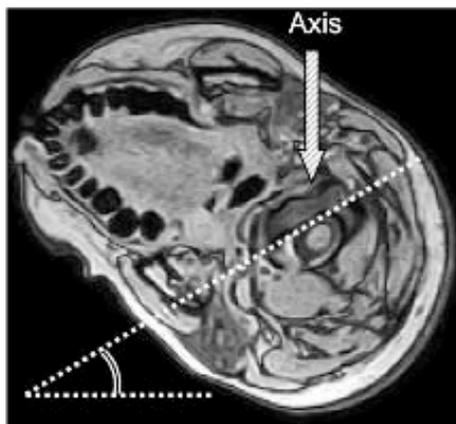


Fig. 4. Rotation of C2. Landmarks for determining rotation were the posterior border of the body of the axis.

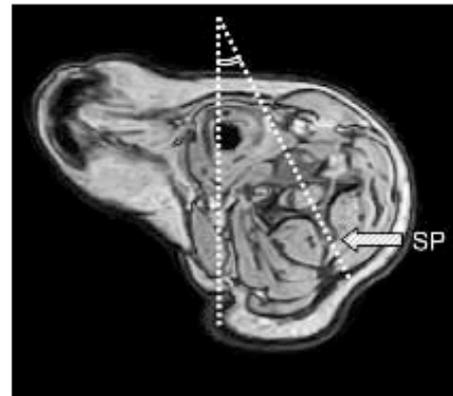


Fig. 5. Rotation of C3 and C4. Landmarks for determining rotation were the midpoint of each spinous process (SP) and vertebral body.

examiners measured the images twice on two separate occasions. On the second occasion, the examiner was blind to the results of the first measurement session.

2.2.4. Statistics

The intraclass correlation coefficients (ICC) were calculated with the use of $ICC_{(1,1)}$ and $ICC_{(2,1)}$ to examine inter- and intra-observer accuracy of MRI data measurements and to estimate the minimum number of measurement repetitions to achieve good measurement repeatability ($ICC > 0.8$). The standard error of measurement (SEM) of the segmental rotation angles from Occiput-C1 to C3-C4 and C4 rotation was calculated for each investigator to examine measurement accuracy of MRI data and Bland–Altman Plots were also examined for measurement error.

A repeated measure ANOVA was used to compare movement patterns of the segmental rotation angles and the C4 vertebral rotations (combined rotation from segments below the C4 vertebra) between the neutral position and the flexed position. The Shapiro–Wilk's test was used to examine for normal distribution of data and post-hoc analysis employed paired *t*-tests and/or Mann–Whitney *U* tests to examine mean differences of segmental rotations and the C4 vertebral rotations between the two neck starting positions. Statistical analysis was performed using SPSS version 18.0 (SPSS Inc., Tokyo, Japan). Statistical significance was set at $P < 0.05$.

3. Results

The intra- and inter-observer ICC and the SEM of the vertebral rotation angles are shown in Table 1. Substantial intra- and inter-observer reliability of the measures was demonstrated and the magnitude of measurement error was low. Based on the results of the $ICC_{(1,1)}$, it was determined that the average value of two measurements, rather than a single measurement, provided higher levels of repeatability ($ICC > 0.8$).

Bland–Altman Plots for the variable showing the lowest and highest ICC values are presented in Fig. 6 (lowest ICC, $ICC_{(1,1)}$ at C2–C3; highest ICC, $ICC_{(1,1)}$ at C1–C2). Most of the data points lay within the 95% limits of agreement except for one data point of the highest ICC.

The total ranges of head rotation in the neutral and flexed positions were $163.0^\circ \pm 8.3^\circ$ and $88.4^\circ \pm 7.6^\circ$, respectively. The mean sagittal angles of the cervical spinal column when the head

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Table 1

The intraclass correlation coefficient (ICC) and the standard error of measurement (SEM – degrees) for segmental rotation angles from Occiput-C1 to C3-C4 and the C4 vertebral rotation angles (combined rotation from segments below the C4 vertebra) with neck in neutral and flexion positions.

	Intra-observer ICC (1,1)		Inter-observer ICC (2,1)	
	Neutral (SEM)	Flexion (SEM)	Neutral (SEM)	Flexion (SEM)
Occiput-C1	0.8 (0.1)	0.7 (0.2)	0.8 (0.1)	0.7 (0.2)
C1-2	0.9 (0.1)	0.9 (0.1)	0.8 (0.4)	0.8 (0.4)
C2-3	0.7 (0.4)	0.7 (0.2)	0.7 (0.4)	0.9 (0.1)
C3-4	0.7 (0.3)	0.7 (0.2)	0.7 (0.3)	0.7 (0.3)
Segments distal to C4	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)	0.9 (0.2)

Values in brackets show SEMs.

was rotated in the neutral and flexed positions were $-3.3^\circ \pm 3.5^\circ$ and $52.4^\circ \pm 10.8^\circ$, respectively.

Preparatory analysis confirmed that the data for Occiput-C1, C1-C2, and C3-C4 were normally distributed. Mean segmental rotation angles (left and right summed) at each cervical motion segment in each neck position (neutral and flexion) are presented in Table 2. Notably, the range of rotation at the C1-C2 level was 51.9% of total head rotation in the neutral position and 73.5% of available range in the flexed position. A repeated measure ANOVA revealed an interaction between the two different neck starting positions and segment levels ($P < 0.0001$). Post-hoc analysis revealed that except for the Occiput-C1 segment, there were significant reductions ($P < 0.0001$) in the segmental rotation ranges with the neck in flexion compared with the neutral neck position.

4. Discussion

This study supports the content validity of the FRT, described by Dvorak (1998), as a test which predominately tests rotation of the atlanto-axial joint. In considering the distribution of segmental rotation between the neutral and flexed neck positions, the segmental rotation between the occiput and C1 was negligible in both test positions, which is consistent with the known kinematics of this motion segment (Bogduk and Mercer, 2000). At the atlanto-axial joint, there was a 16.3% reduction in range of rotation in the flexed compared to the neutral position, but this was minimal compared to the reduction which occurred at the other cervical segments: 68.1% at C2-C3, 61.4% at C3-C4 and 76.9% collectively at the cervical segments distal to C4. Thus, flexing the cervical joints and pre-tensioning the posterior cervical articular and other soft tissues in the neck flexion position has an apparent greater effect on the segments distal to C1-C2. The 16.3% reduction in C1-C2 motion

Table 2

Means and standard deviations of segmental rotation angles from Occiput-C1 to C3-C4 and the C4 vertebral rotation angles (combined rotation from segments below the C4 vertebra) with neck in neutral and flexion positions.

Level	Position	Mean (degree)	Standard deviation (degree)	95% confidence intervals	
				Lower band (degree)	Upper band (degree)
Occiput-C1	Neutral	1.6	1.7	0.8	2.4
	Flexion	1.7	1.7	0.9	2.5
C1-C2*	Neutral	77.6	9.7	72.6	72.9
	Flexion	65.0	7.5	61.4	68.6
C2-C3*	Neutral	8.3	3.5	6.6	9.9
	Flexion	2.6	1.9	1.7	3.6
C3-C4*	Neutral	10.5	3.7	8.7	12.3
	Flexion	4.1	2.4	2.9	5.2
Segments below the C4*	Neutral	65.0	6.6	61.8	68.2
	Flexion	15.0	5.0	12.6	17.4

* $P < 0.0001$.

measured in this study might reflect changes in tension of the soft tissue structures local to this joint including the alar ligaments and tectorial membrane in the FRT (Crisco et al., 1991; Oda et al., 1992). The C1-C2 segment provided 73.5% of the total rotation in the flexed position. This lends supports to the validity of the FRT as an assessment of predominantly atlanto-axial joint rotation.

To our knowledge this is the first study to measure segmental range of cervical rotation during the FRT. All previous reports that have investigated the FRT have used external measurement devices. In the present study, the total range of head rotation in the FRT position was $88.4^\circ \pm 7.6^\circ$. Walmsley et al. (1996) and Amiri et al. (2003) used an external electromagnetic device, the 3Space Tracker system, and reported ranges of $100.8^\circ \pm 12.9^\circ$ and $81.1^\circ \pm 10.3^\circ$ respectively for total head rotation in the FRT position. Hall et al. (2008b) used a Cervical Range of Motion goniometer and recorded 89° of rotation in the FRT. The small differences between our and other studies likely arise from different measurement methods as well as different FRT procedures (Walmsley et al., 1996; Amiri et al., 2003) but the comparability between the MRI and external measures supports the latter's use for a clinical evaluation.

MRI is a highly accurate means of measuring rotation range that has been used extensively in other kinematic studies of the cervical spine (Karhu et al., 1999; Gradl et al., 2005; Ishii et al., 2006; Takasaki et al., 2009b). Despite the number of studies to have used MRI to investigate cervical rotation range, ours is the first to report the reliability and measurement error for this technique. We

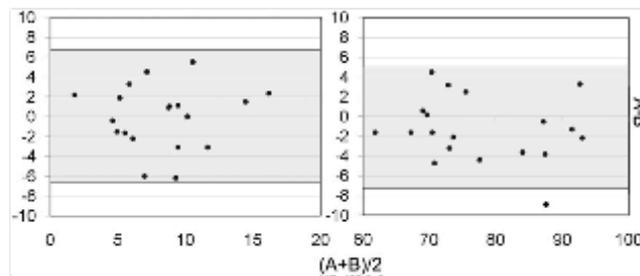


Fig. 6. Bland–Altman Plots for the variable showing the lowest and highest ICC values of vertebral rotation angles. Left image demonstrates the lowest ICC, $ICC_{(1,1)}$ at C2-C3. Right image demonstrates the highest ICC, $ICC_{(1,1)}$ at C1-C2. A - The value of the first measurement (degrees). B - The value of the second measurement (degrees). The area of the 95% limits of agreement (Mean of the difference between A and B \pm 2 standard deviations of the differences between A and B) is shaded.

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found good levels of inter- and intra-observer reliability for the measurement technique. ICCs were greater than 0.7, with narrow 95% confidence interval values for mean range of rotation. Furthermore the largest standard error of measurement was only 0.4°. In addition, Bland–Altman Plots for the lowest and highest ICC values demonstrated that most of the data points lay within the 95% limits of agreement. These indicate the method of measurement is reliable.

The present study had two potential limitations. Firstly, the study included only a small number of subjects and all were female (because of the height restriction to fit in the narrow space of the MRI unit), young and healthy without cervical spine disorders. Nevertheless, Walmsley et al. (1996) found no significant differences between genders for head rotation from a cervical neutral or maximally flexed position, but there were significant differences with age. Therefore, our angular data cannot be extrapolated to older subjects and further study of this age group is required. The second limitation was that segmental movement of the lower cervical segments was not assessed because of technical limitations. Further studies are required to assess rotation at all cervical segments during the FRT.

5. Conclusion

Good levels of inter- and intra-observer reliability were established for the MRI measurement of cervical segmental rotation. With the use of this measurement method, it was demonstrated that head rotation when the neck is in a flexed position occurs primarily at the atlanto-axial joint whereas rotation is markedly restricted at all other cervical motion segments. These data lend support to the content validity of the FRT as a clinical test of atlanto-axial mobility. There can be some confidence that the predominant location of the restriction is at the atlanto-axial joint when side to side differences of rotation are found in the FRT in the clinical assessment of patients with cervical disorders.

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5.7 STUDY 4

Study 4 is encapsulated in the following publication.

Hall T, Briffa K, Hopper D. 2010. The influence of lower cervical joint pain on range of motion and interpretation of the FRT. *Journal of Manual & Manipulative Therapy*. 18(3). 126-131.

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The influence of lower cervical joint pain on range of motion and interpretation of the flexion–rotation test

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Objective: The purpose of this study was to investigate the impact of lower cervical facet joint pain (CFP) on the flexion–rotation test (FRT).

Methods: A single blind, comparative group design was used to investigate whether lower CFP influences FRT mobility and examiner interpretation. Twenty-four subjects were evaluated, 12 with cervicogenic headache (age 26–63 years) and 12 with lower CFP (age 44–62 years), confirmed by therapeutic cervical facet joint intervention. A single blinded examiner conducted the FRT, reporting the test state (positive or negative) before measuring range of motion using a goniometer. Subjects with lower CFP were evaluated by the FRT prior to therapeutic intervention and were excluded from analysis if they did not gain complete symptomatic relief following the procedure. Only subjects with immediate complete relief were included.

Results: The average range of unilateral rotation to the limited side during the FRT was 26 and 37.5° for the cervicogenic headache and lower CFP groups respectively. The difference between groups was significant ($P < 0.01$). Sensitivity and specificity for cervicogenic headache diagnosis was 75 and 92% respectively. A receiver operating curve revealed that an experienced examiner using the FRT was able to make the correct diagnosis 90% of the time ($P < 0.01$), with a positive cut-off value of 32°.

Discussion: These findings provide further evidence for the clinical utility of the FRT in cervical examination and cervicogenic headache diagnosis.

Keywords: Cervicogenic headache, Diagnostic accuracy, Flexion–Rotation test, Sensitivity, Specificity

The flexion–rotation test (FRT) is a commonly used assessment of upper cervical movement and is typically used in differential diagnosis of cervicogenic headache and as a treatment outcome measure.¹ The test is typically performed in supine with the cervical and upper thoracic spine maximally flexed. Passive rotation to the left and right is compared for range, pain provocation and resistance.¹ Anatomical morphology suggests movement during the FRT is likely to be constrained to the C1/2 motion segment as a result of flexing the cervical spine to its end range.² End range flexion theoretically blocks/attenuates movement at segments below C2 by ligamentous tensioning. There is some evidence to support this conjecture, as magnetic resonance imaging has recently been used to measure cervical spine segmental movement *in vivo* during the FRT, where it

was shown that the majority of movement occurs at the C1/2 level.³

Normal range of movement for the FRT is reported as 44–45° to each side,^{4,5} while a cut-off value of 32–33° determines a positive test.^{6,7} Previously the FRT has been investigated in a number of different patient groups including those with cervicogenic headache,^{4,6,7} sub-clinical neck pain,⁵ and migraine with and without aura.^{7,8} Migraine pain had little impact on FRT range of motion.⁹ In contrast an association between sub-clinical neck pain and range of motion during the FRT has been reported.^{5,9} However, the cervical segmental source of the neck pain was not identified, so whether the association identified was related to upper or lower cervical disorders could not be examined.

Presently, the best method for determining from which spinal motion segment pain originates is by diagnostic block.¹⁰ Under ideal circumstances, to control for false-positive responses which occur with a single block,¹¹ diagnostic blocks should be

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performed using placebo controls or comparative local anaesthetic blocks.¹⁰ However, comparative local anaesthetic blocks are not usually performed in general clinical practice. In this setting, if complete symptomatic relief is obtained from blocking, for example, the C4/5 facet joint, this is considered to indicate that segment as the source of the patient's neck pain. If the anatomical theory regarding the relative isolation of the FRT to the C1/2 segment is correct, then pain arising from or dysfunction of motion segments other than C1/2 should have little influence on range of motion recorded during the FRT. If the FRT were to be influenced by the presence of lower cervical facet pain then the validity, sensitivity and specificity of the FRT would be diminished.

The purpose of this study was to investigate the impact of lower cervical facet pain (CFP) (confirmed by therapeutic cervical facet joint intervention) on range of motion recorded during the FRT, and examiner interpretation of the FRT. The hypotheses were that FRT mobility is reduced in subjects with cervicogenic headache when compared to those with lower CFP. Second, an examiner using the FRT is sensitive and specific in identifying subjects with C1/2 dominant cervicogenic headache from subjects with lower CFP.

Methods

A single blind, between group design was used to investigate whether lower cervical joint pain, confirmed by zygoapophyseal joint block, influences FRT mobility and examiner interpretation of the test. The Curtin University Human Research Ethics Committee granted approval for this study. Subjects gave written informed consent prior to the study commencement and were able to withdraw from the study at any time.

Subjects

A sample of convenience of subjects was recruited through advertisements placed in local newspapers and through the University website. Inclusion criteria for this group were based on criteria developed by Sjaastad *et al.*¹² and further developed by Antonaci *et al.*,¹³ with the exception of diagnostic anaesthetic blocks. These criteria include intermittent, side dominant headache of moderate intensity without side shift, headache preceded by neck pain, headache precipitated or aggravated by neck movement or posture and associated neck, shoulder or arm symptoms, thereby fulfilling 5 of 7 criteria outlined by Antonaci *et al.*¹³ as indicative of 'probable' CGH. Additionally headache frequency was at least once per week and episodic headache occurred for more than the previous three months. Exclusion criteria were headache not of cervical origin according to International Headache Society guidelines,¹⁴ and inability to tolerate the FRT.

Subjects with lower CFP scheduled for therapeutic cervical facet joint intervention consisting of cervical facet intraarticular injections, cervical medial branch block or cervical radiofrequency neurotomy were recruited from private physiotherapy clinics in the Perth metropolitan area. Inclusion criteria for this group included episodic or continuous neck pain for more than three months and complete, even if temporary, pain relief from therapeutic cervical facet joint intervention at cervical segments other than at C1/2. Exclusion criteria for this group were cervicogenic headache, arm symptoms, and inability to tolerate the FRT procedure. Subjects thus selected were believed to have neck pain arising from lower cervical motion segments. Table 1 details for each subject the cervical level of therapeutic cervical facet joint intervention.

Sample size estimate was based on data collected from a previous report⁷ and pilot data. *A priori* power analysis determined that a total sample size of 24 subjects (12 in each group) was required to obtain a statistical power of 0.80 with alpha set at 0.05. This was based on a single measurement of the FRT, together with a known mean value of 27° (SD=11) for the FRT in subjects with cervicogenic headache, with a mean value of 41° (SD=5.1) for the lower CFP group. Accordingly 12 subjects with cervicogenic headache (seven female), and 12 subjects with lower CFP (four female) were recruited.

Procedures

Prior to measurement all subjects with cervicogenic headache completed a headache questionnaire to obtain an index of headache severity (0–100, with 100 being maximum severity).¹⁵ This index is based on a composite score of headache intensity, duration and frequency with equal weighting given to each element. Test-retest measures of 20 subjects with cervicogenic headache over 24-hours showed high levels of reliability with ICC_(2,1) of 0.92.¹⁵ Additional information was sought from the subjects with lower CFP, including overall severity of neck pain prior to anaesthetic block, recorded on a visual analogue scale (VAS) consisting of a 10 cm line anchored at one end

Table 1 Cervical level of therapeutic cervical facet joint intervention for each subject (n=12)

Subject	Cervical level blocked
1	C4/5 and C5/6
2	C5/6 and C6/7
3	C3/4
4	C2/3
5	C2/3 and C3/4
6	C5/6 and C6/7
7	C5/6
8	C5/6 and C6/7
9	C4/5 and C5/6
10	C6/7
11	C5/6
12	C4/5 and C5/6



Figure 1 The cervical flexion-rotation test.

with the words 'no pain' and at the other end with 'worst pain imaginable', and duration of symptoms.

One specialist musculoskeletal physiotherapist assessed all 24 subjects while blind to the subject's group allocation. Experienced clinicians using the FRT have excellent inter-rater reliability [ICC 0.93 (CI, 0.87–0.96)].⁶

The FRT is shown in Fig. 1. The subject lay relaxed in supine with the cervical and upper thoracic spine passively flexed to end range, or if pain prevented this, to a comfortable limit determined by the patient. The head was then passively rotated left and right. Range was determined either by the subject reporting the onset of pain, or firm resistance encountered by the therapist, whichever came first. At this point the examiner made a visual estimate of the rotation range and was required to state whether the FRT was positive or negative, and which side was positive. A test was defined as positive where the estimated range was reduced by more than 10° from the anticipated normal range of 44°. ^{4,7} The examiner then repeated the procedure and measured FRT mobility using a cervical range of motion device (CROM). The CROM is a floating compass (Plastimo Airguide Inc. (Compasses), Buffalo Groove, IL, USA) attached to the apex of the head by Velcro straps. ^{4,7}

All subjects were tested once only. Those with cervicogenic headache were tested on a headache free day to negate the influence of headache at the time of testing. ¹⁶ Any subject complaining of headache on the day of testing was required to return on a symptom free day. Subjects with lower CFP were tested days prior to the therapeutic cervical facet joint intervention procedure. Only subjects who subsequently had complete relief of neck symptoms (even if short term) following the therapeutic cervical facet joint intervention procedure were retained in subsequent data analysis. In all, 19 subjects were tested for inclusion in the lower CFP group. Seven were rejected because they did not get complete relief from the therapeutic cervical facet joint intervention. The order in which subjects were presented to the examiner was randomly allocated, so that the

examiner was always blind to subject group allocation.

Statistical analysis

Statistical analysis was carried out using SPSS V17.0. (SPSS Inc., Chicago, IL, USA). An independent *t*-test was used to compare FRT mobility to the most restricted side between the two groups. To calculate the sensitivity and specificity, the subjects with cervicogenic headache were compared to the subjects with lower CFP. The dichotomous variable was determined according to the therapist's identification of the presence or absence of a positive FRT (10° estimated limitation of range). The frequencies used for these calculations are given in Table 2. The relationship between sensitivity and specificity is illustrated in a receiver operating curve that was created using data from the FRT. The receiver operating curve plots the false positive rate on the X axis and 1–the false negative rate on the Y axis. It shows the trade-off between the two rates. If the area under the receiver operating curve is close to 1, this represents a very good test. If the area is close to 0.5, this represents a very poor test, no better than chance at identifying the disease state. The point on the curve nearest the upper left-hand corner represents the value with the best diagnostic accuracy, and this point is selected as the cut-off defining a positive test.

Results

Headache symptoms and other characteristics are shown in Table 2. All underlying assumptions for an independent *t*-test were met. Range of rotation towards the most restricted side was significantly lower in the cervicogenic headache group than the group with lower CFP (Table 2). The difference between groups was significant ($P < 0.01$), with a mean difference of 11.5° (95% CI 16.8, 6.2).

Table 3 outlines the sensitivity, specificity, positive predictive value, and negative predictive value as well as likelihood ratios for cervicogenic headache diagnosis based on interpretation of the FRT. A receiver operating curve (Fig. 2) revealed that presented with a randomly chosen pair of patients, using the FRT, the clinician is able to make the correct diagnosis 90% of the time ($P < 0.01$). Additionally, coordinates on the receiver operating curve indicated that the test value, which provided the highest sensitivity and the lowest 1–specificity, is 32°. In other words, 32° represents the cut-off score for a positive test.

Discussion

To our knowledge, this is the first reported study to compare FRT range of motion determined by an experienced examiner in subjects with cervicogenic headache and lower CFP. On average, range was 11.5° less in subjects with cervicogenic headache than those with lower CFP. Our data for range of motion measured during the FRT are similar to previous

Table 2 Characteristics of the subjects in each group (n=24)

Variable	Group	
	Cervicogenic headache (n=12)	Lower cervical facet pain (n=12)
Gender		
Male	5	8
Female	7	4
Age (years)		
Mean (SD)	42.2 (12.2)	52.1 (5.5)
Range	26–63	44–62
History of pain (years)		
Mean (SD)	4.5 (3.2)	5.9 (2.3)
Range	0.5–12.0	2.0–11.0
VAS for symptoms/10		
Mean (SD)	5.3 (2.0)	6.3 (1.6)
Range	2.7–10.0	2.7–8.7
Index of headache severity (/100)		NA
Mean (SD)	51.2 (14.5)	
Range	33.7–83	
Dominant side of headache		
Left	6	NA
Right	6	
Bilateral	0	
Positive FRT		
Yes	9	1
No	3	11
FRT – range to restricted side (degrees)		
Mean (SD)	26.0 (7.4)	37.5 (5.0)
Range	18–38	24–45
FRT – range to the right (degrees)		
Mean (SD)	31.0 (8.9)	38.9 (5.4)
Range	19–49	24–46

Note: VAS, visual analogue scale anchored at 0 and 10; FRT, flexion-rotation test.

studies using the CROM device in subjects with cervicogenic headache.^{6,8} Mobility towards the most restricted side was 26 degrees in the current study and 22 and 26 degrees in previous reports.^{6,8} Small variation in range may relate to differences in severity of headache symptoms, among the different studies. Previously, variability in headache intensity, duration and frequency have been shown to influence range of motion recorded during the FRT.⁸

Mean range recorded in the subjects with lower CFP was 38°, which is less than the previously reported normal range of 44–45° to each side for the FRT,^{4,5} but within the normal limits of an 'eyeballed' 10° estimated limitation of range. Reduced range may reflect the presence of sub-clinical upper cervical joint dysfunction or may simply be due to the presence of pain itself. The presence of pain (headache) has recently been shown to reduce the measured range recorded during the FRT by an average of 6°.⁸

Table 3 The sensitivity, specificity, positive and negative predictive values as well as likelihood ratios of the cervical flexion-rotation test

Test	Value
Sensitivity	0.75
Specificity	0.92
Positive predictive value	0.90
Negative predictive value	0.79
Positive likelihood ratio	9.38
Negative likelihood ratio	0.27

Previously, consistent with the current study, we have established a goniometer determined cut-off score of 32–33° for a positive FRT,^{6,7} that is well below the mean range recorded for subjects with lower CFP in this study. This indicates that dysfunctional cervical motion segments below C2 do not influence the range sufficiently to change the interpretation of the FRT. This provides further evidence for the validity of the FRT as a test of upper cervical motion. Further evidence of the relative isolation of the FRT to the C1/2 motion segment has recently been demonstrated in a study using magnetic resonance imaging to measure segmental mobility during the FRT.³ In that study, segmental rotation at all cervical segments was measured during axial rotation with the neck in neutral and with the neck in flexion (FRT). Seventy-four percent of the total rotation occurred at the C1/2 motion segment with the neck in a flexed position. The remaining movement arose from all other cervical levels. In addition, when compared to axial rotation in neutral, rotation during the FRT was reduced by more than 73% at all segments apart from at the C1/2 segment, which only reduced by 12%. This might explain our finding that range recorded during the FRT was not greatly influenced by the presence of lower CFP.

The receiver operating curve (Fig. 2) shows the relationship between sensitivity and specificity. The area under the curve represents the ability of the test to discriminate between the diseased and non-diseased

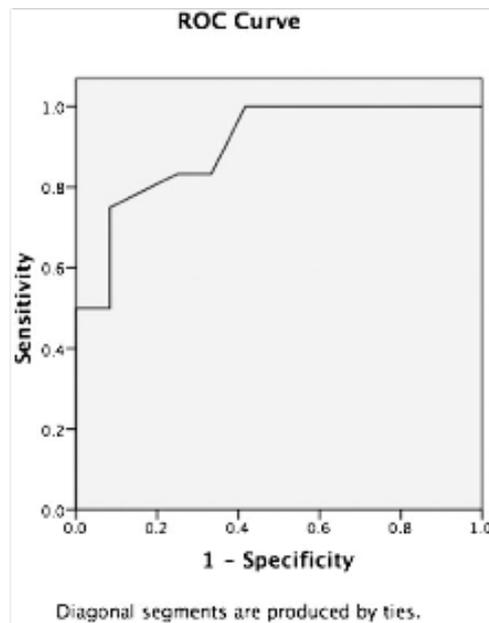


Figure 2 Diagnostic accuracy of the cervical flexion-rotation test. The area under the curve is 0.90 ($P=0.001$, CI 0, 1.0).

state. The receiver operating curve can be interpreted as follows: an area of 0.9, indicates that a randomly selected individual from the cervicogenic headache group has a lower range recorded during the FRT than that for a randomly chosen individual from the lower CFP group 90% of the time.¹⁷ Furthermore, the closer the receiver operating curve value area under the curve is to 1 the better the test, the closer to 0.5 the worse the test. A receiver operating curve value of 0.9, as found in our study, falls within the range 0.75–0.92, which is rated as good.¹⁷ In addition, the positive likelihood ratio was 9.4 indicating high certainty about a positive diagnosis in a positive test, whereas the negative likelihood ratio of 0.27 indicates with high certainty about a negative diagnosis in a negative test. Overall diagnostic accuracy in this study is consistent with a previous report, which found an overall diagnostic accuracy of 91% for the FRT.⁷

A number of other studies have examined the sensitivity and specificity of the FRT in cervicogenic headache diagnosis, although in highly selected homogenous samples.^{6,7} In the present study, sensitivity (75%) and specificity (92%) were consistent with previous reports of high levels of sensitivity and specificity for the FRT when used by experienced examiners.^{6,7} In contrast to those previous studies, this is the first study to identify sensitivity and specificity of the FRT with a comparative group consisting of neck pain patients. The relatively high levels of diagnostic accuracy with which the FRT could discriminate between groups in this study, provides support for the validity of the FRT.

There are potential limitations of this study that may affect the interpretation and generalization of these results. Firstly, subjects were recruited in a manner of convenience that may have introduced some sampling bias. Under ideal circumstances subjects should be recruited from consecutive patients attending a single clinic, but for logistical reasons this was not possible. Secondly, all subjects were tested by the same examiner, which may limit the generalizability of the findings; however, previous research indicates that naive examiners with minimal training can identify a positive FRT with high reliability,⁶ hence examiner experience is not a major factor in the FRT application or interpretation. Third, a single therapeutic cervical facet joint intervention procedure was used to determine the symptomatic segment. We recognize that single blocks have a significant rate of false positive findings.¹¹

Conclusion

Range of motion towards the most restricted side during the FRT is significantly reduced in subjects with cervicogenic headache when compared to subjects with lower CFP. The cut-off value for a positive test is range of motion less than 32°. These results provide evidence that the FRT can discriminate between the presence or absence of cervicogenic headache in subjects with neck pain and the presence of neck pain does not diminish test sensitivity or specificity. These findings provide further evidence supporting the clinical utility of the FRT.

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5.8 SUMMARY OF FINDINGS FROM PART B

The preceding two studies have provided new information regarding the validity of the FRT. Study 3, demonstrated that rotation during the FRT occurs primarily at the C1/2 segment. Minimal movement occurred at all other segments capable of generating headache. Study 4 demonstrated that FRT range of motion deficit was significantly greater in subjects with CGH when compared with subjects with lower cervical facet joint pain. The presence of neck pain from segments below C1/2 did not diminish FRT sensitivity or specificity.

These data lend support to the FRT as a valid clinical test of the C1/2 segment. There can be some confidence that the predominant location of the restriction is at the C1/2 segment when side-to-side differences of rotation are found in the FRT in the clinical assessment of people with cervical spine disorders including CGH.

Chapter 6: Part C

Study 5 and 6

- Clinical utility of the flexion-rotation test

6.1 RESEARCH QUESTIONS

The preceding two studies have established that the FRT is a valid test of dysfunction arising from the C1/2 segment. What is not certain is the frequency with which the C1/2 segment is the cause of CGH. The FRT is a more valuable clinical test if there is a high frequency of involvement of the C1/2 segment in CGH.

The gold standard for the identification of symptomatic spinal motion segments in spinal pain disorders is double-blind therapeutic block procedures such as facet joint injections. However these procedures are not routinely performed in clinical practice, particularly in the upper cervical spine, due to the apparent danger of inadvertent needle placement in this invasive technique. Hence, in the absence of an available gold-standard, manual examination has been employed to identify the symptomatic cervical motion segments in CGH (Zito et al 2006). The reliability of manual examination in the segments capable of generating CGH has not been clearly established.

Hence the following research questions were developed for Study 5:

- 1) What is the reliability of manual examination procedures in identifying symptomatic motion segments above C4 in subjects with CGH?
- 2) What is the frequency that each or multiple segments above the C4 level are the dominant source of pain in subjects with CGH?

6.2 STUDY 5 OBJECTIVES

The objectives of this study were to investigate the reliability of manual examination procedures and frequency that each or multiple segments above the C4 segment were the dominant source of pain.

6.3 STUDY 6 OBJECTIVES

The main objective of this study was to investigate the association between the presence and severity of CGH symptoms and the impairment in range of motion measured during the FRT. A secondary objective was to investigate whether other

subjective features of headache are associated with i) FRT mobility and ii) examiner interpretation of the FRT.

6.4 METHODOLOGY FOR STUDY 5 AND 6

6.4.1 Study design Study 5

A cross-sectional study design was used to investigate the reliability of manual examination and the frequency that cervical motion segments above the C4 level were the predominant source of symptoms in CGH.

6.4.2 Study design Study 6

An observational study design was used to investigate the relationship between the presence and severity of CGH symptoms or associated factors and FRT mobility and examiner interpretation of the FRT.

6.4.3 Sample size calculation Study 5

Sample size estimate for reliability was calculated to be 39 for α level of 0.05, power of 0.8, with a null hypothesis for Kappa of 0 (one-tailed test). However, previously we found only 3/62 subjects had symptomatic dysfunction at C0/1 or C3/4 motion segments in subjects with CGH (Hall et al 2003). Therefore, a sample size of 60 subjects was elected, in order to obtain subjects with segmental dysfunction at all levels above C4. To reduce the risk of examiner bias, arbitrarily, 20 asymptomatic subjects without history of CGH or significant neck pain were also examined, but not included in data analysis. Hence the total sample was 80 subjects.

6.4.4 Sample size calculation Study 6

To allow statistical analysis of all characteristics (headache frequency, intensity, headache episode duration, photophobia, etc), at least five subjects were required per predictor variable. A total of 10 predictors (see below) required a sample size of at least 50 subjects with CGH. Subject recruitment ceased once all predictor variables contained at least five subjects, which occurred at 72. To reduce examiner bias, arbitrarily an additional 20 subjects who had no significant history of

neck pain or CGH and who were of similar age to the subjects with CGH, were included in the sample.

6.4.5 Subjects

Recruitment for subjects was as follows: Subjects with CGH were recruited in a manner of convenience through advertisements placed in local newspapers and through the University website. Asymptomatic subjects were volunteers recruited from Curtin University students.

6.4.5.1 Inclusion criteria

CGH - Subjects were selected based on criteria developed by the IHS (Classification Committee of the International Headache Society 2004) and Sjaastad (1998). These included a primary complaint of side dominant headache without side shift, headache preceded by neck pain, and headache precipitated or aggravated by neck movement or posture. Additionally headache frequency needed to be at least once per week and episodic headaches needed to have been present for more than the previous 3 months.

Asymptomatic - Asymptomatic subjects were selected based on the absence of significant neck pain or CGH.

6.4.5.2 Exclusion criteria

Subjects were excluded in either Study 5 or 6 if they had inability to communicate, inability to tolerate the FRT, if they were receiving physical treatment for their neck (for example physiotherapy or chiropractic), and if they did not provide informed consent.

CGH – Subjects with CGH were excluded if they had continuous headache for more than 48 hours and headache was not of cervical origin. In addition, in Study 5, subjects were excluded if they could not tolerate manual examination of the cervical spine.

Asymptomatic - Subjects were excluded if they had significant history of neck pain or headache (once per month or more).

All participants were given a written information sheet explaining the procedure prior to testing and gave written consent. The Human Research Ethics Committee of Curtin University of Technology granted approval for this study. Subject information sheets, consent forms, and ethical approval documentation are presented in the appendix section (Chapter 10).

6.4.6 Variables

6.4.6.1 Study 5

Independent variables

- Two examiners

Dependent variables

Dependent variables were determined by manual examination

- Symptomatic cervical motion segment (levels C0/1, C1/2, C2/3, and C3/4)
- Dominant symptomatic cervical motion segment (levels C0/1, C1/2, C2/3, or C3/4)
- Single or multilevel symptomatic motion segment
- Examiner agreed frequency of single or multilevel symptomatic motion segment
- Examiner agreed frequency of symptomatic cervical motion segment (levels C0/1, C1/2, C2/3, and C3/4).

6.4.6.2 Study 6

Independent variables

- Two groups - CGH and asymptomatic
- Headache at the time of test occasion

Dependent variables

- Range of rotation to the most restricted side (degrees) recorded during the FRT measured by a modified cervical range of motion device (CROM)
- Examiner interpretation of the FRT (positive or negative)
- Subject and headache characteristics including headache duration, intensity and frequency as well as gender, age, history of headache, dominant side of headache, unilateral nature of headache, presence of photophobia, phonophobia, nausea or headache of pulsating quality.

Reliability of measures

Previous studies conducted by the author have shown excellent inter-tester and intra-tester reliability of FRT measurements, when the test is followed by an immediate re-test, for both asymptomatic subjects, and subjects with CGH (Hall and Robinson 2004; Ogince et al 2007). The examiner in Study 6 was also used for the current study.

6.5 STUDY 5

Study 5 is encapsulated in the following publication.

Hall T, Briffa K, Hopper D, & Robinson K. 2010. Reliability of manual examination and frequency of symptomatic cervical motion segment dysfunction in cervicogenic headache. *Manual Therapy*. 2010. doi:10.1016/j.math.2010.06.002

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Original article

Reliability of manual examination and frequency of symptomatic cervical motion segment dysfunction in cervicogenic headache

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ABSTRACT

This study investigated the reliability of manual examination procedures and the frequency that each or multiple segments in the upper cervical spine above the C4 vertebra were the dominant source of pain in subjects with cervicogenic headache (CGH). Eighty subjects were evaluated, 60 with CGH (39 females, mean age 33 years) and arbitrarily a further 20 asymptomatic subjects (13 females, mean age 34 years) included to reduce examiner bias, but subsequently omitted from data analysis. Two experienced physiotherapists examined on the same day each subject with standard manual examination procedures, independently rating each segment in the upper cervical spine above the C4 vertebra for involvement. Examiners were blind to each other's findings and the subject's clinical status. Standard and adjusted Kappa coefficients were calculated for each segment in symptomatic subjects only. Chi-squared analysis for goodness of fit was used to identify the segment that was most frequently determined the predominant symptomatic segment. Manual examination above the C4 vertebra showed good reliability. The C1/2 segment was most commonly symptomatic, with a positive finding at this segment in 63% of cases. The high frequency of C1/2 involvement in CGH highlights the importance of examination and treatment procedures for this motion segment.

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1. Introduction

Cervicogenic headache (CGH) is a sub-group of secondary headache arising from cervical spine musculoskeletal dysfunction (Classification Committee of the International Headache Society, 2004). Classification of CGH is based on a range of subjective features and physical examination findings, which have been previously described (Sjaastad et al., 1998; Classification Committee of the International Headache Society, 2004). Recently it has been shown that the combination of three tests of cervical spine musculoskeletal function can identify subjects with CGH, from other headache forms, with 100% sensitivity and 94% specificity (Jull et al., 2007). These tests include cervical range of motion, manual examination of the upper cervical spine, and cervical motor control evaluated by the craniocervical flexion test.

One of the defining characteristics of CGH is the presence of cervical joint dysfunction. Dysfunction may involve any of the upper three cervical segments (Zito et al., 2006; Bogduk and Govind, 2009) and can be measured by manual examination (Maitland et al., 2001). Manual examination is a means of

determining from which spinal segment pain arises, and consists of tests of unilateral passive accessory intervertebral motion (PAIM) and passive physiological intervertebral motion (PPIM). This information is important as it focuses the examination on a particular area of the cervical spine and also directs treatment.

Manual examination has high sensitivity and specificity to detect the presence or absence of cervical joint dysfunction in neck pain and headache patients (Jull et al., 1988, 1997; Sandmark and Nisell, 1995). However, these tests involve a high degree of skill on the part of the therapist, and their reliability has been questioned (Seffinger et al., 2004). The apparent inconsistency between sensitivity, specificity and reliability may be a reflection of poor research methods rather than manual examination being an unreliable procedure (Stochkendahl et al., 2006).

The cervical flexion–rotation test is gaining credibility as a useful aid in the classification of CGH (Hall et al., 2008a,b). A positive test is purported to indicate dysfunction at the C1/2 motion segment (Stratton and Bryan, 1994). Although there is no direct research evidence to support this assumption, there is evidence from a number of studies that the flexion–rotation test is positive in subjects with C1/2 segmental dysfunction identified by manual examination (Hall and Robinson, 2004; Ogincic et al., 2007; Hall et al., 2008a,b). The importance of the flexion–rotation test in CGH evaluation and management is dependent on how commonly

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the C1/2 segment is the primary cause of the patient's symptoms. To date, no study has intentionally sought to identify how frequently the individual segments from C0/1 to C3/4 are the dominant cause of CGH or whether multiple segments are involved.

Previously it has been documented that the C1/2 segment was the most symptomatic cervical motion segment in 80% of a sample of 28 subjects with CGH (Hall and Robinson, 2004). Similarly Zito et al. (2006) examined 27 subjects with CGH and reported that C1/2 segmental dysfunction was an important factor in headache diagnosis. In both studies determination of C1/2 segmental dysfunction relied on manual examination. A larger, more heterogeneous sample is required, to further investigate these reports.

Knowledge of the frequency that each cervical motion segment is the predominant source of pain in CGH is important as it informs management. This information also informs the importance of procedures such as the flexion–rotation test. The purpose of this study was to investigate the reliability of manual examination procedures and the frequency that each or multiple segments above the C4 vertebra were the dominant source of pain. The hypotheses were that manual examination is reliable and that the C1/2 segment is most commonly the dominant symptomatic motion segment in subjects with CGH.

2. Methods

A cross-sectional study design was used to investigate the reliability of manual examination and the frequency that cervical motion segments above the C4 vertebra were the predominant source of symptoms in CGH. The Curtin University Human Research Ethics Committee granted approval for this study. Subjects gave written informed consent prior to the study commencement and were able to withdraw from the study at any time.

2.1. Subjects

Sample size estimate for reliability was calculated to be 39 for a single-tailed α of 0.05, a power of 0.8, with a null hypothesis for Kappa of 0. However, as we previously found only three of 62 subjects with CGH had symptomatic dysfunction at C0/1 or C3/4 motion segments (Hall et al., 2003) we increased the sample size to 60 subjects, in an effort to capture some subjects with segmental dysfunction at each segment above C4. To reduce the potential risk of examiner bias, the sample examined was also expanded arbitrarily to include 20 asymptomatic subjects with no history of CGH or significant neck pain. Hence 80 subjects participated in the study. It should be noted however that the purpose of including the additional 20 subjects in the study was not to address the question of whether manual examination can reliably be used to differentiate between subjects with CGH and asymptomatic subjects. For that reason, only 60 symptomatic subjects were included in the data analyses addressing the study hypotheses.

Subjects with CGH were recruited in a manner of convenience through advertisements placed in local newspapers and through the University website. Inclusion criteria for subjects with CGH were based on criteria developed by the IHS (Classification Committee of the International Headache Society, 2004) and Sjaastad et al. (1998). These included side dominant headache without side shift, headache preceded by neck pain, and headache precipitated or aggravated by neck movement or posture. Additional requirements were headache frequency at least once per week and episodic headache for more than 3 months. Exclusion criteria were headache not of cervical origin (IHS, 2004), inability to communicate, inability to tolerate manual examination of the cervical spine above the C4 vertebra, and lack of informed consent.

Accordingly 60 subjects with CGH (39 females, mean age 33 years, range 18–61, SD 8.5) and 20 asymptomatic subjects (13 females, mean age 34 years, range 20–63, SD 11.5) were recruited. In the subjects with CGH, symptoms had been present for an average of 4.5 years (range 1–15, SD 3.14) and average frequency was 2.1 headaches per week (range 1–7, SD 1.29).

2.2. Procedures

Subjects with CGH and asymptomatic controls were examined on the same day by two Specialist Musculoskeletal Physiotherapists who had experience in using the examination procedures. The order in which CGH and asymptomatic subjects were presented to the examiners was randomly allocated, but the order in which the two examiners assessed the subjects was not randomised. Examiners were required to determine the presence and segmental level of symptomatic cervical motion segments by manual examination (Maitland et al., 2001; Monaghan, 2001). The examination consisted of tests of PAIM and PPIM. Examiners were blind to each other and were given no information regarding the symptomatic nature of the subjects. Each subject was given a 1-hour rest period between examiners to minimise the mobilisation effect of examination and to reduce systematic differences in characteristics (van Triffel et al., 2005).

Tests of PAIM were performed with the subject lying prone with their neck resting in a neutral position. The examiner applied progressive unilateral postero–anterior pressure over the articular pillars of the upper four cervical vertebrae, in an attempt to provoke a pain response. Each vertebra was tested a maximum of two times, in an attempt to minimise a mobilisation effect of the test procedure, in an effort to maintain subject consistency for the second examiner. A negative response was no pain on firm pressure. A positive response was to elicit pain, particularly when the patients' exact symptoms were reproduced. The symptomatic segment was defined as the vertebral level where pain was provoked to the strongest extent, or most reproduced the patients' symptoms.

Information gained from PAIM was correlated with knowledge gained from tests of PPIM for each segment C0/1, C1/2, C2/3 and C3/4. These tests were performed with the subject lying supine, with their neck resting in a neutral position. The examiner carried out movement in all planes whilst gently palpating the joint line on one side with their finger-tips (Maitland et al., 2001; Monaghan, 2001). Each side was evaluated in turn. Repeated movement was minimised to a maximum of three movements per motion segment to minimise a mobilisation effect, in an effort to maintain subject consistency for the second examiner. Aberration from the ideal range of motion, termed hypomobility, was noted and correlated with symptom provocation for vertebrae adjacent to this segment. A normal range of PPIM, without pain provocation on PAIM at adjacent segments was defined as a negative finding. A positive finding was determined by hypomobility on PPIM, together with pain provocation from PAIM at adjacent cervical vertebrae. The examiners were required to state which motion segments (C0/1, C1/2, C2/3 and C3/4) were symptomatic. In addition examiners were required to state the dominant segment, a decision based on the segment that was most painful on PAIM, or where PAIM more clearly reproduced the subjects headache symptoms.

Data were collected in a dichotomous form. Each examiner classified all subjects, reporting whether each segment above the C4 vertebra was positive or negative on manual examination and which segment was the dominant source of symptoms (dominant symptomatic segment). It was possible for more than one cervical segment to be symptomatic but examiners were required to nominate one segment as dominant.

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2.3. Statistical analysis

Statistical analysis was carried out using SPSS V17.0. (SPSS Inc., 444 N. Michigan Avenue, Chicago, Illinois, 60611). Alpha was set at 0.05 for each analysis. Only subjects with CGH were included in the analyses.

An inter-rater reliability analysis using Kappa statistics was performed to determine the consistency among raters for the identification of the symptomatic status overall (any segment C0–4), and at each segment above C4. Furthermore inter-rater reliability analysis was performed to determine the consistency among raters for the identification of the most symptomatic motion segment. Simple percentages of agreement between the two examiners were reported for manual examination, as well as the raw numbers of positive and negative examination findings. We also calculated the bias and prevalence indices for each variable. The magnitude of Kappa is affected by both these indices and Kappa needs to be interpreted in the light of information from both (Sim and Wright, 2005). The prevalence index reflects the prevalence of the attribute under examination (Sim and Wright, 2005). If the presence of the attribute is high or low the prevalence index will be high, and the likelihood of chance agreement increases, and Kappa will be reduced. Likewise the bias index reflects agreement between the examiners on the proportion of positive or negative cases. When there is a large bias value, Kappa is higher than when the bias value is low or absent (Sim and Wright, 2005). The prevalence and bias indices may affect the Kappa coefficients, particularly if the index values are greater than 0.5 (Schneider et al., 2008). We used the prevalence and bias values to determine the prevalence-adjusted, bias-adjusted Kappa (PABAK) coefficients (Sim and Wright, 2005). Descriptive statistics and frequency histograms were used to summarise the frequency data. Only where both examiners agreed on manual examination was data included for one-tailed Chi-squared analysis for goodness of fit, to identify the segment that was most frequently determined the predominant symptomatic segment.

3. Results

Within the CGH group, considering all segments above C4, Examiner 1 and Examiner 2 found 51 and 55 of 60 subjects respectively had at least one symptomatic segment (Table 1). The unadjusted Kappa coefficient for inter-rater reliability was 0.68. When determining whether a single segment was positive or negative unadjusted kappa coefficients ranged from 0.61 to 0.71 (Table 1). The bias index was low for all segments but the prevalence index was ≥ 0.5 for C0/1 and C3/4 increasing the likelihood of

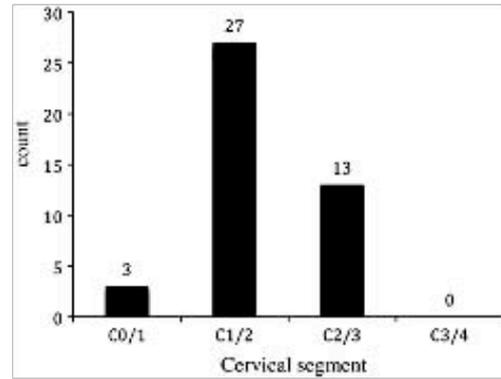


Fig. 1. Frequency histogram for the dominant upper cervical symptomatic segment where both examiners agreed (n = 43).

chance agreement. Prevalence and bias adjusted Kappa was ≥ 0.7 for all four segments of interest.

With respect to the dominant symptomatic segment, Kappa coefficients for inter-rater reliability were 0.40, 0.70 and 0.71 for C0/1, C1/2 and C2/3 respectively. However, the prevalence index was high for C0/1, which was rarely the dominant segment (Table 1). After adjustment the PABAK coefficients were ≥ 0.70 for all three segments. No subjects were found by either examiner to have a dominant symptomatic C3/4 segment so the calculation of Kappa and other coefficients was not appropriate.

Examiners agreed on the segment and/or presence of the dominant symptomatic cervical segment in 43 of the 60 symptomatic cases. In those 43 subjects, C1/2 was the most frequently dominant symptomatic segment ($\chi^2_{(3)} = 41.3$; $p < 0.001$; Fig. 1). As a proportion of subjects with a dominant symptomatic cervical segment, 7% were at C0/1, 63% were at C1/2 and 30% were at C2/3. No subjects had a dominant symptomatic segment at C3/4.

The spread of agreed positive manual examination findings across cervical segments are shown in Fig. 2. The majority of positive findings were at the C1/2 and C2/3 segments. In subjects where a positive segment was detected, examiners agreed on 48 out of 58 occasions as to whether there was a single or multiple positive segments. Eighteen subjects were reported as having a single symptomatic cervical segment and 30 subjects were reported as having multi-level problems.

Table 1
Inter-rater reliability for positive symptomatic segments and dominant symptomatic segments according to manual examination in the 60 subjects with cervicogenic headache. Data include unadjusted Kappa coefficients (95% CI), percentage agreement, prevalence and bias indices, prevalence and bias adjusted Kappa coefficients (PABAK) for positive counts at all segments and at each individual segment. Segment C3/4 was not the dominant segment for any subject.

Test	Unadjusted kappa (95% CI)	PABAK	Percentage agreement	Prevalence index	Bias index	Examiner 1 positive	Examiner 2 positive
Positive at any segment C0/4							
Manual examination	0.20 (0.17, 0.23)	0.64	83.3	0.77	0.07	54	57
Positive at C0/1							
Manual examination	0.64 (0.40, 0.88)	0.74	86.7	0.5	0	15	15
Dominant	0.40 (0.05, 0.75)	0.76	88.3	0.78	0.02	6	7
Positive at C1/2							
Manual examination	0.71 (0.51, 0.91)	0.76	88.3	0.45	0.02	44	43
Dominant	0.70 (0.52, 0.88)	0.70	85.0	0.05	0.03	32	31
Positive at C2/3							
Manual examination	0.70 (0.52, 0.88)	0.70	85.0	0.05	0.05	30	33
Dominant	0.71 (0.51, 0.91)	0.76	88.3	0.45	0.02	16	17
Positive at C3/4							
Manual examination	0.61 (0.37, 0.85)	0.74	86.7	0.87	0.03	14	12

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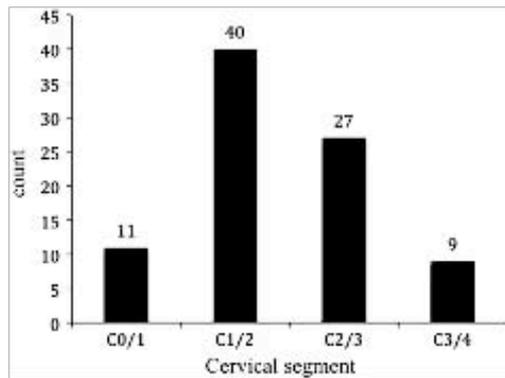


Fig. 2. Frequency histogram of upper cervical segments found positive on manual examination where both examiners agreed ($n = 60$). *Note more than one segment was positive in some subjects.

4. Discussion

This is the first reported study to identify by manual examination the frequency with which motion segments in the upper cervical region are the dominant symptomatic cervical segment in subjects with CGH. The C1/2 segment was identified as the dominant source of symptoms in 63% of cases where examiners agreed on manual examination. Other segments were less frequently dominant, with 30% of cases at C2/3, seven percent at C0/1 and none at C3/4. These results concurred with previous reports that have identified the C1/2 segment as a common source of headache (Hall and Robinson, 2004; Zito et al., 2006). Similarly April et al. (2002) found 62% of subjects with CGH had complete relief of symptoms after lateral atlanto-axial joint blocks.

It is beyond the scope of the present study to identify why the C1/2 segment is more frequently symptomatic, however we propose that differences in anatomical morphology of the C1/2 articulation may be a contributing factor. For example the C1/2 segment is the most mobile in the cervical spine (Bogduk and Mercer, 2000). This large range of motion may create a predisposing factor to mechanical stress at this motion segment. Degenerative changes occur more readily in the lower cervical spine and less frequently in the upper cervical spine, negating the possibility of osteoarthritis as a factor. Furthermore the average age of the group with CGH was 33 years, further reducing the likelihood that osteoarthritis is involved (Taylor and Twomey, 2002). Further studies are required to identify mechanisms involved in CGH evolution to understand why the C1/2 segment is a dominant cause of symptoms.

The results of this study highlight the importance of evaluation of the C1/2 segment in CGH. These results additionally add importance to the flexion–rotation test, as an isolated test of C1/2 motion, which has been shown to be commonly dysfunctional in subjects with CGH (Hall and Robinson, 2004; Hall et al., 2008a,b). The high frequency of C1/2 dysfunction in CGH also has implications for management. It would seem logical that for effective management of CGH, manual therapy intervention should target the C1/2 segment. For example a recent placebo controlled trial found a Mulligan mobilisation technique effective in the long-term management of patients with CGH (Hall et al., 2007). All subjects were purported to have segmental dysfunction at the C1/2 segment based on impairment identified by the flexion–rotation test.

The present study adds to the body of evidence demonstrating cervical joint dysfunction in CGH (Jull et al., 1988, 2007; Jaeger, 1989;

Jensen et al., 1990; Watson and Trott, 1993; Treleaven et al., 1994; Whittingham et al., 1994; Schoensee et al., 1995; Zito et al., 2006; Amiri et al., 2007; Uthakhpur et al., 2009). In clinical practice it is recommended that manual examination should be used in conjunction with other physical tests to improve accuracy in identifying CGH. Particularly as some studies have found evidence of cervical joint dysfunction in subjects with migraine (Kidd and Nelson, 1993; Bevilacqua-Grossi et al., 2009), although a systematic review found very limited evidence for cervical joint dysfunction in migraine, other than in animal models (Robertson and Morris, 2008). Migraine is a common headache form with many similarities to CGH. However, it has been demonstrated that the combination of manual examination, together with cervical range of motion and the craniocervical flexion test differentiates subjects with CGH from those with other forms of headache such as migraine, with 100% sensitivity and 94% specificity (Jull et al., 2007).

The spread of positive findings on manual examination across upper cervical segments in subjects with CGH has not been commonly reported. We found that the C1/2 and C2/3 segments were the most common dysfunctional segments, with lower frequency at the C0/1 and C3/4 segments (Fig. 2). Multi-level cervical involvement was more common than single segment involvement. Zito et al. (2006) performed manual examination in 27 subjects with CGH and reported positive findings in 70% at C0/1, 72% at C1/2, 48% at C2/3, and 20% at C3/4 segments. It is unclear why there was such a big difference between these two studies in the frequency of positive findings at C0/1.

Guidelines for interpretation of Kappa have been reported by Landis and Koch (1977). They considered less than or equal to zero poor, 0.01–0.20 slight, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 substantial, and 0.81–1 almost perfect. In our study standard Kappa coefficients (Kappa range, 0.20–0.71) and adjusted coefficients (PABAK range, 0.64–0.76), fall into the slight, moderate or substantial agreement range. It is of note, however, that there was a large increase in reliability when using the adjusted Kappa coefficients. The unadjusted Kappa coefficient for a positive finding on manual examination at any segment between C0/4 is 0.20, which is considered only slight reliability, yet the PABAK coefficient increases to 0.64 indicating substantial agreement.

The magnitude of Kappa coefficient represents the proportion of agreement greater than that expected by chance (Sim and Wright, 2005). It is important to understand that standard Kappa coefficients are greatly affected by the presence of bias and prevalence. In our study the bias indices were very low but the prevalence indices were high for examiner rating at the C0/1 and C3/4 segments. The prevalence index represents the prevalence of the attribute being tested (Sim and Wright, 2005). In our study there were few cases with positive findings on manual examination at the C0/1 or C3/4 segments. When there is a large prevalence index Kappa coefficients are lower than when the prevalence index is low. A good example of this paradox was shown in a study of inter-rater agreement of measuring mobility in the sacroiliac joint (Schneider et al., 2008). Unadjusted Kappa coefficients ranged from –0.10 to –0.11 but rise to 0.77 and 0.82 after adjustment for the bias and prevalence indices.

Numerous studies have been published investigating various aspects of reliability of manual examination of the spine (Seffinger et al., 2004; van Trijffel et al., 2005). In general low levels of reliability, with low levels of internal and external validity have been reported in a systematic review (van Trijffel et al., 2005). It has been suggested, however, that low levels of reliability may be a reflection of poor study methodology rather than poor reliability of the examination procedure per se (Stochkendahl et al., 2006). For example Smedmark et al. (2000) examined inter-examiner reliability of PAIM tests in the cervical spine. Similar to the present

study examiners had high levels of experience and evaluated the C1/2 segments. Although percentage agreement was high, the standard Kappa coefficient was only 0.28, and the examination procedure was reported as only having fair reliability. In their study there were no reports of the bias or prevalence indices, but the presence of the attribute, in this case a positive finding at the C1/2 segment, was very low, comprising only 3% of the sample. Based on estimates of the raw data (Sim and Wright, 2005) from Smedmark et al. (2000), the PABAK coefficient would rise to 0.74, which indicates substantial agreement. It would appear that previous reports of low levels of inter-examiner reliability for different manual examination procedures, may be partly explained by the failure to adjust Kappa coefficients for the high/low prevalence of the attribute under test (Schneider et al., 2008).

A recent systematic review determined that there was evidence of at least fair level of reliability for determining motion at the C1/2 segment and fair to substantial agreement for the C2/3 segment (van Trijffel et al., 2005). Our study builds on this body of knowledge, demonstrating higher levels of reliability when the prevalence indices are considered. Our study attempted to improve on the methodological quality of previously published studies of reliability. A checklist of criteria for assessing methodological quality of studies on inter-examiner reliability has been reported, and we believe the present study complied well with those criteria (van Trijffel et al., 2005).

There are potential limitations to our study that might influence interpretation of the results. Firstly there may have been a mobilisation effect from the first examiner creating a systematic difference in subject characteristics for the second examiner. A substantial attempt was made to minimise this effect by instructing both examiners to limit the number of repetitions of each test. In addition each subject was given a 1-hour rest to maintain subject test characteristics for the second examiner. However it is possible that a mobilisation effect occurred, which might affect the reliability of the results. Consequently the restriction of normal clinical practice, in an attempt to maximise the quality of the research methodology, may diminish the external validity of these results. Secondly both examiners had a specialist qualification in musculoskeletal physiotherapy, which limits the external validity of the results to similarly qualified clinicians.

5. Conclusions

Manual examination of the cervical spine was found to be reliable in 60 subjects with CGH. Examiners' rating of manual examination identified the C1/2 segment as the most common symptomatic segment, with 63% of cases positive at this segment. The high frequency of C1/2 segmental involvement in CGH highlights the importance of examination and treatment procedures for this motion segment.

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6.6 STUDY 6

Study 6 is encapsulated in the following publication.

Hall T, Briffa K, Hopper D, & Robinson K. 2010. The relationship between cervicogenic headache and impairment determined by the cervical flexion-rotation test. *Journal of Manipulative and Physiological Therapeutics*.

doi:10.1016/j.jmpt.2010.09.002

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THE RELATIONSHIP BETWEEN CERVICOGENIC HEADACHE AND IMPAIRMENT DETERMINED BY THE FLEXION-ROTATION TEST

Toby M. Hall, MSc, Kathy Briffa, PhD, Diana Hopper, PhD, and Kim W. Robinson, BSc

ABSTRACT

Objective: This study evaluates the association between probable cervicogenic headache (CGH) and associated headache symptoms and cervical spine impairment identified by the flexion-rotation test (FRT).

Methods: This was an observational study. Ninety-two subjects were evaluated, 72 with probable CGH and 20 who were asymptomatic. Headache symptoms were evaluated by questionnaire. A single blind examiner conducted the FRT, reporting the test state (positive or negative) before measuring range of motion (ROM). Fifteen subjects reported headache during testing and were subsequently retested when pain-free. A paired *t* test was used to determine whether FRT mobility to the most restricted side differed when the subject was experiencing headache. Univariate linear regression analysis and multiple regression analysis were used to examine the relationship between subject and headache characteristics, and range of motion during the FRT. Logistic regression analysis was used to examine relationships between subject and headache characteristics and whether the FRT was positive or negative.

Results: Mean ROM was significantly reduced ($P < .01$) by 6° in the presence of headache, but this did not influence test interpretation. Regression analysis revealed that half the variance in FRT ROM was explained by an index of headache severity or component parts but not by other headache characteristics.

Conclusions: These findings indicate a relationship between cervical movement impairment and the presence and severity of CGH. (*J Manipulative Physiol Ther* 2010;xx:1-6)

Key Indexing Terms: *Physical Examination; Diagnosis; Headache; Range of Motion*

Headache is a common symptom affecting a large proportion of the general population. Although head pain is a consequence of a variety of different disorders,¹ cervicogenic headache (CGH) is a well-defined subclassification of headache^{1,2} associated with a distinct pattern of impairment of cervical musculo-skeletal structures.³

Some investigators have studied upper cervical joint dysfunction as a characteristic of CGH. Limitation of movement may occur in the cardinal planes³⁻⁵ or may occur during rotation in flexion,^{6,7} a movement purportedly biased to the C1/2 motion segment.^{8,9} In the flexion-rotation test (FRT) procedure, the neck is passively held in end range flexion and rotated to each side (Fig 1), with pain or resistance to movement being the end point. Average

range of motion in healthy subjects is 44°⁶ to each side with a positive test identified if instrument-measured range is less than 33°.⁸ In clinical practice, the FRT is deemed positive if there is an eyeballed visual estimation of 10° reduction in range.⁸

A number of studies have investigated the potential utility of the FRT.^{8,8,10-12} Diagnostic accuracy has been demonstrated in highly selected homogenous groups of patients with migraine with aura, CGH, or healthy controls.^{8,11} In addition, test-retest reliability has been shown on symptom-free days.¹³ Furthermore, there is evidence that the FRT may be useful in determining treatment success.¹⁰ However, it is not known whether the presence of headache at the time of testing affects the results of the test. This has implications from a diagnostic point of view as well as for the use of the test as a treatment outcome measure as symptoms may vary between test occasions.

Findings from the 2 studies^{6,11} that have investigated the relationship between headache severity and impairment measured by the FRT are inconsistent. This may be due to the relatively small sample size in both studies or to the use of a headache index to measure headache severity. It has been suggested that headache frequency is a better measure of headache severity.¹⁴ Alternatively, different unidentified headache characteristics may be correlated with impairment identified by the FRT potentially confounding the results of the test. This information may be important in differential

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Fig 1. Cervical FRT.

diagnosis of patients with more complex multiple headache disorders. In this case, subjective features alone may not be sufficient to identify the presence of CGH and physical examination criteria such as the FRT may improve diagnostic accuracy.

Cervicogenic headache is a chronic problem in a small proportion of the population with headache. Two randomized controlled trials have shown that appropriately directed physiotherapy can be effective for long-term management of CGH,^{10,15} but a systematic review of the use of such treatment for all headache types shows this is not the case.¹⁶ It is therefore apparent that accurate differential diagnosis is essential to ensure that appropriate treatment can be provided.

The primary purpose of this study was to investigate the association between the presence and severity of CGH symptoms and the impairment in range of motion measured during the FRT. A secondary purpose was to investigate whether other subjective features of headache are associated with (i) FRT mobility and (ii) examiner interpretation of the FRT. Such knowledge has the potential to improve the clinical utility of the FRT.

METHODS

In this observational study, the relationship between the presence and severity of CGH symptoms or associated factors and FRT mobility and examiner interpretation of the FRT was investigated. The Curtin University Human Research Ethics Committee approved this study. Written informed consent was obtained before the study commencement and subjects were able to withdraw at any time.

Subjects

Subjects were recruited in a manner of convenience through advertisements seeking volunteers with chronic unilateral headache associated with neck pain placed in local

newspapers and through the University Web site. To allow statistical analysis of all characteristics (headache frequency, intensity, headache episode duration, photophobia, etc), at least 5 subjects were required per predictor variable. A total of 10 predictors (see below) required a sample size of at least 50 subjects with CGH. Subject recruitment ceased once all predictor variables contained at least 5 subjects, which occurred at 72. To reduce examiner bias, arbitrarily an additional 20 subjects who had no significant history of neck pain or CGH and who were of similar age to the subjects with CGH were included in the sample.

Criteria for subjects with CGH were based on those developed by Sjaastad et al² and further evaluated by Antonaci et al.¹⁷ To be included in the study, subjects were required to have intermittent, side-dominant headache of moderate intensity, without side shift. The headache was required to be preceded by ipsilateral neck pain and precipitated or aggravated by neck movement or posture, thereby fulfilling 5 of 7 criteria outlined by Antonaci et al¹⁷ as indicative of "probable" CGH (hereon, CGH infers "probable" CGH). In addition, headache frequency was required to be at least once per week and episodic headache must have occurred for more than the previous 3 months. Subjects were excluded if their headache could be classified into any other specific form according to the International Headache Society headache classification criteria,¹ or if they were unable to communicate or could not tolerate the FRT. Subjects responding to the advertisements were initially screened by either telephone or face-to-face interview according to the inclusion and exclusion criteria.

Procedures

A separate researcher interviewed volunteers for entry-level eligibility, based on the inclusion and exclusion criteria. Before measurement, subjects with CGH completed a headache questionnaire to obtain an index of headache severity (0-100, with 100 being maximum severity).¹⁸ This index is based on a composite score of headache intensity, duration, and frequency with equal weight given to each element. It has been shown to be reliable. Test-retest measures of 20 subjects with CGH over 24 hours showed high levels of reliability with ICC_(2,1) of 0.92.¹⁸ Additional demographic details, including headache characteristics and associated features, were also assessed by questionnaire. These characteristics included history of headache (years), dominant headache side (right or left), unilaterality of headache (yes/no), headache of pulsating quality (yes/no), presence of nausea (yes/no), photophobia (yes/no), phonophobia (yes/no), age (years), and sex.

A single examiner with 15 years of clinical experience in using the FRT assessed all subjects, while remaining blind to the subject's clinical presentation. In the hands of experienced investigators, intrarater reliability for range of motion was reported as 0.95 (95% confidence interval [CI], 0.90-0.98),

with a minimal detectable change of 4.7° for right rotation.¹³ In addition, examiner interpretation of the FRT has been shown to be consistent over time with κ of 0.92.¹³

With the subject relaxed supine and the cervical spine passively maximally flexed, the head was passively rotated left and right (Fig 1). Range was determined either by the subject reporting the onset of pain or by firm resistance encountered by the therapist, whichever came first. At this point the examiner made a visual estimate of the rotation range and was required to state whether the FRT was positive or negative, and which side was positive. A positive test was defined where the estimated range was reduced by more than 10° from the anticipated normal range of 44°. ^{6,11} The examiner then repeated the procedure and measured FRT mobility using a cervical range of motion device. The cervical range of motion device is a floating compass (Plastimo Airguide Inc [Compasses], Buffalo Groove, IL) attached to the apex of the head by Velcro straps.^{6,11}

All subjects were tested on one occasion except those who presented with headache during testing. Subjects with headache at the time of testing were also retested as soon as possible after the headache had resolved. Consequently, 15 subjects were tested on 2 occasions, once with and once without the presence of headache. Subjects who were recalled for a second (pain-free) FRT were requested to refrain from seeking physical treatment for their neck until after the second test.

Statistical Analysis

Statistical analysis was carried out using SPSS V12.0. (SPSS Inc, Chicago, Ill). α was set at .05 for each analysis. A paired *t* test was used to determine whether FRT mobility to the most restricted side differed when the subject was experiencing headache. Univariate linear regression was used to examine the relationship between headache index severity and range of motion during the FRT. Multiple regression analysis (forward stepwise; *P* to enter <.05, *P* to remove >.1) was used to examine the relationships between subject and headache characteristics, and range of motion during the FRT. Logistic regression analysis (forward stepwise; *P* to enter <.05, *P* to remove >.1) was used to examine relationships between subject and headache characteristics and whether the FRT was positive or negative. Before analysis, the data were examined for violation of assumptions for regression analysis, including checking for outliers, normality, homoscedasticity, independence of residuals, and linearity. No violations were found.

RESULTS

Of 154 subjects screened for headache, 82 were rejected for the following reasons; 5 constant headache, 10 no associated neck pain, and 67 with diagnostic features of

Table 1. Characteristics of the subjects with CGH (*n* = 72)

Variable	No. of subjects
History of headache (y)	
Mean (SD)	7.07 (7.3)
Index of headache severity (/100)	
Mean (SD)	55.9 (15.4)
Headache frequency (/100)	
Mean (SD)	51.1 (22.1)
Headache episode duration (/100)	
Mean (SD)	56.4 (26.6)
Dominant side of headache	
Left	25 (34.7%)
Unilateral headache	
Yes	57 (79.2%)
Associated photophobia	
Yes	5 (6.9%)
Associated phonophobia	
Yes	9 (12.5%)
Associated nausea	
Yes	11 (15.2%)
Headache of pulsating quality	
Yes	9 (12.5%)

tension type headache or migraine. Accordingly, 72 subjects with CGH (20 males; mean age, 39 years; range, 21-66 years; SD, 12.8 years) and 20 without neck pain or CGH (age, 35 years; range, 22-61 years; SD, 9.2 years) were evaluated and completed this study.

The headache characteristics of the 72 headache subjects are presented in Table 1. Table 2 shows that range of motion during the FRT measured to the most restricted side was lower in the CGH group than in the asymptomatic group. Seventy-two percent of subjects (52/72) from the CGH group were found to have range less than 32° toward the most restricted side. In contrast, the examiner interpreted the FRT as positive in 78% of subjects (56/72) from the CGH group and 15% of subjects (3/20) from the asymptomatic group. Consequently, in this sample, the FRT had a sensitivity of 0.78, specificity of 0.85, positive likelihood ratio of 5.18, and negative likelihood ratio of 0.26 for distinguishing CGH from asymptomatic controls.

Range of motion during the FRT was less when subjects were experiencing a headache than when they were free of symptoms (Table 2). In the presence of headache, mean range toward the most restricted side during the FRT was 5.9° (95% CI, 7.4° to 4.5°) less than range on the pain-free days (*P* < .001).

Univariate linear regression analysis revealed a significant inverse association between headache severity (according to the headache index) and range of motion toward the most restricted side during the FRT for all subjects with CGH. This was highly significant (*r* = -0.37 *P* = .002).

Exploratory Pearson correlation coefficients revealed poor to valuable relationships (range, 0.02-0.61) with range of motion toward the most restricted side during the FRT as the dependent variable and all other variables. When the

Table 2. Flexion-rotation test range of motion (mean [SD]) to the most restricted side in subjects with CGH and asymptomatic subjects

Variable	Asymptomatic controls (n = 20)	CGH without headache at testing (n = 72)	CGH—subset with headache at testing (n = 15)	
			During headache (n = 15)	Without headache (n = 15)
FRT restricted side	41.5 (6.2)	22.2 (7.7)	25.2 (9.2)	31.1 (7.93)

individual components of the headache index (duration, intensity, and frequency) and other variables (sex, age, history of headache, dominant side of headache, unilateral nature of headache, presence of photophobia, phonophobia, nausea, or headache of pulsating quality) were entered into forward stepwise multiple linear regression analysis with range of motion toward the most restricted side during the FRT as the dependent variable, headache duration, frequency, and intensity were the most significant predictors of range of motion. These variables accounted for 52% of the variance in FRT range of motion ($P < .05$). Once these variables had been entered into the model, none of the remaining independent variables made sufficient additional contribution to the model to meet the entry criterion.

When forward stepwise multiple logistic regression analysis assessed all the headache and subject characteristics, only the standardized headache index scores (z scores) were associated with whether the examiner had assessed the FRT as positive or negative (odds ratio, 2.45; 95% CI, 1.52-3.96). The odds ratio indicates that for each individual, a 1 SD increase in headache severity index increased the odds of a positive FRT by a factor of 2.45 (or 254%).

DISCUSSION

This is the first study to examine in subjects with CGH the relationship between the presence and severity of headache symptoms and the FRT. The study findings of a clear association between range of motion and headache severity, frequency, and duration, together with lack of association with other headache symptoms, and stability of the test in the presence of pain, will assist clinicians to refine and better interpret the FRT. Values recorded during the FRT were similar to previous reports for asymptomatic subjects and subjects with CGH.^{8,8,11,12} Mean range of rotation toward the most restricted side was 22° in the current study and 26° in a previous report.⁸ The slightly greater restriction in the current study may be a reflection of the lower index of headache severity (45% compared to 60%) in the subjects with CGH in the study by Hall et al.⁸ Although diagnostic accuracy was not the primary purpose of this investigation, sensitivity, specificity, and positive and negative likelihood ratios are consistent with previous reports for the FRT when used by experienced examiners.^{8,11} Previously, it has been shown that the FRT has good diagnostic accuracy to identify subjects with CGH from subjects with migraine with aura and asymptomatic controls. Further evaluation of the discriminatory capacity of the FRT in heterogeneous samples of subjects

with headache is required before the diagnostic accuracy of the FRT can be confirmed.

In our sample of subjects with CGH, there was an inverse relationship between headache severity and range of motion. Moreover, each of the individual components of the headache severity index, that is, headache episode duration, intensity, and frequency, was found to make independent contribution to the prediction of impairment identified by the FRT. These findings suggest some value for the FRT in monitoring outcome of management programs for CGH. As headache severity abates, range of motion should increase.

Whether symptoms at the time of examination influence the findings of the assessment is important to take into account when establishing the utility of clinical tests. The presence of headache at the time of testing was not associated with the examiner's interpretation of whether the test was positive or negative so, as a sign of the presence or absence of CGH, the test could be applied even in the presence of headache. In contrast, the reduced range of rotation during the FRT in the presence of headache at the time of testing indicates a need for caution if comparing results on headache and headache-free days, particularly when monitoring treatment outcomes. It is of interest to note that in subjects with episodic or transformed migraine, active cervical range of motion was not found to be influenced by the presence of headache at the time of testing,¹⁹ although range in both migraine groups was reduced when compared to asymptomatic controls. Although it is not possible to be certain why the presence and severity of CGH influences range of rotation during the FRT, it is possible that in subjects with cervical dysfunction the presence of pain induces altered resting muscle tone, thereby restricting range of movement. Further studies to investigate this would be of interest.

We found that sex, age, history of headache, side of headache, photophobia, phonophobia, associated nausea, headache of pulsating quality, and headache at the time of testing did not influence interpretation of the FRT. The findings for age and sex are not surprising as this has been previously reported.¹² Associated features of headache (photophobia, etc) are common complaints of subjects with migraine but less commonly reported by subjects with CGH,²⁰ which is consistent with our findings (Table 1). This result might suggest that some elements of headache, present in CGH, do not relate to dysfunction of the cervical spine, but further studies are required to investigate this. An alternative explanation may be that subjects with headache had more than one type of headache. The absence of an association between some of the headache characteristics that

more commonly present in association with other types of headache suggests that these characteristics are unlikely to confound the results of the FRT or alter its utility if the test was being used for differential diagnosis between different headache types.

The co-occurrence of 2 or more headache types is common in patients with frequent intermittent headaches.^{21,22} In addition, neck pain is common in migraineurs.²³ Hence, clinically determining whether CGH coexists with other headache types in an individual patient requires diagnostic procedures additional to subjective characteristics. The FRT is an easily applied clinical examination procedure. Knowledge that limitation of movement during this test is related to the severity of headache symptoms in CGH provides evidence that the FRT is a useful measure of cervical impairment in CGH evaluation.

Limitations

This study had a number of potential limitations that may affect the external application of these results. We found 22% of subjects with CGH were negative on the FRT. Further research could investigate whether such subjects have headache arising from segments other than C1/2 or their headache is not representative of CGH. Further limitations are the use of only one very experienced examiner and the wide variation in both the history and the severity of headache in this sample.

CONCLUSIONS

Subjects with CGH demonstrated an inverse relationship between an index of headache severity and range of motion measures taken during the FRT. Furthermore, headache frequency, intensity, and duration were the most significant predictors of range of motion measured by the FRT. Although the presence of headache during testing significantly reduces range during the FRT by 6°, it does not influence identification of a positive test. It does however suggest caution is warranted when using the FRT as a treatment outcome measure.

Practical Applications

- Flexion-rotation test (FRT) range of motion is reduced in range in subjects with cervicogenic headache.
- For this group of participants, mean range of motion during the FRT was reduced by 6° in the presence of headache but this did not influence test interpretation.
- Half the variance in FRT range of motion is explained by an index of headache severity or component parts but not by other headache characteristics.

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Summary of findings from part C

The studies undertaken in Part C have provided additional information regarding the clinical utility of the FRT. In Study 5, manual examination of the cervical spine was found to be reliable when used by two experienced examiners in subjects with CGH. Examiners' rating of manual examination identified the C1/2 segment as the most common symptomatic segment, with 63% of cases positive at this segment. The high frequency of C1/2 segmental involvement in CGH highlights the importance of the FRT in CGH evaluation and also highlights the importance of specific treatment procedures for this motion segment.

In Study 6, subjects with CGH demonstrated an inverse relationship between an index of headache severity and range of motion measures taken during the FRT. Furthermore, headache frequency, intensity and duration were the most significant predictors of range of motion measured by the FRT. Although the presence of headache during testing significantly reduces range during the FRT by six degrees, it does not influence identification of a positive test. It does however suggest caution is warranted when using the FRT as a treatment outcome measure.

Chapter 7: Discussion

7.1 INTRODUCTION

CGH is a sub-category of secondary headache believed to arise from convergence of nociceptive input from the upper three cervical nerve roots with trigeminal afferents in the TCN (Bogduk and Govind 2009). Diagnostic criteria for CGH have been established but many of the subjective features of CGH are common to other headache forms, in particular migraine without aura (Yi et al 2005). Consequently incorrect headache diagnosis frequently occurs when relying on subjective features for classification (Pfaffenrath and Kaube 1990; Moeller et al 2008). Aspects of cervical physical examination have been shown to be very useful in classifying CGH including manual examination (Amiri et al 2007; Jull et al 2007). One form of manual examination, the FRT, is used to identify specific cervical spine dysfunction and as an outcome measure following physical intervention (Hall et al 2007).

A number of studies have provided some preliminary evidence of the potential for the FRT to aid in CGH diagnosis (Hall and Robinson 2004; Hall et al 2007; Ogince et al 2007; Smith et al 2007; Hall et al 2008). The studies that make up this doctoral thesis built on this evidence and establish a number of facts. Part A was developed to improve the understanding of the long-term stability, minimal detectable change, and diagnostic accuracy of the FRT in CGH evaluation. Part B established the validity of the FRT as a test of cervical movement impairment at, and pain arising from, the C1/2 level. Part C of this research added to the understandings of the relationship between impairment identified by the FRT and headache symptoms, providing more useful evidence of the clinical utility of the FRT in CGH evaluation.

This chapter will present a discussion of the findings of the six studies reported in relation to the relevant literature. Limitations of the research are outlined and recommendations for future research made. Finally the clinical implications of this research are considered.

7.2 PART A – RELIABILITY AND DIAGNOSTIC ACCURACY OF THE FRT

Headache symptoms are usually evaluated by monitoring the frequency, intensity and duration of headache attacks over days or weeks (Andrasik et al 2005). Indeed, the frequency of headache attack was nominated as the most important indicator of treatment success in a survey of people attending physiotherapy private practice for management of headache (Niere and Robinson 1997). Headache attack frequency in people with CGH is usually intermittent, becoming more constant with chronicity (Sjaastad and Bakketeig 2007). In a large survey of a small town in Norway, the most common attack frequency was one headache per two- to four-weeks (Sjaastad and Bakketeig 2007), indicating a large gap between headache events. Thus to monitor change in headache as a result of management, evaluation of people who suffer with CGH usually entails assessment of headache episodes over prolonged periods of time, usually weeks rather than days. It is therefore very important that measurements taken to measure clinical features of CGH are stable over time. This is necessary to be sure that alteration in assessment parameters are related to the specific intervention rather than random fluctuation in the measurement tool. Normal values for range of movement measured during the FRT in asymptomatic subjects and for subjects with CGH have been established (Hall and Robinson 2004). In addition the FRT has been shown to be a reliable measure of

cervical movement impairment on a test and re-test basis (Hall and Robinson 2004; Ogince et al 2007). The stability of the measurement over time, however, has not been tested. In addition the magnitude of error, or MDC, between repeated trials of the test is unknown.

To our knowledge Study 1 is the first to identify the long-term stability of the FRT over weeks, and the MDC in both asymptomatic and symptomatic people.

A previous study has shown that the FRT has excellent sensitivity, specificity and examiner agreement in the diagnosis of CGH in highly controlled homogenous samples (Ogince et al 2007). In that study subjects were carefully selected. Comparison groups were strictly defined single headache forms (migraine with aura and asymptomatic control), without cervical spine dysfunction. Such careful selection of subjects for comparative groups may have artificially inflated the diagnostic accuracy of the FRT in CGH diagnosis.

Individuals who suffer from headache frequently present with a range of different headache features, sometimes manifesting with more than one headache form. This fact is supported by various investigations of large cohorts of people who suffer with chronic headache suggesting that many individuals report more than one form of headache (Pfaffenrath and Kaube 1990; Fishbain et al 2001; Amiri et al 2007). In a survey of the population of the town of Vaga in Norway 41/75 people diagnosed with CGH were found to have one headache form. The remaining 34 were found to have CGH together with other headache forms (typically TTH or migraine) (Sjaastad and Bakketeig 2007). Classification of headache is thus complicated by the presence of more than one headache form in any individual sufferer of headache.

As each headache form arises from differing underlying pathophysiological processes, management for each condition must vary accordingly. For example CGH

is known to respond to manipulative therapy (Jull et al 2002). However, a systematic review indicated that people who suffer from migraine or TTH do not respond to such forms of treatment (Bronfort et al 2004). Hence, the identification of CGH is important to physiotherapists and other practitioners of manipulative therapy, as it informs the practitioner of the potential for physical treatment.

The FRT may aid in the identification of CGH, but knowledge of the responsiveness of the FRT in differentiating CGH from migraine without aura, or MHF is not known. To our knowledge Study 2 is the first to identify the diagnostic accuracy of the FRT in identifying subjects with CGH from those with migraine without aura, or those with MHF.

7.2.1 Study 1 (Chapter 4.5)

The aims of this study were to identify the long-term stability of the FRT measurements, to investigate the long-term reliability of test interpretation, and to establish the MDC for FRT measurements. Fifteen subjects with chronic CGH were assessed using the FRT on four occasions. These occasions were spread over two-weeks and conducted by an experienced examiner. An additional 10 asymptomatic subjects were included to reduce examiner bias, but were not included in the analysis. The examiner was blind to the subject's symptomatic status. For subjects with CGH there was no significant change in FRT range of motion over days. Intratester reliability for range recorded during the FRT was excellent for right and left rotation. Furthermore examiner interpretation of the FRT was almost perfect according to the Landis and Koch scale (Landis and Koch 1977).

The results for Study 1, demonstrate that measurement of range recorded during the FRT is reliable and stable over time when assessed by a single

experienced examiner. Furthermore examiner interpretation of the test is consistent over time. These results are in keeping with previous findings of high levels of inter- and intra-therapist reliability for the FRT (Hall and Robinson 2004).

Stability for other range of motion measures of the cervical spine have also been investigated over a one-week time period and were found to be less consistent than that found for the FRT (Sterling et al 2002). In the present study SEM's of two degrees and three degrees for right and left rotation respectively were recorded. This is consistent with previous studies of the FRT (Hall and Robinson 2004), but at the lower end of the range shown for studies of active cervical range of motion (Pellechia and Bohannon 1998; Petersen et al 2000; Fletcher and Bandy 2008). Lower levels of error for the FRT when compared with whole cervical range of motion testing may be due to the fact that the FRT is a passive procedure in contrast to cervical range of motion testing, which is active. Passive movement testing may reduce the potential for error.

These results show that the minimal detectable change for FRT range of motion data was 4.7° for right rotation and seven degrees for left rotation. In addition, the standard error of measurement was less than three degrees. Minimal detectable change values indicate that a change in FRT range of motion of at least seven degrees is required to be 90% confident that a change has occurred rather than measurement error. Previously a 10° difference has been estimated as a clinically meaningful difference in range of motion for a positive FRT. The MDC of seven degrees found in this study indicates that a 10° difference in range for a positive FRT is greater than the error-free threshold.

7.2.2 Study 2 (Chapter 4.6)

The aim of this study was to compare the findings of the FRT between subjects with CGH, migraine without aura, and MHF. An additional aim was to identify the diagnostic accuracy of the FRT in CGH evaluation, and to determine the most significant predictors of range of motion during the FRT. Sixty subjects with chronic headache (20 with CGH, 20 with migraine without aura and 20 with MHF) were evaluated by a single experienced examiner using the FRT on a single headache-free occasion. The examiner was blind to the subject's group allocation.

The results indicated that the average range of unilateral rotation to the most restricted side during the FRT was least in subjects with CGH and most in subjects with migraine. Range was significantly reduced in the CGH group when compared with the other two groups, with an additional smaller significant difference being noted between the migraine and MHF. Based on the FRT, an experienced examiner was able to make the correct diagnosis of CGH 85% of the time. Furthermore it was determined that a range of 30° on the FRT can be considered to be the cut-off point for a positive test.

This is the first study to compare FRT range of motion deficits in subjects with CGH, migraine, and MHF, hence no direct comparisons can be made with other research. Mean range in subjects with CGH was consistent with previous reports (Hall et al 2008; Hall et al 2010). In addition mean range in subjects with migraine without aura was consistent with previous reports for migraine with aura (Ogince et al 2007) and only marginally less than asymptomatic controls (Hall and Robinson 2004; Smith et al 2007).

The FRT evaluates range of motion predominantly in the upper cervical spine. Other studies have investigated cervical active range of motion deficits in subjects

with CGH, TTH and migraine. Some studies (Zwart 1997; Zito et al 2006; Jull et al 2007) but not all (Dumas et al 2001; Hall and Robinson 2004) have reported diminished cervical range of motion in subjects with CGH when compared with asymptomatic subjects. Limitation of active movement in the sagittal plane is the major movement loss. Similar deficits in cervical range of motion have been reported in people who suffer from TTH (Fernandez-de-las-Penas et al 2006) and migraine (Fernandez-de-Las-Penas et al 2006; Bevilaqua-Grossi et al 2009), although not for all movements. In contrast, other studies have failed to find evidence of cervical range of motion deficits in people who suffer from migraine (Kidd and Nelson 1993; Dumas et al 2001; Zwart and Sand 2002; Fernandez-de-Las-Penas et al 2006; Zito et al 2006).

One explanation for the inconsistency in reported studies of cervical movement deficits in migraine may be due to the poor methodological quality of studies undertaken. A systematic review of published studies up till April 2006 found no convincing evidence of cervical musculoskeletal dysfunction (including cervical range of motion) in people with migraine, where evaluated studies were of sound methodological quality (Robertson and Morris 2008).

Other reasons for discrepancy between published studies regarding range of motion deficits in headache may be the small sample sizes and differences in subject profiles in the evaluated studies. For example the study by Bevilaqua-Grossi et al (2009) had a small sample size and was considered a pilot study. Furthermore cervical mobility was only reduced by a mean eight degrees in right rotation in those with migraine. Further differences in range of motion were found between people with transformed migraine and episodic migraine. Furthermore there was no association between the side of migraine headache and direction of movement

limitation (Bevilaqua-Grossi et al 2009). This is contrary to range of motion deficits identified by the FRT, which occur predominantly towards the side of pain.

Thus for a person presenting to a clinic with headache, associated neck pain and minor limitation of cervical range of motion does not necessarily indicate CGH. Further physical examination tests are required in that individual to confirm the presence of CGH. These findings further highlight the importance of the FRT in CGH evaluation.

The present study indicates a slightly lower cut off value for a positive FRT when compared with earlier studies. The current study identified a cut-off score of 30°, whereas previously a cut-off score of 32° was reported (Hall et al 2008). This information has implications for clinical practice where diagnosis of CGH might rely on a number of features including the individual's presenting symptoms as well as physical examination findings (Hall et al 2008). As up to 55% of people who suffer from headache have more than one headache form (Pfaffenrath and Kaube 1990; Fishbain et al 2001; Amiri et al 2007; Sjaastad and Bakkeiteig 2007; Sjaastad and Bakkeiteig 2007), the identification of CGH is made difficult by the mixture of headache characteristics. In individuals who have subjective features that do not fit into a specific headache category (or who have evidence of MHF) then the physical examination becomes more important. In this case a lower cut-off score is necessary on the FRT for the examiner to be confident of a diagnosis of CGH. In individuals with a relatively pure form of CGH, clearly defined by the presenting symptoms, then a higher cut-off score might be adequate.

The factors associated with migraine headache in this study were not associated with range of motion deficits determined by the FRT. In contrast, almost half the variance in FRT range of motion was explained by the presence of two

variables potentially indicating cervical spine dysfunction. These were: neck movement or positions that provoke headache, and neck symptoms that precede headache. These factors provide further evidence for involvement of the cervical spine in CGH pathogenesis.

The results of these studies have allowed a greater understanding of the stability, reliability and diagnostic accuracy of the FRT in CGH evaluation. It is concluded that the FRT has a low level of error associated with repeated measurement and measurements taken are stable over a two-week time period. Furthermore, test interpretation is reliable over this time period. Although migraine and CGH have differing underlying pathophysiological mechanisms, they typically present difficulty in differential diagnosis. These results indicate that the FRT can aid in the differential diagnosis of CGH, even when an individual may present with MHF.

7.2.3 Limitations

There are several limitations to these two studies, some of which have previously been discussed in Chapters 4.5 and 4.6. It must be noted that the FRT predominantly evaluates movement impairment at the C1/2 motion segment, and may not adequately test other motion segments or other structures capable of causing CGH. This might explain why six of the 20 subjects with CGH tested negative on the FRT in Study 2. Clinically a negative FRT does not indicate that the individual being tested does not have CGH. Rather the symptomatic cervical motion segment may be C0/1, C2/3 or C3/4. Alternatively pain may arise from myofascial structures (Borg-Stein 2002), or sensitized neural structures (Jull 1997), although such involvement is relatively rare (Zito et al 2006). Hence, the FRT is not the only assessment that

should be carried out on individuals suspected of having CGH. Other tests include cervical spine range of motion in the cardinal planes, manual examination of the upper cervical segmental levels above the C4 vertebra, and craniocervical muscle function (Hall et al 2008; Jull et al 2007; Zito et al 2006).

A further limitation was the inability to fully comply with published guidelines for the classification of CGH (Sjaastad et al 1998) as it was not possible to include cervical spine diagnostic blockade in the identification of CGH. Diagnostic block procedures of the upper cervical spine are not performed routinely by medical practitioners in Perth. Hence subjects in the study could only be characterized as having “probable” CGH, as they fulfilled only five out of seven diagnostic criteria for CGH (Antonaci et al 2001). It is possible that subjects with other headache forms were misclassified and included in Group CGH, thus impairing calculation of the diagnostic accuracy of the FRT in CGH evaluation. If this were the case then the diagnostic accuracy of the FRT is likely to be higher than calculated in Study 2.

Finally the sample size calculation for Study 2 was performed for a difference between groups, when in fact this calculation should have been calculated using the sensitivity of the FRT to identify CGH (Flahault et al 2005). With a sensitivity of 70% and a lower confidence limit of 0.7 the sample size is 248 (Flahault et al 2005). This indicates that Study 2 was probably underpowered.

7.2.4 Directions for future research

Study 1 only investigated intra-therapist reliability over days and weeks. Future studies should investigate inter-therapist reliability over a similar time frame. In addition the minimal clinically important difference for range of motion measured

during the FRT should also be calculated for subjects with CGH and those with MHF including CGH.

Study 2 only investigated migraine without aura. A previous study has investigated migraine with aura (Ogince et al 2007). Future studies should investigate the FRT in other headache forms such as TTH. Furthermore, future studies should also investigate the diagnostic accuracy of the FRT with the comparison group consisting purely of migraine without aura.

7.3 PART B - VALIDITY OF THE FLEXION-ROTATION TEST

7.3.1 Study 3 (Chapter 5.6)

The aim of this study was to investigate the validity of the FRT by measuring and comparing total and segmental rotation from the occiput to the C4 vertebra with the neck in neutral position and in flexion. Magnetic Resonance Imaging (MRI) was used to evaluate 19 asymptomatic subjects, without significant history of neck pain or cervical spine disorders. The angle of rotation was assessed at each vertebral level (Occiput –C4) with the head maximally rotated to the left and right under two conditions – neck in neutral (axial rotation) and in flexion (FRT).

The results indicate that there was a significant difference in the pattern of cervical segmental rotation between axial rotation and the FRT. At the C0/1 segment, there was negligible range recorded either in a neutral or flexed position. In contrast, the most mobile segment was C1/2, providing three quarters of the total rotation during the FRT. At the C1/2 segment, there was a 16.3% reduction in range of rotation in the flexed compared with the neutral position. This was minimal when compared with the reduction that occurred at the other cervical segments: 68.1% at

C2-C3, 61.4% at C3-C4 and 76.9% collectively at the cervical segments distal to C4. These findings lend support to the validity of the FRT as an assessment of movement predominantly at the C1/2 segment (Dvorak and Dvorak 1990).

To our knowledge this is the first study to measure segmental movement during the FRT. MRI is a highly accurate means of measuring segmental motion that has been used extensively in other kinematic studies of the cervical spine (Miyazaki et al 2008; Miyazaki et al 2008; Morishita et al 2008; Morishita et al 2008; Daffner et al 2009; Morishita et al 2009; Takasaki et al 2009). This level of accuracy was reflected in the high levels of intra-observer reliability in the present study. Intra-class correlation coefficients were greater than 0.7 and the largest standard error of measurement was 0.4° . Hence the recorded ranges can be interpreted with a reasonable level of confidence.

It was apparent that flexing the cervical spine had a much greater impact on reducing movement at segments distal to C1/2. Notwithstanding this, the C1/2 segment had 16% less rotation in end range flexion when compared with neutral. This may be explained partly by the difficulty in holding the head and neck in end range flexion in the MRI scanner during the data acquisition process. In the present study a specifically designed piece of apparatus was used to fit in the scanner to hold the neck in flexion with an assistant's help. However, this may not have been as effective as manually holding the neck in flexion. Clinical experience reinforces the importance of maintaining full range flexion when performing the FRT. Failure to do so usually leads to a larger range of rotation than the reported normal range of 44° (Hall and Robinson 2004). Inexperienced examiners record a larger range of rotation than experienced examiners for this reason (Hall et al 2007). Hence, the 12% change

in rotation range between neutral and end-range flexion at the C1/2 segment may simply reflect inability to maintain maximal flexion of the neck during rotation.

Another explanation for the small reduction in rotation range at the C1/2 segment during the FRT may be due to changes in tension of the alar ligaments and tectorial membrane. These ligaments limit axial rotation at this segment (Crisco et al 1991) and are under greater tension in flexion when compared with neutral (Panjabi et al 1991).

Although this is the first study to measure segmental movement during the FRT, other studies have reported range of motion of the whole neck (Walmsley et al 1996; Amiri et al 2003; Hall and Robinson 2004; Ogince et al 2007; Smith et al 2007; Hall et al 2008). In each case external measurement devices have been employed. However, the reported ranges are generally consistent. In the present study range was recorded as 89°. Walmsley et al (1996) and Amiri et al (2003) used an external electromagnetic device, the 3Space Tracker system, and reported ranges of 101° and 81° respectively for total head rotation in the FRT position. Hall et al (2008) used a Cervical Range of Motion goniometer and recorded 89° for total head rotation in the FRT position. Small variation in range between these studies may relate to different test procedures. For example Amiri et al performed the FRT in sitting (Amiri et al 2003). In this study the subjects were examined in supine.

Only the upper four cervical segments are capable of causing CGH (Bogduk and Govind 2009). This study recorded a combined range of 65° rotation at the C1/2 segment during the FRT. When considered as a percentage of the total rotation range available at cervical segments capable of causing headache, this accounts for approximately 90% of the range. This attests to the importance of the C1/2 segment in CGH pathogenesis. According to these results, any individual presenting with a

large deficit of rotation identified by the FRT must have movement impairment of the C1/2 segment. This segment is therefore likely to be a contributing factor to the CGH pathogenesis in that individual.

7.3.2 Study 4 (Chapter 5.7)

The aim of this study was to investigate the impact of lower cervical facet joint pain on range of motion recorded during the FRT, and examiner interpretation of the FRT. Twenty-four subjects were evaluated, 12 with CGH and 12 with lower cervical facet joint pain confirmed by therapeutic cervical facet joint intervention. A single blinded experienced examiner conducted the FRT. The examiner reported the test state (positive or negative) before measuring range of motion. Subjects with lower cervical facet pain were evaluated prior to therapeutic block intervention and were excluded from analysis if they did not gain complete symptomatic relief following the block procedure. Only subjects with immediate complete relief were included.

The average range of unilateral rotation to the limited side during the FRT was significantly less in the CGH group compared with the lower cervical facet pain group. There have been no previous reports of range of motion data for the FRT in subjects with lower cervical facet joint pain. In addition this is the first study to compare FRT range of motion data in subjects with CGH and subjects with lower cervical facet joint pain. Range of motion in subjects with CGH was consistent with previous studies (Hall et al 2008; Hall et al 2010). In contrast, range was significantly greater, by 12°, in subjects with lower cervical facet joint pain.

Despite the block procedure confirming a lower cervical segment as the source of pain, mean range of motion on the FRT was 38°. This is slightly less than

the previously reported normal range of 45° (Hall and Robinson 2004; Smith et al 2007). This small deficit in range may be explained by a number of possible processes. It has been shown that the presence of headache at the time of testing significantly reduces the measured range recorded during the FRT by an average of six degrees (Hall et al 2010). In contrast, in subjects with migraine, active cervical range of motion was not influenced by the presence of headache at the time of testing, according to one study (Bevilaqua-Grossi et al 2009). Whether subjects with lower cervical facet pain had neck pain during the test procedure was not recorded. However, it is possible that neck pain induces changes in neck muscle tone, thereby influencing muscle extensibility and cervical range of motion.

An alternative explanation for the reduced range of rotation in subjects with lower cervical facet pain may be that symptomatic cervical segments were hypomobile and could not contribute towards rotation during the FRT as they would normally. In Study 3 it was demonstrated that approximately 25% of the rotation recorded during the FRT arises from cervical segments below C1/2. Hence impairment in range of motion at symptomatic segments may adequately explain the shortfall of six degrees found in subjects with lower cervical facet pain.

One further explanation for the reduced range of rotation in subjects with lower cervical facet pain may be explained by the presence of sub-clinical upper cervical joint dysfunction that was not sufficient to cause CGH. The presence of sub-clinical pain has previously been shown to influence range recorded during the FRT by eight degrees (Smith et al 2007), similar to the range recorded in subjects with lower cervical facet pain. The presence of sub-clinical neck pain has also been shown to influence cervical active range of movement (Lee et al 2004).

Study 4 found high levels of diagnostic accuracy for the FRT. Based on the examiner's interpretation of this test, sensitivity and specificity for CGH diagnosis was 75% and 92% respectively. An experienced examiner was able to make the correct diagnosis 90% of the time using the FRT. Furthermore it was determined that a range of 32° on the FRT can be considered to be the cut-off point for a positive test.

Despite the deficit in range of rotation in subjects with lower cervical facet pain, only one of 12 subjects were classified as having a positive FRT in this group. In contrast, nine of 12 subjects with CGH were classified positive on the FRT. The high level of diagnostic accuracy may be explained by the “eye-balled” 10° estimated limitation of range for a positive test. Only one subject was deemed to have a FRT range of motion deficit of more than this, and hence a positive FRT.

Previous to these doctoral studies a goniometer determined cut-off score of 32-33° for a positive FRT had been established (Ogince et al 2007; Hall et al 2008). These scores were identified in highly selected homogenous samples (CGH, migraine with aura, and asymptomatic), which is not normal clinical practice. In Study 2 a cut-off point of 30° was identified. The sample in Study 2 represents a more realistic clinical population. Subjects had migraine without aura, CGH or MHF. MHF were included as this is a more common type seen in clinical practice (Pfaffenrath and Kaube 1990; Fishbain et al 2001; Amiri et al 2007). For example, a survey of 196 people with headache found that 45% had single headache form, of which 20% had CGH and 20% migraine (Jull et al 2007). Hence a lower cut-off value of 30° is preferred in general clinical practice, when using a goniometer. A cut-off value of 30° is also well below the mean range recorded for subjects with lower cervical facet pain found in this study. Hence cervical segmental pain and dysfunction, arising from segments below the C2 vertebra, should not influence

determination of a positive FRT. An examiner can be confident that a positive FRT indicates impairment of the C1/2 segment. They need not be aware that the individual being examined may also have pain arising from a lower cervical segment.

7.3.3 Limitations

There are several limitations to these studies, some of which have previously been discussed in Chapter 5.6 and 5.7. In Study 3 intra-tester and inter-tester reliability of the measurement of range of rotation taken from a single digital image was evaluated. Ideally, MRI should be performed on two separate occasions, with a suitable time-interval to evaluate reliability of the measurement technique. However this was not feasible due to the high cost and difficulty in gaining access to the imager. Previously a number of studies have employed the method used in Study 3 to measure kinematics of the cervical spine (Miyazaki et al 2008; Miyazaki et al 2008; Morishita et al 2008; Morishita et al 2008; Daffner et al 2009). In none of these studies was reliability reported. Although the accuracy of MRI appears to be accepted, further studies are required to confirm the accuracy of segmental cervical rotation determined by MRI.

In Study 4, as previously stated, end-range flexion may not have been achieved due to the constraints of the MRI scanner. Failure to achieve end-range flexion may have allowed greater movement to occur than would perhaps occur in the clinical test. Further studies are required to investigate this.

7.3.4 Directions for future research

Study 3 only investigated cervical segmental rotation during the FRT in asymptomatic subjects. Future studies should investigate segmental rotation in subjects with CGH and other headache forms. This would provide information regarding the validity of the FRT in CGH evaluation. In addition, future studies should investigate cervical segmental rotation before and after therapeutic intervention. It would be of value to see if range of motion changes with cervical spine interventions. Furthermore, it may be useful to understand whether range of motion deficits improve as headache symptoms improve. Different interventions could be evaluated to see which form of treatment is most effective in reducing C1/2 segmental movement deficits.

Studies 3 and 4 sought evidence for the validity of the FRT as an isolated test of movement and impairment of the C1/2 segment. This was achieved by determining whether lower cervical facet joint pain influenced the FRT. Future studies should investigate whether patients with pain and dysfunction arising from the C1/2 segment (confirmed by comparative local anaesthetic blocks) have deficits on the FRT. Alternatively, subjects with radiologically confirmed congenital fusion of the C1/2 segment could be tested to evaluate the specificity of the FRT. Biomechanical theory would suggest that a person with a congenital fusion of the C1/2 segment should have gross limitation of the FRT.

7.4 PART C – CLINICAL UTILITY OF THE FLEXION-ROTATION TEST

7.4.1 Study 5 (Chapter 6.6)

The aims of this study were to investigate the frequency with which each or multiple segments above the C4 vertebra were the dominant source of symptoms in subjects with CGH. In doing so the inter-tester reliability of manual examination procedures that were used to identify the symptomatic cervical motion segments was first examined. Eighty subjects were evaluated, 60 with CGH and arbitrarily a further 20 asymptomatic subjects were included to reduce examiner bias. Asymptomatic subjects were subsequently omitted from data analysis. Two experienced examiners evaluated each subject with standard manual examination procedures. Each examiner independently rated each segment above the C4 vertebra for pain and dysfunction.

The C1/2 segment was found to be the most commonly agreed dominant source of symptoms in subjects with CGH. Agreed positive findings at this level occurred in 63% of cases. Other segments were less frequently dominant, with 30% of cases at C2/3, seven percent at C0/1 and none at C3/4. Where examiners agreed on positive cases, a finding of multiple segmental involvement was more common than uni-segmental involvement.

This is the first study to report the frequency with which motion segments in the upper cervical region are the dominant symptomatic segment in subjects with CGH. However, consistent with these results, the C1/2 segment has been previously reported as a common source of CGH (April et al 2002; Hall and Robinson 2004; Zito et al 2006). In one of these studies (Zito et al 2006), dysfunction at the C1/2 segment identified by manual examination was found to be the most important factor

for discriminating subjects with CGH from subjects with migraine with aura and asymptomatic controls. Other studies have demonstrated the importance of anaesthetic block procedures at the C1/2 segment for relief of headache symptoms (April et al 2002). Similarly an anaesthetic block procedure of the C2 nerve root, arising from the C1/2 segment, was the most important procedure to gain complete pain relief of symptoms in a small sample of 14 subjects with CGH (Bovim et al 1992). These results indicate the importance of the FRT in CGH evaluation.

Zito et al (2006) performed manual examination in 27 subjects with CGH and reported positive findings in 70% at C0/1, 72% at C1/2, 48% at C2/3, and 20% at C3/4 segments. In contrast, in the present study only 11 of the 60 subjects showed similar findings to those of Zito et al (2006). It is unclear why there was such a big difference between these two studies in the frequency of positive findings at C0/1. Disparity may relate to differences in sample size or differences in tests of manual examination. Zito et al (2006) used palpation techniques described by Maitland (2001) to identify positive findings. In contrast the present study used similar palpation techniques but in combination with tests of passive physiological inter-vertebral movement (Maitland et al 2001; Monaghan 2001). Only when results from both tests concurred was the cervical segment labeled as positive based on manual examination.

With the findings of these studies in mind, it could be proposed that using a combination of test techniques may be a more rigorous means of identifying positive segments than relying on palpation alone. It is possible that pain provoked by palpation of the cervical spine arises from pressure over tender points in muscles, rather than indicating joint impairment *per se*. Tender points or trigger points are reported to be common in people with headache (Jaeger 1989; Leone et al 1998;

Marcus et al 1999; Freund and Schwartz 2000; Borg-Stein 2002; Moore 2004; Jensen 2005; Fernandez-de-Las-Penas et al 2006; Roth et al 2007). Trigger points in the sub-occipital region are also common (Fernandez-de-las-Penas et al 2006). Hence the high frequency of positive findings at C0/1 reported by Zito et al (2006) may simply be due to tender points in muscle, rather than true articular impairment. Further studies would be required to investigate this.

The only disadvantage to using passive physiological inter-vertebral movement techniques is that they require a significant amount of skill on the part of the operator. Lack of skill may be one reason why a systematic review found these tests to have low levels of reliability, with low levels of internal and external validity (van Trijffel et al 2005). Alternative explanations for low levels of reliability may be poor methodological quality of the studies rather than poor reliability of the examination technique itself (Stochkendahl et al 2006).

The present results show good levels of inter-tester reliability. This may be explained by the fact that examiners were experienced and followed a checklist of criteria developed for improving methodological quality of reliability studies (van Trijffel et al 2005). Additionally, in contrast to the study reported here, some previous reports of reliability of manual examination have not used appropriate statistical analysis (Sim and Wright 2005). For example Smedmark et al (2000) examined inter-examiner reliability of manual examination tests at the C1/2 segment. Although percentage agreement was high, the standard Kappa coefficient was only 0.28, and the examination procedure was reported as only having fair reliability. In that study there were no reports of the bias or prevalence indices, but the presence of the attribute, in this case a positive finding at the C1/2 segment, was very low, comprising only three percent of the sample. Based on estimates of raw data, the

Prevalence Adjusted Bias Adjusted Kappa coefficient would rise to 0.74, which indicates substantial agreement. The findings of good reliability, together with re-evaluation of previously reported data in the present studies, indicate more favorable interpretation of reliability for cervical spine manual examination procedures.

7.4.2 Study 6 (Chapter 6.7)

The aim of this study was to investigate the association between the presence and severity of CGH symptoms and the impairment in range of motion measured during the FRT. A secondary aim was to investigate whether other subjective features of headache are associated with i) FRT mobility and ii) examiner interpretation of the FRT. Ninety-two subjects were evaluated, 72 with CGH and an additional 20 asymptomatic subjects. A single blinded experienced examiner conducted the FRT, reporting the test state (positive or negative) before measuring range of motion.

The results revealed that mean range of motion during the FRT was significantly reduced by six degrees in the presence of headache at the time of testing, but this did not influence the examiner's interpretation of the test. These data indicate that the FRT can be applied and correctly interpreted even in the presence of headache. However, the presence or absence of headache at initial and follow-up evaluation needs to be taken into consideration when using the FRT as a measure of treatment outcome. This would be an additional consideration on top of the minimal detectable change of seven degrees, required to be confident that real change has occurred rather than measurement error (Hall et al 2010).

There have been only two previous reports regarding the presence of pain at the time of testing on cervical spine range of motion. In one study, episodic or

transformed migraine pain at the time of testing did not influence active cervical range of motion (Bevilaqua-Grossi et al 2009). Furthermore no correlation was found between the range of motion during the FRT and the severity of CGH at the time of testing (Ogince et al 2007; Hall et al 2010). Perhaps the presence of pain associated with CGH is a more important influence on range of motion than the severity of the pain itself.

Other studies may have indirectly evaluated the effect of pain on range of motion testing by comparing inter and intra-tester reliability of repeated measurements of cervical range of motion in symptomatic and asymptomatic subjects (Sterling et al 2002; Fletcher and Bandy 2008). In both studies there were reduced levels of reliability in subjects with neck pain when compared with subjects who were asymptomatic. Future studies should investigate the influence of pain at the time of testing on range of motion in patients with neck pain.

Physiotherapists are recommended to assess range of movement when examining patients with spinal pain (Maitland 2001). Limitation of movement is thought to indirectly measure pain and disability, and is therefore used to measure progress in rehabilitation. Such limitation, however, is not always correlated with functional disability. For example no evidence was found for a relationship between lumbar spine range of motion and functional disability in patients with chronic low back pain (Nattrass et al 1999). Similar lack of association between range of motion and pain has been reported for middle-aged females with chronic neck pain (Ylinen et al 2004). In contrast cervical left rotation and flexion movements were correlated with the severity of neck pain in male forestry workers (Hagen et al 1997). Likewise, low back pain severity was correlated with lumbar range of motion (Kang et al 1995).

This is the first study to investigate in detail the correlation between headache and subject characteristics and range of motion recorded during the FRT. The results showed that half the variance in FRT range of motion was explained by an index of headache severity, or component parts of this index, headache frequency, intensity, and duration. In addition examiner interpretation of the FRT was not influenced by other subject or headache characteristics including gender, age, history of headache, side of headache, photophobia, phonophobia, associated nausea, and headache of pulsating quality. The later four criteria are features of migraine. Thus it can be said that range of motion deficits identified by the FRT are not diagnostic features of migraine with or without aura (Ogince et al 2007; Hall et al 2010). It would appear that the correlation between range of motion and headache symptoms only relates to people with CGH. Knowledge that limitation of movement during the FRT is related to the severity of headache symptoms provides evidence that the FRT is a useful measure of cervical impairment in CGH evaluation.

7.4.3 Limitations

There are several limitations to these studies, which have previously been discussed in detail in Chapters 6.6 and 6.7.

7.4.4 Directions for future research

Study 5 only investigated reliability of manual examination of cervical segments above the C4 vertebra. Future studies of reliability should include the whole cervical spine. In addition only specialist musculoskeletal physiotherapists were used as examiners. Future studies should investigate the impact of examiner experience on reliability of manual examination. Finally as the FRT appears to be useful in identifying impairment of the C1/2 segment, other simplified means of

manual examination are required to reduce the complexity of manual examination procedures at the C0/1, C2/3, and C3/4 segments.

Study 6 only investigated the impact of headache at the time of testing on examiner interpretation, and range of motion measured by the FRT. Future studies should investigate the effect of neck pain at the time of testing on these variables. In addition the impact of pain at the time of testing on range of motion in patients with chronic neck pain would also be worth investigating.

7.4.5 Clinical implications

Compared with other forms of cervical spine manual examination procedures, the FRT is a relatively easy method of assessing movement impairment at the C1/2 segment. The technique is usually well tolerated when carried out as a single test. In contrast, repeated application of the FRT in a single data collection session sometimes leads to short-term exacerbation of symptoms. This was the anecdotal finding in two investigations where the FRT was repeated at least eight times, as a result of repeated trials undertaken by two examiners as part of a reliability study (Hall and Robinson 2004; Ogince et al 2007). Experience from testing subjects with CGH using a single examiner, without repeated measures indicates no flare-up of symptoms following the assessment. Furthermore it is not normal clinical practice to repeatedly test the FRT. Hence under normal testing conditions, in routine clinical practice, no exacerbation should be anticipated when using the FRT.

Ease of use of the FRT is demonstrated by the fact that recently qualified physiotherapists with little manual therapy experience and with no previous experience of using the FRT can quickly learn and apply the test with reasonably high level of diagnostic accuracy (Hall et al 2008). Although reported range is

greater when carried out by inexperienced examiners, the examiner's interpretation of the test is consistent with highly experienced examiners with specialist qualifications.

In terms of recognizing a positive FRT, a visual “eyeballed” estimate of range of motion deficit of more than 10° is required. For this purpose no equipment is required. However when measuring change in range of motion as a result of an intervention, the present research suggests that a goniometer would be a more precise method of measurement. Accurate measurement can be accomplished by using a standard compass style goniometer, firmly fixed to the patient's head with Velcro bands. Normal range of motion for the test is 44° to each side (Hall and Robinson 2004). When using a goniometer for measurement, range less than 31° indicates a positive test. Furthermore change in range of more than seven degrees on comparable headache free days is required to be certain that range of motion has improved, as a result of the intervention, rather than random error. Additionally the fact that range recorded and examiner interpretation of the FRT is stable over time indicates that this test is a useful clinical procedure that can be incorporated in clinical practice with ease.

It is important to emphasize that the FRT does not discern all cases of CGH. The FRT is a relatively isolated test of movement impairment at the C1/2 motion segment. This research indicates that approximately 63% of cases with CGH have impairment of the C1/2 segment identified by manual examination. Hence the FRT would be useful in identifying these subjects as well as measuring outcome following intervention. This figure is born out by the high prevalence of FRT range of motion deficits in subjects with CGH reported in an earlier study (Hall and Robinson 2004) and in the current research.

It must be recognized that 37% of subjects with CGH did not have a C1/2 impairment on manual examination. Hence in the presence of a positive FRT, this research indicates that a diagnosis of CGH is highly likely, and that other forms of headache are less likely. However in the absence of a positive test, it is important not to rule out the potential for CGH, as the FRT does not test other motion segments adequately or indeed other upper cervical structures.

In clinical practice it is recommended that the FRT be used to complement other forms of examination to identify patients with CGH. The combination of cervical spine range of motion deficits, pain on palpation of the upper four cervical vertebra, and impairment identified by the craniocervical flexion test accurately identify patients with CGH (Jull 1997; Amiri et al 2007). Adding the FRT procedure to the physical examination of patients with headache, is likely to enhance the clinical decision making process.

Measurement of the scale of range of motion deficit on the FRT also provides some indication of the severity of headache symptoms. This may be useful to measure improvement over time in headache interventional studies.

Knowledge of impairment of the C1/2 segment also directs the physiotherapist to potential therapies, including the Mulligan Concept (Mulligan 2010), passive accessory intervertebral motion (Jull et al 2002), and myofascial treatment techniques (Hopper et al 2006) among others. Techniques described by Mulligan (2006) have been shown to be helpful in the management of CGH in the short- and long-term in subjects with a positive FRT (Hall et al 2007). Intervention based on the Mulligan Concept improved FRT range of motion deficits immediately after the first application. Furthermore daily application of this intervention as a home exercise reduced headache symptoms over a 12-month period.

Chapter 8: Summary and conclusions

8.1 SUMMARY

Headache is a common symptom, which is currently classified according to the underlying cause. Diagnosis is important, particularly for secondary headache, as a successful outcome is only likely if intervention is targeted to the underlying problem.

As has been shown, those who suffer from headache frequently present with a range of different headache features, sometimes with more than one headache form in any individual. As each headache form arises from differing underlying pathophysiological processes, management for each condition must vary accordingly. For example CGH is known to respond to manipulative therapy. However, people with migraine or TTH do not respond to such forms of treatment. Hence, the identification of CGH is important to practitioners of manual therapy, as it informs the potential for treatment.

The literature review has indicated that differentiating migraine from CGH is difficult as CGH and migraine share common features, including the presence of neck pain and perhaps altered cervical mobility. Consequently incorrect diagnosis of migraine is common, likely impacting on the effectiveness of management. Hence the major diagnostic challenge is to find accurate and reliable clinical means of identifying subjects with CGH.

Cervical movement impairment is reported to be an important factor in CGH diagnosis. The FRT is an easily applied form of movement analysis, the aim of which is to identify movement impairment specifically at the C1/2 segment. The general aims of this doctoral research were to improve the understanding of the reliability, long-term stability, diagnostic accuracy, validity and clinical utility of the FRT in CGH diagnosis.

8.1.1 Part A - Reliability and diagnostic accuracy of the FRT

Study 1 found that, for experienced examiners, range of motion recorded and examiner interpretation of the FRT is stable over days and two-weeks. The minimal detectable change for range of motion recorded by the FRT is seven degrees.

Knowledge of the responsiveness of the FRT in differentiating CGH from migraine without aura, or MHF was not known and was the aim of Study 2. This study found that the FRT is significantly more restricted in subjects with CGH when compared with subjects with MHF or migraine. The cut-off scores for a positive FRT were 30°. In these groups, the diagnostic value of the FRT had sensitivity of 0.7, specificity of 0.7, positive predictive value of 0.54, negative predictive value of 0.82, positive likelihood ratio of 2.33 and negative likelihood ratio of 0.43.

It is important to recognize that the FRT is not positive in all patients with CGH. Only 70% of cases of CGH have a positive test. In those patients with a negative test other cervical segments or other cervical structures should be assessed before discounting a diagnosis of CGH.

8.1.2 Part B – Validity of the flexion-rotation test

Cervical spine range of motion deficit identified by active range of motion tests and the FRT are important diagnostic features of CGH and other cervical spine disorders. Movement in the cardinal planes provides information about movement impairment of the cervical spine as a whole, but not about specific segments. In contrast some examination techniques like the FRT are thought to assess movement at a specific cervical motion segment. The literature suggests that impairment identified by such tests should be used as an indicator to apply specific manipulative treatment techniques to the restricted cervical motion segment. In that case the aim is to reduce impairment and consequently decrease symptoms. The examination procedures themselves can also be used as outcome measures of treatment success following intervention to the specific impaired segment.

The biconvex articular surfaces at the C1/2 segment are anatomically unique when compared to other joints in the spine. This anatomical arrangement allows cervical rotation to occur in any neck position, including end-range flexion. Hence biomechanical theory suggests that placing the cervical spine in end-range flexion during the FRT prevents movement at all motion segments apart from at the C1/2 segment.

The validity of the FRT as a test of C1/2 motion deficit has not been directly investigated. To our knowledge Study 3 is the first to measure in vivo cervical

segmental movements during the FRT to confirm the relative contribution of motion at the C1/2 segment to overall head and neck rotation. The results indicate that 75% of the total head/neck rotation during the FRT occurs at the C1/2 segment. The percentage contribution from C1/2 rises to approximately 90% of total rotation when considering only those cervical segments capable of causing headache (C0-4). In contrast negligible movement occurs at the C0/1 segment.

A core principle of manual therapy assessment is that the pain provoked by segmental tests arises from the specific segment being tested. Additionally symptomatic motion segments other than the one under test should not influence range of motion determined by segmental tests. If the FRT is a specific test of C1/2 impairment then symptomatic motion segments at levels other than C1/2 should not influence range recorded during the FRT. Study 4 found that the presence of symptomatic cervical segments below the C2 vertebra does not influence range of motion or interpretation of the FRT.

8.1.3 Part C - Clinical utility of the flexion-rotation test

The aim of Part C was to determine the clinical utility of the FRT in diagnosis and management of CGH. Two studies were conducted. Study 5 sought to identify the frequency with which each or multiple segments above the C4 vertebra were the dominant source of pain in subjects with CGH. Furthermore, the reliability of manual examination procedures was also investigated. The results of this study indicate that manual examination of the segments above the C4 vertebra was reliable. The present series of studies found that in subjects with CGH, the C1/2 segment was the most common symptomatic motion segment. Positive findings on manual examination were found at this level in 63% of cases. Following the C1/2 level, the next most common positive segment was C2/3, with 30% of cases. Only seven percent of cases were positive at the C0/1 segment and none were positive at the C3/4 segment.

When examining patients with spinal pain, physiotherapists routinely assess range of movement. Limitation of movement is believed to correlate with pain and disability, and is therefore used to measure progress in rehabilitation. With regard to the FRT, two previous studies had investigated the relationship between impairment of movement and severity of CGH and provide conflicting evidence of association.

Study 6 investigated the relationship between impairment determined by the FRT and subject and headache characteristics. This study found that half the variance in FRT range of motion was explained by the presence of two variables: neck movement or positions that provoke headache, and neck symptoms that precede headache. Furthermore, range of motion recorded during the FRT was partly explained by an index of headache severity, as well as component parts of this index, comprising headache frequency, intensity and duration. Other subject and headache characteristics did not influence range of motion or interpretation of the FRT.

Study 6 also found that the presence of headache at the time of testing reduces the range of motion during the FRT by a mean of six degrees. While this deficit does not affect examiner interpretation of the FRT, it does warrant caution when interpreting the FRT over time. It is important to consider the presence of symptoms at each test occasion when interpreting the results from the FRT.

8.2 CONCLUSION

The series of studies conducted in this doctoral research has highlighted the central role that the FRT should play in the diagnosis of CGH. CGH principally arises from dysfunction of the C1/2 segment, although usually more than one segment is involved. Determining dysfunction at the C1/2 segment can be reliably achieved by using the FRT as well as manual examination procedures. The FRT, in contrast to manual examination, is an easily applied clinical test that is reliable, when used by experienced or inexperienced examiners. Measurement and interpretation of the FRT is stable over time. Range recorded during the FRT is related to the severity of headache symptoms. The presence of pain arising from segments other than C1/2 does not influence interpretation of the FRT. Finally, the similarity of headache characteristics but difference in cervical spine range of motion deficits (specifically the FRT) between those with migraine and those with CGH highlights the importance of the FRT in headache evaluation.

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Chapter 10: Appendix

10.1 APPENDIX 1: ETHICAL ISSUES

The Human Research Ethics Committee, Curtin University of Technology, approved Studies 1, 2, 4, 5, and 6. The Society of Physical Therapy Science in Japan approved Study 3.

The ethical issues in these studies were addressed by the following means:

- To ensure informed consent the subjects were given a written information sheet explaining the nature of the study and the procedures involved prior to testing (see section 10.1.1). Subjects were asked to read the information sheet, and if willing to participate, to sign the consent form (see section 10.1.2).
- Subjects were able to withdraw from the study at any time without prejudice.
- To ensure anonymity - each subject was allocated a number, which was used to identify the subject for subsequent analysis. All data was recorded on computer. Subject numbers, but not names, accompanied data. Subjects could not be identified by their individual results and only aggregate data was used for reporting purposes.
- The risks associated with the study were explained to the subjects. Subjects were informed that they would experience mild discomfort from the FRT and manual examination, with consequent short-term (24-hour) symptom exacerbation in a small proportion of individuals. Such exacerbation would be consistent with any form of physical examination procedure. The subjects were given the opportunity of contacting the Principal Investigator if any problems arose during or persisted after testing.
- In Study 4, subjects received lower cervical facet block procedures, as part of medical management by their treating medical practitioner. These block procedures were not given as part of the study protocol, hence no additional risk was taken by subjects who took part in this study.

Time commitment – In Study 1 subjects were required to make a time commitment of 20-minutes on a maximum of five occasions. For Study 5, 1.5 hours was required on a single occasion. For the remaining Studies, subjects were required to make a time commitment of a maximum of 30-minutes, also on a single occasion.

Benefits to subjects - when individual problems were identified, education and advice was given, and where needed a follow up referral to a physiotherapist was recommended.

Benefits to the wider community- the results of the study will allow a better understanding of physical examination procedures used in headache diagnosis. Due to the overlap of symptoms seen between CGH and migraine, both conditions are frequently misdiagnosed. Consequently, it is likely that treatment is unsubstantiated and a poor prognosis will follow. Thus, there is a need to determine physical tests that are valid, reliable and sensitive in assisting the diagnosis of CGH. These tests may then provide more objective means of determining clinical outcomes and thereby determining and improving treatment efficacy. Improving headache diagnosis and treatment may also have positive beneficial effects in reducing the significant cost burden of headache to society. Study results will be made available to the physiotherapy community via publication in appropriate journals and conference presentations.

10.1.1 Subject Information Form – Study 1

- Title of Project:** Reliability of the cervical flexion-rotation test over time – a longitudinal study
- Investigator:** Toby Hall (PhD candidate), Specialist Musculoskeletal Physiotherapist, School of Physiotherapy, Curtin University of Technology, WA. Telephone: 0412851385
- Supervisors:** Associate Professor Kathy Briffa & Associate Professor Diana Hopper, School of Physiotherapy, Curtin University of Technology. Telephone: 9266 3666

Purpose of Study

Neck related headaches account for 20% of all chronic headaches. The flexion-rotation test (FRT) is a commonly used test in physiotherapy practice that is used to identify restriction of neck movement at a specific point in the upper neck. This test has been shown to be valuable in diagnosis of neck headaches, and is also used as a means of evaluating effectiveness of treatments applied to the neck. The purpose of this study is to investigate the variability of measurement of the FRT over time (days and weeks). An additional purpose is to see if the presence of a headache at the time of testing alters interpretation of the FRT. Results obtained from this research will help physiotherapists to gain a better understanding of the reliability of the FRT and will expand upon the current knowledge of the clinical utility of the FRT in neck headache evaluation.

Procedures

If you agree to be involved in this study, you will be required to visit Curtin University of Technology, School of Physiotherapy on five occasions within a two-week period. Each session will take approximately 20-minutes.

Visit #1 – Induction Session and first FRT assessment

Upon arrival, you will be required to complete the consent form below. Following this you will be allocated an identification number to be used for all data collection. You will receive instructions about what the FRT will involve and be able to ask questions of the investigator. An experienced physiotherapist will perform the FRT on each occasion. Prior to testing the physiotherapist will attach a measurement device to your head for recording of movement during the testing procedure. The FRT will then be performed. While lying on your back your neck will be tilted forward so that your chin moves towards your chest. Your head will be turned to the left and right as far as it can go without discomfort.

Visit #2 - #4– FRT assessment

Two-days, four-days and two-weeks after your first visit you will need to return to the School of Physiotherapy for repeat evaluation of the FRT. The procedure will be exactly as for visit #1.

Visit #5 – FRT assessment during headache attack

You will need to attend the School of Physiotherapy for an additional evaluation of the FRT during a headache attack. You will be asked to contact the investigator at the onset of your headache to schedule at the earliest opportunity a final evaluation of the FRT. The procedure will be exactly as for visit #1.

The following sections are repeated in Studies 1, 2 4, 5 and 6.

Risks, Discomforts and Benefits:

There are no intended adverse effects associated with this Study. There is a small possibility that the procedure may trigger a headache or neck pain, however these symptoms should be of minor duration. The results obtained from this Study will help expand physiotherapist's current knowledge of physical examination procedures of the neck and in neck headache evaluation.

Confidentiality:

You will be allocated an identification number that will remain confidential to the investigator and the project supervisors. All recorded data will be entered in an excel program, on a computer using your identification number only, no names will be used. Access to the stored data will be restricted by a password known only by the investigators and the project supervisor. All data collected and consent forms will be stored safely in a locked cupboard at the Curtin School of Physiotherapy.

The results of the Study will be reported on, although it will not be possible to identify individual subjects as no identification numbers or names will be included in report material. On completion of the Study, all data will be stored in a secure and confidential location with the project supervisor for five years. After this time, all data will be destroyed. This is a Curtin University of Technology requirement.

Request for Further Information:

You are encouraged to discuss and/or express any concerns or questions regarding this study with the investigator at any time. You should feel confident and secure about your involvement in the study.

Refusal or Withdrawal:

You may refuse to participate in the Study and if you do consent to participate then you will be free to withdraw from the Study at any time without fear or prejudice. If you do decide to withdraw from the Study at any time please contact the investigators at the earliest possible convenience. All data will be destroyed if you do decide to withdraw.

Approval

This study has been approved by the Curtin University Human Research Ethics Committee. The committee is comprised of members of the public, academic, lawyers, doctors & pastoral carers. Its main role is to protect participants. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/-Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au.

10.1.2 Subject Consent Form – Studies 1, 2, 4, 5, and 6

Title of Project: Studies 1, 2, 4, 5, and 6

Investigators: Toby Hall (PhD candidate), Specialist Musculoskeletal Physiotherapist, School of Physiotherapy, Curtin University of Technology, WA. Telephone: 0412851385

Project Supervisor: Associate Professor Kathy Briffa & Associate Professor Diana Hopper, School of Physiotherapy, Curtin University of Technology. Telephone: 9266 3666.

You are of your own accord making a decision whether or not to participate in this research study. Your signature verifies that you have decided to participate in the study, having read and understood all the information accessible. Your signature also officially states that you have had adequate opportunity to discuss this Study with the investigators and all your questions have been answered to your satisfaction. You will be given a copy of this consent document to keep.

I, (the undersigned)

_____ *(Please PRINT)*

of

Postcode _____ Phone _____

consent to involvement in this Study and give my authorization for any results from this Study to be used in any research paper, on the understanding that confidentiality will be maintained. I understand that participation in this Study may cause me a mild headache. I comprehend that I may withdraw from the Study at any time without discrimination. If so, I undertake to contact Toby Hall (Tel. 0412851385) at the earliest opportunity.

Signature _____ *Date* _____

Subject

I have explained to the subject the procedures of the Study to which the subject has consented their involvement and have answered all questions. In my appraisal, the subject has voluntarily and intentionally given informed consent and possesses the legal capacity to give informed consent to participate in this research Study.

Principal Investigator: _____ Date: _____

10.1.3 Subject Information Form – Study 2

Title of Project: Is the flexion-rotation test positive in sufferers of migraine without aura?
Investigator: Toby Hall
Supervisors: Associate Professor K Briffa & Associate Professor D Hopper

Purpose of Study

Neck related headaches account for 20% of all chronic headaches. There is much similarity between another common headache, migraine headache, and neck related headache. Identification of the headache type is made in part on the symptoms as well as by physical examination of the neck. The flexion-rotation test (FRT) is a commonly used test in physiotherapy practice that is used to identify restriction of neck movement at a specific point in the upper neck and has been shown to be positive in 80% of cases of neck headache. This test may therefore be a useful means of differentiating neck headache from migraine headache. The purpose of this Study is to investigate different aspects of the FRT in subjects with migraine and subjects with neck headache. The results obtained from this research will help physiotherapists to gain a better understanding of the relationship between the FRT and headache and will therefore expand upon the current knowledge of the clinical utility of the FRT in headache evaluation.

Procedures

If you agree to be involved in this study, you will be required to visit Curtin University of Technology, School of Physiotherapy on one occasion. The session will take approximately 20-minutes.

Induction Session and assessment

Upon arrival, you will be required to complete the consent form below. Following this you will be allocated an identification number to be used for all data collection. You will receive instructions about what manual examination testing procedure will involve and be able to ask questions of the investigator. An experienced physiotherapist will perform the FRT. Prior to testing the physiotherapist will attach a measurement device to your head for recording of movement during the testing procedure. The FRT will then be performed. While lying on your back your neck will be tilted forward so that your chin moves towards your chest. Your head will be turned to the left and right as far as it can go without discomfort. Following this procedure you will be asked to fill out a simple questionnaire regarding the your headache.

10.1.4 Subject Information and Consent Form – Study 3

This information form and consent form was translated into Japanese language.

Title of Project: Normal kinematics of the upper cervical spine during the Flexion-Rotation Test – in vivo measurements using Magnetic Resonance Imaging

Investigators: Hiroshi Takasaki, Toby Hall, Sadanori Oshiro, Shouta Kaneko, Yoshikazu Ikemoto and Gwendolen Jull

Purpose of Study

Neck related headaches account for 20% of all chronic headaches. There is much similarity between another common headache, migraine headache, and neck related headache. Identification of the headache type is made in part on the symptoms as well as by physical examination of the neck. The flexion-rotation test (FRT) is a commonly used test in physiotherapy practice that is used to identify restriction of neck movement at a specific point in the upper neck and has been shown to be positive in 80% of cases of neck headache. This test may therefore be a useful means of differentiating neck headache from migraine headache. The purpose of this study is to use Magnetic resonance imaging (MRI) to investigate movement of the neck during the FRT. The results obtained from this research will help physiotherapists to gain a better understanding of the validity of the FRT and will therefore expand upon the current knowledge of the clinical utility of the FRT in headache evaluation.

Procedures

If you agree to be involved in this study, you will be required to visit the MRI department at Shinoro Orthopaedic on one occasion. The session will take approximately 60-minutes. Upon arrival, you will be required to complete the consent form below. Following this you will be allocated an identification number to be used for all data collection. You will receive instructions about the testing procedure and you will be able to ask questions of the investigator. A physiotherapist will perform a routine examination of your neck. Following this you will be asked to lay on your back in the MRI machine and images taken with your neck in different positions. Firstly your head/neck will be rotated to the left and right, as far as it can go without discomfort, and held at end range while the MRI scans your neck. Following this your neck will be tilted forward so that your chin moves towards your chest. Your head will be turned to the left and right again as far as it can go without discomfort, again while the MRI scans your neck.

Risks, Discomforts and Benefits:

There are no intended adverse effects associated with this study. The results obtained from this study will help expand physiotherapist's current knowledge of physical examination procedures of the neck and in neck headache evaluation.

Confidentiality:

You will be allocated an identification number that will remain confidential to the investigator and the project supervisors. All recorded data will be entered on to a computer using your identification number only, and no names will be used.

The results of the study will be reported on, although it will not be possible to identify individual subjects as no identification numbers or names will be included in report material. On completion of the study, all data will be securely stored with the project investigator for 5 years.

Request for Further Information:

You are encouraged to discuss and/or express any concerns or questions regarding this study with the investigator at any time. You should feel confident and secure about your involvement in the study.

Refusal or Withdrawal:

You may refuse to participate in the study and if you do consent to participate then you will be free to withdraw from the study at any time without fear or prejudice. If you do decide to withdraw from the study at any time please contact the investigators at the earliest possible convenience. All data will be destroyed if you do decide to withdraw.

Approval

This study has been granted approval by the Society of Physical Therapy Science in Japan.

10.1.5 Subject Consent Form – Study 3

Title of Project: Normal kinematics of the upper cervical spine during the Flexion-Rotation Test – in vivo measurements using Magnetic Resonance Imaging

Investigators: Hiroshi Takasaki, Toby Hall, Sadanori Oshiro, Shouta Kaneko, Yoshikazu Ikemoto and Gwendolen Jull

You are of your own accord making a decision whether or not to participate in this research study. Your signature verifies that you have decided to participate in the study, having read and understood all the information accessible. Your signature also officially states that you have had adequate opportunity to discuss this study with the investigators and all your questions have been answered to your satisfaction. You will be given a copy of this consent document to keep.

I, (the undersigned)

_____ *(Please PRINT)*

of

consent to involvement in this study and give my authorization for any results from this study to be used in any research paper, on the understanding that confidentiality will be maintained. I comprehend that I may withdraw from the study at any time without discrimination. If so, I undertake to contact Hiroshi Takasaki at the earliest opportunity.

Signature _____

Date _____

Subject

I have explained to the subject the procedures of the study to which the subject has consented their involvement and have answered all questions. In my appraisal, the subject has voluntarily and intentionally given informed consent and possesses the legal capacity to give informed consent to participate in this research study.

Principal Investigator: _____

Date: _____

10.1.6 Subject Information Form - Study 4

- Title of Project:** The influence of lower cervical joint pain on sensitivity and specificity of the FRT in CGH evaluation
- Investigator:** Toby Hall (PhD candidate), Specialist Musculoskeletal Physiotherapist, School of Physiotherapy, Curtin University of Technology, WA. Telephone: 0412851385
- Supervisors:** Associate Professor Kathy Briffa & Associate Professor Diana Hopper, School of Physiotherapy, Curtin University of Technology. Telephone: 9266 3666

Purpose of Study

Neck related headaches account for 20% of all chronic headaches. The flexion-rotation test (FRT) is a commonly used test in physiotherapy practice that is used to identify restriction of neck movement at a specific point in the upper neck. This test has been shown to be valuable in diagnosis of neck related headaches, and is also used as a means of evaluating effectiveness of treatments applied to the neck. The purpose of this study is to investigate whether pain and joint disorders arising from the lower neck influence the FRT. Results obtained from this research will help physiotherapists to gain a better understanding of the reliability of the FRT and will expand upon the current knowledge of the clinical utility of the FRT in neck headache evaluation.

You are being invited to participate in this study because you have been scheduled to have a pain relieving procedure to your neck in the near future. If you decide to participate we will compare the results of your neck procedure with our findings from the FRT.

Procedures

If you agree to be involved in this study, you will be required to visit Curtin University of Technology, School of Physiotherapy on one occasion. This session will take approximately 20 minutes.

Induction Session and FRT assessment

Upon arrival, you will be asked to complete the consent form below. Following this you will be allocated an identification number to be used for all data collection. You will receive instructions about what the FRT will involve and be able to ask questions of the investigator. An experienced physiotherapist will perform the FRT. Prior to testing the physiotherapist will attach a measurement device to your head for recording of movement during the testing procedure. The FRT will then be performed. While lying on your back your neck will be tilted forward, so that your chin moves towards your chest either to the end range or to the point at which discomfort arises. Your head will be turned to the left and right as far as it can go without discomfort. You will then be free to leave. We will contact you by telephone shortly after your pain relieving procedure, to find out what effects this had on your symptoms.

10.1.7 Subject Information Form – Study 5

- Title of Project:** Frequency of C1/2 segmental dysfunction as a cause of cervicogenic headache
- Investigator:** Toby Hall (PhD candidate), Specialist Musculoskeletal Physiotherapist, School of Physiotherapy, Curtin University of Technology, WA. Telephone: 0412851385
- Supervisors:** Associate Professor Kathy Briffa & Associate Professor Diana Hopper, School of Physiotherapy, Curtin University of Technology. Telephone: 9266 3666

Purpose of Study

Neck related headaches account for 20% of all chronic headaches. Identification of which part of the neck causes the headache is important as it directs treatment and also highlights the specific area physiotherapists should focus on in their examination. Manual examination, which consists of a number of tests to identify the pain source in the neck, has been shown to be valuable in diagnosis of neck related headache. Testing consists of gentle passive movement of the neck. The purpose of this study is to investigate which part of the neck is the predominant cause of neck related headache. Results obtained from this research will help physiotherapists to gain a better understanding of the source of neck related headache, optimize examination and may help direct treatment.

Procedures

If you agree to be involved in this study, you will be required to visit Curtin University of Technology, School of Physiotherapy on one occasion. The session will take approximately 20-minutes.

Induction Session and assessment

Upon arrival, you will be required to complete the consent form below. Following this you will be allocated an identification number to be used for all data collection. You will receive instructions about what manual examination testing procedure will involve and be able to ask questions of the investigator. Two experienced physiotherapists will separately perform some gentle tests on your neck. While lying on your back with your head on a pillow, the physiotherapists will passively move your neck in various directions while feeling for movement at various points in your neck. Following this you will be asked to lie on your stomach while your neck will be gently palpated and enquiry made as to any discomfort generated.

10.1.8 Subject Information Form – Study 6

- Title of Project:** The relationship between cervicogenic headache subjective features and impairment determined by the cervical flexion-rotation test
- Investigator:** Toby Hall (PhD candidate), Specialist Musculoskeletal Physiotherapist, School of Physiotherapy, Curtin University of Technology, WA. Telephone: 0412851385
- Supervisors:** Associate Professor Kathy Briffa & Associate Professor Diana Hopper, School of Physiotherapy, Curtin University of Technology. Telephone: 9266 3666

Purpose of Study

Neck related headaches account for 20% of all chronic headaches. The flexion-rotation test (FRT) is a commonly used test in physiotherapy practice that is used to identify restriction of neck movement at a specific point in the upper neck. This test has been shown to be valuable in diagnosis of neck headaches, and is also used as a means of evaluating effectiveness of treatments applied to the neck. The purpose of this study is to investigate the relationship between the FRT and headache symptoms. Results obtained from this research will help physiotherapists to gain a better understanding of the relationship between the FRT and headache and will therefore expand upon the current knowledge of the clinical utility of the FRT in neck headache evaluation.

Procedures

If you agree to be involved in this study, you will be required to visit Curtin University of Technology, School of Physiotherapy on one occasion. The session will take approximately 20-minutes.

10.1.9 Induction Session and FRT assessment

Upon arrival, you will be required to complete the consent form below. Following this you will be allocated an identification number to be used for all data collection. You will receive instructions about what the FRT will involve and be able to ask questions of the investigator. An experienced physiotherapist will perform the FRT. Prior to testing the physiotherapist will attach a measurement device to your head for recording of movement during the testing procedure. The FRT will then be performed. While lying on your back your neck will be tilted forward so that your chin moves towards your chest. Your head will be turned to the left and right as far as it can go without discomfort. Following this procedure you will be asked to fill out a simple questionnaire regarding the your headache.

10.2 MEMORANDUM CONFIRMING ETHICAL APPROVAL FOR EACH STUDY

The memoranda confirming ethical approval for each study conducted in Australia are shown in the following section.

10.2.1 Ethical approval Study 1

memorandum		 Division of Health Sciences School of Physiotherapy Telephone +61 8 9266 3618 Facsimile +61 8 9266 3699 Email S.James@curtin.edu.au Web www.physiotherapy.curtin.edu.au
To	Toby Hall c/- School of Physiotherapy	
From	Dr Helen Slater, Coordinator, Ethics Committee	
Subject	Protocol Approval PT0093 Reliability of the cervical flexion-rotation test (FRT) over time - a longitudinal study	
Date	29 October 2007	
Copy	Assoc Prof Kathy Briffa	
File	Ethics File	

Thank you for your application submitted to the School of Physiotherapy Ethics Reviewers for the project titled "Reliability of the cervical flexion-rotation test (FRT) over time - a longitudinal study."

Your application has been reviewed and **is approved**. Please send a final electronic copy and hard copy with signatures to Suzanne James for her records. Approval of this project is for a period of twelve months **29 October 2007 to 29 October 2008**.

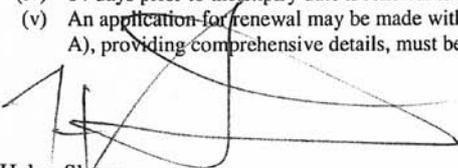
If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately. The approval number for your project is **PT0093**. *Please quote this number in any future correspondence.*

Please note the following:

- You are authorised to commence your research once a response to the queries has been received and approved by the School of Physiotherapy
- The following standard statement **must be** included in the information sheet to participants:

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number PT0093/2007). The Committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. Its main role is to protect participants. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au

- It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants;
- The attached **FORM B** should be completed and returned to the Secretary, HREC, c/- Office of Research and Development when :
 - The project has finished, or
 - If at any time during the twelve months changes/amendments occur, or
 - If a serious or unexpected adverse event occurs, or
 - 14 days prior to the expiry date if renewal is required
 - An application for renewal may be made with a Form B three years running, after which a new application form (Form A), providing comprehensive details, must be submitted.


 Dr Helen Slater
 Coordinator for Human Research Ethics
 School of Physiotherapy

10.2.2 Ethical approval Study 2

memorandum		 Division of Health Sciences
To	Toby Hall c/- School of Physiotherapy	
From	Dr Helen Slater, Coordinator, Ethics Committee	School of Physiotherapy
Subject	Protocol Approval PT0096 Is the flexion-rotation test (FRT) positive in sufferers of migraine without aura?	Telephone +61 8 9266 3618 Facsimile +61 8 9266 3699 Email S.James@curtin.edu.au Web www.physiotherapy.curtin.edu.au
Date	29 October 2007	
Copy	Assoc Prof Kathy Briffa	
File	Ethics File	

Thank you for your application submitted to the School of Physiotherapy Ethics Reviewers for the project titled “*Is the flexion-rotation test (FRT) positive in sufferers of migraine without aura?*”

Your application has been reviewed and **is approved**. Please send a final electronic copy and hard copy with signatures to Suzanne James for her records. Approval of this project is for a period of twelve months **29 October 2007 to 29 October 2008**.

If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately. The approval number for your project is **PT0096**. *Please quote this number in any future correspondence.*

Please note the following:

- You are authorised to commence your research once a response to the queries has been received and approved by the School of Physiotherapy
- The following standard statement **must be** included in the information sheet to participants:

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number PT0096/2007). The Committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. Its main role is to protect participants. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au

- It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants;
- The attached **FORM B** should be completed and returned to the Secretary, HREC, c/- Office of Research and Development when :
 - (i) The project has finished, or
 - (ii) If at any time during the twelve months changes/amendments occur, or
 - (iii) If a serious or unexpected adverse event occurs, or
 - (iv) 14 days prior to the expiry date if renewal is required
 - (v) An application for renewal may be made with a Form B three years running, after which a new application form (Form A), providing comprehensive details, must be submitted.



Dr Helen Slater
Coordinator for Human Research Ethics
School of Physiotherapy

10.2.3 Ethical approval Study 4

memorandum	
To	Associate Professor Kathy Briffa
From	Dr Helen Slater, Coordinator, Ethics Committee
Subject	Protocol Approval PT0115 The influence of lower cervical joint pain on sensitivity and specificity of the flexion-rotation test in CGH evaluation
Date	14 July 2008
Copy	Toby Hall & Associate Professor Diana Hopper
File	Ethics File

Curtin 
University of Technology

Division of Health Sciences

School of Physiotherapy

Telephone +61 8 9266 3618
Facsimile +61 8 9266 3699
Email M.Hogan@curtin.edu.au
Web www.physiotherapy.curtin.edu.au

Thank you for your ethics application for the project “*The influence of lower cervical joint pain on sensitivity and specificity of the flexion-rotation test in CGH evaluation.*” Your application has been reviewed and **is approved**. Please send a final electronic copy and hard copy with signatures to Suzanne James/Marilla Hogan for their records.

Approval for this project is for a period of twelve months **14 July 2008** to **14 July 2009**.

If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately. The approval number for your project is **PT0115**. *Please quote this number in any future correspondence.*

Please note the following:

- You are authorised to commence your research once a response to the queries has been received and approved by the School of Physiotherapy
- The following standard statement **must be** included in the information sheet to participants:

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number PT0115/2008). The Committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. Its main role is to protect participants. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au

- It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants;
- The attached **FORM B** should be completed and returned to the Secretary, HREC, c/- Office of Research and Development when :
 - (i) The project has finished, or
 - (ii) If at any time during the twelve months changes/amendments occur, or
 - (iii) If a serious or unexpected adverse event occurs, or
 - (iv) 14 days prior to the expiry date if renewal is required
 - (v) An application for renewal may be made with a Form B three years running, after which a new application form (Form A), providing comprehensive details, must be submitted.

Dr Helen Slater
Coordinator for Human Research Ethics
School of Physiotherapy

10.2.4 Ethical approval Study 5

memorandum		 Division of Health Sciences
To	Toby Hall c/- School of Physiotherapy	
From	Dr Helen Slater, Coordinator, Ethics Committee	School of Physiotherapy
Subject	Protocol Approval PT0095 Frequency of C1/2 segmental dysfunction as a cause of cervicogenic headache (CGH)	Telephone +61 8 9266 3618 Facsimile +61 8 9266 3699 Email S.James@curtin.edu.au Web www.physiotherapy.curtin.edu.au
Date	17 October 2007	
Copy	Assoc Prof Kathy Briffa	
File	Ethics File	

Thank you for your application submitted to the School of Physiotherapy Ethics Reviewers for the project titled “*Frequency of C1/2 segmental dysfunction as a cause of cervicogenic headache (CGH).*”

Your application has been reviewed and **is approved**. Please send a final electronic copy and hard copy with signatures to Suzanne James for her records. Approval of this project is for a period of twelve months **17 October 2007 to 17 October 2008**.

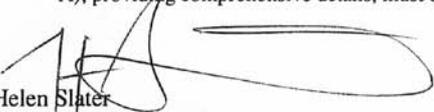
If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately. The approval number for your project is **PT0095**. *Please quote this number in any future correspondence.*

Please note the following:

- You are authorised to commence your research once a response to the queries has been received and approved by the School of Physiotherapy
- The following standard statement **must be** included in the information sheet to participants:

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number PT0095/2007). The Committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. Its main role is to protect participants. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au

- It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants;
- The attached **FORM B** should be completed and returned to the Secretary, HREC, c/- Office of Research and Development when :
 - The project has finished, or
 - If at any time during the twelve months changes/amendments occur, or
 - If a serious or unexpected adverse event occurs, or
 - 14 days prior to the expiry date if renewal is required
 - An application for renewal may be made with a Form B three years running, after which a new application form (Form A), providing comprehensive details, must be submitted.


 Dr Helen Slater
 Coordinator for Human Research Ethics
 School of Physiotherapy

10.2.5 Ethical approval Study 6

memorandum	
To	Toby Hall c/- School of Physiotherapy
From	Dr Helen Slater, Coordinator, Ethics Committee
Subject	Protocol Approval PT0094 The relationship between cervicogenic headache (CGH) subjective features and impairment determined by the cervical flexion-rotation test (FRT)
Date	26 September 2007
Copy	Dr Kathy Briffa
File	Ethics File



Division of Health Sciences

School of Physiotherapy

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Thank you for your application submitted to the School of Physiotherapy Ethics Reviewers for the project titled "The relationship between cervicogenic headache (CGH) subjective features and impairment determined by the cervical flexion-rotation test (FRT)."

Your application has been reviewed and **is approved subject to minor amendments noted in the reviewer's comments**. Please send a final electronic copy and hard copy with signatures to Suzanne James for her records. Approval of this project is for a period of twelve months **19 September 2007 to 19 September 2008**.

If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately. The approval number for your project is **PT0094**. *Please quote this number in any future correspondence.*

Please note the following:

- You are authorised to commence your research once a response to the queries has been received and approved by the School of Physiotherapy
- The following standard statement **must be** included in the information sheet to participants:

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number PT094/2007). The Committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. Its main role is to protect participants. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au

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- The attached **FORM B** should be completed and returned to the Secretary, HREC, c/- Office of Research and Development when :
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 - If a serious or unexpected adverse event occurs, or
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 - An application for renewal may be made with a Form B three years running, after which a new application form (Form A), providing comprehensive details, must be submitted.

Dr Helen Slater
 Coordinator for Human Research Ethics
 School of Physiotherapy

A3. Average duration of headaches

Less than 1 hour	1-2 hours	3-5 hours	6-8 hours	9-12 hours	13-24 hours	1-2 days	More than 2 days
<input type="radio"/>							

B1. Do you associate any of the following with your headache:

- Nausea Vomiting Tinnitus (ringing in the ears)
 Blurred vision Watery eye Pins & needles or numbness

B2. Does headache pain start in your neck? YES NO Or head YES NO

Does your headache change from side to side during an episode? YES NO

Does your headache vary in duration? YES NO

B3. Do you have any warning signs before your headache starts? YES NO

B4. How long do the warning signs last? Hours.... Minutes.....

B5. If you have warning signs please describe them.....

B6. If you have warning signs does your headache start immediately? YES NO

B7. How did your headache first start:

- a) An accident (eg, motor car, sporting, fall) YES NO
 b) Following illness. YES NO
 c) Following stress YES NO
 d) Prolonged sessions at the computer YES NO
 e) Following adverse events, please specify YES NO
 f) Other YES NO
 g) Cannot relate to anything YES NO

C. EFFECT OF MEDICATION ON YOUR HEADACHE

C1. Please give an indication **how much** medication you use in an **effort to control** your headache.

Type of medication	Average tablets per month	Days taking medication per month	Name/Brand of medication (If known to you)
“Over the counter” medication			
Prescribed medication			
Injections for pain			

D. TRIGGERING OR AGGRAVATING FACTORS

Which of the following may trigger or aggravate your headache. Please mark the appropriate box

	Never	Seldom	Mostly	Always
D1. Noise ; Loud music; Banging				
D2. Bright light ; Sunshine; flashing lights				
D3. Sustained neck postures/positions : sitting at computer, driving, watch TV etc				
D4. Neck movements : head turning, looking up, etc				
D5. Alcoholic drinks: red wine				
D6. Foods : Chocolates, Preservatives, etc				
D7. Tension ; Pressure; Stress				
D8. Physical activity e.g. walking up stairs, brisk walking, running				
D9. Menstruation				
D10 Others - Please specify				

E. EASING FACTORS

E1. Is there anything you can do to reduce your headache? YES NO

Which of the following relieves your headache. Please mark the appropriate box

	Never	Seldom	Mostly	Always
E1. Find an easing position for your neck				
E2. Support your neck				
E3. Take medication				
E4. Others - Please specify				