An Investigation into the Role of Targeted Resistance Exercise for the Deep Neck Flexors in Chronic Neck Pain Rehabilitation

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A thesis submitted to the University of Limerick in fulfilment of the requirements for the award Doctor of Philosophy in Clinical Therapies

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Abstract

**Title:** An investigation into the role of targeted resistance exercise for the deep neck flexors in chronic neck pain management.

**Author:** Cliona O’Riordan

Chronic neck pain (CNP) is a common and costly musculoskeletal condition with a lifetime prevalence of approximately 20% worldwide. In most cases the absence of structural deformity leads to a lack of specific diagnosis resulting in it being labelled as non-specific. Research has identified that due to its multi-factorial aetiology; multi-modal management interventions result in more beneficial long term outcomes. A muscular weakness, particularly of the deep neck flexor muscles is present in patients with CNP when compared to healthy counterparts. Clinical guidelines advocate the inclusion of active exercise, (including resistance exercise) as part of a multi-modal physiotherapy intervention for immediate and long-term improvements in isometric strength, reduced pain and perceived disability. Means of providing targeted resistance exercise to the deep neck flexors in patients with CNP outside of clinical and laboratory settings is lacking. The aim of this research study presented in this thesis was to investigate the role of targeted resistance exercise for the deep neck flexors in CNP rehabilitation.

This research study was conducted in four main parts, two systematic reviews, and an examination of the feasibility and effect of a targeted resistance exercise program for the deep neck flexors using a novel deep neck flexor muscle strengthening tool known as “FLEXOR”, in healthy controls and as part of a multi-modal physiotherapy intervention for patients with CNP. An examination of the literature identified the effects of chronic pain on the cervical flexor musculature, as well as determining a FITT (frequency, intensity, time and type) exercise principle for resistance exercise in CNP. Feasibility studies using “FLEXOR” to deliver resistance exercise in a healthy population (n=22) and in patients with CNP (n=26) were conducted. Patients with CNP who used the “FLEXOR” device in conjunction with usual care physiotherapy had immediate and significant improvements in isometric strength, pain and perceived disability. Increases in isometric strength and reductions in pain were significantly different when compared to improvements made by patients who received usual care physiotherapy alone (p=0.01, p=0.02 respectively). A follow up descriptive study with trial participants provided further information on device and study design feasibility, as well as
gaining insight into patient perceptions of the benefits of conducting resistance exercise independently for addressing any of the biopsychosocial issues of chronic pain. This project provides new insights into the feasibility, safety and potential benefits of targeted resistance exercise for the deep neck flexors as part of physiotherapy treatment in CNP management. These findings may guide future research and clinical decision making in treatment planning for patients with CNP.
Declaration

I, the undersigned, declare that the work contained within this thesis is my own original work and the data presented is accurate. Where the use has been made of the work of others it has been fully acknowledged and referenced. I declare that this work has not been submitted for any academic award, or part thereof, at this or any other educational establishment.

Cliona O’Riordan

_________________________

Date:       /       /
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“Whether you think you can, or you think you can’t you’re right”

Henry Ford
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List of Abbreviations

ADLs: Activities of Daily Living
AS: Anterior Scalene
BMI: Body Mass Index
CA: Carotid Artery
CCF: Cranio-cervical Flexion
CCFT: Cranio-cervical Flexion Test
Cl: Confidence Interval
CNP: Chronic Neck Pain
CSA: Cross-sectional Area
d: Mean Difference
DNFs: Deep Neck Flexors
DOMS: Delayed Onset Muscle Soreness
EBP: Evidence Based Practice
EG: Exercise Group
EMG: Electromyography
FITT: Frequency, Intensity, Time and Type
FS: Forward Slide (postural perturbation)
HEP: Home Exercise/Independent Exercise Program
HHD: Hand Held Dynamometer
HRQOL: Health Related Quality of Life
HSE: Health Service Executive
IASP: International Association for the Study of Pain
ICC: Intraclass Correlation Coefficient
IJV: Internal Jugular Vein
LCo: Longus Colli
LLEG: Low Load Exercise Group
LOA: Level of Agreement
MDC: Minimal Detectable Change
MRI: Magnetic Resonance Imaging
MVC: Maximum Voluntary Contraction
NDI: Neck Disability Index
NOS: Newcastle Ottawa Scale
OCEMB: Oxford Centre for Evidence Based Medicine
PEDro Scale: Physiotherapy Evidence Database.
PPI: Patient and Public Involvement
PRIMSA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PVF: Prevertebral fascia
QOL: Quality of Life
RCT: Randomised Controlled Trial
ROM: Range of Motion
RT-UI: Real-time Ultrasound Imaging
RT-US: Real-time Ultrasound
SCM: Sternocleidomastoid
SD: Standard Deviation
SEM: Standard Error of Measurement
SpC: Splenius Capitis
Thy: Thyroid
UC: Usual Care
US: Ultrasound
UT: Upper Trapezius
VAS: Visual Analogue Scale
WAD: Whiplash Associated Disorder
List of Publications

The following is a list of peer-reviewed journal articles and conference presentations, that have been published based on the work contained within this thesis, to date.

Peer Review Journal Publications


Conferences; Oral and Poster Presentations


IP Activity

Invention Disclosure filed with UL TTO for “FLEXOR” a neck strengthening therapeutic tool (2013).
Chapter 1: Background & Introduction to the Research Project
1.0 Introduction

This thesis will describe research undertaken to investigate the role of targeted resistance exercise for the deep neck flexors (DNF) muscles in the management of non-specific chronic neck pain (CNP). This introductory chapter will begin by describing the problem of CNP, the scale of the problem on an individual and societal level. It will identify the risk factors and the reasons why it is important to conduct research in this area. The effects of chronic pain on the cervical musculature will be explained to provide the rationale why resistance exercise is required for the DNFs in this population. This chapter also includes an overview of current management strategies for CNP and their short-comings. In this regard, the research gaps, which this thesis will aim to address, will be identified and described. An introduction to the “FLEXOR” device, a novel strengthening tool for the DNFs, designed and developed prior to the undertaking of this research study will also be provided. This device will be used to deliver targeted resistance exercise to the DNFs throughout this research. Finally, the primary and secondary aims will be outlined and the proposed thesis structure designed to answer these questions will be described.

1.1 Prevalence, Risk factors, Associated costs of Chronic Neck Pain and its Implications

Chronic neck pain is described as the persistence of pain beyond a normative healing time of three months (Remmen 2013). CNP pertains to pain in the region bounded superiorly by the nuchal line and inferiorly by an imaginary line at the transverse process of the first thoracic vertebrae (T1) (Tsakitzidis et al. 2013). The lifetime prevalence of acute neck pain worldwide is reportedly upwards of 70%, indicating that almost three quarters of the population will experience at least one episode of neck pain at some point (Cagnie et al. 2007b, Viljanen et al. 2003). It is reported that 16-25% of patients do not achieve full and complete resolution of their symptoms, resulting in CNP (Fernández-de-las-Peñas et al. 2011, Hoy et al. 2014). Worldwide prevalence figures for CNP vary greatly due to variable definitions of CNP and reporting procedures (Chiarotto et al. 2016, Fejer et al. 2006b, Lock et al. 1999), with highest reported rates in Scandinavian countries (21.3%) compared to mainland European figures of 19%. (Hoy et al. 2014). In the USA, approximately 14.3% of the
population experience CNP, while approximately 5% or 640,000 Australians are affected by CNP (Hush et al. 2009). According to Raftery et al. (2012), 13% of the Irish population experience chronic pain, of this 29.4% is attributable to CNP. Thus, despite the variability in reported prevalence figures, CNP affects a significant proportion of people worldwide.

For the individual with CNP, symptoms are typically characterised by pain on movement, stiffness in the neck and shoulders and in more severe cases, sleep and mood disturbance, dizziness and headaches (Sterner and Gerdle 2004). For five percent of patients with CNP, symptoms can become severely functionally limiting and disabling (Jesus-Moraleida et al. 2011). CNP has a significant economic impact with direct and indirect costs amounting to millions annually due to lost productivity (Côté et al. 2003), sick leave (Hoy et al. 2014), medication consumption (Gross et al. 2004), healthcare system burden (Gaskin and Richard 2012) and compensation claims (Hogg-Johnson et al. 2008). Costs vary depending on population and prevalence. Per capita conservative management of CNP has been reported to cost healthcare systems from $100 to $1797 (Breivik and O’Brien 2013, Gaskin and Richard 2012, Hoy et al. 2014). Costs associated with CNP healthcare amounts to $1.14 billion annually for the Australian economy (Hush et al. 2009, Snodgrass et al. 2016).

While this research thesis provides an in-depth focus on the biomedical aspects of CNP and the role of resistance exercise in the management of CNP in the presence of physical muscular weakness, it is recognised that chronic pain is a multi-faceted phenomenon (O’Sullivan 2005). In accordance with the International Classification of Function, Disability and Health (ICF) (Kostantjsek 2011) the biopsychosocial, environmental and personal factors associated with the development of CNP must also be given equal consideration when discussing and formulating treatment interventions for CNP (Shahidi et al. 2015). Risk factors for the development of CNP can be separated into physical, psychosocial and individual factors (Cagnie et al. 2007b, Kääriä et al. 2012). Women aged between 30-49 years are almost twice more likely to develop CNP than men (Ariens et al. 2000, Cote et al. 2008, Mc Lean et al. 2010). This is postulated to be due to the relative weight of the head (5kg) on the neck and the smaller sized female anatomy (Chiu et al. 2005c). This gender difference reduces after 50 years of age (Hoy et al. 2014), which may be due to differences in exposure
to manual or industrial labouring industries (Guez 2002) and repetitive work (Goode et al. 2010, Carnes et al. 2008) which increase the risk of developing CNP. High emotional stress and work load demands are also postulated to increase the risk of CNP (Patel et al. 2012, Linton and Bergbom 2011) while smoking, a high body mass index (BMI) and previous history of lower back pain (Hogg-Johnson et al. 2008, Kääriä et al. 2012), are also linked to increased risk of CNP development. Of particular note is the link between sedentary lifestyles and increased risk of CNP development, with office-workers twice as likely as the general population to develop neck pain, with a reported prevalence rate of 60% (Cagnie et al. 2007b, Hush et al. 2009). An increased dependence on technology socially and in the workplace, increases the risk of CNP development (Andersen et al. 2011, Falla 2004d, Fejer et al. 2006a). There are also established links to depressed mood, passive coping strategies and fear-avoidance behaviours or beliefs on the development of CNP (Paksaihol et al. 2012). However, the strength of these links is not fully established, as research is still emerging (Pachsaichol et al. 2012). Being female and a previous neck pain appears to be the most strongly linked factors to CNP development (Fejer et al. 2006). As the population ages and exposure to risk factors such as sedentary behaviour and computer use continues to rise, the incidence of CNP is predicted to continue to rise (Cohen 2015), which will have significant implications for the economy, socially and for healthcare provision. It should also be noted that established link Therefore, effective management strategies for CNP are required.
1.2 Management of Chronic Neck Pain

Sixty-five percent of patients with CNP are classified as experiencing non-specific CNP, due to the lack of distinguishable underlying cause or abnormal anatomical structure as the source of pain (Patel et al. 2012, Kääriä et al. 2012). Thus, an abundance of diverse management strategies have been used to treat CNP symptoms, both invasive and non-invasive with varying levels of success (Kay et al. 2005). The proportion of individuals opting for surgical intervention (anterior decompression and fusion) is not well reported in the literature and no randomised controlled trials (RCTs) exist that examine the effectiveness of surgical interventions in the management of patients with non-specific CNP (Beynon et al. 2013, Cohen 2015). The benefit and cost effectiveness of surgical procedures for the management of other forms of CNP (neuropathic pain and cervical radiculopathies) are poorly reported and investigated (Beynon et al. 2013, Cesaroni and Nardi 2010). Most studies investigating the effectiveness of surgical management have small sample sizes of participants (Cohen 2015). A study by Persson et al. (1997), reported significantly greater reductions in pain from surgical interventions (anterior decompression and fusion) in patients with cervical radiculopathy neck pain compared to physical therapy or a collar, however, these results were not significant at one year follow-up.

The majority of patients with non-specific CNP opt for conservative treatment options, consisting mainly of physiotherapy treatment. Due to the multi-factorial nature of CNP, multi-modal treatment interventions that include active exercise, manual therapy, education and self-management strategies result in better outcomes compared to single modalities as these address the body structure, the environmental and personal factors associated with CNP (Childs et al. 2008, Gross et al. 2004). Low to moderate quality evidence exists to support the use of modalities such as manual therapy (Andersen et al. 2014) or manipulation (Sarig-Bahat 2003) over sham or no treatment in patients with CNP. However, no strong evidence exists to propose greater benefits of one modality over another due to large variation in study methodologies, sample sizes, recruitment methods and interventions used in individual studies investigating the effectiveness of a modality or exercise therapy (Childs et al. 2008). Systematic reviews of the literature strongly advocate the inclusion of active exercise as part of multi-modal physiotherapy intervention, including resistance, endurance,
proprioceptive training or aerobic exercise. (Childs et al. 2008, Kay et al. 2005). Patient education in conjunction with active exercise can provide additional benefits in self-efficacy and pain reductions than exercise or education alone (Brage et al. 2015). Whilst a large body of research evidence exists to support the inclusion of active exercise in the management of CNP, no definitive consensus on the most effective frequency, intensity, time and type (FITT principle) of exercise to conduct exists in the current body of literature. Having an evidence informed exercise prescription which is appropriate and effective for use in a patient group is advantageous to clinicians, as employing evidence based techniques and treatment methods are considered good clinical practice (Mc Curtin and Clifford 2015). This gap in the literature underpins one of the research aims of this study. Thus, a systematic review of the literature to investigate the effect of active exercise in people with CNP is needed and will be performed and described in Chapter 3. The aim of this systematic review is to evaluate the studies identified and formulate an evidence informed FITT principle of exercise for patients with CNP, which can be used as part of a multi-modal treatment intervention.

1.3 Effect of Pain on Motor Control of the Cervical Muscles

Research studies that investigated the effect of active exercise in people with CNP found improvements in cervical muscle strength (Ylinen et al. 2003) decreased neck pain (Bertozzi et al. 2013, Chiu et al. 2005b, Häkkinen et al. 2007, Karlsson et al. 2014) and reduced perceived disability (Beltran-Alacreu et al. 2015, Celenay et al. 2016). However, to date the physiological mechanisms for how exercise improves the symptoms associated with CNP, including pain and disability, have not been widely investigated (Karlsson et al. 2015, Jensen et al. 2012, Steiger et al. 2012). There is increasing evidence to suggest that changes to the cervical muscles due to pain play a pivotal role in the transition to or maintenance of chronic pain (De Pauw et al. 2016). At present the underlying pathophysiology of CNP and the mechanism by which pain affects the cervical anatomy is not fully understood (Tsakitzidis et al. 2013, Vos et al. 2008). This may in part be the reason why no definitive care pathway is advised over another, as treatment is directed towards symptoms of CNP and not directly targeting underlying anatomical structures or changes. Thus, to develop and deliver evidence
based and effective clinical assessment and treatment interventions for patients with CNP it is imperative to fully elucidate how pain affects the cervical muscles and how these changes may affect the persistence of pain. This section will explore the possible theoretical reasoning underpinning the role these changes play in CNP.

The cervical muscles are pivotal to the stability and correct functioning of the cervical spine (Punjabi et al. 1994). Research has identified significant alterations in neuromuscular control and activity of both the superficial and deep cervical flexor musculature of patients with CNP (O Leary et al. 2007b). Increased activity of the larger and more powerful superficial flexor muscles (Sternocleidomastoid, Anterior Scalene, Upper Trapezius) has been found in patients with CNP, during upper limb tasks or in cranio-cervical flexion (CCF) (Falla 2004c, Jull and Falla 2016) indicating a redistribution of activity between superficial and deep muscle layers to maintain function in the short-term (Hodges and Tucker 2011). A continuation of altered muscle activation patterns, leads to continued disuse, atrophy and weakness of the DNFs (Dvir and Prushansky 2008, Strimpakos et al. 2004a) while increased activity of the superficial flexors leads to early fatigue of these muscles (Jull et al. 2004b), which can affect load and movement in the area (Hodges and Tucker 2011). Research evidence has hypothesised that a redistribution of activity within and between muscles in the presence of pain is the body’s own means of maintaining homeostasis and function (Hodges and Tucker 2011). These changes in mechanical behaviour can cause modified movement and stiffness, which may encourage further pain or injury threat (Hodges and Tucker 2011). This indicates that pain is much more complex than changes in motor neuron excitability but involves alterations at multiple motor system levels (Tsakitzidis et al. 2013). Whilst beneficial in the short term, for continued function, these changes can increase load in an area and reduce movement, causing further and continued pain. This therefore, allows for continued weakening and inactivity of the DNFs (Cagnie et al. 2011, Javanshir et al. 2010b), over-activity of the superficial flexors (Pearson et al. 2009, Falla et al. 2003b) and a continued cycle of chronic pain.

The DNF muscles are particularly important as they provide tonic stabilisation to the cervical spine, due to their anterior vertebral attachment and flex the head on the neck (cranio-cervical flexion). However, a significant reduction in the activity,
strength and reflexive feed-forward mechanism of the deep cervical flexor muscle group are seen in patients with CNP (Falla et al. 2003a, Falla 2004a, Falla et al. 2004, Falla 2004b, Jull 2000). A weakness of the DNFs affects their ability to maintain stability of the cervical spine and can alter movement and posture (Falla et al. 2006b). Thus, the normal curvature (lordosis) of the cervical spinal can appear flatter in those with CNP (Falla 2004b) indicating that the stabilising role of the DNFs is impaired due to this weakness.

Whilst it is known that changes occur to the deep and superficial cervical flexor muscles in CNP, to the authors knowledge, no systematic review exists that synthesises the information pertaining to the exact functional and morphological changes to the cervical flexor musculature of patients with CNP. Therefore, a second aim of this research thesis is to conduct a systematic review (Chapter 2) to appraise and synthesise the literature that investigated the objectively measurable changes which occur to the cervical musculature in patients with CNP. Such a systematic review can bridge a gap in the current body of literature and provide clinicians with a comprehensive overview of the underlying impairments of a patient with CNP. This will assist clinicians with more targeted assessment and thus better inform treatment planning for patients with CNP. This systematic review will also provide the evidence which underpins the hypothesis of this research thesis; that a weakness of the deep cervical flexors exists in patients with CNP and therefore, targeted resistance exercise is required as part of a multi-modal treatment intervention.
1.4 Resistance Exercise in the Treatment of Chronic Neck Pain

The majority of research evidence to date investigating the effects of resistance exercise in patients with CNP has not specifically targeted the deep neck flexors (Hudson and Ryan 2010, Ylinen et al. 2006, Ylinen 2007). The unavailability of clinically useful resistance exercise tools that can be used by the patient, independently or in a functional position, has meant that resistance exercise interventions that target the DNFs specifically are lacking. Given the known important stabilising role of the DNFs (Cagnie et al. 2011, Bogduk 2011) it is important to develop a means of effectively strengthening these muscles to optimise cervical spine function and minimise CNP symptoms. This section aims to highlight some of the current methods available for delivering resistance exercise for the cervical musculature and to demonstrate the need for the development of a clinically useful and functional exercise tool to provide strengthening exercise for the deep cervical flexors in patients with CNP.

1.4.1 Current Strengthening Methods

Some methods currently available to strengthen the neck flexors include purpose built fixed units, for example the “Multi-Cervical Unit™” (BTE Technologies, Hanover, Maryland, USA). The “Multi Cervical Unit™”) is an objective assessment and rehabilitative tool for neck pain and whiplash associated injuries, allowing for objective evaluation of cervical range of motion and isometric strength. Its computerised interface records in real-time cervical spine movement and isometric strength in all three planes of movement. It has been extensively used in air-force pilots and military personnel to good effect, resulting in increased isometric strength, reduced disability and pain and its benefits are well published (Burnett et al. 2005, Chiu et al. 2005b, Keating et al. 2005, Taylor et al. 2006). However, due to its large expense and fixed position the device is not readily available clinically and not suitable for independent use outside of therapy.

A second method includes the use of the Pressure Biofeedback Unit (Holden, Chattanooga, Tennessee). This bio-feedback tool was designed to facilitate muscle re-education through low load endurance type exercise and was initially designed for use
with the deep abdominal muscles in people with lower back pain (O Leary et al. 2005, Lima et al. 2012, Sedaghat et al. 2007). Over the last fifteen years, research by (Falla 2004a, Falla 2004b) has seen the Pressure Biofeedback Unit adapted for use at the cervical region for assessing and treating neck pain, which included increases in isometric neck strength (Falla et al. 2006a) The Pressure Biofeedback Unit allows the user to exercise the deep stabilising muscles (Longus Colli, Capitis, Rectus Capitis) by exerting a pressure against an inflatable cushion placed under the cervical lordosis and conducting CCF. A pressure gauge connected to the inflatable cushion acts to display the pressure exerted, thus providing visible feedback instantly to the user. Full CCF, the predominate movement created by the deep cervical flexors is approximately 16-20 degrees of movement (Bogduk 2011) and creates pressures of between 20-30mmHg on the pressure gauge of the Pressure Biofeedback Unit. Asymptomatic control subjects are typically able to sustain such contractions at the upper limits, however individuals with CNP have been shown to display inabilities and altered muscle recruitment patterns when initiating the CCF movement (22mmHg), as well as at the end of the range, i.e. 28-30mmHg (Cagnie et al. 2011). Due to the design of the device it can lead to incorrect technique during its use independently (Jull and Falla 2016, O Leary et al. 2011). Moreover, the Pressure Biofeedback Unit is restricted to being used in supine lying only, which in terms of practicality is limiting for patients and does not reflect the functional movements of these deep cervical flexors.

Additionally, TheraBand™ and purpose built head-harnesses have been used to hang weights and provide resistance to head movements for patients with CNP in clinical settings ((Chiu et al. 2002, Rodriguez and Burns 2008). These methods while clinically feasible, relatively cheap and readily available are not specific to the deep cervical flexors and therefore do not directly target the proposed weakness of these muscles.
1.4.2 “FLEXOR”

“FLEXOR” (Figure 1.1) is a novel strengthening tool which was designed and developed within the University of Limerick with the aim of delivering resistance based exercise for the deep neck flexors in a functional manner and that can be used independently. However, prior to the conduction of this research study its feasibility and effectiveness had not been investigated.

Figure 1.1: “FLEXOR” device design
“FLEXOR” as identified through regulatory assessment procedure is; “a rehabilitative exercise device intended for medical purposes, such as to measure, evaluate and increase the strength of muscles and range of motion of joints. “FLEXOR” is classified as a Class I medical device under European Union Medical Device Directive and is defined as a low risk non-invasive device (Further details in Appendix A).

The hypothesis of “FLEXOR” is that it provides targeted strengthening of the DNFs by activating these muscles in a functional CCF movement (Falla 2004b). “FLEXOR” enables the user to perform CCF exercises while providing variable resistance to a movement at self-controlled speed. “FLEXOR” is an open-backed collar, which sits between the upper cervical border of first cervical vertebrae (C1) and inferiorly on the shoulders and sternum. Its size is based on the 95th percentile for males and females and the telescopic chin bracket allows for an individualised fit. It is proposed that repeated movement through range against a resistance of at least 50% of an individual’s maximum voluntary contraction (MVC) is associated with increased strength and often hypertrophy when carried out for at least 6-8 weeks (Campos et al. 2002). Therefore, it is hypothesised that “FLEXOR” by its design, could provide an individualised targeted resistance DNF exercise programme suitable for independent use by patients with chronic neck pain (Further details on the “FLEXOR” device and its proposed mechanism of action can be seen in Appendix A).
1.5 Research Aims & Thesis Structure

The primary aim of this research thesis is to investigate the role of targeted resistance exercise for the deep neck flexors in the management of chronic neck pain. As part of this research project, it is a secondary aim to investigate and establish the feasibility of a targeted resistance exercise intervention for the DNFs using a novel strengthening tool, “FLEXOR” in a patient population. In an attempt to answer the research questions and establish the effectiveness of “FLEXOR”, a number of studies are required. It is important to assess the feasibility, safety usefulness and effectiveness of the “FLEXOR” device in a healthy population, prior to investigations with a patient population. Therefore, using the FITT principle which will be established through the systematic review in Chapter 3, a feasibility study in a healthy population using “FLEXOR” will be conducted and described in Chapter 5. Information gathered from this feasibility study will be further added to informing the primary research question by developing a pilot randomised controlled trial (RCT) with patients with CNP and will be described in Chapter 6.

Thus, the objectives of this research project were to;

- Critically appraise and synthesise the literature that investigates the changes in the cervical flexor musculature in the presence of persistent pain and their role in CNP.
- Synthesise the evidence on the effect of active exercise in the treatment of chronic neck pain and develop a FITT exercise prescription of resistance exercise for patients with chronic neck pain.
- Determine the feasibility, safety and effectiveness of a targeted resistance exercise intervention for the deep neck flexors, using a novel strengthening tool “FLEXOR” in healthy people and patients with CNP.

Figure 1.2 summarises the research process designed and developed to answer the research question and address the primary and secondary aims of the research project. It also highlights the connections between each phase in informing and answering the research question.
To inform the research aims, a number of studies were required and will be presented in the research thesis as the following:

Chapter 2: “What is the Effect of Chronic Pain on the Cervical Musculature” will present a systematic review of the literature that will evaluate and synthesise the evidence of changes to the cervical flexor musculature in the presence of pain. This chapter will provide important information justifying the need for resistance exercise in CNP management.

Chapter 3: “Active Exercise in Chronic Neck Pain: The FITT principle” a second systematic review will be undertaken to identify, evaluate and synthesize the available literature on active exercise in CNP. It is the aim of this review to form a FITT principle of exercise for resistance exercise for patients with CNP. This FITT principle will be used to inform later stages of the research project when investigating the feasibility of a resistance exercise intervention in the management of CNP.
Chapter 4: “Reliability of a Measurement Method for the Cross-sectional Area of the Longus Colli Using Real-time Ultrasound Imaging”. This chapter will describe a study that will be undertaken to establish the intra-rater reliability of a method to measure the cross-sectional area (CSA) of the Longus Colli (LCo) in a healthy population.

Chapter 5: “Effectiveness and feasibility of “FLEXOR” to provide targeted resistance exercise to the deep neck flexors; A healthy population study”; this chapter will outline a study which will be undertaken to establish the feasibility of a study design using the “FLEXOR” device, the suitability of chosen outcome measures and study design prior to investigations with patients with CNP. The results of this study will be used to inform later research studies investigating patients with CNP.

Chapter 6: “The Effectiveness of a Targeted Resistance Exercise Intervention for the Deep Neck Flexors using “FLEXOR”; A Pilot Randomized Controlled Trial”. This chapter will outline the main multi-centre pilot patient trial undertaken as part of the research project. It will investigate the feasibility of an evidence informed targeted resistance exercise intervention using a novel strengthening tool in patients with CNP, when used as part of usual care physiotherapy. This research study will be pertinent to the primary research question of establishing the role of targeted resistance exercise of the DNFs in the management of CNP.

Chapter 7: “FLEXOR” a descriptive follow-up study” will outline a follow-up research study conducted to further explore results that will be found in the pilot RCT. This study will aim to evaluate subjective feedback from participants of the pilot RCT and to highlight any issues relating to the feasibility of the study or device design. It will be an aim of this study to consolidate any information gathered which may be used to provide guidance or suggestions for the future development of and research related to the “FLEXOR” device.

Chapter 8: “General discussion” will provide a platform where consolidated information which emerges from the research process will be discussed in the context of informing the current evidence base, its clinical implications and how it can inform future research in the area.
Chapter 2: The Effect of Chronic Pain on the Cervical Flexors; A Systematic Review
2.0 Introduction

Chronic neck pain is a common musculoskeletal problem worldwide with reported prevalence figures ranging from 8.35% to 49% (Ehrlich 2003, Viljanen et al. 2003, Raftery 2011). An increasing prevalence of CNP creates a socio-economic burden (Hoy et al. 2014), as CNP can quickly lead to severe limitations in everyday functioning, prolonged sick leave and an increase in medication consumption (Binder 2007). Those with CNP are twice as likely to seek medical care compared to the general population (Viljanen et al. 2003). This has considerable implications for direct health care costs, lost productivity, compensation and disability allowances (Cagnie et al. 2007a). Per capita, chronic neck pain has been reported to cost healthcare systems from $100 to $1797 (Breivik and O'Brien 2013, Gaskin and Richard 2012, Hoy et al. 2014, Hush et al. 2009). Research outlining the exact pathophysiology of chronic neck pain is equivocal (Evans 2014, Malfliet et al. 2015). Indeed, the definition of non-specific neck pain is defined as pain present in the absence of an identifiable source, resulting in generalised neck symptoms, provoked by maintained postures or neck movements (Falla 2004a, Ehrlich 2003). To better inform clinical assessment and treatment methods, it is imperative to gain further knowledge on the effect of persistent
pain on the cervical anatomy and the subsequent impairments seen in the presentation of a typical patient with CNP. While evidence suggests changes to the cervical flexor muscles play a role in CNP, no systematic review of the literature exists which identifies, evaluates and synthesises the evidence of these changes.

Chronic neck pain is defined as pain originating from the region bounded superiorly by the superior nuchal line and inferiorly by an imaginary line through the spinous process of the first thoracic vertebrae (Gross et al. 2012) lasting longer than three months (Ehrlich 2003). The cervical spine is a complex biomechanical region that has many muscles attaching here to create movements of the head and neck. Cervical muscles are described according to two distinct groups, pertaining to their anatomical location; superficial and deep (Falla 2004b). Together these muscle layers provide 80% of the cervical spine’s mechanical stability (Panjabi et al. 1998) supporting the head’s orientation relative to the torso (O’Leary et al. 2007). The osseoligamentous systems provide the remaining 20% of the cervical stability (Panjabi et al. 1998). Both the deep and superficial muscle layers work concurrently in the cervical region and are affected by the presence of persistent pain, differentiation between both muscle layers is important to acknowledge as the influence of pain on both is different (Falla 2004b). The deep cervical flexor muscles, in particular Longus Colli (LCo) and Capitis have a well-established important role in neck stabilisation anteriorly due to their anatomical insertion, producing tonic stabilising activity at the neck (Jull and Falla 2016). The changes that occur in the deep muscle layer include alterations in muscle function, muscle morphology and muscle activity (Falla 2004b, Johnston et al. 2008, Jull et al. 2009, O Leary et al. 2007c), leading to incorrect muscle recruitment patterns and increased activity of the superficial layer (Sternocleidomastoid (SCM), Anterior Scalenes (AS) and Upper Trapezius (UT) muscles). The resultant changes in movement patterns are postulated to cause pain and early muscle fatigue of the superficial cervical muscles (Falla 2004a, O Leary et al. 2007c, Pearson et al. 2009, Strimpakos et al. 2004b).

To date much of the literature has focused on assessing the effectiveness of specific treatment interventions for the management of CNP symptoms (Gross et al. 2004, Häkkinen et al. 2007, Kay et al. 2005, Miller et al. 2010, Ylinen et al. 2003). Further research attention has been given to establishing the reliability, validity and
psychometric properties of objective assessments to measure cervical muscle function (de Koning et al. 2008, Strimpakos and Oldham 2001). However, limited attention has been given to objectively measuring the effects of chronic pain on the cervical musculature in patients with CNP compared to healthy individuals.

De Pauw et al. (2016) conducted a systematic review examining morphological changes only to the cervical musculature (flexors and extensors) of patients with whiplash associated disorders (WAD) and non-traumatic or non-specific neck pain. However, of the three articles included which reported findings from patients with non-specific neck pain, only data on CSA of the cervical extensors were reported. Therefore, to the authors knowledge, no published systematic review exists which provides a comprehensive synthesis of the research examining changes to the cervical flexor musculature in people with non-specific CNP. Therefore, this study will aim to identify and synthesise the literature which uses objective measurement methods to quantify the changes to the cervical flexor musculature in patients with CNP compared to healthy individuals. Having a structured and synthesised overview of the changes to the cervical flexor muscles can provide clinicians and researchers with a more evidence informed understanding of the symptoms and limitations of a patient with CNP, thereby assisting in the development of appropriately targeted and individualised treatment interventions.
2.2. Methodology

2.2.1 Data Sources and Searches

The search was conducted by one researcher and studies were systematically identified from a literature search using AMED, PubMed, CINAHL, MEDLINE, Biomedical Reference Collections, Academic Search Premier, PEDro, Cochrane and SPORTDiscuss. Databases were searched in April 2013 and a further search completed in June 2016, aiming to identify all available studies published since 2001 which objectively quantified the differences between a chronic neck pain population and healthy controls. The following search terms were used: “chronic neck pain” and “cervical muscles”, “strength”, “motor control”, “electromyography”, “cross-sectional area” and “muscle morphology”. Furthermore, a hand search was conducted on the reference lists of articles retrieved and included in the systematic review.

2.2.2 Study Selection

Studies that used a cross-sectional, cohort or observational design that investigated one or more objective measures of the cervical flexor musculature in patients with chronic neck pain and an asymptomatic population were selected. These study designs were deemed most appropriate for likely relevance to the research question with a comparison of two groups for exposure or presence of a disease without an intervention included.

The suitability of articles was determined during a screening process. Article titles and abstracts were screened independently against predefined inclusion and exclusion criteria (Table 2.1), after which inapplicable articles were excluded. All remaining potentially eligible articles were further screened for final inclusion through reading of the full article. In cases of uncertainty, a second reviewer was consulted and a consensus on inclusion was reached through discussion. Only articles published from 2001 to the present day were included in this review in an attempt to use the most up to date relevant published literature. Research articles published since 2001 only were chosen as a systematic review by Strimpakos and Oldham published in 2001, identified the most reliable and valid methods of objective assessment of neck function. Therefore, literature published since then using objective measurements of
function were chosen. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al. 2009) flow diagram of study search and selection can be seen in Figure 2.1.

<table>
<thead>
<tr>
<th>Table 2.1: Inclusion Criteria Applied to Retrieved Studies.</th>
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<tbody>
<tr>
<td>a) Articles available in the English Language.</td>
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<tr>
<td>b) Published since 2001 to the present day.</td>
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<tr>
<td>c) Methodology included an assessment of the cervical flexor muscles using at least one non-invasive objective method (to include but not limited to; manual muscle testing, hand held dynamometry, fixed frame dynamometry, isokinetic dynamometry, real-time ultrasound, electromyography,).</td>
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<tr>
<td>d) Chronic pain was defined as the presence of symptoms beyond a three-month period.</td>
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<tr>
<td>e) The articles had to provide data/measure of cervical musculature in healthy controls and people with CNP (specifically but not limited to objective methods listed in point c).</td>
</tr>
<tr>
<td>f) Studies of any design which compared healthy controls to patients with CNP (cross-sectional, case-control, observational, cohort designs were included (Level 2b according to OCEMB (2009) (Howick et al. 2011).</td>
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<tr>
<td>g) Studies including participants aged 18 years and over.</td>
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2.2.3 Data Extraction & Risk of Bias in Individual Studies

Study details pertaining to the objective measure used, study sample characteristics (sample size, gender, age range, duration of pain, assessment method) as well as study methodology and results observed for CNP patients and an asymptomatic population were extracted. Methodological quality was evaluated using the Newcastle Ottawa Scale (NOS) for case control studies. This checklist has established content validity and inter-rater reliability for assessing non-randomized studies in meta-analyses (Stang 2010). The NOS is based on a star scoring system where a maximum of one star can be awarded for each numbered item within the selection and exposure categories and two within the comparability category, giving a maximum score of nine. This checklist was used to evaluate included articles of case-control design across six domains including a description of the patient group and the control group, declaration of any selection bias, exposure, blinding if applied and confounders.
2.3 Results

2.3.1 Study Selection

Literature searches identified 781 articles, following the removal of duplicates, 425 articles were screened for eligibility. A further 409 were excluded for not meeting the study inclusion criteria, leaving 16 articles. A further article was excluded as it was established that data for whiplash patients were not significantly separated from those with non-specific neck pain for data extraction. This left fifteen articles for qualitative synthesis. See Figure 2.1 PRISMA flow diagram below.
Figure 2.1: Search Strategy Based on PRISMA Flow Diagram

- Records identified through database searching (n = 781)
  - Records after duplicates removed (n = 425)
    - Records screened (Titles & Abstracts) (n = 425)
      - Records excluded (n = 409)
        - No assessment of the cervical flexors, published before 2001, incorrect study design, no objective measurement method assessed
      - Full-text articles assessed for eligibility (n = 16)
        - Full-text articles excluded, with reasons (n = 1)
          - Data for whiplash associated disorder patients (WAD) pooled with idiopathic neck pain patients
    - Studies included in qualitative synthesis (n = 15)
2.3.2 Study Characteristics

Sample sizes amongst included articles ranged between 8 and 126 participants, with a mean of 55.6 in total. Reporting of ages varied amongst included articles, age range or mean age was reported, participants ranged in age from 18-60 years with an average age of 36.75 years for patients with CNP and 35.23 years for healthy controls. Ten articles did not report a mean duration of pain for the CNP group, based on the remaining five articles, 6.82 years was the mean pain duration for patients in the CNP group. Five of the studies used only female participants which reduced the influence of gender differences in observed results (Cagnie et al. 2007a, Lindstrom et al. 2011, Lindstroem et al. 2012, Mc Gaugh and Ellison 2011, O Leary et al. 2007c, Ylinen et al. 2004b). Nine studies reported measures of isometric strength (Cagnie et al. 2007a, Falla et al. 2004, Kumar and Prasad 2010, Lindstroem et al. 2012, Lindstrom et al. 2011, O Leary et al. 2007c, Pearson et al. 2009, Scheuer and Friedrich 2010b, Ylinen et al. 2004a), four studies of CSA of the deep cervical flexor muscle the LCo (Javanshir et al. 2011a, Jesus-Moraleida et al. 2011, Mc Gaugh and Ellison 2011, Javanshir et al. 2011b) and five studies reported electromyography (EMG) muscle activity of the superficial cervical flexor muscles (Boudreau and Falla 2014, Falla et al. 2004, Kumar and Prasad 2010, Lindstrom et al. 2011)
<table>
<thead>
<tr>
<th>Study Name</th>
<th>Study Design</th>
<th>Assessment Method</th>
<th>Sample Size</th>
<th>Healthy Controls</th>
<th>Duration of Pain (Mean &amp; SD)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boudreau and Falla (2014)</td>
<td>Cross-sectional</td>
<td>EMG</td>
<td>30</td>
<td>16</td>
<td>8.9±7.8 years</td>
<td>35.6±10.00</td>
</tr>
<tr>
<td>Cagnie et al. (2007a)</td>
<td>Cross-sectional</td>
<td>Isometric strength</td>
<td>30</td>
<td>96</td>
<td>Not given</td>
<td>20-59</td>
</tr>
<tr>
<td>Falla et al. (2004)</td>
<td>Cross-sectional</td>
<td>1)EMG 2) Isometric Strength</td>
<td>20</td>
<td>20</td>
<td>9.1±8.7 years</td>
<td>29.0±6.8</td>
</tr>
<tr>
<td>Javanshir et al. (2011a)</td>
<td>Cross-sectional</td>
<td>CSA LCo</td>
<td>20</td>
<td>20</td>
<td>Not given</td>
<td>31.0±5.0</td>
</tr>
<tr>
<td>Javanshir et al. (2011b)</td>
<td>Cross-sectional</td>
<td>CSA LCo</td>
<td>15</td>
<td>10</td>
<td>Not given</td>
<td>34.3±5.5</td>
</tr>
<tr>
<td>Jesus-Moraleida et al. (2011)</td>
<td>Cross-sectional</td>
<td>CSA LCo</td>
<td>31</td>
<td>31</td>
<td>Not given</td>
<td>29.65±5.79</td>
</tr>
<tr>
<td>Jull et al. (2004b)</td>
<td>Cross-sectional</td>
<td>1)EMG 2) Cranio-cervical flexion test</td>
<td>25</td>
<td>25</td>
<td>8.5±6.00</td>
<td>40.3±9.2</td>
</tr>
<tr>
<td>Kumar and Prasad (2010)</td>
<td>Cross-sectional</td>
<td>EMG</td>
<td>34</td>
<td>63</td>
<td>Not given</td>
<td>18-60</td>
</tr>
<tr>
<td>Lindstroem et al. (2012) *</td>
<td>Cross-sectional</td>
<td>EMG</td>
<td>13</td>
<td>10</td>
<td>7.1±6.0</td>
<td>37.00±7.8</td>
</tr>
<tr>
<td>Lindstrom et al. (2011) *</td>
<td>Cross-sectional</td>
<td>Isometric Strength</td>
<td>34</td>
<td>14</td>
<td>Not given</td>
<td>18-50</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Method</td>
<td>Sample size</td>
<td>Age (months)</td>
<td>Force (lbs)</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>-----------------</td>
<td>-----------------------------</td>
<td>-------------</td>
<td>--------------</td>
<td>--------------</td>
<td></td>
</tr>
<tr>
<td>Mc Gaugh and Ellison (2011) *</td>
<td>Cross-sectional</td>
<td>CSA LCo</td>
<td>3</td>
<td>5</td>
<td>Not given</td>
<td>33.0±11.2</td>
</tr>
<tr>
<td>O Leary et al. (2007c) *</td>
<td>Cross-sectional</td>
<td>Isometric Strength</td>
<td>46</td>
<td>47</td>
<td>6.1±4.4 (months)</td>
<td>37.0±10.1</td>
</tr>
<tr>
<td>Pearson et al. (2009)</td>
<td>Cross-sectional</td>
<td>Isometric Strength</td>
<td>14</td>
<td>28</td>
<td>Not given</td>
<td>36.6±10.8</td>
</tr>
<tr>
<td>Scheuer and Friedrich (2010a)</td>
<td>Cross-sectional</td>
<td>Isometric Strength</td>
<td>53</td>
<td>42</td>
<td>Not given</td>
<td>49.7±10.47</td>
</tr>
<tr>
<td>Ylinen et al. (2004b) *</td>
<td>Cross-sectional</td>
<td>Isometric Strength</td>
<td>21</td>
<td>21</td>
<td>Not given</td>
<td>48.0±8.0</td>
</tr>
</tbody>
</table>

**Table 2.2: Details on study design, objective assessment method and participant demographics of included studies.**

(* denotes studies which included female participants only)
2.3.3 Risk of Bias and Level of Evidence

As per the NOS, most methodological flaws were due to a lack of adequate reporting of the control sample and selection biases. The manner of participant recruitment of both healthy controls and chronic neck pain patients varied between studies, ranging from recruitment through pain management centres (Lindstroem et al. 2012), outpatient physical therapy departments (Javanshir et al. 2011a), hospital advertisements (Cagnie et al. 2007a), email (O Leary et al. 2007c), work place occupational health centres (Ylinen et al. 2004b) and university campuses (Jull et al. 2004b, Lindstrom et al. 2011). Therefore, there is a potential for recruitment bias in some individual studies. Duration of pain for the CNP groups was not disclosed in 10 of the included studies. Additionally, several studies failed to disclose any reports of blinded assessment. Due to the nature of the review and the research question, articles retrieved and reviewed were mainly of observational cross-sectional design. This would indicate a level 2b moderate quality according to the Oxford Centre for Evidence Based Medicine (OCEBM) ratings (Howick et al. 2011). Table 2.3 demonstrates the NOS checklist for each of the included studies. Studies which scored low (≤ 6) on the NOS were not excluded from this review. These studies (Javanshir et al. 2011a, Javanshir et al. 2011b, McGaugh and Ellison, 2011) scored lower due to a lack of reporting on control groups. Therefore, results from these studies must be interpreted with caution.
<table>
<thead>
<tr>
<th>Study</th>
<th>Case definition</th>
<th>Representative of cases</th>
<th>Selections of controls</th>
<th>Definition of controls</th>
<th>Control for objective outcome measure</th>
<th>Ascertainment of exposure</th>
<th>Same method of ascertainment for participants</th>
<th>Non-response rate</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boudreau and Falla (2014)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8 (high)</td>
</tr>
<tr>
<td>Cagnie et al. (2007a)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8 (high)</td>
</tr>
<tr>
<td>Chiu et al. (2005c)</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8 (high)</td>
</tr>
<tr>
<td>Falla et al. (2004)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>9 (high)</td>
</tr>
<tr>
<td>Javanshir et al. (2011a)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6 (low)</td>
</tr>
<tr>
<td>Javanshir et al. (2011b)</td>
<td>1</td>
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<td>0</td>
<td>0</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>6 (low)</td>
</tr>
<tr>
<td>Jesus-Moraleida et al. (2011)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7 (high)</td>
</tr>
<tr>
<td>Jull et al. (2004a)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>9 (high)</td>
</tr>
<tr>
<td>Kumar and Prasad (2010)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6 (low)</td>
</tr>
<tr>
<td>(Lindstroem et al. 2012)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>9 (high)</td>
</tr>
<tr>
<td>Study</td>
<td>Item 1</td>
<td>Item 2</td>
<td>Item 3</td>
<td>Item 4</td>
<td>Item 5</td>
<td>Item 6</td>
<td>Item 7</td>
<td>Item 8</td>
<td>Score</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>--------</td>
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<td>--------</td>
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<td>--------</td>
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<td>-------</td>
</tr>
<tr>
<td>Lindstrom et al. (2011)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7     (high)</td>
</tr>
<tr>
<td>Mc Gaugh and Ellison (2011)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6     (low)</td>
</tr>
<tr>
<td>O'Leary et al. (2007)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7     (high)</td>
</tr>
<tr>
<td>Pearson et al. (2009)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8     (high)</td>
</tr>
<tr>
<td>Scheuer and Friedrich (2010a)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8     (high)</td>
</tr>
<tr>
<td>Ylinen et al. (2004b)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8     (high)</td>
</tr>
</tbody>
</table>

Table 2.3: Risk of bias assessment using the Newcastle Ottawa Scale for included studies.
2.3.4 Results Synthesis

2.3.4.1 Muscle Strength

Nine studies reported measures of isometric strength (Cagnie et al. 2007a, Falla et al. 2004, Kumar and Prasad 2010, Lindstroem et al. 2012, Lindstrom et al. 2011, O Leary et al. 2007c, Pearson et al. 2009, Scheuer and Friedrich 2010b, Ylinen et al. 2004a) (Table 2.4). For measures of isometric strength, fixed frame dynamometry using a load cell or strain gauge to report values in Newton’s was the common method of assessment. However, it should be noted that the instrumentation, testing position and procedure used varied greatly amongst individual studies, which may explain the large variation in isometric strength values obtained between studies for both healthy controls and patients with chronic neck pain, e.g. 16.7±3.4N, 58.8±18.3N to 97.7±40.0N. Measurements taken in sitting (Ylinen et al. 2004b) or standing (Lindstrom et al. 2011) were significantly larger than a supine lying measurement (Cagnie et al. 2007a). Testing familiarisation procedures were commonly part of all methods of assessment for isometric strength and an average or the highest maximum voluntary contraction (MVC) effort was recorded. Therefore, it is important to consider the methodology used to measure isometric strength when observing results. Significantly higher isometric strength values in favour of the healthy controls were seen when compared to patients with CNP in three studies (Kumar and Prasad, 2010, Linstroem et al. 2012, Ylinen et al. 2004b) with reductions ranging from 20-40N. These studies scored between 6 and 9 in the NOS.

2.3.4.2 Cross-sectional Area

Four studies measured CSA of the deep cervical flexor muscle, the LCo (Javanshir et al. 2011b, Javanshir et al. 2011a, Jesus-Moraleida et al. 2011, Mc Gaugh and Ellison 2011). Literature on measurements of CSA of the deep cervical flexor muscles is sparse, however measurement methods are quite similar between studies, as it is anatomically dependent. Statistically significantly smaller CSA of the LCo was observed in patients with CNP when compared to healthy controls with reports of a mean difference of 0.04cm$^2$ (Mc Gaugh and Ellison 2011), with p values of <0.01 (Javanshir et al. 2011a).
2.3.4.3 Electromyography

Five studies, scoring between 6 and 9 on the NOS, measured EMG muscle activity of the superficial cervical flexor muscles (Boudreau and Falla 2014, Falla et al. 2004, Jull et al. 2004b, Kumar and Prasad 2010, Lindstrom et al. 2011). For measures of EMG activity of the superficial muscle layer, namely the Sternocleidomastoid, Anterior Scalene, Splenius Capitis (SpC) Upper Trapezius, skin preparation procedures and electrode placement were standardised (Falla et al. 2002). Measurements of EMG activity during neck movements or during sub-maximal effort movements were readily measured in studies included. Reporting of EMG results varied between studies. Significant alterations in the EMG activity of the Sternocleidomastoid, Anterior Scalene and Splenius Capitis was measured in people with CNP compared to healthy controls p<0.05 in four studies (Boudreau and Falla, 2014, Jesus-Moraleida et al. 2011, Jull et al. 2004b, Lindstoem et al. 2012), including delayed onset activity times, or increased superficial flexor muscle activity in cervical movements and upper limb tasks. Studies which investigated EMG activity of the deep cervical flexors (Falla et al. 2003a) could not be included in this review as they required invasive methods of fine wire electrodes and were therefore not within the inclusion criteria of this review.
<table>
<thead>
<tr>
<th>Study Name</th>
<th>Outcome(s) Assessed</th>
<th>Result</th>
<th>Healthy</th>
<th>Explanation of Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boudreau &amp; Falla (2014)</td>
<td>EMG</td>
<td>Muscle Activity onset times: Forward Slide (postural perturbation (FS) SCm: 83.3± 8.0 EMG amplitude SCm 206.0±50.4 (% increase in postural perturbation relative to baseline)</td>
<td>Muscle Activity onset times: FS 86.3±4.4 EMG amplitude SCm 115.9±15.7 (% increase in postural perturbation relative to baseline)</td>
<td>Reduced activation and delayed onset in SCm &amp; SpC for CNP patients in 4 postural perturbations (forward, backward slide and forward/backward head tilt), with FS most significant</td>
</tr>
<tr>
<td>Cagnie et al. (2007a)</td>
<td>Isometric strength</td>
<td>16.7±3.4N</td>
<td>16.6±3.3N</td>
<td>P=0.897</td>
</tr>
<tr>
<td>Falla et al. (2004)</td>
<td>1)EMG</td>
<td>0.58 μV, 0.44μV</td>
<td>0.52 μV, 0.34 μV</td>
<td>AS &amp; SCm @ 50% MVC, p=0.23,0.21 (respectively) p=0.75</td>
</tr>
<tr>
<td></td>
<td>2) Isometric Strength</td>
<td>66.9±18N</td>
<td>73.3±37.7N</td>
<td></td>
</tr>
<tr>
<td>Javanshir et al. (2011a)</td>
<td>CSA LCo</td>
<td>0.66±0.11cm² (Dominant LCo) 0.68±0.07cm² (Non-dominant LCo)</td>
<td>0.85±0.11cm² (Dominant LCo) 0.85±0.11cm² (Non-dominant LCo)</td>
<td>Mean Diff 0.19±0.03cm² (Dominant LCo) Mean Diff 0.17±0.03cm² (Non-dominant LCo)</td>
</tr>
<tr>
<td>Javanshir et al. (2011b)</td>
<td>CSA LCo</td>
<td>0.78±0.15cm² (R LCo) 0.69±0.10cm² (L LCo)</td>
<td>0.85±0.21cm² (R LCo) 0.87±0.12cm² (L LCo)</td>
<td>No P value for statistical significant difference reported</td>
</tr>
<tr>
<td>Jesus-Moraleida et al. (2011)</td>
<td>CSA LCo in CCFT</td>
<td>Not provided</td>
<td>Not provided</td>
<td>Controls showed significantly higher recruitment values and thickness of LCo than CNP patients during latter stages of CCFT (28-30 mmHg), p&lt;0.05</td>
</tr>
<tr>
<td>Study</td>
<td>Measurement</td>
<td>CNP Values</td>
<td>Healthy Values</td>
<td>p-value</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------------------</td>
<td>-------------------------</td>
<td>---------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Jull et al. (2004b)</td>
<td>EMG</td>
<td>Not provided</td>
<td>Not provided</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kumar and Prasad, (2010)</td>
<td>Isometric Strength</td>
<td>51.89±27.38N</td>
<td>55.84±16.99N</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EMG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lindstroem et al. (2012)</td>
<td>Isometric Strength</td>
<td>97.7±40N</td>
<td>143.0±41.4</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>EMG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lindstrom et al. (2011)</td>
<td>Isometric Strength</td>
<td>97.9±31.9N (Flexion)</td>
<td>118.3±36.9 (Flexion)</td>
<td>p=0.06</td>
</tr>
<tr>
<td></td>
<td>CSA LCo</td>
<td>Not provided</td>
<td>Not provided</td>
<td></td>
</tr>
<tr>
<td>O'Leary et al. (2007c)</td>
<td>Isometric Strength</td>
<td>48.7±23.6 (secs)</td>
<td>66±31.5 (secs)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson et al. (2009)</td>
<td>Isometric Strength</td>
<td>43.4±36.3N</td>
<td>80.8±35.0N</td>
<td>p=0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scheuer and Friedrich (2010a)</td>
<td>Isometric Strength</td>
<td>6.5±3.3 kgs (63.74±32.36N)</td>
<td>14.8±6.2kgs (145.14±60.80N)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ylinen et al. (2004b)</td>
<td>Isometric Strength</td>
<td>53.8±18.3N</td>
<td>75.7±23.54N</td>
<td>Mean difference= 21.8N, p=0.002</td>
</tr>
</tbody>
</table>

Table 2.4: Observed differences between CNP and healthy control subjects
2.4 Discussion

Findings from studies included for review identified that characteristics of the cervical flexor musculature differ between healthy participants and people with chronic neck pain when assessed for muscle strength (isometric), muscle CSA, activation patterns and activity. Due to the observational design of the studies reviewed it is difficult to ascertain whether these differences are a cause or a direct result of chronic neck pain.

2.4.1 Strength

Isometric strength was found to be significantly lower in patients with chronic neck pain compared to healthy controls in three studies. Figures indicate an average reduction ranged between 20N-40N in peak isometric strength, with variations in reported figures dependant on assessment methods (Ylinen et al. 2004b, Pearson et al. 2009). Barton and Hayes (1996) found isometric cervical flexor strength in those with CNP was 50%-81% of that in healthy controls. This result is comparable to the findings of this review (Kumar and Prasad, 2010, Linstroem et al. 2012, Ylinen et al. 2004b). A loss of physical conditioning through avoidance of regular everyday activities can contribute to the reduction in strength (Meulders et al. 2011, Leeuw et al. 2007, Lindstrom et al. 2011). Some research suggests that strength measurements are not accurately reproducible in those with pain due to fear avoidance mechanisms (Strimpakos et al. 2004a, Strimpakos 2001). Contradictory reports however suggest that the presence of pain is poorly correlated with strength. According to Lindstroem et al. (2012), 65% of patient’s experience pain during an isometric MVC effort. Fear of pain or an exacerbation of pain accounts for 13.4% of the variability in MVC figures between both healthy and CNP counterparts, however, best multivariate analysis of results still leave 71.8% of variability in MVC figures in CNP patients unaccountable (Lindstroem et al. 2012). Thus, it can be hypothesised that a weakness may exist in the muscles tested and the differences observed between CNP and healthy populations cannot be attributed to the presence of pain alone.

It must be acknowledged that isometric strength testing is not without its flaws. According to a review by Strimpakos and Oldham (2001) it is difficult to recommend
one method of instrumentation, either hand-held or fixed frame specific purpose, for measuring strength over another in people with chronic neck pain due to questionable reliability and validity of devices and methodologies used in most individual studies. The fear of pain or presence of pain whilst conducting strength assessments is hypothesized to lead to discrepancies in establishing a reliable strength measure (Strimpakos and Oldham 2001). Given the proposed inhibitory effects of pain on muscle and the fear avoidance techniques used by patients with CNP, a voluntary maximal effort or contraction may not always be possible (Pearson et al. 2009). However, isometric strength testing is credited for its simplistic implementation clinically (Schroeder et al. 2007) it is usually an inexpensive process (hand held dynamometry or manual muscle testing), it can be easily controlled and performed quickly, therefore, it is a much-used clinical measurement for strength testing (Pekünlü and Ozsu 2014). Standardising a protocol of assessment of the specific muscle/s of interest can increase the reliability and repeatability of the measure (O'Riordan et al. 2014). This is important when making recommendations on methods to assess neck pain symptoms. Using a standardised measurement method, with one assessor can increase the validity of measurements of isometric testing of the DNFs clinically. Undertaking intra and inter-rater reliability analysis of a proposed testing method is necessary prior to the use of isometric strength testing as an outcome measure.
2.4.2 Electromyography

Results of this review found there was a significantly greater level of activity in the superficial cervical flexors; the Sternocleidomastoid, Splenius and Upper Trapezius muscles compared to those in healthy controls during head movements, upper limb tasks and head perturbations in four studies (Boudreau and Falla 2014, Jull et al. 2004b, Kumar and Prasad, 2010, Linstrom et al. 2012). According to Kumar and Prasad (2010), EMG activity demonstrated reduced pain threshold strength values for patients with CNP to be between 67-82% of their MVC for males and 48-67% for females.

In patients with CNP, both Lindstroem et al. (2012), Falla et al. (2004) and Jull et al. (2004a) identified increased activity and increased normalised root mean square values of the superficial flexor muscles in all stages of the CCFT compared to healthy controls. This indicates that greater levels of muscle motor unit recruitment are required to produce an equivalent amount of force in patients with CNP compared to controls (Falla et al. 2004). It may also indirectly suggest a decrease in activity of the deep cervical flexor muscle layer, as load and force is redistributed between muscles in the presence of pain (Hodges and Tucker 2011) and would account for an increased activity of the superficial layer to maintain function and homeostasis (Murray and Peck 2007).

A reorganisation in the neuromuscular control of the cervical musculature causes a shift in muscle synergies to allow for continued cervical spine function and force production despite the presence of pain (Dvir and Prushansky 2008, O'Leary et al. 2007). Thus, the superficial muscles assume the role of the deep muscles. Whilst desirable in the interim, in the long-term effects are detrimental (Murray and Peck 2007). These long-term effects include muscle overload of the superficial muscle layer during functional and low load upper limb tasks. Moreover, this disuse of the DNFs leads to inactivity, atrophy and dysfunctional movement patterns, e.g. reduced ability of the Upper Trapezius to return to relaxed state (Cagnie et al. 2011, Falla 2004d, Falla 2004a). The presence of this neuromuscular reorganisation beyond the acute phase of injury is also hypothesised to contribute to the development of a chronic pain and may partially explain the histological changes seen in the deep cervical muscles in the long term (Cagnie et al. 2007a, Sterling et al. 2005). Biopsies suggest a relative
loss of Type I fibres and an increase in Type II fibres in CNP patients, thus contributing to early fatigue of the deep muscles (Kumar and Prasad 2010).

While EMG can provide good insight into muscle activity pre-and post-treatment interventions for CNP, it has some disadvantages. It is not readily available clinically and can also be time consuming (Dvir and Prushansky 2008, Kumar and Prasad 2010). Cross-talk between proximally located muscles in a small area is also possible, leading to inaccuracies in results (Netto et al. 2008). Disadvantages relating to its use in this muscle group include the ability of surface electrodes to only assess superficial muscle groups and more accurate analysis of the deep muscle layer requires an invasive process which is inappropriate for clinical practice (Falla 2004d, Falla 2004a) and therefore not entirely feasible for assessing the function and activity of the DNFs or the effectiveness of an exercise intervention for the deep cervical flexors.
2.4.3 Muscle Cross-sectional Area

Muscle size or cross sectional area is a good indicator of muscle strength, force production and functional ability (Javanshir et al. 2010b). A positive linear force-CSA relationship, has been shown to exist for many large muscle groups, thus indicating that as CSA increases, so too does the force generated by that muscle (Maughan et al. 1984). This review identified reductions in LCo CSA in patients with CNP compared to healthy controls by approximately 0.19 +/- 0.03 cm$^2$ (0.11-0.25 cm$^2$) for the dominant sided LCo (Javanshir et al. 2010b). Measures of anterior-posterior diameter and lateral dimensions also followed this pattern for neck pain patients compared to healthy individuals (Javanshir et al. 2010b). The mean and lower 95% confidence intervals between groups were greater than the standard of error of measure (SEM) of the CSA measurement supporting the presence of a true difference between groups (Javanshir et al. 2010b). Javinshir et al. (2011a), suggested that the differences in cross sectional area between healthy subjects and people with CNP was due to the muscle disuse or inhibition, which would support the previous claims of reduced activity of the LCo and deep cervical flexors in cranio-cervical flexion tests in patients with CNP (Falla 2004b, O Leary et al. 2007c).

Assessing CSA using real-time ultrasound has many advantages with few limitations; real time feedback can be used during assessment and evaluation of treatment, as well as during rehabilitation. It is however, also dependant on the ability of the user and despite its increasing accessibility is still expensive for use clinically (Whittaker et al. 2007).
2.5 Limitations of the Review

It is important to note that this review is not without its limitations. These limitations are acknowledged and justified where possible and include;

Only one reviewer conducted the study retrieval and screening process, however, means to overcome any selection bias were addressed through rigid inclusion/exclusion criteria. Each article selected for inclusion was inspected for methodological quality using a standardised and reliable checklist (Stang 2010). Any doubt concerning an article’s appropriateness for inclusion was neutralised through discussion with other research group members and a majority consensus required before inclusion. Due to the design of the research question and study aims, articles most appropriate to answer same were of cross-sectional or cohort design (considered Level 2b in OCEBM scale). As noted in Table 2.3, information pertaining to the recruitment of control subjects were absent from four articles, indicating lower quality studies (≤6) as per the NOS. Thus, the conclusions of this review must be interpreted with caution. Small numbers of studies (≤5) identified significant differences for each individual outcome including isometric strength. EMG activity of the superficial flexors and CSA of the LCo. Similarly, reporting of confounding variable such as BMI and percentage breakdown of females: males was not reported in each study.

This review synthesised the information available on the effects of persistent or chronic pain on the cervical flexor musculature of patients with idiopathic neck pain. Patients with whiplash associated disorders were not included as previous investigation into this patient group have showed significantly different muscle alterations to those with idiopathic neck pain, including fatty infiltration of the deep cervical flexors, resulting in an increased CSA of the LCo muscles. Therefore, this patient population may require a separate review of the literature pertaining to changes within this population. One study which included whiplash patients (Jull et al. 2004b) was included in this review. It should be noted that there were three distinct groups included in this study (healthy controls, whiplash group and insidious onset neck pain patients) and only data pertaining to the control and insidious neck pain patients were used in this review.

It was deemed inappropriate to conduct a meta-analysis as part of this current review, due to the small number of studies included. Moreover, there was large
variation in methodological techniques used in each individual study, including patient
demographic (mean age, duration of pain) and instrumentation used, therefore results
of any meta-analysis may have been misleading and inconclusive.

This review looked solely at the effects of chronic pain on the cervical flexor
musculature as it has been postulated that in chronic neck pain populations dysfunction
and weakness of the cervical flexors may be a cause or result of pain (Cagnie et al.
2007a). However, it should be acknowledged that these muscles are just some of those
affected by chronic pain in the cervical region and it is recommended that a clinical
assessment of function and strength in all planes of movement be conducted to provide
a more comprehensive view of overall cervical function (Strimpakos 2001). Although
not within the scope of this review, evidence suggests that there is also a reduction in
strength of the cervical extensors and an over-activity of the superficial upper
Trapezius muscles (Schomacher and Falla 2013) as well as reductions in the CSA of
outlined the detailed morphological changes to the cervical extensors, however no
such review existed for the cervical flexor musculature, hence the aim of this review.
A comprehensive clinical analysis of both muscle groups is required when assessing
and treating a patient with CNP, as these muscles work synergistically with the deep
cervical flexors (Schomacher and Falla 2013).
2.6 Clinical Implications and Conclusions

This review appraised and synthesised literature which used objective measurements to identify changes in the cervical flexor musculature in patients with chronic neck pain compared to healthy individuals. This review was required to improve the clinical understanding of the influence of chronic pain on cervical musculature. Results of this review should be interpreted with caution given the quality and number of studies included and the lack of meta-analyses. However, there is some moderate quality evidence to suggest that in the presence of chronic pain, significant reductions in isometric strength, changes in muscle activation and recruitment patterns, as well as muscle area size are identifiable. These variations between healthy and patients with CNP can be used to inform clinical rehabilitation approaches and the evaluation of same. Providing a synthesis of the research evidence of these changes identifies that in the presence of chronic pain, a weakness of the cervical flexor musculature may exist and an atrophy of the deep cervical flexor can occur. Therefore, there is rationale to suggest that targeted resistance exercise for this muscle group could provide beneficial outcomes when used as part of a multi-modal treatment approach. Therefore, more in-depth investigation of the effect of targeted resistance exercise of the deep cervical flexors is warranted. Information and results generated as part of this review were used to inform latter stages of the research study including the identification of appropriate objective outcome measures.
Chapter 3: Chronic Neck Pain & Exercise Interventions: The FITT principle
3.1 Introduction

Hudson and Ryan (2010) report that neck pain is one of the most prevalent and costly musculoskeletal conditions in western society. It is estimated that up to 67% of adults will experience neck pain at some stage in their lives (Viljanen et al. 2003). In European populations between 15 and 19% of cases will develop into a chronic state (Manchikanti et al. 2012). Worldwide, this figure is up to 20% of the population reporting chronic neck problems at any one time (Bronfort et al. 2001). Those experiencing chronic pain are twice as likely to present to health care services compared to the general population (Bekkering et al. 2003). Compensation, health care service provision and loss of productivity due to sick leave days accumulate to large amounts of money for states each year (Viljanen et al. 2003). Epidemiological studies of chronic neck pain prevalence are limited in Ireland. A study by Raftery et al. (2011) found that of the 13% of the population who suffer from chronic pain, 29.4% of these suffered from neck pain. In 2008, an estimated €5.34 billion or 2.86% of the GDP was spent on chronic pain in Ireland, second to lower back pain chronic neck pain accounts for a large proportion of this expenditure. Data from the United States indicates that 14.3% of the population are experiencing chronic neck pain. Similar to this are Australian figures which indicate approximately 640,000 Australians experience chronic neck pain costing the state almost $1.14 billion annually in
associated health care (Snodgrass et al. 2016). National figures from the Netherlands indicated that $686 million was spent in 1996 on chronic neck pain (Borghouts 1999). Data from the United Kingdom suggest that costs for private physiotherapy care for chronic neck pain amounts to an approximated £296 per individual, with figures reaching upwards of £1911 when referred to more than one service, e.g. pain clinic and physiotherapy, which is commonly the case in chronic pain (Carnes et al. 2008).

For this review, chronic pain is defined in accordance with the International Association for the Study of Pain (IASP) and the American Pain Society, as pain that persists beyond normative tissue healing time which is defined as 3 months. Chronic neck pain for this review includes pain experienced in the anatomical region of the cervical spine between first and seventh cervical vertebrae (C1 and C7) and surrounding musculature only, excluding the shoulders. Studies including patients with non-specific or insidious onset chronic neck pain only are included in this review. Mechanisms for the development of chronic pain are not fully understood; however, it is known that pain can become more complex in its pathophysiology than that of the original insult or injury (O Sullivan 2005). Chronic musculoskeletal pain can develop because of an injury or insult, followed by neurogenic inflammation, hyperalgesia and allodynia (Moseley and Flor 2012). The transmission of repeated pain signals produces functional and structural changes in the nervous system and central sensitization occurs, followed by a loss of nociceptive control (Moseley and Flor 2012, Whitten et al. 2005).

Evidence suggests that being female, white and middle-aged increases the risks of neck pain becoming chronic (Goode et al. 2010, Guez 2006, Manchikanti et al. 2009, Webb 2003). Ylinen et al. (2007), Webb et al. (2003), Guez et al. (2006) and colleagues report that the incidence of chronic neck pain in female’s ranges from 7-22% compared to 5-16% in men. A history of previous neck pain or similarly, a whiplash-associated accident can increase the chances of developing chronic neck pain (Verhagen et al. 2007). However personal, societal and environmental factors can influence the development of a whiplash-associated disorder. Although a weaker correlation exists, occupation is a risk factor in the development of chronic neck pain (Croft et al. 2001). Sedentary lifestyles, office-based workplaces and an ever-increasing reliance on technology has increased the prevalence of neck pain in recent
years (Falla et al. 2006a). Additionally, Manchikanti et al. (2009) found that industrial workers and manual labourers were at increased risk of developing chronic pain. Statistics indicate that 16% of manual labourers and 74% of crane operators experienced chronic neck pain (Croft et al. 2001).

With an increasing prevalence of chronic neck pain (Fejer et al. 2006a) it is important to determine physiotherapy treatment interventions which are cost effective, time efficient and patient appropriate (Verhagen et al. 2007). A range of strategies to tackle chronic neck pain have been examined, from single modalities to combination interventions (Kay et al. 2005). Single modality treatment approaches are deemed to be an inaccurate representation of clinical best practice for individual patients (Gross et al. 2004, Gross et al. 2012). A large variety of physiotherapeutic interventions are available for the treatment of chronic neck pain including manual therapy, spinal manipulations, passive therapies, relaxation techniques, electrotherapy and stress management, and active exercise (Kay et al. 2005, Gross et al. 2012, Childs et al. 2008).


Active exercise is proposed to target the muscles which may be damaged during injury. Resultant strains and tears of the stabilising systems (including the deep muscles and ligaments) can result in dysfunctional movement patterns because of a lack of motor control at the cervical spine (Falla 2004b). Superficial neck muscles replace the actions of the deep muscles resulting in early fatigue, over activity and pain; therefore, active exercise can work effectively to rehabilitate the injured musculoskeletal structures and correct movement patterns (Falla, 2004b).

In the same way as medication is prescribed in required dosages, applying a similar degree of precision to prescriptions of physical activity is required, hence the development of the frequency, intensity, time and type (FITT) format. Despite the high incidence of chronic neck pain and the extensive evidence for the benefits of active
exercise for the treatment of associated symptoms, there is a paucity of evidence to recommend a definitive FITT principle in this population (Childs et al. 2008). Through this method, exercise may be tailored to an individual’s needs accordingly for the type of exercise undertaken, at what level of exertion (intensity), how often and for what duration (Oberg 2007).

Therefore, it is the aim of this review to evaluate and present the research for active exercise in the treatment of chronic neck pain in a FITT format to identify which exercise interventions are associated with the most optimal outcomes and which other treatment modalities the exercise compliments. It is also an aim to identify what further research may still be warranted for developing an effective exercise intervention in a chronic neck pain population.

3.2 Methodology

The following databases were searched between April and November 2012, for relevant articles: The Allied and Complementary Medicine Database, Cumulative Index to Nursing and Allied Health, MEDLINE, SPORTDiscus, Biomedical Reference Collection, and Academic Search Premier. Keywords search terms included “chronic”, “neck”, “pain”, “exercise” as single words and in combinations. This identified 256 articles. Further studies were sourced via reference lists of appropriate articles. See the PRISMA flow diagram in Figure 3.1 for full details.

The abstracts were read to ascertain relevance based on the following inclusion criteria: (1) published material; (2) research conducted between the years 2000 and 2012; (3) research examining the effects of active (where active was defined as an exercise in which the participant actively engages muscles of an affected limb/area to create motion or movement in direct contrast with a passive approach where a patient relies on an external stimulus to move a limb or limb segment) exercise in a chronic neck pain population where chronic neck pain was defined as the presence of pain for at least 3 months; (4) exercise that was used as part of a stand-alone or multimodal treatment approach to chronic neck pain to include advice/education as a component of treatment; (5) research that took the format of a randomized controlled trial (RCT), controlled trial, cross-sectional study, or pilot/feasibility trial; and (6) research that examined the effects of exercise on >1 outcome measure (e.g. strength, pain,
disability, health-related quality of life). Articles were excluded if they were not published in English as a primary language, no form of active treatment was given, and there was no control or alternative therapy group for comparison.
3.3 Results

This search strategy identified sixteen studies for inclusion in this literature review. Details of article retrieval process can be seen in a PRISMA flow diagram (Moher et al. 2009) in Figure 3.1 below.
<table>
<thead>
<tr>
<th>Study</th>
<th>Randomised Allocation</th>
<th>Concealed Allocation</th>
<th>Groups similar at baseline</th>
<th>Blinded (participants)</th>
<th>Blinded (assessors)</th>
<th>Blinded (therapists)</th>
<th>Received Treatment/Control or intention to treat</th>
<th>Between Group stats for @ least one outcome</th>
<th>Measure of @ least one outcome from 85% of original group</th>
<th>Point measure of variability for @ least one key outcome</th>
<th>Level of Evidence (Oxford Scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andersen et al. (2011)</td>
<td>Yes</td>
<td>NO</td>
<td>Yes</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>6</td>
</tr>
<tr>
<td>Bronfort et al. (2001)</td>
<td>Yes</td>
<td>NO</td>
<td>Yes</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>6</td>
</tr>
<tr>
<td>Chiu et al. (2005b)</td>
<td>Yes</td>
<td>NO</td>
<td>Yes</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Chiu et al. (2005b)</td>
<td>Yes</td>
<td>NO</td>
<td>Yes</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Evans et al. (2012)</td>
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<tr>
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<td>Yes</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>Yes</td>
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<tr>
<td>Häkkinen et al. (2007)</td>
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<tr>
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<td>NO</td>
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<td>Jull et al. (2009)</td>
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<td>NO</td>
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<td>Yes</td>
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<tr>
<td>Salo et al. (2012a)</td>
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<td>NO</td>
<td>Yes</td>
<td>NO</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Study</td>
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<td>Yes</td>
<td>NO</td>
<td>Yes</td>
<td>NO</td>
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<td>Viljanen et al. (2003)</td>
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<td>Wailing et al. (2000)</td>
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<td>Yes</td>
<td>Yes</td>
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</table>

Table 3.1: Appraisal using the Physiotherapy Evidence Database Scale (PEDro) scale for each of the studies reviewed.

The PEDro Scale is available online (http://www.pedro.org.au/english/downloads/pedro-scale/).
<table>
<thead>
<tr>
<th>Study</th>
<th>Sample Size (n=)</th>
<th>Symptom Duration (mean in years ± St.dev)</th>
<th>Gender Distribution (%)</th>
<th>Age (mean in years ± St.dev)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Andersen et al. 2011)</td>
<td>198</td>
<td>&gt;3 months</td>
<td>12.12% Female</td>
<td>44±11</td>
</tr>
<tr>
<td>(Bronfort et al. 2001)</td>
<td>191</td>
<td>5</td>
<td>59.2 % Female</td>
<td>45±10.5</td>
</tr>
<tr>
<td>(Chiu et al. 2005a)</td>
<td>218</td>
<td>1</td>
<td>66.7% Female</td>
<td>44.31±9.77</td>
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<tr>
<td>(Chiu et al. 2005b)</td>
<td>218</td>
<td>&gt;1 year</td>
<td>68% Female</td>
<td>45±3.0</td>
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<tr>
<td>(Evans et al. 2012)</td>
<td>270</td>
<td>9.4±9.1</td>
<td>77% Female</td>
<td>46.3±10.7</td>
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<tr>
<td>(Falla et al. 2006a)</td>
<td>58</td>
<td>7.9±6.4</td>
<td>100% Female</td>
<td>37.9±10.2</td>
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<tr>
<td>(Häkkinen et al. 2007)</td>
<td>101</td>
<td>5.8±2.4</td>
<td>100% Female</td>
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<td>(Hudson and Ryan 2010)</td>
<td>12</td>
<td>7±5.7</td>
<td>66.66% Female</td>
<td>42.7</td>
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<td>(Jull et al. 2009)</td>
<td>46</td>
<td>10.1±10.6</td>
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<td>(Salo et al. 2012a)</td>
<td>101</td>
<td>5.8</td>
<td>90% Female</td>
<td>41±9</td>
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<td>(Stewart et al. 2007)</td>
<td>134</td>
<td>9.0±2.4</td>
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<td>43.3±14.7</td>
</tr>
<tr>
<td>(Taimela et al. 2000)</td>
<td>76</td>
<td>&gt;3months</td>
<td>73% Female</td>
<td>47.±16.8</td>
</tr>
<tr>
<td>(Viljanen et al. 2003)</td>
<td>393</td>
<td>11±5.7</td>
<td>100% Female</td>
<td>45±6.6</td>
</tr>
<tr>
<td>(Wailing et al. 2000)</td>
<td>103</td>
<td>6.75±3.51</td>
<td>100% Female</td>
<td>38.1±6.1</td>
</tr>
<tr>
<td>(Ylinen et al. 2003)</td>
<td>180</td>
<td>9±6</td>
<td>100% Female</td>
<td>46±6</td>
</tr>
<tr>
<td>(Ylinen 2007)</td>
<td>180</td>
<td>9±6</td>
<td>100% Female</td>
<td>46±6</td>
</tr>
</tbody>
</table>

Table 3.2: Demographic details of patients included in each of the individual studies.
<table>
<thead>
<tr>
<th>Author</th>
<th>Resistance/Strengthening</th>
<th>Endurance</th>
<th>Dynamic</th>
<th>Stretching</th>
<th>Manual Therapy</th>
<th>Other Training</th>
<th>Proprioception / Postural</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Jull et al. 2007)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>CCF</td>
<td>√</td>
</tr>
<tr>
<td>(Andersen et al. 2011)</td>
<td>✓</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Advice/Education</td>
<td>X</td>
</tr>
<tr>
<td>(Bronfert et al. 2001)</td>
<td>✓</td>
<td>X</td>
<td>X</td>
<td>✓</td>
<td></td>
<td>Aerobic Exercise</td>
<td>X</td>
</tr>
<tr>
<td>(Chiu et al. 2005a)</td>
<td>✓</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>TENS</td>
<td>X</td>
</tr>
<tr>
<td>(Chiu et al. 2005b)</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td>X</td>
<td>X</td>
<td>Infrared Irradiation</td>
<td>X</td>
</tr>
<tr>
<td>(Evans et al. 2012)</td>
<td>✓</td>
<td>X</td>
<td>X</td>
<td>✓</td>
<td></td>
<td>Education</td>
<td>X</td>
</tr>
<tr>
<td>(Falla, 2006)</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>(Häkkinen et al. 2008)</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>(Hudson and Ryan 2010)</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
<td></td>
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<tr>
<td>(Miller et al. 2010)</td>
<td>✓</td>
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<td>X</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>(Salo et al. 2012a)</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>(Stewart et al. 2007)</td>
<td>✓</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Aerobic Exercise, Advice/Education</td>
<td>X</td>
</tr>
<tr>
<td>Taimela et al. 2000</td>
<td>X</td>
<td>✓</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Advice, Education, Behavioural Support, Relaxation Techniques</td>
<td>X</td>
</tr>
<tr>
<td>(Viljanen et al. 2003)</td>
<td>X</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td>X</td>
<td>Relaxation Techniques</td>
<td>X</td>
</tr>
<tr>
<td>(Wailing et al. 2000)</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Advice, Coordination training</td>
<td>X</td>
</tr>
<tr>
<td>(Ylinen et al. 2003)</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td></td>
<td>Aerobic Exercise (Controls)</td>
<td>X</td>
</tr>
<tr>
<td>(Ylinen 2007)</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 3.3: Details of the active exercise intervention in each individual study.
<table>
<thead>
<tr>
<th>Study</th>
<th>Frequency</th>
<th>Intensity</th>
<th>Time</th>
<th>Type</th>
<th>Results (Effects on Strength, Pain, Disability, Other)</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Andersen et al. 2011)</td>
<td>5 t/week</td>
<td>Moderate to high based on TheraBand™ colouring red, green and blue (red TheraBand™=moderate for women, green for men etc.)</td>
<td>Exercise Intervention 10 weeks 2-12 minutes’ exercise sessions (total of between 10 &amp; 60 mins exercise a week)</td>
<td>Strengthening/Resistance (TheraBand™ training)</td>
<td>Between Group differences after 10 weeks Neck Pain Disability (0-10) 2min exercise group v Control: -1.4 (-2.0 to .07) p&lt;0.001, 12-minute exercise group vs. Control -1.9 (-2.5 to -1.2) p &lt;0.001 2min v 12 min exercise groups 0.5 (-0.3 to 1.3) p=0.12 Muscle Strength (Nm) 2min exercise v Control: 2.0 (0.5 to 3.5) p=0.008 12 minute v Control: 1.7 (0.2 to 3.3) P=0.02 2 min v 12-minute exercise group 0.3 (-1.3 to 1.8) p=0.74</td>
<td>Individual</td>
</tr>
<tr>
<td>(Bronfort et al. 2001)</td>
<td>1 t/week</td>
<td>Low load individualised</td>
<td>12-week exercise intervention 12 month follow up Max 45 minute exercise session duration</td>
<td>Pain Scores Baseline to 11weeks Spinal Manip &amp; Exercise (1) 56.0± 15.0 to 23.6±18 MED X group (2) 57.1±15.0 to 24.1±19.7 Spinal Manip Group (3) 56.6±12.8 to 31.3 ±21.8 1vs. 2: effect size 0.03 CI 0.41 to 0.35 1 v 3: effect size -0.25 CI -0.12 to -0.61 2 v 3: effect size -.28 CI 0.10 to -0.66</td>
<td></td>
<td>Individual</td>
</tr>
</tbody>
</table>
| Study (Chiu et al. 2005a) | Frequency | Exercise | Intervention Duration | 6-Week Treatment Period | 6-Month Follow Up | Neck Disability Index Baseline to 11 wks.;
1: 26.4± 8.5 to 14.1±8.7
2: 26.7±10.4 to 12.4±9.9
3: 27.8±10.3 to 15.8±12.3
Neck Disability Index
1 v2: effect size 0.16 CI 0.54 to -0.22
1 v 3: effect size -0.14 CI 0.22 to -.57
2 v3: effect size -0.27 CI 0.10 to 0.65 |
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2 t/week</td>
<td>20% of 12 rep maximum</td>
<td>6-week treatment intervention 6 month follow up Exercise sessions of 45-minute duration</td>
<td>6-week treatment period, 6 month follow up</td>
<td>Pain: VPNS Mean Difference: Control; 0.30±2.48 (0.475), TENS group; 0.60±2.54 (0.027), Exercise; 1.57±2.67 (&lt;0.001) Disability NPQ Mean Diff: Control; 0.23±0.63 (0.003), TENS; 0.38±.60 (&lt;0.001), Exercise; 0.39±0.62 (&lt;0.001). Neck Muscle Strength (N) Control; 1.25±3.94 (0.03), TENS; 1.42±3.90 (0.02), Exercise: 2.28±4.22 (&lt;.001) Control group differences were not maintained @ 6 month follow up</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Chiu et al. 2005b)</td>
<td>2 t/week</td>
<td>EG: 8-12 rep max or 30% of MVC and increased by 5% when a set of 12 was achieved</td>
<td>6-week exercise intervention 6 month follow up</td>
<td>Strengthening/Resistance Education/advice</td>
<td>Pain Scores as per VPNS after 6-week intervention Mean Difference Control vs. Exercise 1.0 (CI 0.2 to 1.7) p=0.01</td>
<td></td>
</tr>
<tr>
<td>Individual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evans et al. 2012</td>
<td>2 t/week (Supervised or Independent sessions)</td>
<td>Partially Individualised (load &amp; repetitions) according to abilities of individual, e.g. baseline 3 sets of 15-25 reps using variable head-weights of 1.25 -10lbs.</td>
<td>Hourly sessions for a 12-week treatment period (Follow up @ 12 months)</td>
<td>Strengthening</td>
<td>Mean Differences @ 12 weeks from Baseline Pain (11 box numerical rating scale) Exercise vs. Exercise &amp; Manual Therapy -1.19 (CI -.89 to .51) p=.100 Exercise &amp; Manual Therapy vs. Home Exercise Program -1.27cm (CI-.1.96 to .58) p=.001 Exercise vs. Home Exercise Program -1.07cm (-1.77 to 0.38) p=.0001 Neck Disability Index Exercise &amp; Manual Therapy vs. Exercise -2.26 (CI -5.43 to .92) p=.0265 Exercise &amp; Manual Therapy vs. Home Exercise Program -4.66 _-7.80 to -1.52) p=.001</td>
<td>Northwick Park Neck Pain Questionnaire Mean Difference Control v Exercise 0.2 (0.0 to 0.4) p=0.03 Isometric Strength Significant increase (26.1`%-45.7%, p&lt;0.01) in all six directions. @ 6 weeks significantly better improvements (mean diff; 0.4-2.2lbs, p=0.57-0.00) in the exercise group compared to control group. Not significant @ six month follow up</td>
</tr>
<tr>
<td>Study</td>
<td>Intensity</td>
<td>Type</td>
<td>Duration</td>
<td>Intervention</td>
<td>Results</td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
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<td>-----------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>
| (Falla et al. 2006a)   | Twice Daily | 12 Rep Max | 10-20 mins daily over 6 weeks | Strengthening/Resistance                                                  | EG↓ 1.1cm VAS  
LLEG↓ .9cm VAS  
EG↑ MVC 10.1± 17.3N  
LLEG↑ 1.8 ±  Not Specified |
| (Häkkinen et al. 2008) | 3 t/week  | Strength Group= 80% of Maximum Voluntary Contraction | 12 months | Pain (VAS) ↓ by 37mm in Strength & Stretching Groups (-44 to -30).  
Stretching Only group ↓ -32mm (-39 to -25mm).  
Complete Pain Relief by 51% of Strength & Stretch Group, 42% of other.  
Insignificant change p=0.88 (CI -7, 7).  
Neck Disability significantly lower @ 12 months p< 0.001, no discernible difference in change between two training groups.  
Isometric Neck Strength Mean Difference @ 12 months, Strength & Stretch Group increase of 9N (3 to 15), Stretch Only 9 (3 to 14), p=0.88 |
<table>
<thead>
<tr>
<th>Study</th>
<th>Frequency</th>
<th>Intervention Details</th>
<th>Exercise Group</th>
<th>Comparison</th>
<th>Pain</th>
<th>Disability</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Hudson and Ryan 2010)</td>
<td>1 t/week X 1 hour with Physio (MMG) 20 min session with Physio 5-8 times (UC)</td>
<td>Undisclosed</td>
<td>1 hour a week for 6 weeks</td>
<td>Strengthening/Resistance</td>
<td>Statistically significant improvements in pain &amp; disability p&lt;0.01 pre- to post-intervention, not statistically significant between groups, p=0.67 (pain) and p=0.84 (disability). Pain: Multimodal Group &amp; Usual Care ↓ 5/10 VAS Neck Disability Index ↓ 12.3% &amp; 7.4% in Multimodal Group and Usual Care Group Respectively</td>
<td>Pain: Multimodal Group &amp; Usual Care ↓ 5/10 VAS Neck Disability Index ↓ 12.3% &amp; 7.4% in Multimodal Group and Usual Care Group Respectively</td>
</tr>
<tr>
<td>(Jull et al. 2007)</td>
<td>7 t/week</td>
<td>Low load: against gravity Strengthening Group: Individualised 12 rep max, progressions based on 50% of 10 rep max, 75% 10 Rep Max, 10 Rep max load</td>
<td>6-week exercise intervention (1 hour a week with Physio) &amp; 10-20 mins of daily exercise</td>
<td>Cranio-cervical Flexion training, proprioceptive training</td>
<td>↓ EMG activity in superficial neck flexors in CCF group p&lt;0.001 Increase in Deep Neck Flexor EMG activity in CCF group p=0.05 ↓ Pain Scores as measured on VAS p=0.001 in CCF group, Strength group p&lt;.05 CCF ↓ -2.8cm. Proprioception training group ↓ -1.9cm Neck Disability Index Score: CCF Group -5.0 ±4.2, Strength Group -3.5±2.3</td>
<td>Individual</td>
</tr>
<tr>
<td>References</td>
<td>Frequency</td>
<td>Intervention Details</td>
<td>Exercise Intervention</td>
<td>Statistical Results</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------</td>
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<td>----------------------</td>
<td>-----------------------</td>
<td>---------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Salo et al. 2012a)</td>
<td>1-2 t/week</td>
<td>80% of Maximum Voluntary Contraction of neck musculature</td>
<td>12-month exercise intervention</td>
<td>Significant increase in 5/8 HRQOL dimensions in the Combined Strengthening &amp; Stretching Group namely physical and social functioning, bodily pain and health perceptions and role physical. For the Strengthening group improvements were seen in 4/8 of these dimensions. Bodily pain decreases increased weekly exercise adherence in the combined therapy group $p=0.05$, CI 0.00-0.27. Physical functioning improvements in the strengthening group resulted in increased weekly exercise adherence $p=0.03$, CI 0.03-0.42.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Stewart et al. 2007)</td>
<td>2t/week</td>
<td>Described in text as “individualised, progressive &amp; sub-maximal”</td>
<td>6-week intervention, 1-hour exercise sessions.</td>
<td>Combination Therapy; Strengthening, Endurance, Coordination Aerobic</td>
<td>Pain: VAS Combination Therapy vs. Advice/Control; -1.1 (CI-1.8, -0.3, $p=0.005$) not significant @12 months $p=0.590$. Neck Disability Index CombG vs. Advice; -2.7 (CI -4.5, -0.9, $p=0.004$) not significant @ 12 months $p=0.08$.</td>
<td></td>
</tr>
<tr>
<td>(Taimela et al. 2000)</td>
<td>1 t/week</td>
<td>Low load &amp; low progressions</td>
<td>12-week intervention Follow up @ 12 months</td>
<td>Relaxation Therapy, proprioceptive exercise, education</td>
<td>Pain as per VAS @ baseline 55±21mm for both Active Exercise Group and Home Exercise Group, Control Group @ 6 weeks, Active mean VAS 22mm, Home 23mm, Control 39mm, $p=0.018$.</td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Interventions</td>
<td>Duration</td>
<td>Therapy</td>
<td>Outcomes</td>
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<td></td>
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<tr>
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<td>---------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Viljanen et al. 2003</td>
<td>3 exercise sessions a week or 5 relaxation sessions a week</td>
<td>12-week treatment intervention</td>
<td>Dynamic or Relaxation therapy</td>
<td>Mean Difference in Pain reports as per VAS @ 3 month follow up Dynamic Group vs. Control .2 (CI -0.4 to 0.7) @ 12 months 0.5 (CI -0.7 to 0.3) Mean Difference in Dynamic Muscle Strength @ 3 months DyG vs. Control 0.1 (CI -2.2 to 2.5) @ 12 months -6 (-3.2 to 2.1) Mean Difference in Disability as per Neck Disability Index: @ 3 month follow up DyG vs. Control 0.8 (CI -1.9 to 3.6) @ 12 months -1 (CI -3.0 to 2.9)</td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td>Ylinen et al. 2003</td>
<td>3-5 t/week</td>
<td>12-month intervention</td>
<td>Strengthening &amp; Endurance</td>
<td>Neck Pain VAS: Controls ↓ -16mm (CI -22 to -9) Endurance Group -35mm (CI -42 to -28) Strength Group: -40mm (-48 to -32) P&lt;=0.001 (Endurance vs. Control, Strength vs. Control) Neck Disability Index Control; -12 (CI -15 to -81) Endurance Group; -22 (CI -26 to -19)</td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td>(Ylinen 2007)</td>
<td>As 2003 study</td>
<td>As 2003 study</td>
<td>As 2003 study</td>
<td>3 year follow up from initial 2003 study</td>
<td>Median VAS @ 3 year follow up 14 (CI 4,39) P=0.069</td>
<td>Median NDI value @ 3 year follow up 12 (CI 4,22) p=0.072</td>
</tr>
<tr>
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<tr>
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<td></td>
<td>Strength Group: -23 (CI-27 to -20)</td>
<td>P=&lt;0.001 (Endurance vs. Control, Strength vs. Control)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Isometric Strength</td>
<td>Strength Group ↑ MVC 110% (Flexion)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>76% (rotation) 69% (extension)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Endurance Group ↑ MVC 28% (Flexion), 29% (rotation), 16% (extension)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Controls ↑MVC 10%, 10%, 7% (flexion, rotation &amp; extension respectively)</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.4: Methodological design and results of each of the studies reviewed.
3.4 Discussion

Research in the 1990’s (Kay et al. 2005) found inconclusive evidence for the effects of exercise on mechanical neck pain. This has been refuted by research over the last decade with resounding evidence for the benefits of active exercise in a treatment intervention above passive alternatives (Gross et al. 2004, Verhagen et al. 2007, Bronfort et al. 2001). For this review, the studies included will be discussed in terms of the frequency with which the active exercise is undertaken, the intensity at which the exercise is conducted, the time spent exercising and the type of exercise undertaken (the FITT principle).

3.4.1 Frequency

Exercise frequency varied amongst studies included in this review, see Table 3.4, with interventions typically ranging from three sessions a week to daily sessions with benefits visible from all frequencies (Andersen et al. 2011, Chiu et al. 2005b, Evans et al. 2012, Falla 2006, Hudson and Ryan 2010, Häkkinen et al. 2008, Salo et al. 2012, Stewart et al. 2007, Ylinen 2003). Positive outcomes were reported for pain intensity, isometric strength, health related quality of life, and perceived disability in trials which incorporated 3 exercise sessions a week (Andersen et al., 2011, Chiu et al. 2005b, Häkkinen et al. 2007, Ylinen et al. 2003, Ylinen, 2007).

Studies demonstrating significant increases in isometric strength utilised an exercise frequency of between 3 and 5 times a week (Falla, 2006, Ylinen et al. 2003, Wailing et al. 2000). Programs which involved daily exercise over a 10-week period demonstrated beneficial effects for a reduction in neck pain and an increase in isometric strength (Andersen et al. 2011). Falla (2006) found statistically significant increases of 10.1 ± 17.3N in their endurance strength training group, while there were gains of 1.8 N identified in participants of the low load cranio-cervical flexor muscle group for the same frequency and intervention duration. Interventions of at least three sessions weekly produced gains in strength, which agrees with known resistance training benefits and its effects as established by the American College of Sports Medicine Guidelines (ACSM 1995). Hudson and Ryan (2010), Evans et al. (2012) and colleagues reported beneficial outcomes; the most notable outcomes included
reductions in pain intensity and perceived reductions in disability from lower frequency exercise interventions (i.e., 1-2 sessions/week). Häkkinen et al. (2008) reported statistically and clinically significant reductions in pain (37mm [51%] on a visual analogue scale (VAS) in the strengthening and stretching group and 32mm [42%] in a stretching group) from exercising 2.1 times a week and as little as 1.1 times in the fourth quarter of a 12-month intervention. Additionally, significant range of motion (ROM) and isometric strength gains were visible in both groups for flexion-extension and lateral flexion (Table 3.4).

While an exercise frequency was determined per the study design (e.g. 3 times/wk.), adherence to the exercise protocol appeared to vary quite substantially (1,5,31). Although exercise frequency was, on average, 3 times per week, many studies, such as that of Viljanen et al. (2003) found that over a 12-week period, training adherence only ever reached approximately 39% (1.7 times/wk.) of expected figures. Salo et al. (2012) also reported significant benefits in health-related quality of life and an associated decrease in pain intensity from exercising as little as twice a week. Participation in an active exercise intervention appears to have positive effects on pain intensity and isometric strength, even when desired frequencies are not adhered to. This suggests that undertaking exercise as little as twice a week is beneficial, given the known benefits of exercise on general health and wellbeing in a chronic pain population (Gross et al. 2012). Many of the studies included in this review, such as Salo et al. (2012), Evans et al. (2012) and colleagues, incorporated education (see Table 3.4) into their interventions as part of a multimodal approach; as such, it cannot be assumed that benefits seen were due to exercise alone because benefits may also be attributable to this. High-frequency exercise interventions are not deemed appropriate for a population with chronic neck pain because of adherence barriers. According to patient reports, training frequency decreased after the initial intervention had ended, with some decreasing from an expected 3 times a week to 1.9 times a week by the end of the first year (Salo et al. 2012a). Findings, therefore, suggest that the most beneficial frequency of exercise to target pain, weakness, and quality of life in a population of people with chronic neck population with a varying age range is 3 times per week.
3.4.2 Intensity

Training intensity varied depending on the type of exercise being investigated, that is, resistance or endurance. Resistance regimes usually conducted exercises based on percentage values ranging between 20% and 70% of an individual’s maximal voluntary contraction (MVC) (Table 3.4). For strength or resistance training, baseline measurements of maximal voluntary contraction were determined using manual muscle testing methods with hand held dynamometers or purpose built fixed frame dynamometers, or as commonly seen one repetition or twelve repetition maximums (Ylinen et al. 2003). Endurance training pertaining to the training of a larger group of muscles, i.e. the deep or superficial cervical muscles or larger shoulder muscles, to increase muscular stamina, can be influenced by the ability of the cardiovascular system to provide oxygen rich blood to the area being exercised. These interventions were based on a lower intensity and primarily based on gravity, intending to increase physical muscular endurance (Helgerud et al. 2001). The mean age of participants across the studies in this review was mid-forties, with age ranges spanning between 18 and 63 years. Therefore, to target the training needs of individual participants, exercise prescription was predominantly individualised. Minimum intensity thresholds were set at or above which participants were expected to work to induce strength benefits (Falla, 2006, Häkkinen et al. 2007, Chiu et al. 2005b, Ylinen et al. 2003). In a study by Ylinen et al. (2003), the resistance training group conducted multi-directional strengthening exercises, (e.g. flexion, lateral flexion and rotation) using elastic-bands, whereas endurance group conducted lower intensity exercises against gravity. Both groups showed significant gains in strength (Table 3.4). Observed baseline levels of strength were so low in the sample population (such that five of the participants in the endurance training group struggled to lift their head from the bed) that strength gains were visible from exercising at an intensity as low as working against gravity. This finding strengthens the recommendation for individually tailoring exercise interventions; low intensity is defined as against gravity and medium to high intensity being against gravity with further added resistance (Andersen et al. 2011).

To combat adverse effects of training, such as delayed onset muscle soreness (DOMS) or an increase in pain, which may impact end results, a variety of studies
reviewed here (see Table 3.4) incorporated lower intensity resistance training for some exercise sessions. For example, in a study by (Ylinen et al. 2006) participants conducted exercise sessions at the prescribed intensity on day 1 of the exercise intervention with the following exercise session participants only required to work at half that prescribed intensity. This was a measure taken to reduce excessive loading on musculoskeletal systems and aerobic endurance.

Progressive intensities are required to avoid plateauing and enable continued training gains (Evans et al. 2012, Chiu et al. 2005a). For example, Chiu et al. (2005b) commenced training at 20% of MVC values; exercise intensity progressed in increments of 5%, as an individual was able to conduct a set of 12 repetitions of flexion strengthening exercises (Table 3.4). Falla (2006) used an alternative approach by conducting a two-phase strengthening program. Phase 1 consisted of 12 repetitions set (prescribed weight based on 12 repetitions maximum weight) for the first two weeks. The remaining 4 weeks of the 6-week exercise intervention were then spent executing 15 repetitions per set. Because both had positive results, designing an exercise protocol which allows participants to become accustomed to an exercise before increasing the intensity is beneficial and positively effects outcomes.

Although high dose/intensity exercise programs were seen to lead to reduction in neck pain (Evans et al. 2012), low dose or low load endurance exercise programs were still seen to have advantageous results (Falla, 2006). For endurance interventions, intensity was based on gravity, for example supine lying and lifting head against gravity (Ylinen et al. 2003). This surprising result has been hypothesized to be the result of a learning effect involved in the movement and the low strength baseline values of participants. Therefore, from collating and reviewing the evidence, training intensity in a chronic neck pain population should be individually tailored based on baseline abilities as defined by an individual’s MVC values.
3.4.3 Time

The time spent exercising in an individual exercise session as well as the length of time the intervention lasted varied in length between studies (Table 3.4). It is difficult to ascertain the actual cumulative time spent exercising over the course of an intervention due to a lack of adherence by participants once an initial supervised exercise intervention was completed (Andersen et al. 2011, Evans et al. 2012, Häkkinen et al. 2008, Ylinen, 2007). Single exercise bouts ranged from 10 minutes to one hour in duration in the studies reviewed, however, exercise interventions usually ranged from six weeks to twelve weeks with follow ups at three, six and twelve months (Andersen et al. 2011, Chiu et al. 2005b, Evans et al. 2012, Falla, 2006, Häkkinen et al. 2008, Hudson and Ryan 2010, Salo et al. 2012, Stewart et al. 2007 Taimela et al. 2000, Ylinen et al. 2003). Results were seen from exercising for as little as 10 minutes a day three times per week (Chiu et al. 2005b, Salo et al. 2012,). Because exercising a specific muscle group for an hour at a time may not be desirable for this population, a regime which provides clinically significant results in the least time spent exercising should be utilised, i.e. between 2 and 20 minutes per session (Evans et al. 2012).

The duration of exercise interventions varied with effective interventions ranging from 6 weeks to 3 years. Generally, interventions ranged from between 6 weeks and 12 weeks, with follow ups occurring over a year long period. Short duration interventions have been shown to produce immediate benefits in isometric strength, pain intensity and perceived disability; however, long-term follow ups show that if exercise is not conducted after the initial intervention is over, benefits are lost (Evans et al. 2012, Häkkinen et al. 2008, Viljanen et al. 2003, Ylinen et al. 2003, Ylinen, 2007). Outcomes found to be statistically significantly different immediately after an intervention were not found to be so one year later in most studies that conducted such follow ups (Chiu et al. 2005b, Evans et al. 2012,., Stewart, 2007, Viljanen et al. 2003). Therefore, it is important to take overall findings including long-term benefits of exercise interventions into consideration when formulating an optimal exercise intervention. Because episodes of chronic pain may be transient, it is important to maintain exercise levels beyond that of the initial scope of the study to maintain long-term benefits (Bronfort et al. 2001, Evans et al. 2012). Strength or resistance training
interventions need to be a minimum of 6 weeks’ duration to ensure there is sufficient opportunity for muscle hypertrophy to occur (Chiu et al. 2005a, Andersen et al. 2011, Ylinen et al. 2003). Although interventions seen in this review were scheduled for a similar length in duration, the actual cumulative time spent exercising may have differed greatly. For example, Evans et al. (2012) conducted an exercise intervention that lasted 12 months; however, during that time only 20 hours of supervised exercise were conducted. Salo et al. (2012), provided an intervention of the same length time but with a desired accumulative exercise duration of 156 hours over the course of the year (see Table 3.4). Both methodologies had significantly desirable outcomes in their respective interventions. One must consider how likely an individual is to adhere fully to a year-long program or to attend 20 supervised physiotherapy sessions when formulating an optimally effective intervention. Salo et al. (2012) aimed to have an accumulative exercise duration of approximately 156 hours over the course of a year, however, according to exercise diaries kept by patients, the reality showed that by the final quarter of the trial period, approximately 1 hour of exercise as opposed to the desired three were being performed by participants over a weekly period.

Therefore, when examining the time spent exercising and the duration of an exercise intervention to provide the most optimal results, it is recommended that interventions must last at least 6 weeks for physiological benefits to occur. Exercising for between 12 and 45 minutes produces the best results with 30-45 minutes being a reasonable and largely attainable exercise session duration.

3.4.4 Type

Clinical guidelines by the Orthopaedic section of the American Physical Therapy Association (Childs et al. 2008) detailed that exercise should be part of a treatment intervention for chronic neck pain. Along with stretching, co-ordination, centralization procedures, nerve mobilizations, traction, manual therapy, patient education and counselling, active exercise in the form of strengthening and/or endurance exercise are advocated. Though these guidelines formed similar conclusions to this review, the novelty of providing an exercise prescription in a FITT format makes this review clinically applicable.
Although, there has been much debate as to which form of exercise is most beneficial, a combination of both resistance and endurance exercise as well as stretching, reaps the greatest benefits for participants (Miller et al. 2010, Salo et al. 2012a, Stewart et al. 2007, Ylinen et al. 2003). These studies showed immediate and some long-term benefits in increased isometric strength, a desirable outcome from a physiotherapy perspective, as it is widely postulated that the deep cervical flexor muscles are substantially weaker in those with chronic neck pain. Strengthening exercises for these muscles are also of benefit, the stabilising role of the deep neck flexors at the cervical spine is commonly affected in chronic neck pain and these exercises help build the endurance required to maintain head postures over an extended period (Falla et al. 2006b).

Evaluation of the studies in this review demonstrate that, resistance exercise made up approximately 50% of most interventions, with the remainder being devoted to stretching, aerobic exercise and/or education, to target the known weaknesses that may occur in the cervical musculoskeletal system (Ylinen et al. 2003, Hudson and Ryan 2010, Evans et al. 2012).

It was rarely observed that both resistance and endurance exercise were part of the same exercise program, rather the individual types of exercises were compared directly for their effectiveness. This may be because of the study methodology and aim to determine the benefits of any one active exercise form in a chronic neck pain population before combining different forms of exercise. According to this review and clinical guidelines there is evidence for the beneficial effects for of both forms of exercise. A combination of strengthening, stretching and aerobic exercise appear to have the most beneficial effects on isometric strength and a reduction in pain intensity and disability with an overall increase in perceived wellbeing (Childs et al. 2008).

The integration of aerobic exercise into many of the studies reviewed here (Evans et al. 2012, Salo et al. 2012, Stewart et al. 2007, Ylinen et al. 2003,) resulted in increased positive health related quality of life perceptions (Salo et al. 2012), patient satisfaction and global perceived benefit (Chiu et al. 2005b). Though not commonly investigated, potential benefits from proprioceptive exercises and joint position training as studied by Jull et al. (2009) found that joint position error was statistically significantly improved. There were also advantageous results seen for reduced pain
and disability scores in the same training group when compared to a cranio-cervical flexion training regime. Therefore, including one or more of the above in an exercise intervention could produce favourable outcomes (Hudson and Ryan 2010, Ylinen et al. 2003).
3.5 Barriers to Exercise (Adherence, Adjuncts, Delivery)

The importance of education in a chronic pain population has long been established, primarily in a chronic back pain population (O’Sullivan 2005). Fear avoidance and a lack of understanding of exercise benefits are characteristics of those with chronic pain (Kay, 2005). These characteristics are postulated to be causative factors in the development of a chronic pain state (O’Sullivan, 2005). Studies in Table 3.3 which included education as a component of a multimodal approach had beneficial results, such as reduced perceived levels of disability. A Cochrane review by Gross et al. (2012) found evidence of varying quality which suggests that education in chronic neck pain is beneficial for improvements in pain, function and quality of life and exercise adherence. These results are further mirrored by studies in this review (Table 3.4) (Salo et al. 2012). Therapeutic patient education should emphasize a patient centred approach to specifically fit the needs of a patient (Gross et al. 2012).

Adherence is predominantly only a superficially measured secondary outcome in chronic pain population studies (Evans et al. 2012). The type of delivery of an intervention appears to effect adherence to a program and designing what is perceived to be an optimal exercise intervention for a chronic neck pain population is of little significance if it is not going to be adhered to. Though it may be suggested that conducting exercise in a group setting would encourage participation due to the socialisation and group dynamic factors, it was found that in fact supervised group sessions offered little additional benefits from individual sessions (Evans et al. 2012). Psycosocial factors including depression and anxiety are reported to affect between 20% to 50% of people with chronic pain (Whitten et al. 2005). Experiencing such symptoms can affect a patient’s ability to participate in their own self-care, and poses difficulties in modulating pain due to altered neurotransmitter balance (Whitten et al. 2005). The presence of such symptoms must be acknowledged when developing a treatment intervention for this population. Inclusion of psychosocial or counselling components as part of an intervention in parallel with education may be beneficial in increasing adherence in future studies.

According to Yllinen et al. (2003) the potential barriers to adherence include the seasonal variation of symptoms. Pain is exacerbated in the autumn with some relief in the spring; therefore, the timing of an intervention may have a bearing on observed
results. Studies in this review did not declare the time of year the interventions were undertaken, making it impossible to draw conclusions on what intervention had the best outcome based on the time of year at which it was conducted.

Exercise interventions reviewed here were largely conducted either in home, community centres or in hospital settings, therefore cost effectiveness must also be considered in the development and delivery of an optimal program. Viljanen et al. (2003) attempted to reproduce the beneficial effects found by Ylinen et al. (2003) in a more cost effective home based setting. Though results were not of statistical or clinical significance the availability for patients to conduct exercise in a more cost effective manner than being supervised by a health professional is an important factor, particularly in current economic climates.
3.6 Limitations

3.6.1 Methodological Bias

Articles included and discussed in this review were critically appraised for their study methodology and resultant findings, studies were of moderate quality. Literature searches, article selection, data extraction and synthesis were conducted by only one reviewer. This potentially creates a selection bias which should be considered when interpreting the conclusions drawn from this review. However, where question arose over the appropriateness of inclusion of a study, members of the research team were consulted and majority consensus was required before being included. Articles retrieved were applied to previously outlined inclusion and exclusion criteria to determine suitability, as well as being assessed using the PEDro Scale to determine levels of evidence. Most studies reviewed were of good (score of 6 or 7) and not excellent (score of ≥10) methodological quality. Exercise interventions are difficult to blind from the participants themselves due to the study nature. Therefore, it is possible to say that results seen in this review may have been biased. Therapist and assessor blinding though not commonly seen in the studies here (Table 3.1) can strengthen findings and eliminate bias (Salo et al. 2012a).

3.6.2 Multimodal Approach

Many of the studies reviewed here were of multimodal approach, education or manual therapies were always given in conjunction with exercise, thus it is important to consider this when interpreting the findings and recommendations outlined in this article as confounding variables cannot be ruled out.

3.6.3 Outcome Assessment

Some studies discussed in this review (Table 3.4) utilised subjective outcomes as their primary evaluation methods. Self-assessment can lead to bias and may not be a true indication of the results of an intervention. Objective measures are always more accurate.
3.7 Conclusion

The aim of the systematic review in this chapter was to evaluate and synthesise the evidence for active exercise in the treatment of chronic neck pain and to formulate an optimal exercise dosage using the FITT principle of exercise. Despite a large body of evidence on the topic area, a FITT exercise dosage for use in patients with chronic non-specific neck pain had not previously been formulated. This may, in part be due to the methodological variations and limitations of previous research in the area, including those studies in this current review. Methodological limitations as identified in quality appraisal stages of this review including a lack of concealment to training groups, lack of blinding for therapists and assessors, variations in participant characteristics, exercise protocols used, participant diagnoses, duration and severity of symptoms as well as inconsistency in follow up assessments. As moderate quality studies were included in this review (PEDro scale ≥5), results should be interpreted with caution. It should also be noted that the findings of this review were compiled using evidence from non-specific neck pain patients, this leads to leads to a reduced ability to extrapolate or generalise outcomes to patient subgroups with CNP.

The findings of the review agree with previously established guidelines for a chronic neck pain population, which state that programs should be multimodal to include active exercise and education. Based on this review, exercise which was conducted on average three times per week, at an intensity reaching up to 80% of maximum voluntary contraction, for between 20-60 minutes per session, over a period of 6-12 weeks can result in immediate and short-term (< 12 weeks) reductions in pain and disability, as well as increased strength and health related quality of life. There is moderate quality evidence to support the use of endurance exercise (low-load) for patients with CNP. Similarly, resistance exercises to increase isometric strength of the deep cervical flexors is warranted to ensure correct deep neck muscle recruitment and function (Falla et al. 2006a). Incorporating aerobic exercise as part of a multi-modal treatment intervention is purported to result in increased perceived feeling of global wellbeing and health related quality of life (Salo et al. 2012).

Further research is required to examine the feasibility and effectiveness of the FITT principle developed through this systematic review to provide targeted resistance exercise to the weakened deep cervical flexors in patients with CNP. A
targeted and individualised home based exercise regime using this FITT principle and the “FLEXOR” device to target the deep cervical flexors as part of a multi-modal physiotherapy intervention may provide more beneficial outcomes than current usual care physiotherapy alone. The FITT principle determined in this review, as well as the methodological limitations identified in the current body of available literature will be considered and used in the development and delivery of an exercise intervention in a healthy population (Chapter 5) and pilot RCT (Chapter 6) study using a specifically designed resistance exercise tool “FLEXOR” as part of the overarching research design of this current project.

3.8 Clinical Implications

The findings of this review can be used by clinicians to provide a clinically applicable FITT exercise intervention for a non-specific chronic neck pain population. It would be beneficial to incorporate or devise a future intervention trial for this clinical population utilising the proposed FITT principle to assess its effectiveness for outcomes such as isometric strength, pain, neck disability and health related quality of life, to cement the findings of this review and further the level and scope of evidence for active exercise in a chronic neck pain population.
3.9 Research Update

A further literature search was conducted to identify any new evidence published since this current systematic review in 2014. The same search engines and key search words were used. This identified a further 262 results published between 2014 and 2016. After adjusting for duplicates, reading titles and abstracts for appropriateness for inclusion as per the criteria for the original systematic review, 12 randomised controlled trials and 2 systematic reviews were identified (PEDro scale ≥ 6/10) which investigated the effect of an active exercise form compared to a control group or sham treatment. However, no other article was identified that attempted to formulate a FITT principle of exercise for use in CNP rehabilitation or to establish which type of exercise intervention proved more beneficial over another.

3.9.1 Risk of bias of included studies

Methodological limitations including a lack of blinded assessors/therapists (Borisut et al. 2013, Cheng et al. 2015, Javanshir et al. 2015, Karlsson et al. 2014, Rudolfsson et al. 2014) were seen in five studies. Single-blinding of assessors to treatment group allocation was seen in two studies (Beltran-Alacreu et al. 2015, Rudolfsson et al. 2014). Sample sizes ranged from 46 to 108 participants (Falla et al. 2013, Rudolfsson et al. 2014). Some attempts to synchronize start times for all participants to reduce seasonal effects of CNP were also made (Rudolfsson et al. 2014).

3.9.2 FITT Principle

Frequency; Exercise regimes encouraged participants to perform exercise three times per week, between 1-2 times per day, similar to the FITT dosage of exercise formed by the original review.

Intensity; varied amongst individual studies dependent on the exercise intervention. Endurance based exercise interventions involving CCF using a Pressure Biofeedback Unit was based on low-load pre-determined targets (20mmHg-30mmHg), (Ahkter et al. 2013, Gallego-Izquierdo et al. 2016). Strengthening type interventions utilised individualised intensities based on measures of 1 or 12 repetition maximum (Borisut et al. 2013) or measures maximum of isometric strength.
Time; There was large variation in time duration of these studies, ranging from three weeks (Akhter et al. 2014, Beltran-Alacreu et al. 2015, Celenay et al. 2016) to 12 months (Karlsson et al. 2014) with the majority being 6-12 weeks (Borisut et al. 2013, Falla et al. 2013, Gallego Izquierdo et al. 2016).

Type; Seven studies investigated the effect of a strengthening/resistance type exercise regime compared to control groups (Akhter et al. 2014, Borisut et al. 2013, Celenay et al. 2016, Falla et al. 2013, Karlsson et al. 2014, Rudolfsson et al. 2014,(Thompson et al. 2016) whilst five studies investigated lower load endurance type exercise regimes or alternative (proprioception or Pilates interventions) (Brage et al. 2015, Beltran-Alacreu et al. 2015, Gallego Izquierdo et al. 2016).


Studies which implemented education or addressed the cognitive and psychosocial aspects of chronic neck pain resulted in significant improvement in health-related quality of life (Beltran-Alacreu et al. 2015, Thompson et al. 2016.). Two systematic reviews of RCTs (Bertozzi et al. 2013, Chih-Hsiu et al. 2015) identified that longer duration exercise interventions, i.e. 12 months resulted in longer term improvements at 3 year follow up whilst shorter duration interventions had less significant and smaller effect size pooled results at such time points.
This updated literature review suggests that the original FITT principle developed is still in line with current research and investigations into its potential feasibility and effectiveness in a CNP population are required. This would assist in potentially determining a definitive exercise regime that is generalizable for subgroups of CNP patients to provide medium and long-term improvements from CNP symptoms.
Chapter 4: Reliability of Real-Time Ultrasound Imaging for the Longus Colli
4.1 Introduction

The deep cervical flexors, namely LCo and Capitis, function to stabilise the cervical spine during dynamic activity due to their direct cervical vertebral attachment (Falla et al. 2006b). Similar to the dysfunction identified in the lumbar paraspinal muscles in people with chronic lower back pain (Moseley and Flor 2012); altered function and weakness has been identified in the deep cervical flexor muscles in those presenting with CNP (Falla et al. 2003a, Jull et al. 2009, Kristjansson 2004). Up to 70% of the population experience neck pain at some point in their lives (Viljanen et al. 2003), with approximately 20% (Falla, 2004b) of these going on to experience persistent pain with frequent or daily recurring symptoms (Ehrlich 2003). Thus, it is important for clinicians to objectively assess these muscles to ascertain if weaknesses exist and target them in an individually tailored treatment programme.

Due to the deep location of the LCo and Capitis, traditional methods of assessment such as palpation are difficult to perform accurately. Manual muscle testing of the deep cervical muscles in isolation is also difficult to execute without recruiting the superficial cervical muscle layer (Cagnie et al. 2009). Techniques to specifically isolate the deep cervical flexors using fine electromyography wires as
developed by Falla (2004a), whilst effective and highly accurate, are invasive, uncomfortable and clinically inapplicable. Objective methods such as real-time ultrasound (RT-US) and magnetic resonance imaging (MRI) have become popular, both clinically and for research purposes, to assess and measure muscle characteristics including; muscle fibre pennation, fascicle length and CSA (Bemben 2002). CSA is a useful measure as studies have shown a strong correlation between muscle CSA and muscle strength (Maughan et al. 1983, Maughan et al. 1984).

MRI & RT-US have proven reliability for use on a variety of muscle groups (Whittaker et al. 2007) to provide an objective measure of muscle atrophy or hypertrophy. Muscle impairment may persist after pain symptoms have ceased and specific muscle re-training may be required. MRI & RT-US can be used to assess muscle activity, atrophy, hypertrophy and activation reliably if required (Javanshir et al. 2010a, Tsao and Hodges 2007). MRI provides multi-planar images; however, its disadvantages include high cost and limited accessibility, as well as limited real-time capacity and obvious reduced patient group tolerances (e.g. claustrophobic, metallic implants, pacemakers and pregnancy). In comparison, real-time ultrasound is cost effective, accessible, clinically applicable, and portable (Campbell et al. 2005). In addition, RT-US can help guide rehabilitation through its ability to provide instantaneous feedback in real-time for clinicians and can be used to capture dynamic images, thus allowing observation of movement patterns, muscle contractile abilities, activation deficits, muscle recruitment patterns and morphological changes (Henry and Westervelt 2005, Mc Gaugh and Ellison 2011, Whittaker et al. 2007).

Unlike MRI, the quality of the image obtained from real-time ultrasound machines are highly dependent on the experience of the user and can be viewed as a major disadvantage (Whittaker et al. 2007). RT-US has been used extensively with “excellent” intra-rater reliability, as well as “good” inter-rater reliability and validity in larger groups of muscles such as the quadriceps and hamstrings complexes and in the lumbo-pelvic region (Van et al. 2006), however, its use at cervical spine level and associated musculature is sparse (Cagnie et al. 2009, Javanshir et al. 2010). Previous research examining the reliability of ultrasound imaging for measuring the CSA of the Longus Colli has varied in terms of methodology and consequent results. Intra-rater reliability figures varied with intra-class correlation values ranging from 0.71-0.90,
whilst inter-rater reliability values ranged from 0.68-0.82 (Cagnie et al. 2009, Javinshir et al. 2011b, McGaugh and Ellison, 2011,). Inter-rater reliability of LCo CSA measurements for inexperienced RT-US users ranged from 0.68 (95% Confidence Interval (CI) 0.44-0.87) (McGaugh and Ellison, 2011) to 0.81 (95% CI 0.64-0.90) (Cagnie et al. 2009). In a study by McGaugh and Ellison (2011) the physiotherapists only received three hours of RT-US tuition from an experienced user, resulting in a lower inter-rater reliability. Whilst the examiners used in the study by Cagnie et al. (2009), were more experienced, this was reflected in the subsequently higher inter-rater reliability co-efficient, thus identifying the overwhelming influence of experience on RT-US use.

Given the limited published research in this area, this current study was undertaken in a healthy population to determine if a novice ultrasound user with limited experience could agree favourably with an experienced ultrasound practitioner using an on-screen measurement method. Thus, the objectives of this current study were 1) determine the intra-rater reliability of an ultrasound imaging protocol for measuring the CSA of the LCo in a healthy population and 2) determine the inter-rater reliability between a novice ultrasound user and an experienced ultrasound practitioner using a RT-US imaging measuring protocol for the LCo.

4.2 Materials & Methods

4.2.1 Recruitment and subjects

Volunteers were recruited through a general email from a sample of convenience within a university population for this ethically approved reliability study (Appendix B) (Ethics number 2012_11_01_ EHS). Subject demographics including age, weight and height of the sample group were recorded in Table 4.1. Subjects were included if they reported an absence of neck pain or cervicogenic headaches in the six weeks prior to testing and at the time of testing (Cagnie et al. 2009). Exclusion criteria included a history of neck or back trauma, neurological and/or inflammatory disorders, dizziness, vestibular symptoms, allergies to ultrasound gel. All participants read an information leaflet (Appendix C) and gave written consent prior to participation (Appendix D).
4.2.2 Study Design & Procedure

Ultrasound images were captured on two different occasions, one week apart. Images were captured using a GE Healthcare (Fairfield, Connecticut, USA) LOGIQ e Ultrasound machine with a 12 MHz linear array probe. Images were captured at a frequency of 8 MHz and at an average depth of 3-4cm in line with previous research guidelines (McGaugh and Ellison, 2011, Cagnie et al. 2009). Relaxed state ultrasound images were captured by a physiotherapist, a novice RT-US user, who had received tuition from assessor 2 (an experienced and qualified RT-US sonographer) and had conducted independent practice using RT-US for a minimum of 10 hours, on two test occasions, one week apart. On-screen CSA measurements of the Longus Colli muscle were conducted independently by both assessors at different times. Measurements were made using the measure mode setting on the GE Healthcare LOGIQ e Ultrasound machine. One continuous trace of the muscle borders was made using the “roller-ball” mouse on the machine. Both assessors were blinded to the other assessor’s on-screen measurements until data was accumulated for statistical analysis. One CSA measurement of each LCo image was made by both assessors.

4.2.3 US Imaging Technique

Subjects lay supine with a rolled towel positioned posteriorly to flatten the cervical lordosis (Javanshir et al. 2011a). The thyroid cartilage was identified by placing the probe perpendicular to the longitudinal axis of the anterior aspect of the neck. The probe was then moved distally approximately two centimetres, this corresponds with the level of the fifth and sixth cervical vertebrae (Cagnie et al. 2009, McGaugh and Ellison, 2011). This level is chosen as it permits clear visualisation of the Longus Colli, where the muscle attaches laterally to the anterior tubercle of C6 and at this level it is not overlapped by Longus Capitis (Cagnie et al. 2009). The probe was moved one centimetre laterally left and right of the lower laryngeal prominence of the thyroid cartilage (Javinshir et al. 2011a). The Doppler feature was used to verify the correct location by identifying the carotid artery and inferio-medially the LCo (McGaugh and Ellison, 2011) (Figure 4.1).
Anatomical landmarks used to identify the Longus Colli muscle borders included; the carotid and internal jugular vein (antero-laterally), the thyroid cartilage (antero-medially) with the recto-pharyngeal space superiorly as per previous research protocols (Cagnie et al. 2009, Javanshir et al. 2010). (Figure 4.2)

Figure 4.1: Imaging protocol and probe placement for Longus Colli.
4.2.4 Statistical Analysis

Cross-sectional area measurements for left and right Longus Colli muscles were collected from both assessors and inputted to SPSS Version 20.0 for statistical analysis. Both left and right CSA images of the Longus Colli were taken on two occasions from 22 subjects, thus n=44 images were selected for analysis. Reliability analyses including ICC equations (1,1) for intra-rater reliability and (2,1) for inter-rater reliability were conducted on CSA measurements from day 1 and day 2 and day 2 only respectively. Average CSA measurements and mean difference in CSA from Day 1 and Day 2 were calculated to construct the Bland and Altman (1986) graphical representation for intra-rater reliability. Similar methods were used for calculating average and mean differences in CSA measurements between raters for inter-rater reliability. In accordance with Shrout and Fleiss (1979) ICC correlation coefficients were deemed “excellent”, >0.75, “moderate” (>0.50 <0.74) or “poor” (<0.49).
4.2.5 Data Analysis

The standard error of a measurement (SEM) quantifies the extent to which a test provides accurate scores. A low SEM indicates high levels of score accuracy and vice versa.

\[ \text{SEM} = \text{Standard Deviation (SD) from the 1}^{\text{st}} \text{ test} \times (\sqrt{1 - \text{ICC}}) \times (\sqrt{1 - \text{ICC}}) \]

Minimal Detectable Change (MDC) indicates the magnitude of change below which there is more than 95% chance that no real change has occurred.

\[ \text{MDC} = 1.96 \times \text{SEM} \times \sqrt{2} \]
### 4.3 Results

Baseline characteristics of all 22 participants can be seen below in Table 4.1.

<table>
<thead>
<tr>
<th></th>
<th>Women (N= 15)</th>
<th>Men (N= 7)</th>
<th>Overall (N=22)</th>
</tr>
</thead>
</table>
| **Age (years)**  
(mean± SD)                                                         | 22.27±4.5             | 35±10.86             | 26.23±9.14              |
| **Weight (kg)**  
(mean ± SD)                                                        | 64.33±6.3             | 86±24.15             | 70.86±14.46             |
| **Height (m)**  
(mean ± SD)                                                       | 167.13±8.28           | 178.82±13.7          | 171.28±10.71            |
| **CSA LCo (cm²)**  
(mean and SD)                                                       | .65±0.17              | 0.65±.17             | 0.67±0.16               |

**Table 4.1: Subject Demographics**

#### 4.3.1 Intra-rater Reliability

The ICC coefficient for intra-rater reliability was “excellent” Shrout and Fleiss (1979), with a ratio of 0.90 (Table 4.2). The results from the Bland and Altman (1986) method as shown in Figure 4.3, demonstrate the narrow limits or small differences between measures, which indicates favourable levels of agreement (LOA) between measurements (95% LOA -0.17-0.15). The mean difference for cases is small (-0.01cm²) and the points are distributed reasonably near zero.

#### 4.3.2 Inter-rater Reliability

The ICC coefficient for inter-rater reliability was moderate according to Shrout and Fleiss (1979) 0.61 (Table 4.2). The mean difference between measures was substantially larger than that of the intra-rater reliability (0.26cm²). Figure 4 4 indicates a bias as all but 3 points lie above zero, indicating that assessor 1 systematically reported smaller measurements than assessor 2. This bias is also reflected in the 95% CI for d which were 0.19-0.33. Zero does not lie within the intervals, indicating a bias between the two assessors. Only one case lay outside the 95% limits of agreement as seen in Figure 4.4 (Bland and Altman, 1986).
Intraclass Correlation Coefficient (ICC) & Bland & Altman Method (cm²)

<table>
<thead>
<tr>
<th></th>
<th>ICC</th>
<th>95% CI</th>
<th>d</th>
<th>SE of d</th>
<th>95% CI for d</th>
<th>SD (difference)</th>
<th>95% Limits of Agreement (± 1.96SD cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inter-rater Reliability</strong></td>
<td>0.61</td>
<td>0.37-0.77</td>
<td>0.26</td>
<td>0.03</td>
<td>0.19-0.33</td>
<td>0.21</td>
<td>-0.15-0.67</td>
</tr>
<tr>
<td><strong>Intra-rater Reliability</strong></td>
<td>0.90</td>
<td>0.83-0.95</td>
<td>-0.01</td>
<td>0.01</td>
<td>-0.30-0.02</td>
<td>0.08</td>
<td>-0.17-0.15</td>
</tr>
</tbody>
</table>

Table 4.2: Inter and intra-rater reliability statistics for both ICC coefficient and Bland & Altman methods (ICC; Intraclass correlation co-efficient, 95%CI; 95% confidence intervals, d; mean difference, SE of d; Standard error of the mean)
4.3.3 Standard Error of the Measurement & Minimal Detectable Change for Intra & Inter-rater Reliability

Standard error of measurement figures and minimal detectable change figures can be seen below in Table 4.3. Based on figures for intra-rater reliability a minimal detectable change of 0.30cm$^2$ of the LCo muscle would be the smallest change in score or size that could be detected beyond random error. For inter-rater reliability, this is even larger at 0.75cm$^2$. These figures are dependent on the sample size distribution. Figure 4.5 and 4.6 indicate best agreement on a measurement between Assessor 1 and Assessor 2. As can be seen measures were as close as 0.02cm$^2$ in the difference. Larger discrepancies in measurement can be seen in Figure 4.7 and 4.8, where a difference of 0.42cm$^2$ in CSA measurements can be seen. Poor border identification may be the cause of larger measuring discrepancies between Assessors (McGaugh and Ellisson, 2011).

<table>
<thead>
<tr>
<th></th>
<th>SEM (cm$^2$)</th>
<th>MDC (cm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intra-rater Reliability</strong></td>
<td>0.11</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>Inter-rater Reliability</strong></td>
<td>0.27</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Table 4.3: Minimal Detectable Change and Standard Error of Measurement for inter and intra-rater reliability
**Figure 4.3:** Bland and Altman (1986), plot showing mean difference and limits of agreement for intra-rater reliability of real-time ultrasound imaging for the Longus Colli in a healthy population.
Figure 4.4: Bland and Altman (1986) plot showing mean difference and limits of agreement for inter-rater reliability of real-time ultrasound imaging for the Longus Colli in a healthy population.
Figures 4.5 & 4.6: Ultrasound images demonstrating on-screen CSA measurements by Rater 1 (Expert Assessor-left) & Rater 2 (Novice Assessor-right), where agreement was most favourable. For this image, there was a difference of 0.02cm$^2$ between measurements by both raters.
Figure 4.7 & 4.8: Ultrasound images demonstrating on-screen CSA measurements by Rater 1 (Expert Assessor-left) & Rater 2 (Novice Assessor-right), where agreement was not favourable. For this image, there was a difference of 0.42cm² between measurements by both raters. Distinguishing the posterior border of the muscle in this image, as mentioned in the discussion is an area for discrepancy between raters.
4.4 Discussion

4.4.1 Intra-rater Reliability

The intra-rater reliability for real-time ultrasound in measuring the CSA of the Longus Colli in a healthy population was excellent (ICC’s 0.90, 95% CI 0.83-.95). This is comparable to available published literature for ultrasound of the Longus Colli and is higher than intra-rater reliability figures by McGaugh and Ellison (2011) and Javanshir et al. (2011b), who reported ICC values ranging from 0.67 and 0.87. Possible causes of this may be due to the combination of anatomical referencing and the Doppler feature in identifying the correct location in this study. Published research for the reliability of ultrasound imaging for measuring the CSA of the Longus Colli in both healthy and neck pain populations has varied in terms of methodology and consequent results. Intra-rater reliability figures ranged from 0.71-0.90, (Cagnie et al. 2009, McGaugh and Ellison, 2011, Javanshir et al. 2011b). Levels of experience of assessors ranged from novices to experienced, however, all had received some level of training in ultrasound imaging of the Longus Colli. The methods of measurement, frequency used and field depth, as well as the equipment used, including probe type may be attributable to the differences observed in results between this current study and previous research.

The limits of agreement suggest a narrow margin of variability in measurements taken between day 1 and day 2 (-0.17-0.15) (Table 4.2). The mean difference (-0.01), close to zero indicates excellent agreement and little variability in measurements between test occasions (Rankin et al. 2005). Thus, confirming that the current protocol utilised in this study is reliable in a healthy population over two testing occasions for a novice ultrasound user. Hence, using a combination of anatomical reference points and the Doppler feature, if available on the ultrasound machine is an effective means of increasing standardised imaging and reliability in measuring the Longus Colli on different test occasions by the same assessor.

4.4.2 Inter-rater Reliability

ICC’s for inter-rater reliability in this current study were “moderate” (ICC 0.61) 95% CI (.38-.77), but in line with other research (McGaugh and Ellison, 2011) (Figure 4.4). Cagnie et al.(2009) previously demonstrated moderate inter-examiner
reliability (ICC .68, 95% CI 0.48-0.81) for measurements of the Longus Colli in healthy subjects. Javinshir et al. (2011b) have demonstrated within-day and between day reliability of between 0.71-0.81 for subjects with mechanical neck pain, showing that real-time ultrasound is a reliable tool for patients with neck pain as well as healthy populations. This finding in the current study may be attributable to a combination of factors. The large limits of agreement (-0.15-0.67) between assessors display large variability for inter-rater reliability of ultrasound for this muscle. The intervals are wide reflecting the small sample size (<50) and the great variation in differences (Bland and Altman, 1986). The mean difference was also quite large (0.26cm²) and not as close to zero as the authors would have desired (Table 4.2). This would indicate a systematic bias and that the experienced assessor (Assessor 2) had larger measurements compared to Assessor 1. Figures 4.5-4.8 demonstrate best agreement and largest discrepancy for CSA measurements of the LCo between both assessors. As can be seen, measurements were as close as 0.01cm² or as large a difference as 0.42cm². It is important to note that, variability in measurement may have been influenced by the novice assessor (Assessor 1), being able to observe the image and muscle borders in real-time. However, due to the study methodology, this was not possible for Assessor 2. As the inter-rater reliability can only be classed as “moderate” it is important to consider the reasons for differences between this current study and previous research in the area. McGaugh & Ellison (2011) found smaller mean differences for inter-rater reliability (0.04cm²) and narrower limits of agreement, ±0.23cm². Both assessors in McGaugh and Ellison (2011) study had similar levels of training in ultrasound imaging and both were present at the time of image collection. A similar ultrasound machine was used in this procedure; however, different frequency settings were utilised, which may have contributed to different results found between studies. As can be seen in Table 4.3, a large standard error of measurement for inter-rater reliability was calculated and a concurrently large minimal detectable change of 0.75cm². This is in keeping with the wide limits of agreement obtained for between-rater measurements.

In the case of inter-rater reliability agreement on identification of the muscle borders may account for the “moderate” reliability found in this current study, particularly the lateral border can cause great difficulty due to the indistinct outline of the muscle, thus making verification variable. The posterior border can be difficult to delineate due to the acoustic shadow of the trachea (Javanshir et al. 2010).
4.4.3 Cross-sectional Area Measurements

When looking at exact figures of CSA of the Longus Colli in this study, the average CSA was 0.67±0.16cm$^2$. This is substantially smaller than the average CSA’s measured in previous literature (Javanshir et al. 2011b), e.g. controls 0.85±0.11cm$^2$ and neck pain patients 0.66±0.11cm$^2$. Similarly, Cagnie et al. (2009) reported an average CSA of 1.22±0.27cm$^2$ in healthy controls. The differences observed as previously mentioned may be due to the different ultrasound machines utilised in each study, the method by which the CSA was measured, either on-screen or an alternative software program. The majority of this group were also females (n=15) and as Javanshir et al. (2011) demonstrated, there is an effect of sex on CSA of muscle size. Findings from an ANCOVA showed a significant difference in the CSA of the Longus Colli between men and women (p=0.018) in healthy people only. This may also account for the variances seen in CSA figures between this study and previously published research.

4.4.4 Limitations

Conflicting interpretations of muscle borders and anatomical reference points by different assessors may have led to the over or under estimation of the muscle borders and the subsequent CSA measurements for both intra and inter-rater reliability (Whittaker et al. 2007).

As the aim of this current study was to determine the reliability of an onscreen measurement protocol between two assessors it is important to note that this measurement involved the use of a roller mouse; varying abilities in the use of this type of control may have influenced the disparities in measurements calculated for both intra and inter-rater reliability statistics, this should be carefully considered in interpreting the results of this current study (McGaugh and Ellison, 2011).

As with all reliability studies, it should be noted that regardless of the reliability tests conducted and subsequent results, the comparison of reliability results between studies is limited unless the size and attributes of the sample populations tested in each case are extremely similar (Rankin et al. 2005).
4.4.5 Possible Clinical Applications

This protocol was used in a healthy population; future research is required to investigate if similar or improved reliability can be achieved in a CNP clinical population. Evidence suggests that the DNFs of those with neck pain are impaired and appear more marbled, i.e. containing more fatty infiltrate than healthy controls, making border identification more difficult (McGaugh and Ellison, 2011). Thus, it is important to have excellent reliability in a healthy population, to aim to be equally reliable in a neck pain population. Additional statistical analyses were conducted to find the SEM of images in this current study to provide evidence of precision of measurements taken. For intra-rater reliability this was 0.11cm², this is reasonably close to zero and indicates how accurate the measurements were. Minimal detectable change (MDC) was also calculated, this gives an indication of the minimal change required for that change to be attributable to an intervention, in this case 0.30cm². This figure is quite high, given the small CSA of the muscle.

As can be seen from this current study, intra-rater reliability of Longus Colli measurement for a novice real-time ultrasound user is “excellent”. However, the reliability for on-screen CSA between two assessors is only moderate. RT-US was more reliable when one individual is conducting re-assessments, thus clinically, it is more advantageous if one clinician can perform all assessments, this may not always be possible and whilst it is considered an objective measure it is still largely dependent on the user (Whittaker et al. 2007).

4.4.6 Conclusion

Assessments of the deep cervical flexors which are impaired in neck pain are difficult to execute reliably in a clinical setting, but is a requirement in a chronic neck pain population. Real-time ultrasound is a feasible and evidently reliable method to conduct such an objective assessment of muscle function for an individual assessor but less so between two assessors. Further research to determine if this current study protocol is as reliable in a chronic neck pain population is required as well as determining if a significant difference exists between the CSA of the Longus Colli in healthy controls and those with neck pain.
Chapter 5: Healthy Population Study using “FLEXOR”
5.1 Introduction

Neck pain is a prevalent musculoskeletal condition (Sarig-Bahat 2003, Hudson and Ryan 2010) affecting up to 67% of individuals at one point in their lives (Bronfort et al. 2001). Left untreated neck pain can develop into a state of chronicity due to changes in the neuromuscular system (Whitten et al. 2005). Up to 22% of women and 16% of men experience chronic neck pain symptoms (Hudson and Ryan 2010). Although not life threatening, CNP can limit every-day activity and participation resulting in significant socio-economic burden and costs (Evans et al. 2012). Therefore, developing feasible and effective treatment interventions are imperative to reduce the economic burden of CNP.

Evidence of the exact under-lying pathophysiology of chronic neck pain is equivocal (Hodges and Tucker, 2011) and as such a paucity exists on a consensus on best treatment strategies (Childs et al., 2008, O’Riordan et al. 2014). It is argued that a weakness of the cervical musculature, notably the deep cervical flexors has a significant role in the cause-effect relationship of chronic neck pain development (Falla 2004b, O Leary et al. 2007c, Pearson et al. 2009). Moderate quality evidence exists for the inclusion of resistance exercise in multi-modal treatment interventions in the management of CNP (Childs et al. 2008, Kay et al. 2005, Sarig-Bahat 2003).
Strengthening or resistance type exercise, when used as part of a multi-modal treatment intervention for chronic neck pain has previously been shown to increase isometric strength, reduce pain, disability and improve patient satisfaction (Ylinen et al. 2003, Ylinen 2007, Andersen et al. 2011, Evans et al. 2012, Chiu et al. 2002, Chiu et al. 2005b). Strengthening or resistance exercise is postulated to target observed weaknesses of the cervical musculature by increasing muscular strength, thereby augmenting improved movement strategies and muscle recruitment patterns (Falla 2004b). It can be hypothesised that strengthening of the deep cervical muscles may reduce the strength deficit commonly observed in patients with CNP may positively influence the symptoms of CNP including pain and disability (Häkkinen et al. 2008).

Providing targeted strengthening interventions for the deep cervical flexors has been difficult to date due to the lack of a suitable exercise tool. Current therapy adjuncts in this population to increase neck muscle strength include TheraBands™, head weight or the Pressure Biofeedback Unit (Stabilizer, Chattanooga, Holden, TN) (Ylinen et al. 2003, Jull et al. 2009). However, these typically target all cervical muscles, and were not designed specifically to target the deep layer. As outlined in Chapter 1 and Appendix A, “FLEXOR” was designed to target the weakness of the deep cervical muscles specifically, providing resistance to cranio-cervical flexion movements. This movement is targeted specifically as it is one of the main roles of the deep cervical flexors known to be affected by chronic pain (Falla 2004a, Falla 2006, Jull et al. 2009). As “FLEXOR” is a novel device, no pre-existing data is available to advocate its inclusion in clinically used treatment interventions for patients with CNP. As CNP figures continue to rise (Hoy et al. 2010) it is imperative that healthcare providers have access to feasible and effective treatment strategies and tools to increase the efficacy and outcomes of treatment.

In line with frameworks which outline processes for developing complex interventions, proof of concept or modelling phase research trials are recommended as part the piloting/feasibility phase (Craig et al. 2006). Prior to developing and implementing a multi-centre patient pilot RCT to investigate the feasibility of a targeted exercise intervention using a novel strengthening tool in patients with CNP, it is important to consider some conducting pilot work to investigate the feasibility of a proposed study methodology and any safety issues which may arise from using a novel strengthening tool (Tickle-Degnen 2013). Based on this, a single group
feasibility study was designed, with the primary aim of investigating the feasibility of
the proposed study methodology using the “FLEXOR” device to deliver a targeted
resistance exercise intervention and a research evidence informed exercise dosage (O’
Riordan et al. 2014) in a healthy population. It is also important to investigate the
appropriateness and suitability of proposed outcome measures to detect change. This
included determining the intra-rater reliability of hand held dynamometry for the
cervical flexors the effectiveness of “FLEXOR” to provide resistance exercise to the
deep cervical flexors and to highlight any safety issues or adverse reactions to using
“FLEXOR” and its associated exercise prescription, that would need to be considered
prior to developing a similar investigation for patients with CNP.
5.2 Methods

5.2.1 Ethics

Ethical approval was sought and obtained from the Science & Engineering Research ethics committee in the University of Limerick (2012_07_04_S&E).

5.2.2 Participants

Participants were recruited via email (Appendix E) circulated to students and staff within a university setting. In accordance with predetermined inclusion and exclusion criteria, individuals were deemed eligible for inclusion if they were aged between 18-65 years, had no previous neck trauma or were currently not experiencing neck pain.

Individuals were excluded from participation if they could not speak English, were allergic to ultrasound gel, had previous history of or were complaining of chronic mechanical non-specific pain at the time. In this instance, chronic neck pain was defined as; neck pain of unknown cause or origin felt at the base of the skull and shoulder area with subsequent restrictions of neck movement, which may be associated with muscle strains, ligament sprains or bad posture (Taimela et al. 2000). Individuals were also excluded if known to be experiencing vertigo, dizziness, nausea or vomiting; were demonstrating neurological symptoms including altered sensation in the shoulder and neck area; had undergone previous neck or shoulder surgery; had a diagnosed cervical spine disorder including but not limited to disc prolapse, spinal stenosis, instability, spasmodic torticollis, peripheral nerve entrapment; inflammatory rheumatic diseases, severe psychiatric illness or other illnesses that prevent physical loading; diagnosed with fibromyalgia; individuals who had participated in a neck exercise intervention similar to this in the previous 12 months; and pregnant females were also excluded. (Hudson and Ryan 2010, Falla et al. 2013). Once deemed eligible for participation individuals were invited to attend for assessment. A signed consent form was required prior to confirmation of participation (Appendix G)
5.2.3 Assessment Procedure and Outcome Measures

Anthropometric characteristics including age, weight and height were retrieved (Table 5.1). Participants were assessed on three occasions, baseline, midway (4 weeks) and again at the end of the 8-week exercise intervention.

Primary outcome measures included monitoring and quantifying;

Exercise adherence through the distribution of self-reported exercise diaries. Adherence was assessed through an exercise diary which was given to all participants at the beginning of the trial. Individuals were asked to fill in weekly details of exercises undertaken. Any additional strengthening exercises undertaken outside the “FLEXOR” regime were to be documented.

Safety issues; participants were advised to monitor any reaction to exercise using the “FLEXOR” and to report any safety concerns or adverse reactions immediately.

Dropout rates were also monitored to assess exercise intervention suitability (Thabane et al. 2010). Dropout rates were measured at mid-way and final assessment time points.

Further feasibility outcomes included the appropriateness and suitability of proposed outcome measures to detect change. This included objective measurement of the CSA of the deep cervical muscle, LCo using RT-UI. A GE Healthcare (Fairfield, Connecticut, USA) LOGIQ e Ultrasound machine was used. RT-US imaging has been used reliably in previous studies of the deep cervical flexion as outlined in Chapter 4 (Cagnie et al. 2009, McGaugh and Ellison 2011). Participants lay in supine, with a rolled towel placed beneath their neck to ensure comfort, alignment and optimum visualisation of the LCo on the ultrasound (McGaugh & Ellison 2011). With a 12 MHz linear array probe, a frequency of 8 MHz was used at a depth of 3-4cm to visualise the LCo. To standardise the level at which each image was taken for every individual, the top of the thyroid cartilage was found by placing the transducer perpendicular to the long axis of the anterior aspect of the neck. The probe was then moved distally approximately 2cm to the lower laryngeal prominence of the thyroid cartilage, this is approximately the level of the fifth/sixth cervical spinous process. C5/6 is deemed the most appropriate level for capturing the LCo at this level there is no overlap of the
Longus Capitis, another deep cervical “FLEXOR” (Javanshir et al. 2010b). Anatomical landmarks were used to standardise each image left and right for each of the participants; a) vertebral body, b) Thyroid gland, c) sternocleidomastoid muscle, d) carotid artery, e) rectopharyngeal space (Javanshir et al. 2010b). The Doppler feature on the ultrasound machine was used to confirm the anatomical position. Images were taken for the right LCo first and then the left. Images were saved and CSA measured using on-screen software in accordance with published literature (Javanshir et al. 2010b, Cagnie et al. 2009).

A second objective outcome included using a hand-held dynamometer (HHD) (J Tech Power Track) to measure the isometric strength of the cervical flexors during a cranio-cervical flexion movement. Hand held dynamometry has also been used extensively to measure isometric strength of many individual muscles and muscle groups in the body including the cervical muscles (Silverman et al. 1991). A HHD (J Tech Power Track, Salt Lake City, UT) was used to assess isometric strength of the cervical flexors. Participants were seated, with feet placed on the floor and arms crossed over their chest. With the HHD placed underneath the chin, participants were asked to conduct a “chin to chest movement” as forcefully as possible against assessor’s resistance in accordance with similar research procedures (Rezasoltani 2003). Three attempts of maximum voluntary contraction were measured, with 10 second rest between measurements (Silverman et al. 1991). Average torque was calculated and saved. This was completed twice at baseline assessment (the second measurement was used to provide data for intra-rater reliability data for the proposed method to measure isometric strength of the cervical flexors using a HHD), and once at both mid-way and final assessments.

5.2.4 Intervention

Following the assessment procedure, standardised instructions were provided to participants by the assessor on the correct use of “FLEXOR” and execution of the exercise intervention. An individualised prototype “FLEXOR” device was provided to participants (individualised for resistance intensity and neck size). Resistance was based on 50% of the average MVC calculated during the above detailed assessment procedure. Expected exercise frequency from participants was three times per week,
3 sets of 10 repetitions 3 times a day (Ylinen et al. 2003, O Riordan et al. 2014). A mid-way assessment was completed after four weeks and assessments of isometric strength and CSA of the LCo were repeated. Any exercise progression at this mid-way point was based on peak MVC values calculated. Increases in resistance were between 2 and 10% of mean MVC values calculated. Final assessment was conducted at the end of the 8-week exercise intervention period.

5.2.5 Statistical Analysis

Data gathered was inputted into SPSS version 20.0 and assessed for normality. Appropriate parametric and non-parametric tests were used to examine the pre-and post intervention results for isometric strength values and measures of CSA of the LCo. Reliability statistical analyses was conducted on baseline values of isometric MVC to establish intra-rater reliability ICC values for HHD.
5.3 Results

Researchers received 35 replies to the recruitment email, through screening for inclusion/exclusion criteria 25 participants were deemed eligible for participation, 4 individuals withdrew their initial interest prior to beginning the trial due to timetabling conflicts, which resulted in 21 participants (11 males, 10 female). A flow-diagram of participant recruitment can be seen in Figure 5.1 below.

Data was normally distributed and appropriate paired T-tests were used to assess differences between baseline and final data for both objective outcomes of isometric strength and CSA of the LCo as measured by RT-UI.

<table>
<thead>
<tr>
<th></th>
<th>Male (n=11)</th>
<th>Female (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>23.45±3.04</td>
<td>22.80±4.46</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.90±1.</td>
<td>1.65±0.6</td>
</tr>
<tr>
<td>Weigh (kg)</td>
<td>95±8.54</td>
<td>64.10±9.03</td>
</tr>
</tbody>
</table>

Table 5.1: Baseline characteristics (mean values and standard deviations).
Figure 5.1: Flow diagram displaying group numbers for baseline, mid-way and final assessments, as well as study dropouts.
5.3.1 Feasibility (Exercise Adherence, Drop Out, Device Robustness, Safety Issues)

Exercise adherence, as based on self-reported exercise diaries indicated that for the 8 weeks, individuals exercised on average 2.1 times per week, representing a 70% exercise adherence rate. No adverse reactions were reported by participants from conducting an exercise intervention using “FLEXOR”. No ill effects were reported subjectively by patients. Participants who dropped out were contacted to ascertain reasons of cessation, these included; student placement off university campus, prior knowledge of unavailability for final assessment, lack of adherence to exercise program in initial weeks. Four “FLEXOR” devices had to be replaced during the intervention, due to breakages of the chin lever and the coil spring used to provide resistance. This had implications for the seamless continuation of exercise throughout the exercise intervention period. Issues with the device were addressed prior to the pilot RCT discussed in Chapter 6 (see Appendix 1).

5.3.2 Isometric Strength

Mean maximal voluntary contraction values for three trials of cranio-cervical flexion are listed below (Table 5.2). Values given are in newton’s (N).

<table>
<thead>
<tr>
<th></th>
<th>MVC Baseline</th>
<th>MVC Mid-way</th>
<th>MVC Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>69.06±9.37</td>
<td>90.87±13.52</td>
<td>100.34±12.12</td>
</tr>
<tr>
<td>Female</td>
<td>60.30±6.74</td>
<td>72.60±6.15</td>
<td>94.33±9.50</td>
</tr>
<tr>
<td>Overall</td>
<td>64.89±9.19</td>
<td>79.91±6.16</td>
<td>96.96±1.80</td>
</tr>
</tbody>
</table>

Table 5.2: Mean and SD of MVC (Ns) for cranio-cervical isometric strength at baseline (day 1) and mid-way (day 2) and final assessment (post 8-week exercise intervention).
<table>
<thead>
<tr>
<th></th>
<th>Mean Diff</th>
<th>SD</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline-Midway</strong></td>
<td>16.45</td>
<td>±9.99</td>
<td>(10.91, 21.98)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td><strong>Midway-Final</strong></td>
<td>16.01</td>
<td>±9.25</td>
<td>(10.67, 21.36)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td><strong>Baseline-Final</strong></td>
<td>33.48</td>
<td>±12.22</td>
<td>(26.96, 39.99)</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Table 5.3: Mean difference or increase in isometric strength (in Newton’s) of the cervical flexors (irrespective of gender) following an 8-week exercise intervention using “FLEXOR” and resultant p values of statistical significance.

Mean differences in isometric strength from baseline to final assessment in the single group showed highly significant p values of less than <.01 (Table 5.3) and Figure 5.2.
Figure 5.2: Bar-chart with error bars (1 standard deviation) representation of mean MVC at baseline (day 1), mid-way (day 2) and final assessment.
5.3.3 Cross-sectional Area

The cross-sectional area was measured for both left and right LCo muscles at baseline, mid-way and final assessment. Results are given in cm$^2$.

<table>
<thead>
<tr>
<th>CSA (LCo)</th>
<th>Baseline</th>
<th>Mid-Way</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>0.57±0.11</td>
<td>0.58±0.11</td>
<td>0.67±0.15</td>
</tr>
<tr>
<td>Left</td>
<td>0.60±0.11</td>
<td>0.62±0.09</td>
<td>0.67±0.13</td>
</tr>
</tbody>
</table>

Table 5.4: Mean and standard deviations of left and right cross-sectional area (cm$^2$) of the Longus Colli muscle. Baseline n=21, Mid-way n= 15. (Both genders analysed together to aid heterogeneity of sample group).

<table>
<thead>
<tr>
<th>(CSA Right)</th>
<th>Mean Diff</th>
<th>SD</th>
<th>95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline-Midway</td>
<td>0.07</td>
<td>±0.08</td>
<td>(-0.05, 0.04)</td>
<td>0.78</td>
</tr>
<tr>
<td>Midway-Final</td>
<td>0.12</td>
<td>±0.22</td>
<td>(-0.01, 0.24)</td>
<td>0.07</td>
</tr>
<tr>
<td>Baseline-Final</td>
<td>0.13</td>
<td>±0.19</td>
<td>(0.02, 0.28)</td>
<td>0.02*</td>
</tr>
</tbody>
</table>

<table>
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<th>SD</th>
<th>95% CI</th>
<th>P Value</th>
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<tr>
<td>Midway-Final</td>
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<td>(-0.04, .14)</td>
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<tr>
<td>Baseline-Final</td>
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<td>±0.18</td>
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<td>0.56</td>
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</table>

Tables 5.5 & 5.6: Mean increase in cross sectional area of the right and left Longus Colli respectively and resultant p values.

Only data for the right Longus Colli CSA showed statistically significant increases between baseline and final assessment 8 weeks later (p=0.02).
5.3.4 HHD Intra-rater Reliability for the Cervical Flexors

The ICC coefficient for intra-rater reliability of the HHD for measuring isometric strength of the cervical flexors can be described as “excellent” in accordance with Shrout and Fleiss (1979), with a ratio of 0.91 (95% CI 0.79, 0.96). This indicates that the standardised method proposed within this study methodology is reliable and repeatable and can therefore be reliably used as an outcome measure following an exercise intervention, if repeated measures are conducted by the same assessor.
Figure 5.3: Bar-chart representation of CSA of the LCo (Left and Right) increase from baseline, mid-way and final assessments.
5.4 Discussion

The purpose of the current study was to investigate the suitability of a study design to detect change following an exercise intervention, safety of using the “FLEXOR” device and the appropriateness of proposed outcome measures, prior to developing and implementing a pilot RCT for patients with CNP. Findings from this study identified significant increases in isometric strength as early as four weeks into the exercise intervention that was further increased by the end of the eight weeks with an overall increase of 33.48 ±12.22 N (p <0.001) overall. LCo CSA significantly increased by 0.13±0.19cm² (p=0.02) for the right side, however, the observed change for the left LCo was smaller and not significant (0.09±0.18cm²). Average weekly exercise adherence by participants was less than required and anticipated. However, no adverse reactions to exercise using “FLEXOR” were highlighted or reported. Some issues with device robustness were highlighted, which were taken into consideration prior to the design of a multi-centre pilot RCT for patients with CNP (Appendix 1).

5.4.1 Feasibility

Average weekly exercise adherence for this study was seen to be 2.1 times a week; an anticipated exercise adherence was three times per week. This indicates exercise adherence was approximately 70% overall. Adherence to exercise in a healthy population should be substantially higher than that in a population with a chronic condition (Schwarzer et al. 2011). It may be argued that due to the voluntary nature in recruitment and participation, compliance may have been higher (Beinart et al. 2013). Given this study was conducted in a healthy population, subsequent pilot RCT should further assess adherence and the feasibility of the exercise intervention in a patient cohort. In accordance with the FITT principle established in Chapter 3, an exercise frequency of three times a week is associated with optimal outcomes from an exercise intervention. Based on the results of this study, the likelihood of achieving such adherence in a patient population in a pilot RCT may need to be considered, while aiming for a similar adherence rate of at least 70% adherence may be more attainable. Previous research from a population of people with chronic neck pain indicated an average adherence of 1.9 times a week (Bronfort et al. 2003), similar or higher would be desirable when investigating a patient population. Bio-psychosocial factors and
barriers to exercise including pain, depressive moods and fear avoidance may all contribute to a reduced exercise adherence for those with chronic pain (Meulders et al. 2011, Salo et al. 2012b, Viljanen et al. 2003).

No adverse reactions from using “FLEXOR” were reported throughout the duration of the current study. No dropouts were reported due to the device or its associated exercise intervention. Again, this positive outcome must be interpreted with caution due to the healthy population investigated. Dropout rates and attrition levels may be higher in a patient population, due to an increase in pain from exercise (George et al. 2008). However, maintaining a low dropout rate due to adverse reactions appears feasible based on results observed here. Issues with the device robustness were highlighted as replacement devices were required on several occasions. These replacements were required by participants using the device at higher levels of resistance. As these were healthy participants baseline strength levels were higher, therefore resistance settings were also higher. This may not be such an issue in a patient population with expected lower baseline strength levels, however, significant improvements in device design are required prior to investigation of feasibility of such a study design with patients with CNP. This would include a change from a coil spring to something more robust such as a torque spring and more durable and thicker plastic material (Appendix A).

5.4.2 Isometric Strength

Baseline strength figures seen in this study were slightly lower than some previous research in a healthy population as measured in a sitting position (see Table 5.2). Falla et al. (2004) reported mean isometric strength of the cervical flexors of 73.3 ±37.7N. However, figures in this study were higher than other reported figures by Kumar and Prasad (2010), who indicated mean isometric strength was 55.84±16.99N in a healthy population. Differences observed between studies may be attributable to varying equipment used to measure strength. Hand held dynamometry has been used previously to reliably measure isometric strength both at the cervical flexors (Silverman et al. 1991) and for larger muscle groups in the body (Strimpakos et al. 2004b). The mean age of healthy participants in each study may also have a consequence on results found. In a study by Falla et al. (2004), the mean age was 30.0
±7.6 years, while this study was slightly lower at 23.45±3.04 for men and 22.80±4.46 for females.

Increases in isometric strength demonstrated in this study are higher than increases seen using a similar exercise prescription in patients with CNP (Ylinen et al. 2003, Häkkinen et al. 2008). This may be mostly attributable to the obvious differences between populations assessed and subsequent attitude towards exercise. Maximum voluntary contraction efforts of those with chronic neck pain may be affected by “fear-avoidance” behaviours (Leeuw et al. 2007) and a desire to not re-injure during testing with maximal forces (Pearson et al. 2009). Similarly, this same belief may influence their ability to conduct resistance/strengthening exercises and subsequently influence final results (Pearson et al. 2009).

Incidentally, differences in assessments methods and strengthening regimes may account for differences observed between studies (Strimpakos 2001, Seng et al. 2002). Therefore, this highlights the need for ensuring that the measurement method for isometric strength in a study is reliable and repeated by the same assessor (Seng and Lam 2002). Intra-rater reliability for the method of strength testing in this study was “excellent” (Shrout and Fleiss, 1979) with an ICC of 0.91. Every precaution was taken in this current study to minimise bias by standardising procedures (Ylinen et al. 2003).
5.4.3 Longus Colli Cross-Sectional Area

Baseline CSA values were similar to those found in previous research (Cagnie et al. 2009, Mc Gaugh and Ellison 2011, Javanshir et al. 2011a) which is expected as similar aged healthy populations were used in this study and the methodology for capturing images of CSA were based on these published studies. Statistically significant increases in CSA of the LCo were seen for the right LCo and not the left. Correlation co-efficients for cervical muscle strength and CSA increases for this sample population were “weak”, (r=0.346). This suggests that the strength gains seen in this current study may not be attributable to muscle hypertrophy (Aagaard 2003), however further investigation is warranted in a larger sample size population and in a patient group.

5.5 Conclusion and Implications

Undertaking an 8-week exercise intervention three times a week, at an intensity of at least 50% of one’s MVC using “FLEXOR” resulted in statistically significant increases in isometric cervical muscle strength and CSA of the Longus Colli in a healthy population. Using the “FLEXOR” device and the proposed FITT exercise intervention did not highlight any safety issues or adverse reactions. Outcome measures proposed detected change following an exercise intervention in a healthy population. However, the generalisability and applicability of results of this study are limited by the single group study design, as well as the small sample size included and the healthy population investigated. However, positive results highlighted here indicate further investigation in patients with CNP is warranted through a pilot RCT study design to assess the feasibility of similar parameters, following significant alterations to the “FLEXOR” device design.
Chapter 6: A Targeted Resistance Exercise Intervention for the Deep Neck Flexors using “FLEXOR”; a Pilot Randomised Controlled Trial
6.0 Introduction

Chronic mechanical neck pain (CNP) is a prevalent musculoskeletal condition with a lifetime incidence rate of between 45%-67% (Falla et al. 2013, O Leary et al. 2011). With its high point prevalence\(^6\) and recurrence risk\(^7\) CNP results in large economic and societal costs due to lost productivity in the work place, sick leave and associated healthcare costs (Gross et al. 2005). The exact aetiology and pathophysiology of chronic neck pain are still unknown. In most cases, there is no radiological evidence of abnormality of the anatomical cervical structures as a definitive source of pain (Bogduk 2011).

Over the course of time, various concepts have been proposed to explain the link between pain and alterations in motor activity. Most recently, due to an increased understanding of the multi-dimensional nature of pain, a more comprehensive theory “the integrated pain adaptation model” (Hodges and Tucker, 2011) has emerged to explain alterations in motor control and activity in the presence of pain. The

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\(^6\) Point prevalence: is the number of persons with a condition in a time interval (e.g., one year) divided by number of persons in the population (Côté et al.1998).

\(^7\) Recurrence risk: the chance that a disease/symptom will occur again (Côté et al. 2004)
“integrated pain adaptation model” suggests that pain is a unique individual reaction, based on the anatomical and functional complexities of the sensory-motor system and the multi-dimensional individualized experience of pain (past experiences, pain beliefs, self-efficacy, catastrophizing). Altered movement strategies are now believed to develop to maintain homeostasis and minimize pain and metabolic costs (Tsakitzidis et al. 2013). However, it is possible that these changes in movement can lead to further pain and injury for unknown reasons (Hodges and Tucker, 2011). For patients with CNP, evidence has shown that continued fear avoidance, due to the presence of pain, leads to muscle atrophy and reduced activity of the agonists, i.e. the stabilising deep cervical flexor muscles (Lund et al. 1991, Javanshir et al. 2015) and increased activation of the larger superficial antagonistic muscles (Falla 2004d). This can lead to significant alterations in the function and role of the deep cervical flexor muscles in patients with CNP (Snodgrass et al. 2016). Furthermore, reflex inhibition due to nociceptive input can lead to maladaptive muscle recruitment patterns (Lindstroem et al. 2012, Meulders et al. 2011). This neuromuscular induced shift in muscle synergy allows cervical function to continue, thus maintaining homeostasis, however there is inhibited movement efficiency (Farina et al. 2005, Sohn et al. 2000). It is therefore plausible to suggest that this prolongs the presence of pain and may cause further injury. The full relationship between pain and muscle activity in patients with chronic neck pain is complex and may not be fully attributable to just one pain theory (Hodges and Tucker, 2011).

Conservative treatment described in the literature as non-invasive and non-surgical treatment is the mainstay of CNP management (Verhagen et al. 2007). In accordance with the Oxford level of evidence (Howick et al. 2011), moderate quality evidence exists for immediate and short-term improvements in pain following manual therapy (Lluch et al. 2014, Miller et al. 2010, Schomacher and Falla 2013, Ylinen 2007). However, it has limited benefits in maintaining such effects long-term (Miller et al. 2010). Similarly, there is moderate quality evidence for the short and long-term benefits of active exercise conducted as a stand-alone treatment for CNP symptoms. Exercise has shown to negate the strength deficits seen in patients with CNP, stimulate morphological adaptations and provide pain relief (Childs et al. 2008, Hakkinen et al. 2003, O’Riordan et al. 2014, Salo et al. 2012, Ylinen et al. 2007). Combining manual therapy and exercise in a multi-modal rehabilitation program, provide greater
improvements in clinical outcomes including increased strength, reduced pain and patient perceived disability (Childs et al. 2008, Falla et al. 2013, O’Leary et al. 2011). Due to the multi-dimensional nature of pain and large range of physical and psychological alterations associated with CNP, multi-modal treatment approaches are superior to unimodal methods.

Previous studies investigating exercise in CNP rehabilitation have been performed using general resistance based programs (Falla et al. 2006a) or a CCF movement based program (Falla 2004b, Jull et al. 2009). These exercise interventions were performed in non-functional positions or using an apparatus that is not clinically convenient or for independent use. Conducting functional-based exercise has been found to improve outcomes for other musculoskeletal disorders (de Vreede et al. 2005, Lehtola et al. 2012). Therefore, it is important to determine if similar benefits can be seen in treating people with chronic neck pain. To the authors knowledge, the effects of a specific and targeted resistance exercise regime that aims to recruit the DNFs in a functional position in people with CNP has not been investigated. In this regard, the “FLEXOR” device, a novel strengthening tool was designed for this intended purpose. The “FLEXOR” device was designed to provide targeted, individualised and progressive resistance type exercise to the deep cervical flexors during a functional cranio-cervical flexion movement.

High quality research evidence is needed to inform and implement evidence based practice (Mc Curtin and Clifford 2015, Sackett 1996). Such high-quality research evidence requires an appropriate study design to answer the research question (Thompson et al. 2016). To investigate the effectiveness of new treatment modalities, randomized controlled trials (RCT) are recognized as the gold standard of study designs (Arain et al. 2010, Cartwright 2010, De Serres et al. 2013)). The successful development and implementation of an RCT can encounter many barriers from a design perspective and thus, it is prudent to undertake pilot work prior to fully engaging in a large study (Scurlock-Evans et al. 2014, Tickle-Degnen 2013). Therefore, pilot RCTs are recommended to investigate the feasibility of the study design in the intended population and highlight and any barriers to the success of a larger scale RCT. Conducting a pilot RCT requires an assessment of the feasibility of the study design, including recruitment processes and rates, randomisation processes,
appropriateness of proposed outcome measures, monitoring adherence and minimising drop-out rates, which have all been previously identified as obstacles to conducting adequately powered RCTs (Avery et al. 2014).

In this way, the primary aim of this pilot RCT was to investigate the feasibility of a study design for a targeted resistance exercise intervention, using “FLEXOR” as part of a usual care physiotherapy intervention in patients with CNP. The secondary aim was to investigate if the inclusion of “FLEXOR” in usual care physiotherapy, resulted in significant improvements in strength, pain relief and perceived disability, over and above results from usual care physiotherapy for CNP alone, with an aim to informing future larger scale randomised controlled trials.
6. 2 Methods

6.2.1 Study Design

This was a multi-centre pilot randomised controlled trial. Data was collected from December 2013 to April 2015. The protocol and development of the study design was compliant with the CONSORT statement (Moher et al. 2009). Ethical approval was sought and obtained from the relevant Clinical Research Ethics Committee and Health Service Executive Ethics Committees prior to the commencement of data collection (Appendix H and I).

6.2.2 Participants and Randomisation

Individuals aged over 18 years, attending one of five Health Service Executive (HSE) physiotherapy departments and private practice settings for symptoms of chronic non-specific idiopathic mechanical neck pain\(^8\) were invited to participate by their physiotherapist. Eligibility criteria were developed in line with previous research in the area (Salo et al. 2012, Ylinen et al. 2003). Individuals were excluded if diagnosed with fibromyalgia (Haikkenen et al. 2004), cervical spine disorders including disc prolapse, spasmodic torticollis, peripheral nerve entrapment, severe psychiatric illness or any condition that may prevent physical loading such as pregnancy (Andersen et al. 2011, Chiu et al. 2005, Stewart et al. 2010.). Individuals were also excluded if their neck pain was attributed to any inflammatory or infectious disease, displayed neurological symptoms such as pins and needles or altered sensation in the neck, arms or shoulders, bilateral arm pain, signs and symptoms of vertigo or balance problems with nausea or dizziness (Ylinen et al. 2003). Individuals who had been participating in any similar neck rehabilitation exercise programme in the previous 12 months were excluded due to possibility of contamination (Salo et al. 2012). The attending department physiotherapist screened patients for eligibility. All participants received an information leaflet (Appendix J) about the study and provided written informed consent (Appendix K) before taking part. Following screening for

\(^8\) Chronic idiopathic non-specific mechanical neck pain: defined as pain of insidious onset that persists beyond normative tissue healing time, defined as three months in the anatomical area of C1-7 and surrounding musculature (Ehrlich, 2003)
eligibility and consent, contact information was forwarded to the research investigator and a baseline assessment organised.

After the baseline assessment, eligible participants were randomly allocated to either the Usual Care (UC) or “FLEXOR” group, using a sealed brown envelope system. The creation of the random allocation sequence generator was conducted by an independent mediator, otherwise uninvolved with the study (Hudson and Ryan 2010, Stewart et al. 2007).

6.2.3 Primary Outcome Measure

Feasibility of the study design was appraised by recording and measuring:

i) Referral rates: this study was a pilot study and aimed to recruit at least 50% of the total participants required for an adequately powered RCT study within a 12-month period (Avery et al. 2014). Referral rates, based on numbers of participants who were referred to the trial and went on to receive the intervention during the recruitment period were monitored (Tickle-Degnen 2013). This was completed by the principal investigator to assess recruitment processes and test the appropriateness of recruitment methods.

ii) Dropout or attrition rates: As per the Centre for Evidence Based Medicine for RCT quality appraisal, maintaining attrition rates below 20% was desired (Charlesworth et al. 2013). Drop-out rates were monitored following acceptance into the study and undergoing the baseline assessment. The randomisation process was also monitored to highlight any issues with the correct implementation of the randomisation and allocation processes.

iii) Adherence to an exercise intervention was monitored through self-completed exercise diaries. In line with previous CNP research, adherence of at least 2.1 out of 3 times per week (> 70%) was required at a minimum to be considered successful (Bronfort et al. 2003) (Appendix O).
iv) Safety issues or adverse reactions/effects: reported adverse effects, injuries sustained or safety issues highlighted from the intervention and device were recorded (Tickle-Degnen 2013).

6.2.4 Secondary Outcome Measures

Secondary objective outcome measures included isometric strength and Longus Colli (LCo) CSA to assess objective changes in the musculature following the intervention. In addition, subjective outcomes included pain (visual analogue scale – VAS) and patients perceived disability (neck disability index – NDI). All participants were assessed at two time points: prior to participation (baseline) and eight weeks later (immediately after completing the intervention). A questionnaire was also administered to ascertain demographic details including age, weight, height, pain duration, employment status and medication consumption. The main investigator made weekly telephone contact (SMS or phone call, according to preference of each individual participant). This was a means of monitoring weekly subjective updates by participants, voicing any adverse reactions and was supplementary to their weekly or biweekly physiotherapy appointments (physiotherapy scheduling was dependent on both patient and therapist availability, however all patients received between 4 and 7 physiotherapy sessions). Participants using “FLEXOR” were advised to discontinue exercise in the presence of any adverse effects. They were also advised to contact a member of the research team immediately or to inform their physiotherapist.

6.2.4.1 Isometric Strength

The average of three maximal voluntary contraction efforts (MVCs) during isometric CCF was calculated (Strimpakos et al. 2004a), using a J-tech Power Trek hand held dynamometer (HHD) (Midvale UT, USA). Due to the movement conducted and equipment used, it is difficult to rule out activity from the superficial muscles (Strimpakos and Oldham 2001). However, efforts were made to minimise variation as patients were shown and asked to practice the movement three times prior to MVC testing. The assessments were conducted in a sitting position to allow replication of the required exercise intervention using “FLEXOR”. Participants sat with their back
supported in a chair, feet on the floor and hands across their chest but unrestrained. Participants were instructed to bring their “chin to their chest” in a maximal effort against the resistance of the investigator. This method has established reliability for measurement of neck flexor muscle strength, with intra-rater reliability of between 0.63-0.98 and inter-rater reliability of 0.88 (Agre et al. 1987, Ylinen and Ruuska 1994).

6.2.4.2 Cross-Sectional Area of the Longus Colli

With the subject in supine lying, a relaxed state real-time ultrasound image (RT-US) of the deep cervical flexor muscle Longus Colli was taken using a LOGIQ e GE Healthcare ® (USA) ultrasound machine. Anatomical reference marks were used as per previous research (Cagnie et al. 2009, McGaugh and Ellison 2011, O’Riordan et al. 2016). Real-time ultrasound for CSA measurement of the Longus Colli has established reliability with intra-rater reliability of 0.88-0.98 and inter-rater reliability of more modest figures of between 0.68-0.74 (Javinshir et al. 2010, O’Riordan et al. 2014). Its use as an outcome measure following a resistance exercise intervention for the DNFs has not been reported extensively in published literature to date. To the knowledge of the authors, only one other study has reported the use of RT-US as an outcome measure following an exercise intervention (Javanshir et al. 2015).

6.2.4.3 Subjective Assessments

The VAS was used to assess pain (Appendix M). The VAS has an established reliability for use in acute and chronic pain with test-re-test reliability index in literate individuals of 0.94 (Hawker et al. 2011). Perceived disability was assessed using the Neck Disability Index. The NDI is a 10-item scale, which reports functional perceived disability due to neck pain symptoms (Appendix N). The index includes seven questions related to activities of daily living (ADLs), two related to pain and one question related to concentration. Subjects are asked to pick from the six statements given, which reflected their situation closest. The NDI has a proven test-re-test reliability with intraclass correlation coefficients (ICCs) of 0.82-0.89 (Mc Carthy et al. 2007) and a minimal detectible change (MDC) of 20% (Cleland et al. 2008).
6.2.5 Intervention

6.2.5.1 Usual Care (UC) Group

The Usual Care (UC) group received usual physiotherapy management as determined by their chartered physiotherapist throughout the duration of the trial. Physiotherapy treatment provided was documented as per local policy and access to same was given to the research investigator. This information was grouped into manual therapy (including passive mobilisation, soft tissue release, trigger point release), dry needling, electrotherapy, education, active exercise (DNF recruitment, postural exercises (usual care group only)), stretching or “other” to determine a typical “usual care physiotherapy” intervention. Details of usual care components by percentage patients who received each modality in both groups can be seen in Table 6.2 below.

6.2.5.2 “FLEXOR” Group

The “FLEXOR” group continued to receive usual care physiotherapy as per their physiotherapist’s treatment plan (with the exception of any active exercise) and additionally received a “FLEXOR” device to perform specific targeted resistance exercise programme.

The “FLEXOR” device is a novel strengthening tool designed to provide specific resistance training to the deep neck flexor muscles in individuals with CNP. The “FLEXOR” device (Figure 1.1), sits on the neck. It features a chin bracket that extends outwards and is collapsed by the wearer against a pre-tensioned spring to provide a resistance to movement (measured in Newton’s). Feasibility and safety of use were first established in a healthy population (Chapter 5). A FITT (frequency, intensity, type, time) exercise principle for CNP was determined through a comprehensive systematic review of the literature pertaining to active exercise in the treatment of CNP (Chapter 3). As per these newly established FITT guidelines, the FLEXOR group conducted three sets of 10 repetitions (chin bracket collapses) three times a day, three times a week. Thus, an individualised weekly programme included approximately 10-20 minutes of resistance exercise, three times weekly. As identified
in the systematic review, interventions lasting a minimum of six weeks and up to one year resulted in beneficial outcomes (Chiu et al. 2005, O’Riordan et al. 2014, Salo et al. 2012, Ylinen et al. 2004). A minimum of six weeks’ resistance work is required for possible muscle hypertrophy (Schoenfeld 2011). Thus, an intervention period of eight weeks’ duration was used in this study. This timeline for intervention was also aligned clinically with physiotherapy treatment times for patients with CNP, as determined through direct contact with practising chartered physiotherapists.

The baseline resistance setting was established for each “FLEXOR” participant using fifty percent of the average MVC identified at baseline assessment. This force was converted to a number on the “FLEXOR” device using an algorithm, (minimum 20N to a maximum 45 N) and the appropriate spring setting applied. Individuals in the “FLEXOR” group were educated on a one to one basis in the correct use of the “FLEXOR” device by the assessor. “FLEXOR” users were responsible for keeping an exercise diary throughout the eight-week intervention, to monitor adherence.
6.2.6 Sample Sizes

This was a pilot study, a version of a main study, conducted with the primary aim of testing feasibility of the study design for use in a larger RCT. In accordance with a review by Arian et al. (2010), a pilot RCT need not report typical sample size calculations but focus on feasibility of the study design components (e.g. recruitment rates, follow up assessments) as was the case in the current study. However, in the same review it was noted that sample size calculations are still commonly reported in pilot studies to ensure adequate numbers to examine critical parameters (Arian et al. 2010). In lieu of this, sample size calculations were estimated and based on previous studies in the subject area (Falla et al. 2006, Hudson and Ryan 2010, Jull et al. 2009,) as well as detecting a minimum mean difference of 10N in isometric strength between the “FLEXOR” group and the Usual Care group determined through results of the healthy participant trial (Chapter 5). Allowing for a 25% dropout rate and assuming a standard deviation (SD) of 11.7N (as per a healthy population study Chapter 5) and an alpha level of 0.05, a desired power of 90% would require n=46 participants (23 per group). Based on previous research (Cleland et al. 2008) a 10N change in isometric strength is deemed statistically and clinically meaningful. This study aimed to recruit 50% of the sample size required to power a larger trial within the recruitment timeframe of twelve months, to ensure that as a pilot study it was suitably powered (Tickle-Degnan, 2013).

6.2.7 Statistical Analysis

Data was analysed using SPSS version 22.0 and analyses were conducted on an intention to treat basis (Gupta 2011). Data was assessed for normality and appropriate parametric or non-parametric equivalent tests for normal and non-normally distributed data, respectively, were performed. Paired sample T-tests were conducted on within group data to determine pre-post intervention changes in mean scores for all normally distributed measures. Two-way analysis of covariance (ANCOVA) was performed for each of the patient related outcomes with respect to group (Usual Care or “FLEXOR”) and time (pre-post) as factors. At the end of the pilot RCT effect size and power calculation were conducted using mean change in the isometric strength (measured in Newtons), using software program G-power version
3.1. An effect size of greater than 0.2 and less than 0.5 was regarded as small, between 0.5 and 0.8 medium and $\geq 0.8$ as large (Cohen 1977). An alpha level of 0.05 was set for all tests. This information was required to inform a larger RCT. Exercise adherence was calculated as a percentage and frequency based on expected total number of exercise sessions to be completed, thus, ensuring against falsely inflated adherence levels. Relationships between outcomes were assessed using the appropriate Spearman’s (non-normally distributed data) or Pearson correlation tests (for normally distributed data), for resultant r values and direction of relationship, if any.
6.3 Results

Participant enrolment, randomisation and retention flow is presented in Figure 6.1 consort flow chart (Moher et al. 2009). Thirty-two (n=32) patients with chronic neck pain were assessed for eligibility and twenty-six (n=26) were randomised into groups. Baseline demographic details and baseline secondary outcome measure values for all participants are displayed in Table 6.1 below.
CONSORT 2010 Flow Diagram

Figure 6.1: Participant flow and retention.

*Adverse Reaction to exercise refers in this instance to an exacerbation of CNP symptoms including crevice-genic headaches, which ceased immediately by not using “FLEXOR”.

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Table 6.1: Baseline characteristics of the “FLEXOR” group and UC group. Values represent mean & standard deviation. There were no statistically significant differences between groups at baseline (p>0.05) for all above measures.

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>“FLEXOR”</th>
<th>Usual Care (UC)</th>
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<tbody>
<tr>
<td>(N=26) 15 F, 11 M</td>
<td>(N=14) 9 F, 5M</td>
<td>(N=12) 6F, 6 M</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>48.58 ±14.47</td>
<td>49.64 ±6.4</td>
<td>47.33 ±16.62</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.32 ±13.29</td>
<td>75.31 ±15.23</td>
<td>73.35 ±11.29</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.69 ± 0.12</td>
<td>1.68±0.11</td>
<td>1.71± 0.13</td>
</tr>
<tr>
<td>Pain Duration (years)</td>
<td>5.39 ±9.98</td>
<td>3.64 ±3.28</td>
<td>7.42 ±14.33</td>
</tr>
<tr>
<td>VAS (Pain) Baseline</td>
<td>49.62 ±14.28</td>
<td>51.07 ±15.21</td>
<td>47.92 ±13.55</td>
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<tr>
<td>VAS (Pain) Post Intervention</td>
<td>24.88±15.95</td>
<td>20.49±15.75</td>
<td>30.00±15.22</td>
</tr>
<tr>
<td>Disability NDI (%) Baseline</td>
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<td>38.07±15.23</td>
<td>40.33±18.78</td>
</tr>
<tr>
<td>Disability (NDI %) Post</td>
<td>25.23±17.22</td>
<td>20.71±17.16</td>
<td>30.50±16.42</td>
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<tr>
<td>Isometric Strength MVC (N) Baseline</td>
<td>65.13±11.22</td>
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<td>67.09±12.83</td>
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<tr>
<td>Isometric Strength VC (N) Post</td>
<td>86.04±18.66</td>
<td>91.19±22.55</td>
<td>80.02±10.83</td>
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<tr>
<td>CSA LCo Left Baseline (cm²)</td>
<td>0.86±0.14</td>
<td>0.86±0.15</td>
<td>0.86±0.15</td>
</tr>
<tr>
<td>CSA LCo Left Post (cm²)</td>
<td>0.87±0.15</td>
<td>0.88±0.14</td>
<td>0.87±0.14</td>
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<td>CSA LCo Right Baseline (cm²)</td>
<td>0.86±0.15</td>
<td>0.85±0.15</td>
<td>0.86±0.15</td>
</tr>
<tr>
<td>CSA LCo Right Post (cm²)</td>
<td>0.88±0.14</td>
<td>0.88±0.15</td>
<td>0.87±0.14</td>
</tr>
</tbody>
</table>
6.3.1 Feasibility of Targeted Resistance Exercise for the DNFs

A member of the “FLEXOR” group reported an adverse effect to the intervention, which was documented and led to the one study dropout. These adverse effects included a subjectively reported exacerbation of CNP symptoms, including a cervico-genic headache, which reduced to baseline levels following the immediate disuse of “FLEXOR” and cessation of the exercise intervention. This indicated an attrition rate of 4%. Overall, exercise adherence was calculated at 93%, indicating that patients in the “FLEXOR” group conducted the exercise intervention on average 2.8 times a week (n=22.4/24 times over the eight-week period). Although, not initially investigated within the aims of this study, it was found that individuals (n=3) who used the device at higher levels of resistance (i.e. ≥ level 15 on the device, equating to 35N or above), required frequent replacement of the device throughout the duration of the intervention (between 1 and 3 times), due to spring failures and chin bracket breakages.

Sub-categorisation of physiotherapy interventions provided to all participants are presented in Table 6.2. Each participant (n=26) received education from their physiotherapist, variations in manual therapies were provided (mobilisation, manipulation, myofascial trigger point therapy, dry needling). Overall, there was a similar distribution in modalities used by physiotherapists in the management of both groups, as only five different physiotherapists were involved in the management of the participants involved in the trial. Those in the “FLEXOR” group did not receive any additional deep neck flexor recruitment exercises, but could conduct static stretching including stretches for the upper fibres of Trapezius, Sternocleidomastoid and the Rhomboid muscles.
Recruitment rates were significantly lower than anticipated and the recruitment period was extended for a further six months beyond the initial twelve-month period. The recruitment rate, based on number of final participants for the period of recruitment, was 1.44 participants per month. As noted, sample size calculations prior to the pilot RCT were undertaken based on a change in isometric strength of 10N in a healthy population following an 8-week exercise intervention using “FLEXOR”. This indicated that for 90% power, sample sizes of 23 participants per group (n=46) were required. Therefore, as the aim of the feasibility study was to recruit 50% of this figure during the recruitment period, this was achieved.

Table 6.2: Conservative Physiotherapy modalities provided by Chartered Physiotherapists (distribution of modality across groups as a percentage of the group figures as identified by patient records).
6.3.2 Between Group Results

There were no statistically significant differences between both groups for any patient related outcome at baseline (p > 0.05). Mean within-group differences (pre-post intervention) for all patient related outcomes are presented in Table 6.3. Both groups displayed significant changes in all secondary outcome measures including isometric strength, pain and perceived disability, with the “FLEXOR” group performing better for all measures. The “FLEXOR” group showed a mean increase in isometric strength of 27.74N ±17.70 N (p<0.01), compared to the UC group who had a mean increase of 12.94±6.49 (p<0.01) (difference between groups p=0.01). (Figure 6.2)

![Graph showing isometric strength changes](image)

**Figure 6.2:** Mean isometric strength changes pre-and post intervention for “FLEXOR” group and UC group.

*= Significant within-group difference pre-post intervention*
Both groups also showed significant pre-post intervention (within-group) reductions in perceived pain scores (UC group p<0.001, “FLEXOR” group p<0.001), (Figure 6.3). There was also a significant difference between-groups post intervention of p=0.02, with the “FLEXOR” group performing significantly better with a mean improvement of 30.58mm on the VAS.

Figure 6.3: Mean pain scores (VAS) pre-and post-intervention for “FLEXOR” group and UC group.

* = Significant within-group difference pre-post intervention
Similarly, both groups had a within-group pre-post intervention reduction in perceived disability at the end of the eight weeks, with a statistically significant reduction in disability index score for the “FLEXOR” group (17.36±13.47%) (p<.001), and UC group (9.83±8.72%), respectively. This reduction was also clinically significant (Jacobson and Truax 1991). The difference in NDI score between groups post intervention was not significant (p=0.08).

Figure 6.4: Perceived disability NDI (%) scores pre-and post intervention for “FLEXOR” group and UC group.
6.3.3 Cross Sectional Area

Measures of CSA of the left and right LCo as determined using RT-UI, demonstrated no differences between the groups at baseline (p > 0.05). Post-intervention measures showed a mean change of $0.02 \pm 0.04 \text{cm}^2$ for the left LCo, $0.03 \pm 0.02 \text{cm}^2$ for the right LCo for the “FLEXOR” group (p=0.04, 0.01 respectively). Mean CSA changes of $0.09 \pm 0.20 \text{cm}^2$ (p=0.15) and $0.01 \pm 0.20 \text{cm}^2$ (p=0.05) for the left and right LCo in the UC group were measured respectively. These differences were not significant between the groups post intervention (p=0.29, p=0.13, for left and right LCo, respectively).

Figure 6.5: CSA of the Left Longus Colli (cm$^2$) pre-and post intervention for “FLEXOR” group and UC group.
Figure 6.6: CSA of the Right Longus Colli (cm$^2$) pre-and post intervention for “FLEXOR” group and UC group.
<table>
<thead>
<tr>
<th>Outcome</th>
<th>“FLEXOR”</th>
<th>Usual Care</th>
<th>Between Group Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Diff &amp; SD</td>
<td>95% CI</td>
<td>p value</td>
</tr>
<tr>
<td>Isometric Strength (MVC, N)</td>
<td>27.74±17.70</td>
<td>17.52-37.96</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pain (VAS)</td>
<td>30.58±13.58</td>
<td>22.73-38.42</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Perceived Disability (NDI%)</td>
<td>17.36±13.47</td>
<td>9.58- 25.14</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LCo CSA Left (cm²)</td>
<td>0.02±0.04</td>
<td>0.001-0.43</td>
<td>0.04</td>
</tr>
<tr>
<td>LCo CSA Right (cm²)</td>
<td>0.03±0.02</td>
<td>0.01-0.04</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Table 6.3: Primary and secondary patient related outcome measures at baseline and post intervention data for the UC group & “FLEXOR” groups. Mean difference between baseline and post-intervention assessments, Standard Deviation, p value and 95% confidence intervals of the change in primary and secondary outcomes measures and between group p value.
6.4 Discussion

This was the first study of its kind to investigate the feasibility of the proposed study design and effectiveness of a targeted resistance exercise intervention for the deep neck flexors using the novel strengthening tool for the deep neck flexors, “FLEXOR”. As this was a pilot study, the preliminary results highlight positive indications for the inclusion of a targeted resistance programme for the deep neck flexors as part of a multi-modal usual care physiotherapy intervention. Further investigation is therefore suggested to establish if such an intervention can afford greater benefits for increase increased strength, reduced pain and disability for patients with chronic non-specific neck pain above that currently offered from usual care practices alone.

Issues related to the primary outcome of study design feasibility, in particular referral rates were highlighted throughout the course of the study. These require appropriate attention for future larger clinical trials (Tickle-Degnen 2013). Recruitment rates achieved the required 50% for this pilot RCT using the original estimates but only after the recruitment period was extended beyond the initial one-year period (by six months). Further investigation is warranted to identify the causes of low referral in this pilot study so that similar issues can be prevented in future larger scale clinical trials (Scurlock-Evans et al. 2014). Research has found that recruitment in RCTs and investigations using novel therapy adjuncts/devices can struggle to reach adequately powered sample sizes for reasons including: trial design, a lack of pre-existing results from a patient population and issues related to the therapy adjunct itself (Tickle-Degnen 2013). Further investigation with both participants and physiotherapists involved in this trial is required to fully ascertain reasons for the below expected recruitment. Although not specifically an original aim of this feasibility trial, it was highlighted through subjective feedback that the mechanical robustness of the “FLEXOR” device may have affected patient satisfaction with the device and trial participations and/or referral rates by clinicians to the research trial.

An exercise adherence rate of 92.85% (on average 2.8 t/week or approximately 22.4 of the 24 required exercise sessions completed) was achieved in line with the study
This high exercise adherence rate can be viewed positively to indicate that this programme is a feasible way for patients with CNP to participate in an active exercise programme independently. Maintaining a weekly exercise diary and weekly communication has been shown to increase patient adherence to an exercise intervention (Jordan et al. 2010) which may explain the high exercise adherence rates seen in this current study.

Only one adverse reaction was reported, leading to one dropout. This was most likely due to an increase in exercise induced muscle soreness (George et al. 2008). This equates a low dropout rate of 4%, this is in line with similar previous studies (Ylinen et al.) and much lower than other reported research in a similar population (Bronfort et al. 2001). The adverse effects can be classified as minor given that symptoms returned to baseline once the exercise programme using the “FLEXOR” device was discontinued. No other safety issues or injuries were identified or reported throughout the interventions. Andersen et al. (2014) highlighted a similar increase in pain post-strengthening exercise in their strength training group, during the early stages of a ten-week exercise intervention therefore, it could be postulated that similar reactions from strength training using “FLEXOR”

Secondary outcome measures of this pilot RCT, indicated immediate changes in strength for the “FLEXOR” group. Positive improvements were also seen in the UC group. Despite baseline similarities, those in the “FLEXOR” group increased their mean isometric strength by double that of their UC group counterparts (27.74N and 12.94N, respectively). The increase in isometric strength for the “FLEXOR” group in this pilot RCT, following a resistance exercise program are consistent with findings in previous research in the area (Andersen et al. 2011, Bronfort et al. 2001, Falla et al. 2013 Ylinen et al. 2003). Moderate quality level evidence exists for the benefits of manual therapy for immediate hypoalgesia (O Leary et al. 2007a) and for increasing isometric strength (Damgard et al. 2013, Ludvigsson et al. 2015) in neck pain populations. Likewise, moderate quality evidence exists for the inclusion of active exercise in a chronic neck pain
population for similar benefits (Childs et al. 2008, Gallego-Izquierdo et al. 2013, Falla et al. 2013). Therefore, mean increases in strength in the UC group post-intervention are unsurprising and may be partly explained by the inclusion of manual therapy and some active exercise as part of the usual care physiotherapy intervention (33.33% of patients received active exercise). It is important to note that 86% of patients in the “FLEXOR” group and 84% of those in the UC group received manual therapy, only 33.33% of the UC group received a form of active exercise, whilst all members of the “FLEXOR” group received active resistance exercise. Research has shown that in similar CNP populations, motor control (including motor unit recruitment for force output) (O Leary et al. 2007a) is not spontaneously improved by manual therapy alone (Lluch et al. 2014). Therefore, the active exercise component in the “FLEXOR” group may explain the larger increases in strength and additional benefits seen in the “FLEXOR” group. However, as sample sizes were small and due to the pilot design of this RCT, these results must be interpreted with caution. Interestingly as there was no significant difference between groups for LCo CSA increases post-intervention (Table 6.3), the larger increase in isometric strength seen in those in the “FLEXOR” group may be attributable to a neural adaption mechanism from motor control enhancement, coupled with a reduction in nociception from active exercise (Nikander et al. 2006, Rodriquez and Burns 2008) and increased motor neuron recruitment (Falla et al. 2006a, Falla et al. 2013, Jull et al. 2009), however, further investigation is required to confirm same.

Both the “FLEXOR” and UC groups reported a mean decrease in pain of 3.05±1.36cm (p<0.001) and 1.79±1.63cm (p<0.001) on the VAS scale, respectively. Research indicates a change in scores of at least 1.1cm and 1.3 cm on the VAS is statistically and clinically meaningful (Hawker et al. 2011). These changes are deemed clinically meaningful for both groups in the current study, i.e. it could be suggested that the treatment can have a practical and noticeable effect on daily life (Jacobson and Traux 1991). On average, the “FLEXOR” group reduced their NDI score by 27% (p<0.001). More modest improvements were seen in the UC group with mean postintervention reductions of 9.83% (p=0.02). Whilst still significant and clinically meaningful, the reduction was less than that of the “FLEXOR” group. A reduction of between 1.6% (Vos
et al. 2008) to 10.2% and above (Cleland et al. 2008) is deemed clinically significant. In this regard, it may be plausible to suggest that there may be additional biopsychosocial benefits for patients in using the “FLEXOR” device or a self-administered exercise tool/intervention (Salo et al. 2012). Self-management in chronic conditions is associated with improved outcomes in self-efficacy and aspects of health status (Barlow and Sheasby 2002). The incorporation of “FLEXOR” as an additional component of usual care physiotherapy for chronic neck pain rehabilitation for its benefits in day-to-day patient function and management should be further investigated in future studies, as it was outside the scope of the current pilot RCT.

Undertaking exercise in a targeted and functional manner, such as during cranio-cervical flexion (i.e. similar to the movement elicited using “FLEXOR”) may result in correct movement pattern and motor unit acquisition (Falla et al. 2013; Jull et al. 2007, O’Leary et al. 2007;). Low load endurance exercise interventions which targeted the deep cervical flexor muscles through cranio-cervical flexion, have also resulted in increased activity of the deep neck flexor muscles, and reduced activity of superficial muscles, (Falla 2003a, Falla 2004a, Falla 2006, Jull et al 2004b). As the resistance component of this treatment intervention included CCF, it could be hypothesised that increased motor neuron output from the deep cervical flexors, resulted in increased isometric strength and reduced pain scores in the “FLEXOR” group. This is supported by previous research, which suggests that a neural rather than peripheral adaption to resistance exercise occurred in similar populations over a similar timeframe (Folland and Williams 2007). This may also help explain the larger increase in strength seen in the “FLEXOR” group compared to the Usual Care (UC) group. Results observed from measuring the CSA of the LCo muscles would also suggest that neural and peripheral adaptations were in occurrence during the intervention (Gabriel et al. 2006).

Participants of the current pilot RCT had baseline LCo CSA figures below normative healthy control figures (O’Riordan et al. 2016 Chapter 4). Baseline CSA figures of LCo in both groups was 0.86cm² and are in keeping with previously published reports of CSA figures of the same muscle in patients with CNP (Javanshir et al. 2011a). A prospective based study would be required to determine if this difference CSA LCo was
a cause or effect of chronic pain. This would also provide further insight into pain adaption theories and models of altered muscle recruitment patterns previously posited (Javanshir et al. 2015, Lund et al. 1991). Post-intervention CSA figures indicated an increase in the left and right LCo in the “FLEXOR” group (p=0.04, 0.01 respectively) and an increase in the right LCo CSA for the UC group (p=0.05).

Previous reliability tests using the same measuring protocol for RT-UI of the LCo indicated a minimum detectable change of 0.30 cm$^2$ and a standard error of measurement of 0.11cm$^2$ for the LCo (O’Riordan et al. 2016). This indicates that the changes in CSA identified in this study may be due to measurement error rather than true muscle hypertrophy, as the change in pre-post measurements is considerably less than the minimum detectable change outlined above. Between group mean changes from measures of Longus Colli CSA left and right were not statistically significant (p=0.29, 0.13 respectively). It is important to note that LCo measurements were coded by left and right LCo in this study and not by dominance. Javanshir et al. (2011a) reported different LC measurements for dominant and non-dominant LCo CSA in patients with CNP, with the dominant LCo being smaller. It is possible therefore that the asymmetry in measurement between left and right LCo CSA in this study is attributable to this size variation between dominant and non-dominant sides (Javanshir et al. 2011).

To the author’s knowledge, only one research study has previously examined the change in CSA of the LCo muscle following an exercise intervention. Javanshir et al. (2015) demonstrated a change in the CSA of the LCo (p<0.001, mean increase of 0.167cm$^2$) following a 10-week CCF exercise intervention in patients with CNP. Differences in exercise interventions used, exercise duration, equipment used, larger sample sizes, group demographics and baseline CSA figures may all account for the differences observed between the findings of this study and that of Javanshir et al. (2015). According to Rezasoltani et al. (2010) an increase of 2.2mm$^2$ (0.02cm$^2$) is considered the minimum increase in CSA for real change when measuring the cervical extensors. Hypertrophic changes to the Splenius Capitis, Semispinalis Capitis, Semispinalis Cervicis and Multifidus of up to 25% have also been reported following a 12-week resistance program in patients with CNP (Conley et al. 1997). Based on the findings by Javanshir et
al. (2015) it is important to note that true hypertrophy of the deep flexors is possible. However, it could be suggested that a longer exercise intervention using “FLEXOR” may be required to provide similar results and should be investigated as part of future research.
6.5 Limitations of Study Design and Considerations for Future Research

There are some limitations with this pilot RCT study design and outcome measures used, which should be addressed in future studies. It is recommended that future studies limit the confounding variables between groups, as this would provide considerably greater insight to the potential benefits of “FLEXOR” as part of usual care physiotherapy for patients with CNP. As this study design involved the use of usual care physiotherapy for all participants, there is inevitable variation between therapists and the care provided based on each individual participant’s presentation. However, reflective of existing practice, when recruiting from a clinical setting, standardising treatment is difficult and may not be appropriate as this would affect an individual’s right to individualised and best practice treatment.

Additionally, including a blinded assessor to perform the baseline and post intervention assessment would also reduce detection bias (Grimes and Schulz 2002). Due to the study design implemented in this current study, this was not possible. However, every effort was made to standardise all procedures. The primary researcher responsible for the investigation and assessments was a qualified chartered physiotherapist and had previous experience with the study design, assessment protocols and a high intra-rater reliability for use of real-time ultrasound for measuring the CSA of the Longus Colli, as well as using a hand-held dynamometer for measuring cervical flexor muscle strength. Furthermore, subjective outcomes including the NDI have standardised instructions for completion and reporting.

For future studies, it may be a consideration to include additional outcomes measures, such as electromyography (EMG) analysis (Strimpakos and Oldham 2001). This would assist in determining the direct changes a resistance exercise regime causes to the activation patterns of the cervical musculature. Including a means of measuring any changes in activity of the superficial muscle layer post resistance exercise intervention would assist in determining if true changes are seen in the deep cervical flexor muscles without requiring invasive direct techniques similar to the method used by Falla (2004a).
The primary purpose of this current pilot RCT study was to assess the feasibility of the study design. Therefore, timeline of physiotherapy provision and patient access did not allow for long-term follow-up of patient related outcome measures beyond the scope of the intervention. Ylinen (2007), indicate that conducting resistance exercise may need to be continued for up to a year to maintain beneficial effects of exercise. Including a period of follow-up with re-assessment at 3, 6 and 12 month intervals would determine if there were any medium or long-term benefits maintained from resistance training over and above that of usual care physiotherapy alone. Thus, future larger scales studies should consider a long-term follow-up of patients.

6.6 Conclusion

This pilot RCT was conducted with the primary aim of investigating the feasibility of a study design for a targeted and individualized resistance exercise intervention, as part of usual care physiotherapy for use in patients with CNP. A further secondary aim of investigating the effectiveness of the “FLEXOR” device as a means of providing resistance exercise to the deep neck flexors in patients with CNP was also included. Data collated from this pilot RCT indicate that changes to the recruitment processes are required for a larger RCT study design. The FITT exercise intervention using “FLEXOR” has good adherence rates, with only one mild adverse reaction noted. This pilot RCT also provided original contribution to the body of literature with secondary outcome data and results, which indicated that there are potential benefits from using “FLEXOR” as part of usual care physiotherapy including increased isometric strength and reduced pain. Future larger scale RCTs should be designed that address the issues with recruitment rates as identified in this current study and reduce confounding variables to increase the strength and generalisability of findings.
Chapter 7: Exploring Patient and Healthcare Providers’ Perceptions of Participation in a Research Study; a Mixed-Methods Study Design
7.1 Introduction

Researcher can encounter many barriers to the development and successful completion of good quality RCTs (Nilsagård and Lohse 2010, Parahoo 2000, Pollock et al. 2000). Pilot RCTs are recommended to evaluate the feasibility of a study design prior to the undertaking of the same trial design on a larger scale (Thabane et al. 2010). Following the completion of the pilot RCT, the views and opinions of the “FLEXOR” trial participants and physiotherapists can be evaluated through a follow up methods. As part of this research thesis, this was required to highlight any key areas of stakeholder (physiotherapists and patients) satisfaction or dissatisfaction in the trial and device design which may have positively or negatively influenced the success of the pilot RCT. Patient experience is increasingly recognised as an important factor in research as it and can positively or negatively impact outcomes of research and treatment. Therefore, obtaining and evaluating subjective feedback from those involved in the research process can be valuable in the guiding and developing future research needs.

Follow-up questionnaires have been shown to be an appropriate method of gaining pertinent information from patients or study participants, which can be further used to
supplement the results obtained via objective outcome measures (Tijou et al. 2010). This feedback from patients can be used to effectively inform evidence based research. Delivering evidence based and research based treatment options is considered a cornerstone of best practice for allied health professionals in the modern era (McCurtain and Clifford 2015). Evidence based practice is the integration of best research evidence with clinical experience and patient values. Evidence based decision-making and the delivery of evidence based treatment options are influenced by many factors, including the “four pillars of evidence” (Sackett 1996). These four pillars are; research evidence (the use of evidence-based therapies in clinical practice), practice evidence (the informing of treatment decisions or use of therapies based on clinicians or that of their colleagues and peers, sometimes in the absence of strong research evidence for a treatment), patient-centred evidence (the direct involvement of patients in their own treatment planning and goal setting, as well as patient characteristics informing treatment options, involving patients in the therapeutic process has shown to have longer lasting changes (Delsignore and Schnyder 2007) and contextual or pragmatic evidence (this pillar highlights the complex environment of the clinical setting and identifies that treatment options are often based on efficacy and speed of results from treatment, staff, resource and funding (Thompson et al. 2002). Clinicians purportedly aim to employ evidence based practice where possible to ensure a quality service to patients (Scurlock-Evans et al. 2014).

It is important to understand from the user and healthcare providers’ viewpoint, the positive and negative aspects of research participation, as well as identifying the barriers, if any, which existed for the participation in research involving a novel therapy adjunct such as “FLEXOR”. It is also an important means of highlighting any key areas in the trial design which would require amending for future research.

Undertaking research that acknowledges each of these four pillars is considered best practice (Thompson et al. 2002). As each pillar of evidence adds to the totality of evidence and supports the knowledge gained from research evidence. A comprehensive approach to research by recognising the four pillars of evidence successfully may increase the likelihood of translating research evidence findings into clinical practice. Therefore,
in line with conducting research which addresses the “four pillars of evidence” and further to the research evidence pillar which was investigated throughout this overall research thesis, the patient, practice and contextual pillars of evidence were investigated further in this study. The patient and healthcare provider’s experience of participation in this research project, which involved a novel therapy adjunct were explored through a follow-up mixed-methods questionnaire.

The primary aims of this follow-up questionnaire study were to obtain the opinion of physiotherapists and patients involved in the “FLEXOR” research trial on:

a) “FLEXOR” research study design (including assessments, referral and exercise intervention)

b) “FLEXOR” device design (fit for intended purpose)

The secondary aim was to investigate if any issues highlighted as part of the primary aims had a consequential effect on the success of a new research involving a novel therapy adjunct.
7.2 Methods

7.2.1 Study Design & Questionnaire Population
A descriptive study design using a follow up mixed-methods questionnaire was used to obtain level of agreement and opinion to address each of the study aims. Questionnaires were forwarded to 26 patients (n=14 “FLEXOR” group, n=12 Usual Care group) and five physiotherapists who participated in the “FLEXOR” research pilot RCT. They were each sent a copy of an invitation to participate, an information leaflet, consent form and questionnaire (Appendices Q, R, S, T, U), along with a return stamped addressed envelope. Participants were given written instructions and guidance on how to complete the questionnaire sections appropriate to them and were asked to return it at their earliest convenience.

7.2.3 Ethical Approval
The relevant ethical approval for the study was obtained from the Cork Research Ethics Committee (CREC) (Appendix P). Participants were assured of anonymity and that no information would be forward to third parties or used outside the scope of the research.

7.2.4 Instrumentation and Testing Procedure
A questionnaire was developed by the research team to obtain specific information about the “FLEXOR” research study, as no appropriate questionnaire was available. The questionnaire design was informed by research evidence, primary investigators’ experience and post-trial informal feedback from participants and physiotherapists involved with the study. It was piloted amongst health care professionals (n=8) and three academic staff with experience in questionnaire design to ensure content matched study aims, readability and understanding.
The final questionnaire (Appendix T and U) consisted of four sections with 18 items in total. The sections were broadly categorised according to the following components in keeping with the study aims;

1. Demographic details of the respondents.
2. Study design: assessment and recruitment processes and exercise intervention employed
3. “FLEXOR” device design and appropriateness for use by patients with CNP

Respondents were requested to provide their subjective level of agreement to statements using a five point Likert Scale, ranging from strongly agree to strongly disagree from left to right. Open ended questions asked for patient’s opinions on best and worst features of the “FLEXOR” device and participation in a research study.

7.2.5 Statistical Analysis

Numerical data was inputted to SPSS Version 22.0 file. Participants were grouped according to their trial group (“FLEXOR” or Usual Care). The data obtained from the physiotherapists was analysed separately. Descriptive statistics were used to describe the frequency of responses to each question and displayed graphically in tabular or bar-chart form.

7.2.6 Inductive Thematic Analysis

Answers to open questions underwent inductive thematic analysis using a framework outlined by Braun and Clarke (2006). Responses to the four open ended questions were read and re-read by the principal investigator and all initial ideas were noted. Early codes were generated in a systematic fashion across the data set, relevant to the number of repeated iterations of similar codes in each question. All relevant codes were then collated into potential themes. These themes were then checked in relation to the initial codes. Final analysis of themes relating back to research question saw the emergence of a least one theme per open ended question.
7.3 Results

A total of n=26 (15 females, 11 males) individuals who participated in the “FLEXOR” research trial were contacted. Of those, 18 responded with completed questionnaires, resulting in a response rate of 69%. Ten women (55.6 %) and eight men (44.4%) replied. A higher response rate was seen from the “FLEXOR” group (78.6%, n=11, while seven responses were received from the Usual Care (UC) alone group (44.4% response rate). Descriptive analysis of responses by participants indicated that half of the respondents to the participant questionnaire were aged between 45-54 years (27.8%, n=5), with five respondents aged between 25-44 (27.8%), while the remainder (44.4%, n=8) were >55 year of age.
### 7.3.1 “FLEXOR” Trial Participants; (pain duration, frequency, post physiotherapy improvement)

#### Table 7.1: Duration of Chronic Neck Pain Symptoms (Prior to participation in the “FLEXOR” research trial).

<table>
<thead>
<tr>
<th>Duration</th>
<th>“FLEXOR”</th>
<th>Usual Care</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency (n)</td>
<td>Percent</td>
<td>Frequency (n)</td>
</tr>
<tr>
<td>&gt; 3 months &lt; 1 year</td>
<td>3</td>
<td>27.3</td>
<td>0</td>
</tr>
<tr>
<td>1-2 years</td>
<td>2</td>
<td>18.2</td>
<td>4</td>
</tr>
<tr>
<td>2-3 years</td>
<td>2</td>
<td>18.2</td>
<td>0</td>
</tr>
<tr>
<td>3-4 years</td>
<td>1</td>
<td>9.1</td>
<td>1</td>
</tr>
<tr>
<td>5+ years</td>
<td>3</td>
<td>27.3</td>
<td>2</td>
</tr>
</tbody>
</table>

Frequency analysis of responses by question and group were conducted and Fisher’s exact tests were performed rather than chi-squared analysis as this test is more accurate in small sample sizes (i.e. expected frequency less than ten) (Mc Donald 2014). Results indicated that prior to participating in the trial, over half (54.5%, n=6) of the respondents to the participant questionnaire in the “FLEXOR” group experienced pain daily, a third (36.4%, n=4) frequently (3-5 times/week) and only 1 individual (9.1%) experienced pain occasionally (2-3 times/week). Following the trial, 18.2% (n=2) still reported daily pain, 27.3% (n=3) experienced pain occasionally (2-3 times/week), while more than half of the respondents to the participant questionnaire in the “FLEXOR” group (54.3%, n=6) rarely experienced pain. When compared to the UC group, majority (57.1%, n=4) of the respondents to the questionnaire experienced pain daily pre-physiotherapy intervention, while the remainder 42.9% (n=3) experienced pain frequently (i.e. > 3 times/week). Following the trial, the same percentage (57.1%, n=4) of UC patients experienced pain occasionally (< 3 times/week) and 42.9% (n=3) experienced pain rarely. Thus, indicating that subjectively pain improved for both groups during the “FLEXOR” intervention.
Fisher’s exact tests found no statistically significant difference in pain frequency between groups pre-or post-participating in the trial (p=0.77, p=0.51 respectively). Thus, both the UC and “FLEXOR” intervention afforded similar subjectively reported benefits in pain reduction.

The majority (69.9%, n=8) of “FLEXOR” participants who responded to the questionnaire agreed that physiotherapy helped their neck pain. In the UC alone group almost all respondents (88.4%, n=6) agreed that physiotherapy significantly improved their symptoms. Fisher’s exact test was insignificant for between group differences (p=>0.05).
7.3.2 Patient-centred Evidence; Patient Perceptions of “FLEXOR” Device and Trial design

The majority respondents to the questionnaire from the “FLEXOR” group participants strongly agreed that they understood the need to strengthen their deep neck muscles (72.7%, n=8). A high proportion (72.7%, n=8) also agreed that the “FLEXOR” device provided a feeling of independence in one’s own care and increased feeling of control. Over half also strongly agreed (63.4%, n=7) that they adhered fully to the “FLEXOR” exercise regime, while most 81.9% (n=9) were in agreement to feeling significantly stronger following the intervention. All but one participant in the “FLEXOR” group (91%, n=10) disagreed that using the “FLEXOR” device was time-consuming or inconvenient. Most “FLEXOR” group participants (90.9%, n=10) agreed that “FLEXOR” was easy to use. Similarly, 90.9% (n=10) of respondents felt that “FLEXOR” significantly improved the outcomes of their physiotherapy treatment. All participants (100%, n=11) agreed that they were satisfied with the results provided to them at the end of the trial and almost all were satisfied having participated in the research study (90.9%, n=10).

Below Figure 7.1 illustrates patients’ responses related to “FLEXOR” ease of use and comfort, as well as giving an indication of device robustness. According to most users, “FLEXOR” is easy to use (90.9%, n=10). Figure 7.2 also demonstrates patients’ opinions on the benefits of “FLEXOR” including a subjective increased feeling of being stronger (81.9%, n=9). The majority of “FLEXOR” patients also felt more in control of their care using “FLEXOR” (72.7%, n=8).
Figure 7.1: “FLEXOR” group participants’ perceptions of the “FLEXOR” device.

Figure Legend
A) “FLEXOR” was easy to use,
B) “FLEXOR” was comfortable to wear,
C) The “FLEXOR” device was robust.
Figure 7.2: Questionnaire respondents’ perceptions on the benefits of “FLEXOR”

A) My neck felt stronger after using “FLEXOR”
B) Using “FLEXOR” increased my feeling of control in my own care and self-management
C) Using “FLEXOR” improved my overall physiotherapy experience
D) I would recommend “FLEXOR” to family and friends with chronic neck pain
Figure 7.3: Outlines “FLEXOR” users’ opinions on the “FLEXOR” trial design, exercise intervention and subsequent satisfaction in participation in novel research.
7.3.3 Practice Evidence; Physiotherapists Responses

Four of the five physiotherapists responded to the questionnaire (80%), 75% (n=3) of whom had over 10 years’ clinical experience. Three (75%) of the physiotherapist respondents were aged between 35-44, while the remaining one (25%) was aged between 25-34 years. Two respondents (50%) indicated that they treated between 10-20 patients with CNP annually, while the other two treated between 20-30 and between 30-40 patients with CNP annually. On average, four to five physiotherapy treatment sessions were considered the norm when treating patients with CNP. Five physiotherapists involved in the “FLEXOR” research trial were contacted for feedback. An 80% response was obtained (3 women, 1 man). (The fifth physiotherapist was not available at the time of questionnaire distribution).

7.3.4 Practice Evidence; Physiotherapists Perceptions of the Role of Strengthening the Deep Neck Flexors and Role of “FLEXOR”

Frequency analysis was conducted on the responses provided by physiotherapists on their perceptions of the role of the deep neck flexor muscles in patients with CNP, the importance of strengthening and their experience with the research trial. The majority (75%, n= 3) of physiotherapists who responded to the questionnaire agreed that the deep neck flexor muscles are weak in patients with CNP and 75% (n=3) strongly agreed that strengthening of these muscles is an important component of physiotherapy rehabilitation (Figure 7.4). All respondents agreed that informing their patients of the research trial was worthwhile. However, half (50%, n=2) of the physiotherapists agreed that referring patients to the trial was time-consuming. There was also a spread in levels of agreement from “agree” (50%, n=2), to “disagree “(25%, n=1) that patient information from the trial was relayed in a timely fashion and aided the overall treatment plan (Figure 7.5). All respondents (100%, n=4) agreed that “FLEXOR” was fit for its intended use and fulfilled its intended role (Figure 7.5).
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Figure Legend

A) All patients with chronic neck pain have weak deep neck flexors

B) Deep neck flexors strengthening is an important part of a physiotherapy intervention for patients with chronic neck pain

C) “FLEXOR” is beneficial in the treatment of all patients with chronic neck pain

D) “FLEXOR” fulfills its intended role.

Figure 7.4: Physiotherapists Perception of Deep Neck Flexor Involvement and weakness in patients with chronic neck pain.
Figure Legend
A) It was worthwhile informing all my patients with chronic non-specific neck pain about the “FLEXOR” trial.
B) I was adequately informed about the trial design (recruitment, referral, eligibility)
C) Referring patients to the “FLEXOR” trial was time consuming
D) The exercise intervention used with “FLEXOR” was adequate to ensure strengthening of the deep neck flexors.

Figure 7.5: Physiotherapists Perception of Feasibility Study Trial Design
7.3.5 Inductive Thematic Analysis; Open Ended Questions

Following the inductive thematic analysis outlined in the methods section, at least one theme emerged for each open-ended question. Participants and physiotherapists responded to open ended questions on the best and worst features of the device and advantages and disadvantages of participating in the “FLEXOR” research study. Table 7.2 describes the early codes generated from analysis, indicating the frequency of repetition of each code. Themes which emerged and quotes from participants and physiotherapists related to these themes are given in Table 7.3. Given the limited number of physiotherapists (n=4), these themes must be interpreted with caution.
<table>
<thead>
<tr>
<th>Question</th>
<th>Participants (Frequency of Response)</th>
<th>Physiotherapists (Frequency of Response)</th>
</tr>
</thead>
</table>
| **Best Features of “FLEXOR”** | Ease of Use (72.7%, n=8)  
Comfortable (9%, n=1)  
Portable/Adjustable (9%, n=1)                                                        | Ease of use (75%, n=3)  
Compact (25%, n=1)  
Portable/Lightweight (25%, n=1)                                                              |
| **Worst Features of “FLEXOR”** | Broke Easily (36.36%, n=4)  
None (36.36%, n=4)  
Poorly Made (27.28%, n=3)                                                           | Broke Easily (50%, n=2)  
Large/Bulky (50%, n=2)                                                                                                     |
| **Advantages of Participation** | New information/education on neck pain (36.36%, n=4)  
Stronger (18.18%, n=2)  
Helped neck pain (18.18%, n=2)  
More inclined to be adherent to exercise (18.18%, n=2)  
New method to address neck pain (90.9%, n=1)  
Extra-assessments were beneficial to me (18.18%, n=2) | Opportunity to be involved in research (50%, n=2)  
New information on DNF training and rehabilitation possibilities (50%, n=2)  
Liked concept of device and trial (25%, n=1)  
Highlighted awareness of 3d printing for use in physiotherapy (25%, n=1) |
| **Disadvantages of Participation** | None (n=8, 72.7%)  
Time Consuming (n=1, 9.09%)                                                            | None (n=2, 50%)  
Too many other things happening in department to prioritise “FLEXOR” trial (n=1, 25%)  
Contributing factor to losing a patient due to adverse reaction to the exercise intervention (n=1, 25%)  
Arrived in department mid-way through recruitment drive and never fully committed to the study (n=1, 25%) |

Table 7.2: Frequency of responses from open-ended questions for both “FLEXOR” users and physiotherapists.
<table>
<thead>
<tr>
<th>Question</th>
<th>Theme</th>
<th>Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Best features of the device</strong></td>
<td>Ease of Use</td>
<td>“The “FLEXOR” device was easy to use and I found myself being more inclined to do those exercises than anything else given to me by my physio” -” FLEXOR” participant</td>
</tr>
<tr>
<td></td>
<td>Mechanical Robustness of “FLEXOR”</td>
<td>“FLEXOR” was easy to you, anywhere”- “FLEXOR” participant</td>
</tr>
<tr>
<td></td>
<td>New information on neck pain and exercise (CNP patients theme)</td>
<td>“Easy to use device for most patients –Physiotherapist</td>
</tr>
<tr>
<td></td>
<td>Opportunity to be involved in new research (Physiotherapist theme)</td>
<td>Device kept breaking, had to get 2 new devices sent to me during my time, which was inconvenient as it stalled my exercise regime” “FLEXOR” participant</td>
</tr>
<tr>
<td><strong>Worst features of the device</strong></td>
<td></td>
<td>“Device broke easily, which was inconvenient as my momentum with the exercise program was halted waiting for a new device to be delivered”- “FLEXOR” participant</td>
</tr>
<tr>
<td><strong>Advantages of participating in the research</strong></td>
<td></td>
<td>“I learned more about my condition and the need for strengthening and the need for activity, which I found really helpful and motivating”- “FLEXOR” participant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“I like the concept behind the product and enjoyed being part of the trial, some patients benefited from the treatment, however an adverse reaction to the exercise was a contributing factor to losing that patient, I believe”- Physiotherapist</td>
</tr>
<tr>
<td>Disadvantages of participation</td>
<td>No disadvantage perceived (Participants) Environmental</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>“I thoroughly enjoyed being part of the “FLEXOR” research, I didn’t see any disadvantage of it” “FLEXOR” participant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>“I found it difficult to give time to the “FLEXOR” trial and really pay attention to referring patients, there was a lot happening in the department at the time and sometimes I forgot about it”</td>
<td></td>
</tr>
</tbody>
</table>

Table 7.3: Themes established as per open ended questions by both “FLEXOR” participants and physiotherapists (Direct Quotes from “FLEXOR” users and physiotherapists.)
7.4 Discussion

This descriptive follow up study used a mixed-methods questionnaire to obtain feedback from patients and physiotherapists who participated in the “FLEXOR” research trial. In this way, three of the four pillars of evidence based practice (practice, patient-centred and contextual evidence) were investigated and used to inform future research directions for the “FLEXOR” device, as well as to highlight any key barriers to uptake of research involving a novel therapy adjunct. It should be noted that due to the nature of the study, responses were from the small sample sizes of the “FLEXOR” pilot RCT outlined in Chapter 6, the results must be interpreted with caution and related to the context of the “FLEXOR” research. The response rate to the questionnaire was 69% for patients, and 80% for physiotherapists, which is consistent with other research which reported ranges between 40% and 80% (Larmer et al. 2002, Reid et al. 2002). Previous research has indicated that sending personalised invitations to potential participants increases response rate (Heerwegh et al. 2005) which may account for the high response rate. A higher response rate from a small sample size population is viewed favourably, as it can provide more comprehensive feedback (Cole et al. 2014).
7.4.1 Patient Evidence; Trial Design

*Patient centred evidence,* relates to determining client’s values and treatment preferences. This is considered essential for the development of meaningful therapeutic partnerships and client valued outcomes (Rappolt 2003, Tickle-Degnen 2000), active engagement by patients in the treatment process, including goal setting and decision making and is largely encouraged (Hoogeboom *et al.* 2014). It is accepted that patients should be part of the treatment process; however, often patients are not included when decisions on treatment provision or service delivery are made (Bennett and Bennett 2000). Subjective information from patients on their illness and the meaning of which can offer important and unique perspectives which can inform a treatment decision (Cicerone 2005). Whilst a patient’s experience of their condition and treatment is subjective, the report of their experience provides pertinent objective data which can be used for informing evidence based treatment practice (Cicerone, 2005). In this regard, attaining subjective feedback from patients following their participation in the “FLEXOR” study is an important means of informing future studies and thus, informing the evidence based research process.

Results from the questionnaire indicated that patients who responded to the questionnaire felt they benefited from extra assessment and access to further outcome measures throughout their involvement in the “FLEXOR” research trial (Figure 7.3, Table 7.2 and 7.3). Results also identified that participants disagreed that it was inconvenient to undergo extra assessments, in addition to the time for physiotherapy (73.2%, n=8). It could be inferred, therefore that a study design, like that used during the “FLEXOR” pilot RCT involving additional contact time with researchers and extra assessment is not a negative aspect of or a barrier to uptake of research participation by patients.

It was hypothesised that the “FLEXOR” device would promote self-management of CNP symptoms through independent exercise. This was confirmed by the high
percentage of patients who agreed that using “FLEXOR” increased their feeling of independence in their own care (72.7%, n=8). Self-management and ownership of one’s care has been seen to increase short-term benefits of physiotherapy intervention and symptoms of chronic pain including CNP (Bodenheimer et al. 2002, Escolar-Reina et al. 2009). Furthermore, longer-lasting benefits are seen from treatment when patients can attribute change to their own efforts (McCurtain and Clifford 2015). Thus, incorporating self-management strategies should be an aim of any active physical activity based physiotherapy intervention for those with a chronic condition. The concept of self-management and ownership of care is gaining popularity in musculoskeletal physiotherapy (Littlewood et al. 2012). The current study found that most respondents agreed that using the “FLEXOR” device improved their outcomes post intervention (e.g. strength, disability, pain). Positive changes in patient related outcome measures are known to increase exercise adherence to physical activity (Jack et al. 2010). Similarly, low in-treatment pain rates are a beneficial means of reducing barriers to exercise adherence (Jack et al. 2010) Positively influencing a patient’s viewpoint on their role in their own care may be difficult given that chronic pain conditions can have adverse effects on perceptions of self-efficacy (Ehde and Turner 2014, Higgs et al. 2004). Therefore, providing an easy to use self-administered exercise tool like “FLEXOR”, which has been shown to have few adverse effects may facilitate exercise adherence and improve patient related outcomes in a chronic neck pain population. This positive patient based feedback may be used to advocate for further research investigating “FLEXOR” in larger and other sub-groups of chronic neck pain patients.

7.4.2 Patient Evidence; “FLEXOR” Device Design

Despite positive feedback from participants on the device concept, some negative aspects of the “FLEXOR” device were also highlighted; specifically, poor product robustness as evidenced through feedback in open ended questions. Established barriers to patient uptake of and engagement with therapy adjuncts include ease of use, durability, appearance, comfort and secondary adverse complications (Howland et al. 2006, O’Halloran et al. 2007). The undesirable aspect of the “FLEXOR” device’s lack of
mechanical robustness may have skewed patients’ opinion of the device and study. The identification that “FLEXOR” design and durability was below patient’s levels of satisfaction should be considered for future versions of product development before any further patient use. Attaining a higher level of patient satisfaction with the product (Howland et al. 2006) and limiting gaps in active treatment times or time spent away from active exercise is warranted for treatment success (Escolar-Reina et al. 2009).

This opinion was echoed by the physiotherapists in the “FLEXOR” research study. Scurlock-Evans et al. (2014) established that 30% of American physiotherapists base their treatment modality choices and gain most knowledge from their patients’ feedback. Therefore, the poor feedback on the device robustness by patients may also have unfavourably affected willingness of clinicians to refer patients to the “FLEXOR” research trial. It is also well established that a healthcare provider’s belief and perception of a treatment can largely influence the beliefs of their patients (Carroll et al. 2007, Scurlock-Evans et al. 2014) and that healthcare providers can influence patients’ adherence, engagement with, and clinical outcome of research (Howland et al. 2006). Therefore, consideration of the healthcare provider’s satisfaction with a device is also important during research, as a negative opinion may have an unfavourable impact on their desire to promote research involving the device or participate in a research trial.

7.4.3 Practice and Contextual Evidence; Barriers to Uptake of Research

Contextual or pragmatic evidence and relates to obstacles of implementing research in the clinical setting (Thompson et al. 2002) including service policies, cost effectiveness and resource availability (McCurtin and Clifford 2015). The overall process of rehabilitation is a complex and a multi-faceted process (McCurtain and Clifford 2015). Despite clinicians’ desirable intentions to be active in research studies, generating new evidence that informs best practice procedures, to do so, is not always as seamless conducted as anticipated (Scurlock-Evans et al. 2014). Some of the contextual barriers to evidence based new research include; a lack of time and resource limitations, lack of
clarity or education, misconceptions regarding the evidence (Scurlock-Evans et al. 2014), healthcare-providers’ attitude towards the research trial and the therapy adjunct design.

Evidence suggests that the majority of healthcare providers hold positive opinions about conducting and participating in research (Scurlock-Evans et al. 2014, Thompson et al. 2002). However, questionnaire responses by physiotherapists in this study indicated that half (50%, n=2) agreed that referring patients to the trial was time consuming. This finding suggests that participation in research by clinicians can be hindered for many reasons including; time and workload constraints and resource limitations (Dannapfel et al. 2013, Parahoo 2000, Pollock et al. 2000). This finding may explain the low recruitment rates seen during the “FLEXOR” pilot RCT. Therefore, understanding the influence of time and workplace constraints on patient referral rates provides a good indication of possible causes of low recruitment levels in research. Future studies, using “FLEXOR”, or similar trial designs should consider making the recruitment and referral process for therapists as minimally invasive and time effective as possible. This may include being present on site to inform patients of the research and the screening of patients for eligibility (Tickle-Degnan 2003).

*Practice evidence* has been shown to be of importance when informing decisions on evidence based practice. Clinicians are more likely to use treatment modalities known to work quicker and in a shorter period of time regardless of an evidence base (Profetto-McGrath 2005). Treatment decisions are also based on knowledge of treatments from post-graduate courses, reading or peer-approval (Mc Curtin and Clifford 2015). Therefore, practice evidence plays a significant role when undertaking new research, and in particular research involving a novel therapy adjunct such as “FLEXOR”. As in the absence of evidence or notoriety amongst patients or colleagues, the uptake of novel research or therapy adjunct may be slow (Scurlock-Evans et al. 2014). Practice evidence in relation to the “FLEXOR” pilot RCT was addressed through informal contact with clinicians (i.e. chartered physiotherapists) prior to the undertaking of the pilot RCT outlined in Chapter 6. As part of this study clinician’s opinion was sought through a mixed-methods questionnaire design to obtain their expertise and retrospective post-research involvement opinion on the feasibility of “FLEXOR” device and trial design and effectiveness.
Despite positive perceptions and attitudes by physiotherapists towards the “FLEXOR” device (Figure 7.4), reaching the required number of participants for an adequately powered pilot RCT remained an issue. Interestingly, it is known that thirty-five percent of American physiotherapists in a survey indicated that treatment choice is based on the known effectiveness of a modality (Scurlock-Evans et al. 2014). This may have had implications for patient referral in the early stages of the “FLEXOR” trial recruitment. In the absence of any prior patient results, feedback or experiences on which to base their own views, physiotherapists may have been reluctant in referring patients to the trial. Moreover, a research study’s aims and findings may not align with clinical practice, which may negatively impact on the success of the implementation of the research study (Mota da Silva et al. 2015). There is also a possibility that practitioners may lack a skill set, motivation or desire to change current practice (Caldwell et al. 2007, Heiwe et al. 2011). Constraints within the practice environment can also lead to reduced engagement with research (Rappolt 2003), physiotherapists in this study highlighted how departmental pressures prevented their full engagement with the “FLEXOR” research process. It is important to consider that physiotherapists responses were limited to four, as such concrete conclusions from responses are difficult to form, therefore a further focus group or follow up interview may be appropriate. Anonymous surveys allow for honest and open feedback and are beneficial in forming discussion points for further follow-up.
7.4.4 Limitations

Participants were recruited from a sample of convenience of individuals who had previously participated in a pilot RCT feasibility study and therefore, a bias may exist in the results (Ganguli et al. 1998). As participants had a previous relationship with the research team, there may have been a tendency to respond more positively. However, participants were assured of anonymity and were encouraged to provide truthful answers. Feedback from physiotherapists was limited to four responses, due to the small potential sample pool size. However, as the “FLEXOR” research trial was a pilot RCT, which utilised the delivery of “usual care” physiotherapy, maintaining small numbers of physiotherapists involved was desirable to minimise the variation between treatment modalities.

Limitations in the design and scope of the questionnaire also exist. It is important to note that research has shown that the positioning or layout of Likert scales in the English language with the positive to negative, from left to right, leads to higher or more positive scores being obtained on the topic question (Hartley 2013) which may have impacted responses in this current questionnaire study. The time required by physiotherapists to refer eligible patients to the trial emerged as a significant disadvantage of to the study design. Due to the questionnaire design this could not be further explored, as it was not within the original research aims. Physiotherapists who responded negatively to the time it took to refer patients to the study did not expand further on this point in the open-ended question section, therefore further information on why time constraints were such a significance could not be investigated further.

It is known that healthcare providers are more likely to engage in and promote research when they are directly involved (Littlewood et al. 2013, Parahoo 2000). Physiotherapists in the “FLEXOR” trial were not required to conduct any data collection for patients. The “FLEXOR” study methodology was designed to standardize procedures and outcome assessment, reduce confounding variables and increase validity of findings. Therefore, physiotherapists may have felt on the periphery of the research being conducted and thus, this may account reduced research engagement. For future studies, it
may be beneficial to introduce methods of patient and public involvement (PPI) early in the research process. PPI is described as research aimed at involving members of the public as partners in a research, rather than having research conducted on them (Littlewood et al. 2013). The aim of PPI is to create patient focused research based upon the needs of the of the patients and public and has become a significant feature in research development in recent years (Jones et al. 2009). Direct engagement by clinicians in research development and areas of research interest, study methodology design may provide a greater feeling of responsibility or involvement with a research process (Littlewood et al. 2013).

7.4.5 Considerations for Future Studies and Clinical Practice

For future research, further consideration should be given to increased engagement with the healthcare provider, for example, using PPI methods earlier in the research process, providing collaborative incentives (Dickson et al. 2013), engaging the patient demographic to assist in determining research aims (Tickle-Degnen 2000) and goals and study design may be of benefit. Using PPI methods to establish a collective ownership of research and emphasising the practical implications of research from the initial stages can reduce the barriers to recruitment by healthcare providers (Littlewood et al. 2013), therefore helping to negate barriers to recruitment in novel research trials.

A large proportion (66%) of research trials do not reach their intended sample sizes (Tickle-Degnan 2000). Despite healthcare providers believing they refer acceptable numbers of patients for recruitment, eligibility criteria and screening of patients can often exclude a large proportion of referrals. Thus, eligibility criteria should be scrutinized to ascertain if they will not have a limiting effect on recruitment and research success (Bower et al. 2014). Furthermore, careful consideration of the patient referral processes in future research related to “FLEXOR” and its effect on healthcare providers is warranted. Future studies should consider includes utilising simple protocols and study designs, research participation invitations as well as personal site visits, as well as adequate, regular and timely result provision (Bell-Syer and Moffett 2000).
7.5 Conclusion

The aim of the study was to investigate the opinions and perceptions “FLEXOR” research participants (patients with CNP and physiotherapists) with a view to informing patient, practice and contextual evidence bases for future research practices using “FLEXOR”. Given the small sample size conclusions can only be drawn in the context of the “FLEXOR” research. However, feedback received highlights that significant attention could be given to improving the “FLEXOR” device and its mechanical robustness prior to any further investigations of its use in a patient population. Furthermore, possible changes to the study design may be required to ensure adequate sample sizes be recruited in larger RCTs. Any future studies using “FLEXOR” should have balanced consideration of both the research needs, but also the needs and requirements of patients and the healthcare providers involved.
Chapter 8: General Discussion
8.1 Summary of Key Findings and Their Impact on Research and Clinical Practice

The primary purpose of this research thesis was to provide a detailed account of the role of targeted resistance exercise for the DNFs as part of the management of patients with CNP. The secondary aim of this research was to investigate the feasibility and effectiveness of the targeted resistance exercise intervention for the DNFs, using a novel strengthening tool; “FLEXOR”. Each stage of this research produced significant, novel and clinically applicable findings that informed the overall aim and structure of the research project, as well as the current body of literature.

A paucity in the exact aetiology and underlying pathophysiology of chronic neck pain exists specifically in relation to the development and persistence of chronic pain (Evans 2014, Malfliet et al. 2015, Rebbeck et al. 2006). Much of the published literature to date has speculated that changes to the cervical musculature play an important role in the disease process (Falla 2004a, Falla 2004b, Falla et al. 2006). Prior to undertaking this research study, no systematic review of the literature had been performed that specifically investigated the effect of pain on the deep cervical flexor musculature using objective outcome measures. Thus, the systematic review outlined in Chapter 2 was performed. This review of the empirical literature highlighted a small number of studies which identified significant strength deficits in the cervical flexor musculature in patients with CNP. Morphological alterations including atrophy of the deep cervical flexor muscles of patients with idiopathic neck pain were also possible. These findings were similar to a previous systematic review for the cervical extensor muscles in patients with CNP (DePauw et al. 2016). The findings of the systematic review in this research study were also in agreement with baseline isometric strength and LCo CSA figures of CNP patients in the pilot RCT outlined in Chapter 6, which were below normative data figures (Kumar & Prasad, 2010, Lindstroem et al. 2011, Pearson et al. 2009, Ylinen et al. 2003) and those of the asymptomatic population included in Chapter 5. Therefore, the systematic review (Chapter 2) and data from Chapter 5 further inform the current body of evidence that suggest the reduced force output potential of the deep cervical flexor muscles may explain the decrease in isometric strength identified in patients with CNP (Whittaker et al. 2007).
More pointedly the reduced strength may lead to alterations in muscle function, compensatory or incorrect movement patterns and muscle fatigue. All of which, may cause and prolong the presence of pain and cause subsequent limitations in function and disability (Tsakitzidis et al. 2013).

Recognising the limitations of the systematic review outlined in Chapter 2 the results collated can be cautiously applied to some of the underlying principles of pain theories to explain how a weakness and subsequent pain and perceived disability are present in some patients with CNP. A physical change in the cervical flexor musculature may be explained by a combination of several principles outlined in the “integrated pain adaptation model” theories (Hodges and Tucker 2011). This research study exclusively recruited patients with idiopathic and non-specific neck pain. Whilst no anatomical structure may be injured or damaged, an aggravating posture (e.g. office work, sustained flexion) or poor movement quality may be a sufficient initiating factor to alter the sensory-motor system supplying the cervical flexors (Borisut et al. 2013). This alteration can lead to decreased agonist action of the deep cervical flexors which in turns leads to the loss of the stabilizing action of these muscles (Jull and Falla 2016). Decreased stabilisation of the anterior aspect of the cervical spine may result in smaller and slower or abnormal movement and increased antagonistic activity, thereby altering typical movement and muscle recruitment patterns of the cervical spine (Murray and Peck 2007). This may be why the deep cervical flexors have been recognised as being weakened and underactive in patients with chronic neck pain previously (Falla 2004, Falla et al. 2006, O’Leary et al. 2009, Jull et al. 2007) and the pilot RCT of Chapter 6. This, in turn can lead to muscle hyperactivity and fatigue (of the superficial neck flexors) and perpetuate the cycle of pain. This further highlights the multi-faceted nature of pain as it affects multiple levels of the nervous system (Hodges and Tucker, 2011) and identifies that CNP should be treated with multi-modal approaches for best outcome (Childs et al. 2008).

In the presence of pain, research postulates that patients avoid movement due to fear of further exacerbation or injury (Chiu et al. 2005b, Kumar & Prasad 2010, Lindstroem et al. 2012) and disuse of the muscles may cause further weakness. As the body aims to maintain homeostasis (Hodges and Tucker 2011), alternate muscle
recruitment patterns develop to maintain function (Cheng et al. 2015). This includes hyperactivity of the superficial cervical flexor muscles. This process and self-regulation of the neuromuscular system can add to the cyclic action or presence of pain. Thus, it is hypothesized and investigated in this research thesis to address this possible weakness, directly, as part of a management strategy for CNP to break this cycle, reduce pain and improve perceived disability. Using this research evidence a rationale was developed within this research thesis to provide a resistance exercise for the deep neck flexors in patients with CNP. Strengthening the deep cervical muscles through movement against a resistance can cause hypertrophy and thus, increase force output potential, as shown by the results of the pilot RCT in Chapter 6.

Having established that a weakness of the deep cervical flexors can be present in patients with CNP and to inform the overall research questions, a further systematic review (Chapter 3) was performed to quantify the benefits of active exercise in treating the symptoms of CNP. From conducting this systematic review, it was clear that a wealth of evidence on the benefits of active exercise on CNP symptoms existed. However, this systematic review also highlighted a dearth of information on an evidence-informed and clinically applicable exercise prescription for resistance exercise, in a FITT format for use in people with CNP. While acknowledging the limitations of this review, the FITT principle of exercise developed can be used to bridge a gap in the literature between the known benefits of resistance exercise and provided a clinically applicable exercise prescription for the deep cervical flexors. This FITT exercise principle significantly informed the exercise intervention component for the latter stages of the research process (Chapter 5 and Chapter 6) to inform the research hypothesis.

This research thesis established that a strength deficit of the cervical flexor musculature can exist and an evidence informed resistance exercise FITT prescription developed to target this. It was deemed important to further inform the research question to examine the implementation of this theoretical knowledge in the context of both the wider literature and clinical practice. In this regard this research study aimed to establish the feasibility of a targeted resistance exercise intervention using a novel strengthening tool, “FLEXOR” in patients with CNP. The results of the pilot RCT provided positive
indications that targeted CCF resistance exercise, can significantly increase muscular strength, over and above that currently provided as part of usual care physiotherapy interventions. However, as these results were generated from a pilot RCT, further research on a larger scale is advisable. Changes in strength from exercising with “FLEXOR” resulted in similar and better increases in strength seen from previous research using more non-specific type strengthening exercises and with less specific equipment (Bronfort et al. 2003, Salo et al. 2012, Ylinen et al. 2007). The design of the “FLEXOR” device allows patients to actively strengthen their deep stabilising muscles in a functional position, which is shown to have more effectiveness in other patient groups (Lehtola et al. 2012). The pilot RCT study identified that the use of functional active movements to train and increase muscular strength may provide more beneficial results than isolated or non-functional exercise positions (de Vreede et al. 2005). Within the context of the literature, improvements seen from actively contracting the deep agonist cervical flexors muscles in a functional position may work through numerous mechanisms including; improved coordination and muscle activation patterns or increased motor-unit recruitment, improved neuromuscular efficiency and motor control strategies (Borisut et al. 2013). Thus, resulting in increased neural adaptation and an immediate or acute change in strength (Gabriel et al. 2006), reducing pain symptoms and improving functional capacity of patients with CNP. Therefore, the preliminary results established from pilot work in this research study indicate that this novel tool, “FLEXOR” is feasible for use in delivering targeted resistance exercise for the DNFs and warrants further investigation. The beneficial outcomes observed from using “FLEXOR” add original input to the current body of literature on the treatment of chronic neck pain.

In order to inform the primary and secondary research question, information and results generated in the early background literature and subsequent methodology phases of the research process were used to develop both the design of the “FLEXOR” device, a healthy population trial (Chapter 5) and the multi-centre pilot RCT study design outlined in Chapter 6. Results of the healthy population study (Chapter 5) identified that “FLEXOR” was safe for its intended use. Furthermore, suggestions on clinically applicable outcome measures for use with the deep cervical flexors as established in the
systematic review in Chapter 2, verified that the use of RT-US was a reliable outcome measurement method of measuring the CSA of the LCo. Results of pilot RCT established the feasibility of the proposed study design and secondly, established that the “FLEXOR” device was effective for most participants in providing targeted resistance exercise for the DNF in a CNP population. This study was a culmination of previous steps in the research process and results indicated positive outcomes for the inclusion of the “FLEXOR” device as a component of multi-model physiotherapy treatment program for most patients with non-specific CNP. Significant improvements in strength were seen in patients who used the “FLEXOR” device as part of their usual care multi-modal treatment intervention. These results were like previous research which utilized either a stand-alone strengthening intervention or a strengthening program in combination with another treatment modality (Borisut et al., 2013, Falla et al., 2013, Ylinen et al. 2004). An increase of 27.74±17.7N for isometric flexion was seen in the “FLEXOR” group in the study detailed in Chapter 6, this was considerably more than some previous research (Ahkter et al. 2013, Chiu et al. 2005, Hudson and Ryan 2010). However, study methodologies differed to that used in the pilot RCT outlined as part of this research, which may account for the varying results, including the duration of an intervention (Chiu et al. 2005, Ahkter et al. 2013), exercise intensity and exercise format (HEP, supervised physiotherapy exercise sessions) (Akhter et al. 2013, Borisut et al. 2013). Reductions were found in perceived pain and self-reported disability following the use of “FLEXOR” as part of usual care physiotherapy. These findings were also in line with previous research where decreases of between 1.63cm and 2.4cm were achieved compared to the 3.58cm decreased in the “FLEXOR” users (Evans et al. 2012, Salo et al. 2012, Ylinen 2007). These similar results in pain and disability reductions were typically observed in studies which investigated multi-modal treatment approaches also (Borisut et al. 2013, Beltran-Alacreau et al. 2013).

The pilot RCT results showed positive signs for the effectiveness of the FITT exercise principle for strengthening the deep cervical flexors in a CNP patient population. This has positive implications for clinical practice as the newly established FITT principle can provide clinicians with an evidence informed exercise prescription that can be easily prescribed to patients with non-specific neck pain. This also has implications for research,
as it would be beneficial to conduct supplementary research to investigate the effectiveness of the FITT exercise principle in other CNP subgroups.

The overarching framework of the research process outline in this thesis was to develop research evidence that would inform clinical practice in the treatment of people with CNP and provide original input to the current body of literature. Clinical decision making is guided by research evidence (Thompson et al. 2002) thus, it is imperative to deliver treatment interventions which are evidence based (Howland et al. 2006), have established effectiveness (Scurlock-Evans et al. 2014) and are clinically appropriate (Thabane et al. 2010). To this end, following an investigation of the feasibility of the study design and effectiveness of the device, a descriptive follow-up questionnaire based study was designed to obtain patient and clinician opinion (Prion and Adamson 2015). Findings from this questionnaire based study were significant to the overall research aims of this thesis with respect to the “FLEXOR” device and “FLEXOR” based research, as it provided the only subjective insight from participants in the research study (Tijou et al. 2010).

As clinicians and researchers understanding of pain and its effect on individuals grows, it is important to note that pain is a unique and complex response to a physical insult or injury and is a multi-dimensional phenomenon which affects the sensory-motor system (Hodges and Tucker 2011). Pain is a perceptual response that is not only affected by the structure or degree of physical injury but also an individual’s attitude, experience and beliefs towards pain (e.g. pain belief, pain avoidance, catastrophizing) (Moseley and Flor 2012). Patients are also more likely to respond positively to a treatment intervention that has few or no adverse reactions (Jack et al. 2010) and one in which they can attribute a degree of responsibility for an outcome to themselves (McCurtain & Clifford, 2015). As the adverse reactions to using “FLEXOR” were low in this study, and exercise was conducted independently, it could be suggested that patients may be more likely to respond positively to an intervention using an adjunct such as “FLEXOR”, more than usual care alone.
Findings from the follow-up questionnaire (Chapter 7), provided valuable insight into the opinions of stakeholders involved in the “FLEXOR” research study, on both the study and device design. Results indicated that patients felt more in control of their own care by conducting exercise independently. This independence and self-management strategy afforded to patients in their own care by using the “FLEXOR” device may have had psychological as well as physical benefits (George et al. 2008). Incorporating self-management methods, like those seen by using “FLEXOR” may positively influence a model of ownership or self-control over a chronic pain state. Self-management strategies are proposed to have significant effects on various domains of chronic pain conditions including participant engagement, self-efficacy, mood, physical symptoms and function, hence why “FLEXOR” may address both the physical and biopsychosocial components of a chronic pain state (George et al. 2008). Thus, this may further explain the greater reductions in pain and disability, as well as the increase in strength from using the “FLEXOR” device over and above the benefits afforded from usual care physiotherapy alone. This encouraging outcome adds to the growing body of evidence for the benefits of self-management of chronic illness (Schulman-Green et al. 2016, Thompson et al. 2016) and should be further investigated as part of future research.
8.3 Research and Clinical Impact

8.3.1 Research Implications and Considerations for Future Research

Issues with the prototype “FLEXOR” device, in particular its robustness at higher resistance intensities, as identified throughout the research process and again in the follow-up questionnaire (Chapter 7) would require production and design improvements prior to any further larger scale RCT investigations of its use in a CNP population. Issues related to the study design were also highlighted. The patient referral process was viewed as time-consuming by referring physiotherapists. It must be noted that despite this only being an issue for two of the physiotherapists who responded to the questionnaire, with only a small number of physiotherapists involved in the study (n=5), it is still of significance within the context of “FLEXOR” research. Thus, any future research may require careful methodological consideration of the referral process to maximise cooperation by clinicians and facilitate adequate patient referral rates for suitably powered studies. Using research outcomes to enlighten future research is considered good practice and informs evidence based practice (Scurlock-Evans et al. 2013).

This research thesis generated pilot data that “FLEXOR” has beneficial outcomes for a cohort of patients with non-specific idiopathic neck pain. These early data figures indicate “FLEXOR” may provide improvement over and above those achieved through usual care alone. Further research is recommended to determine which, if any sub-groups of patients with CNP are more responsive to an exercise intervention (Remmen et al. 2013, Tsakitzidis et al. 2013) using “FLEXOR”. Sub-stratification of patients based on duration of pain, location of pain or presence of yellow flags was not possible in the current study due to the small sample sizes and study aims. Future research studies could consider such an aim to determine which patient demographic are more likely to respond more positively to a self-managed individualised and progressive resistance exercise program. Sub-stratification or classification of patients with other chronic pain conditions, such as chronic non-specific lower back pain have been shown to provide considerable
advantages in allowing for individualised and targeted treatment interventions for patients (O Sullivan 2005).
8.3.2 Clinical Implications

The establishment of the FITT exercise principle for patients with CNP can be viewed positively as a novel finding of the overall research project. Noting its limitations, this FITT principle can considerably add to the body of current literature and knowledge on the prescription of exercise for patients with CNP. It provides clinicians with an optimal exercise prescription for patients with CNP. The effectiveness of the FITT principle was investigated in both healthy individuals and patients with CNP. The high exercise adherence rate (93%) in the pilot RCT as well as the low dropout rate (4%) indicate it is feasible for use with patients with mild-moderate severity CNP and moderate disability as per the NDI. Interventions that do not cause headaches or adverse reactions are shown to have higher completion rates (De Pauw et al. 2016) and thus, the FITT principle may be used with most patients who present with CNP, as only one adverse reaction was noted pilot RCT study.

This research study identified that real-time ultrasound, where available, is a feasible and reliable method of assessing changes in muscle CSA in the DNFs of patients with chronic neck pain, both as a form of assessment and evaluation of treatment effectiveness following a physiotherapy treatment intervention. A significant increase in the CSA of the LCo was found in the patient group who performed a resistance exercise regime using “FLEXOR” in the pilot RCT (Chapter 6), therefore, suggesting real-time ultrasound can be clinically used to detect a change following treatment. This is significant given the increase in use and availability of real-time ultrasound for clinical and research purposes (Whittaker et al. 2005). Being able to objectively measure the cervical musculature of patients with CNP in a clinical setting can allow for more specific and targeted treatment methods as well as evaluating the benefits of treatment.
8.4 Limitations of the Research Study

The overall research study has some limitations, which include the use of a small homogenous sample size in the pilot RCT. Therefore, results found may not be generalizable to different sub-classifications of patients with chronic neck pain (Button et al. 2013). However, it is noteworthy that patients for this research project were recruited from a primary care clinical setting, thus. This sub-group of patients are most likely to be found in a primary care clinical setting as conservative physiotherapy is most efficacious in this patient group (Childs et al. 2008, Kay et al. 2005).

The small sample size was limited by service provision restrictions and caseloads of practising physiotherapists involved in the research. There was a limited number of patients available during the timeframe of recruitment. It is important to note that the sample sizes recruited during the pilot RCT stages were adequate to fulfil the primary aims of the feasibility aspect of the pilot RCT research study. As findings of this research study highlighted beneficial effects of using “FLEXOR” as part of usual care treatment, future investigations with larger sample sizes are justified for increased power and extrapolation of findings.

Patients included in the pilot RCT were considered to have moderately disabling CNP according to the NDI results at baseline. Therefore, further investigation into the effectiveness of a similar study and exercise design in patients with mild or severe CNP is warranted. Again, patient availability was based on physiotherapy caseloads and waiting lists and could not be stratified by severity.

It was not within the scope of the current research study to determine if there are long-term benefits of using the “FLEXOR” device with its associated FITT resistance exercise program. Thus, this research theses could not investigate if the benefits of “FLEXOR” above UC or indeed the benefits of UC alone were still significant at six and twelve month intervals following the intervention. Future research could allow for a period of follow up, as this may add insightful information to the proposed benefits of “FLEXOR” for use in a CNP population. Previous research has indicated that a resistance program may have to be continued for a twelve-month period for long-term effects.
(Ylinen 2007). Therefore, any future research using “FLEXOR” should consider a period of follow up.

8.6 Conclusion

The aim of this research project was to investigate the role of resistance exercise for the deep neck flexors in the treatment of chronic neck pain. Careful consideration was given to the process which would answer the research aims and questions. Results established from each stage of the research project provided novel and original results which are clinically applicable and can easily inform future research in the area. Pilot study results indicate that there are positive indications for the use of the “FLEXOR” device, as part of a multi-modal physiotherapy intervention to provide significant benefits in increasing strength and reducing pain and disability. The establishment of the FITT exercise dosage for patients with CNP ensures that findings of this research project are clinically applicable and can continue to enhance future research and clinical treatment practices for patients with CNP.
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Appendix A: “FLEXOR” Design and Development

As introduced in Chapter 1, “FLEXOR” is a novel strengthening tool which was designed and developed within the University of Limerick prior to the commencement of the current research project. “FLEXOR” was designed with the aim of delivering resistance based exercise to the deep neck flexors in a functional manner and that can be used independently to aid current physiotherapy treatment for CNP.

“FLEXOR” is an open-backed collar type device, which sits between the upper cervical border of first cervical vertebrae (C1) and inferiorly on the shoulders and sternum. Its size is based on the 95th percentile for males and females and the telescopic chin bracket allows for an individualised fit. In conjunction with product designers, engineers and physiotherapists, and research outcomes outlined throughout this thesis, the design of “FLEXOR” altered significantly from its original design to end prototype product used in this research study (see Figure A.1 and A.2)

The original “FLEXOR” device used elastic bands to provide resistance. It was envisioned that bands with varying elasticity would allow a user to change resistance. However, elastic bands have non-linear elastic characteristics, thus the method of providing resistance was changed to torsion springs. Using a torsion spring a gear mechanism was designed to allow for varying resistance settings. Furthermore, the location of the spring house was also repositioned to be anatomically closer to the fulcrum of the cranio-cervical flexion movement. The chin bracket included a retractable feature allowing for custom fitting. “FLEXOR” is made through a 3D printer using Acrylonitrile Butadiene Styrene (ABS) and a medical foam insert.
Figure A.1: Original “FLEXOR” device design

Figure A.2: Final “FLEXOR” prototype
“FLEXOR” Hypothesis

The hypothesis of “FLEXOR” is that it provides targeted strengthening of the deep neck flexors by activating these muscles in a functional cranio-cervical flexion movement (Falla et al., 2004). “FLEXOR” enables the user to perform cranio-cervical flexion exercises while providing variable resistance to a movement at self-controlled speed. The total range of cervical motion is approximately 110 degrees (approximately 16° of cranio-cervical flexion) (Falla and Jull, 2003). Cervical flexion is typically limited by bony impact, as well as the lengthening of the posterior muscles against the weight of the head (Trapezius, Splenius Capitis, Longissimus Capitis, Semispinalis Capitis). By adding resistance to this movement, it is hypothesised that “FLEXOR” could have strengthening type effects on the deep cervical flexors. The Atlanto-Occipital joint is of particular note in the “FLEXOR” device design. At this joint, there is approximately 16-20 degrees of flexion. The movement at this joint is brought about by the sliding of the lateral masses of the Atlas. The occipital condyles of the Atlas move backwards during flexion, whilst the Occiput bone moves away from the posterior arch, separating the arches of the Atlas and Axis. The position of the torsion spring house sits at the approximate level of the Atlanto-Occipital joint (Figure 2), therefore replicating the cranio-cervical flexion movement occurring at this level.
Figure A.3: “FLEXOR” device in situ (neutral)

Figure A.4: “FLEXOR” device with bracket compressed
Appendix B: Ultrasound Reliability Study Recruitment Email

Inter & Intra Rater Reliability of Ultrasound Imaging for Measuring Cross-Sectional Area of the Longus Colli.

Are you interested in taking part in an ethically approved research study that uses Real-time Ultrasound Imaging to examine the muscles of the neck?

- Are you aged between 18 and 65 years of age?
- Are you currently healthy and free of neck pain?
- Do you have just one hour to spare?

If you answered "Yes" to all the above and you would like to take part, please read the attached participant information sheets.

If you are interested in being part of this study, please read the attached information sheet and contact Cliona (cliona.oriordan@ul.ie) or Amanda (Amanda.Clifford@ul.ie)

Thank you

________________________________________
Cliona O’Riordan MISCP
PhD Researcher
Department of Physiotherapy
University of Limerick
Email: Cliona.ORiordan@ul.ie
What is this study about?

The Longus Colli is a muscle located on the front aspect of the neck; it is one of the muscles responsible for creating a “yes” nodding movement or bringing your chin to your chest. It is responsible for maintaining the stability of the head on the neck and normally functions without problems in a healthy population. This muscle is part of the deep neck flexor group and as the name suggests, lie deep under other muscles in your neck, therefore, traditional methods such as palpating the muscles to assess their functioning is difficult. Real-time Ultrasound Imaging equipment, over recent years has emerged in this field as a diagnostic or biofeedback tool as well as an objective quantitative measure of muscle function. This study is being conducted to determine the reliability of using a real-time ultrasound machine to measure the cross-sectional area of the Longus Colli muscle and to determine how reliable the assessor using the equipment is over two test occasions in a healthy population. The information gathered by this reliability study in a healthy population will be used to inform future studies using the same method when working with a chronic neck pain population, as the Longus Colli and the deep neck flexor muscles have been shown to be dysfunctional in those who suffer from chronic neck pain.
**What will I have to do?**

If you are deemed eligible to participate in this study you will be asked to attend the Health Sciences building in the University of Limerick at a time convenient to you. An opportunity to ask any questions you may have will be given before you are asked to sign the consent form. Baseline information including age, weight, height, etc. will be taken. You will then be asked to lie on your back on a plinth and have a towel rolled and placed under the curve in your neck. You will be asked to keep your hands by your side while a physiotherapist uses a real-time ultrasound machine to capture an image of the Longus Colli muscle. A small probe covered with ultrasound gel will be placed on the front of your neck. Images for both the left and right Longus Colli muscles will be taken. The images will be saved and the assessor will measure the cross-sectional area of the muscle using software available on the machine at that time. On a second occasion this procedure will be repeated in its entirety. Testing on both occasions will take approximately 30 minutes. The saved images will be given to another experienced physiotherapist who will conduct the same cross-sectional area measurements; these will be used for comparison with Assessor 1.

**How long will the study last?**

The study will take place across two test occasions each lasting approximately 30 minutes and will be arranged for a time that suits you.

**What are the benefits?**

As this is a reliability study, there may not be any direct benefits for you in taking part. However, the data collected from this study will benefit the researchers as information on how reliable the tester and the equipment being used to measure the cross-sectional area of the muscle in question is, is important for informing future studies in other healthy and chronic neck pain populations.

**What are the risks?**

As all procedures to be used are non-invasive there are very few risks in partaking in this study. Those who are allergic to ultrasound gel are excluded from participating in this
research study. All jewellery around the neck area will be removed prior to testing to avoid any obstructions during testing. First aid trained personnel will be on hand should any adverse effects occur.

**What if I do not want to take part?**

Participation is entirely voluntary and participants will be informed that they can withdraw at any time without reason. This will not affect their relationship or any future relationship with the research team.

**What happens to the information?**

All information gathered during the study will remain confidential and anonymous. Codes will be assigned to every participant and subjects will not be referred to by name in any part of the study. Information will not be forwarded to any outside party. At the end of the study information gathered will be statistically analysed using appropriate methods and used as part of a research project. At the end of the study the information will be stored in a locked cabinet in an office in the Health Sciences Building in the University of Limerick for 7 years in accordance with ethics regulations.

**Who else is taking part?**

Approximately 30 other participants will take part in the study. These will all be healthy individuals from the University of Limerick.

**What if I have more questions or do not understand something?**

If further information is required, you can contact the project investigators through the contact details below. You may contact the research team at any stage throughout the course of the study. You will be given sufficient time to read this information leaflet and ask any questions before signing the consent form, if you wish to participate in the study.
What happens if I change my mind during the study?
As participation is entirely voluntary you are free to withdraw from the study at any time for any reason, with no further consequence and with no effect on any future relationship with the research team.

Contact names:
Clíona O’ Riordan PhD Reseracher, Clinical Therapies Cliona.Oriordan@ul.ie
Dr. Amanda Clifford Lecturer Amanda.Clifford@ul.ie
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John Cussen Product Designer John.Cussen@ul.ie
Karen McCreeesh Health Research Board Fellow/Lecturer KarenMcCreeesh@ul.ie

If you have concerns about this study and wish to contact someone independent, you may contact:

Chairman Education & Health Sciences Research Ethics Committee
EHS Faculty Office
University of Limerick
Tel (061) 234101
Email: ehsresearchethics@ul.ie
Appendix D: Ultrasound Reliability Study Consent Form

PARTICIPANT CONSENT FORM

Inter & Intra Rater Reliability of Ultrasound Imaging for Measuring Cross-Sectional Area of the Longus Colli.

2012_11_01_EHS

I, ........................................................[PRINT NAME], give consent to my participation in the above-named research project

In giving my consent I acknowledge that:

1. The procedures required for the project and the time involved (including any inconvenience or risk, and their implications) have been explained to me, and any questions I have about the project have been answered to my satisfaction.

2. I have read the Participant Information Sheet and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

3. I understand that I can withdraw from the study at any time, without affecting my relationship with the researchers now or in the future.

4. I understand that my involvement is strictly confidential and no information about me will be used in any way that reveals my identity.

5. I understand that being in this study is completely voluntary – I am not under any obligation to consent.
Contact Details:

Name: .............................................................. ................................................

Address:____________________________________________

____________________________________________________________

____________________________________________________________

Email: _______________________________________________________________________

Telephone number: __________________________________________

Signed: ______________________ Date: / /

Investigator Contact Details:

Cliona O’Riordan
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If you have concerns about this study and wish to contact someone independent, you may contact:

Chairman Education & Health Sciences Research Ethics Committee

EHS Faculty Office

University of Limerick

Tel (061) 234101

Email: ehsresearchethics@ul.ie
Appendix E: Healthy Feasibility Trial Recruitment Email

Deep Neck Flexor Strengthening Program Using “FLEXOR”
2012_07_04_S&E

Would you like to take part in an ethically approved study which will use a new strengthening device for the neck muscles as part of an 8-week exercise program?

- Are you aged between 18 and 40 years of age?
- Are you currently healthy and free of neck pain?

If you answered “Yes” to all the above and you’d like to take part, please read the attached participant information sheets.

The study will take place over an 8-week period beginning in September.

If you are interested, please read the attached information sheet and contact Clíona (cliona.oriordan@ul.ie) or Amanda (Amanda.Clifford@ul.ie)

Thank you

Clíona O’Riordan MISCP
PhD Researcher
Department of Physiotherapy,
University of Limerick.
Appendix F: Healthy Feasibility Trial Information Sheet

Deep Neck Flexor Strengthening Program Using “FLEXOR”
2012_07_04_S&E

What is this study about?

The aim of this study is to investigate the effectiveness of a non-invasive muscle strengthening device for the deep neck flexors, (the muscles located at the front of your neck) in a healthy population.

What will I have to do?

If you decide to participate in this study, by signing the consent form you will be agreeing to participate in an 8-week long exercise intervention using the “FLEXOR” device. The “FLEXOR” device is a simple exercise tool which helps to strengthen the muscles that lie deep at the front of your neck and are responsible for stabilising your neck, as well as helping to produce flexion movements of your head on your neck. These muscles are commonly weak and injured in those who have chronic neck pain or suffer from a whiplash associated disorder. The “FLEXOR” device aims to rehabilitate and strengthen these muscles in a functional way. Before it can be used in a clinical setting with people who experience chronic neck pain, we need to show that it works in a healthy population.

As part of the study you will be asked to conduct exercises using the device for up to 5 times a week over an 8-week period. An appointment will be made for you at your convenience to meet with the physiotherapist who is part of this research team, to conduct baseline measurements before the commencement of the study. These measurements will include using Electromyography or EMG to analyse the activity of the muscles in your
neck during a neck flexion movement. This will involve placing EMG electrodes on the surface of the skin.

Real-time Ultrasound will also be used to take images of the muscles in question, i.e. the deep neck flexor group. These images will be taken in a relaxed state as well as during contraction. A hand-held dynamometer will be used to objectively measure the strength of the neck muscles during a flexion movement, this measure will be used to inform what exercise intensity you should be exercising over the 8-week period. The intensity at which you conduct these exercises will be determined on your individual results of maximum muscle strength of the involved muscles at your neck. You will then work against this resistance to induce strength gains at the muscles in your neck.

A description of the exercises which you will be asked to conduct will be given to you by the physiotherapist for you to take home.

In addition to the strengthening exercises you be asked to conduct some simple stretching exercises for the larger muscles in the shoulders and neck. Again, a hand-out with the description on how to conduct these exercises will be given to each participant as well as demonstrations by the physiotherapist.

As part of the study you will also be asked to keep an exercise diary, outlining the days on which you conducted the exercises, as well as any other form of exercise undertaken. This is required to inform the research team of exercise adherence throughout the 8 weeks.

Once the physiotherapist is satisfied that the exercises are understood and can be conducted independently by the individual they will begin the 8-week exercise program. At the end of the 8 weeks’ participants will be asked to come back and undergo a repeat assessment of the above outcome measures.

You will also be given a questionnaire on this day for feedback on your thoughts about the device, changes you feel should be made or any other comments you may have.
**How long will the study last?**

The exercise intervention is to last for 8 weeks. Baseline and follow-up assessments will take approximately one hour each. Independent exercise sessions should take approximately 30-45 minutes a day and as such should not be an inconvenience to daily scheduling.

**What are the benefits?**

The benefits of participating in this study include receiving an evidence based exercise intervention from a physiotherapist to strengthen the neck muscles, as well as having the opportunity to undergo physiotherapy assessments that would not be given as standard. Should these assessments flag up any anomalies these will be relayed to the participant. Furthermore, there are benefits for the research team in conducting this validity trial as the results will be used to inform future studies that will include using individuals from a clinical population.

**What are the risks?**

As all procedures to be used are non-invasive there are very few risks in partaking in this study. Those with allergies to take and ultra sound gel are excluded from participating. The “FLEXOR” device will be fitted to the size of the individual’s neck and should not cause any pain or discomfort. All exercises will be explained and demonstrated for participants and the physiotherapist will ensure that individuals can perform the exercises correctly before allowing them to conduct these exercises independently. Exercise intensity is individualised and should not have any adverse effects, should there be any adverse effects from exercising with the “FLEXOR” device, and participants will be strongly advised to inform the research team where they will be immediately referred to the appropriate healthcare services.

**What if I do not want to take part?**

Participation is entirely voluntary and participants will be informed that they can withdraw at any time without reason. This will not affect their relationship or any future relationship with the research team.
What happens to the information?

All information gathered during the study will remain confidential and anonymous. Codes will be assigned to every participant and subjects will not be referred to by name in any part of the study. Information will not be forwarded to any outside party. At the end of the study information gathered will be statistically analysed using appropriate methods and used as part of a research project. At the end of the study the information will be stored in a locked cabinet in an office in the Health Sciences Building in the University of Limerick for 7 years in accordance with ethics regulations.

Who else is taking part?

Approximately 20 other healthy individuals will partake in this study; these will all be aged between 18-40 years and from the University population.

What if I have more questions or do not understand something?

If further information is required, you can contact the project investigators through the contact details below. You may contact the research team at any stage throughout the course of the study.

What happens if I change my mind during the study?

As participation is voluntary you are free to withdraw from the study at any time for any reason, with no further consequence.
Contact names:
Cliona O’ Riordan (PhD Student, Clinical Therapies) cliona.oriordan@ul.ie
Dr. Amanda Clifford (Lecturer) Amanda.Clifford@ul.ie
Pepijn Van De Ven (Senior Research Fellow ECE Dept.) Pepijn.VandeVen@ul.ie
John Cussen (Product Designer) johnmcussen@ul.ie.com

If you have any concerns regarding this study, please contact:

Science & Engineering Research Ethics Committee
Faculty of Science & Engineering,
University of Limerick
SciEngEthics@ul.ie
061-202666
Appendix G: Healthy Feasibility Trial Consent Form

Study title: Deep Neck Flexor Strengthening Program Using “FLEXOR”
2012_07_04_S&E

PARTICIPANT CONSENT FORM

I, .............................................................................[PRINT NAME], give consent to my participation in the above-named research project

In giving my consent I acknowledge that:

1. The procedures required for the project and the time involved (including any inconvenience or risk, and their implications) have been explained to me, and any questions I have about the project have been answered to my satisfaction.

2. I have read the Participant Information Sheet and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

3. I understand that I can withdraw from the study at any time, without affecting my relationship with the researchers now or in the future.

4. I understand that my involvement is strictly confidential and no information about me will be used in any way that reveals my identity.

5. I understand that being in this study is completely voluntary – I am not under any obligation to consent.
6. If I agree to participate in an interview, I understand that I can stop the interview at any time if I do not wish to continue, the audio recording will be erased and the information provided will not be included in the study.

7. I consent to: – (please tick the relevant box below)

i) Audio-taping  YES ☐ NO ☐

ii) An interview  YES ☐ NO ☐

v) Receiving feedback about the study  YES ☐ NO ☐

Contact Details:

Name: ________________________________________________

Address: _____________________________________________
____________________________________________________
_____________________________________________________

Email: ________________________________________________

Telephone number: ___________________________________

Signed: ___________________________ Date: ______________
Investigator Contact Details:

Cliona O’Riordan
cliona.oriordan@ul.ie
PhD Researcher Principal Investigator

Dr. Amanda Clifford
Amanda.Clifford@ul.ie
Lecturer, Co-Investigator

Pepijn Van DeVen
Pepijn.VanDeVen@ul.ie
Co-Investigator

John Cussen
John.Cussen@ul.ie
Product Designer, Co-Investigator

If you have concerns about this study and wish to contact someone independent, you may contact:

Science & Engineering Research Ethics Committee
Faculty of Science + Engineering,
University of Limerick,
Ireland

Tel: +353-(0)61-202666
Appendix H: Pilot RCT Ethical Approval Letter (Cork Research Ethics Committee)
20th September 2012

Dr Amanda Clifford
Lecturer in Physiotherapy
Department of Physiotherapy
Health Sciences Building
University of Limerick

Re: An Investigation into the functional rehabilitation of the deep neck flexors using FLEXOR.

Dear Dr Clifford

Expedited approval will be granted to carry out the above study at:

- South Lee Primary Community & Continuing Care Services & West Cork
- North Lee Primary Community & Continuing Care Services

subject to receipt of the following:

- Original Signed Application Form
- Final Version of Your Health and Well-Being Questionnaire (The Committee cannot approve sample documents)
- Exercise Diary (Cannot approve sample documents)

The following documents have been approved:

- Information Sheet
- Consent Form
- Baseline Characteristics
- Visual Analogue Scale
- Neck Disability Index
- Feedback Questionnaire
- Insurance Certificate.

The co-investigator involved in this study will be:

- Cllona O’Riordan.

Yours sincerely

Dr Michael Hyland
Chairman
Clinical Research Ethics Committee
of the Cork Teaching Hospitals

The Clinical Research Ethics Committee of the Cork Teaching Hospitals, UCC, is a recognised Ethics Committee under Regulation 7 of the European Communities (Clinical Trials on Medicinal Products for Human Use) Regulations 2004, and is authorised by the Department of Health and Children to carry out the ethical review of clinical trials of investigational medicinal products. The Committee is fully compliant with the Regulations as they relate to Ethics Committees and the conditions and principles of Good Clinical Practice.
Appendix J: Pilot RCT Patient Information Sheet

18th September, 2012.

Ms. Cliona O’Riordan,
Department of Physiotherapy,
Health Sciences Building,
University of Limerick,
Limerick.

Re/ Protocol Title
An Investigation into the Functional Rehabilitation of the Deep Neck Flexors using FLEXOR

Dear Ms. O’Riordan,

I am in receipt of your study as above submitted for review by our Research Ethics Committee. I have reviewed the contents of same.

I wish to advise that I have given your study Chairperson ethical approval.

You should note that your study cannot commence until you also receive approval from the Risk Management Department. You are obliged to inform us as soon as your study is completed or if it terminates early for any reason. This approval will be issued to you shortly.

I wish you every success with your study.

Yours sincerely,

Marie Hickey Dwyer,
Consultant Ophthalmic Surgeon,
Chairperson, Research Ethics Committee.
An Investigation in the Functional Rehabilitation of the Deep Neck Flexors using “FLEXOR”

What is the study about?

This study aims to examine the effectiveness of current physiotherapy methods in the treatment of chronic neck pain. Chronic neck pain is defined as constant or frequently occurring neck pain for longer than 3 months. It is also an aim of the study to investigate the effectiveness of a novel device known as “FLEXOR” in strengthening the deep neck flexors the muscles which are responsible for providing stability in and around the neck. These muscles are located at the front of your neck. These muscles are commonly affected and weakened and often a source of pain in those with chronic neck pain.

What will I have to do?

As a participant in this study you will be agreeing to participate in an 8-week multimodal exercise intervention, i.e. an exercise intervention provided to you by your physiotherapist that will consist of a range of different components and exercises, including stretching and strengthening exercises.

You will be asked to sign a consent form, thereby agreeing to be part of the study. A physiotherapist will then assess you for your eligibility to participate in the study.

An appointment will be made for you to attend an assessment with a member of our research team where a range of measures will be taken. These will be known as your baseline measurements.

These measures will include using a hand-held dynamometer, a small hand held instrument which will be used to measure the strength of the muscles in your neck.
Real- Time Ultrasound imaging will be used to take images of the deep neck flexors in the front of your neck.

Along with these objective measures, you will be asked to fill in a variety of questionnaires relating to your pain intensity on the day of the assessment, a neck disability index which gives an insight into how disabling your neck pain is and a health-related quality of life questionnaire.

You will then be randomised into one of two groups. Those who are randomised into the “FLEXOR” group will use the “FLEXOR” device to conduct their strengthening exercises instead of the usual care strengthening exercises provided by a physiotherapist.

A physiotherapist will show you how to conduct all the exercises expected of you and you will be provided with written instructions of the same. Only when both the physiotherapist and you are content that you can perform the exercises correctly will you be deemed able to conduct them yourself at home.

You will still have contact with your physiotherapist and can get further treatment if required.

Following the 8-week exercise intervention the same measurements will be carried out again.

During the 8 weeks, you will be asked to fill out an exercise diary, which you will be provided with in the beginning of the trial. In this you should keep track of how many times a week you exercised and for how long.

**How long will the study last for?**

The initial exercise intervention will last for 8 weeks. You will be advised to conduct your exercises independently at home at least three times a week, for approximately 30 minutes per session. You will be advised to continue exercising following the intervention, as chronic pain episodes can be transient and there is much scientific evidence to suggest that maintaining good exercise levels can have long term beneficial results.

**What are the benefits?**
The benefits from participating in this study include receiving evidence based and up to date physiotherapy treatment. Furthermore, you will receive additional assessments and monitoring on several occasions beyond what is usually given as standard care from a physiotherapist.

Moreover, by participating in this study you will be supplying the research team with invaluable information on the effectiveness of current physiotherapy interventions and how they can be improved and if part of the “FLEXOR” group will be providing information on the effectiveness of the device in a clinical population.

**What are the risks?**

The risks associated with participating in this study are minimal and transient. The assessments which will be carried out on you are all non-invasive.

Exercise will be prescribed on an individual basis and based on your exercise capacity; exercise intensity will be incrementally increased when it is deemed appropriate. Should any adverse effects occur, please notify your physiotherapist and/or the research team immediately and they can direct you towards the appropriate healthcare services.

**What if I do not want to take part?**

Participation is completely voluntary and you are under no obligation to take part in this study. You are free to cease participation or withdraw from the study at any stage without having to give reason. This will not affect the treatment that you will receive from your physiotherapist or affect your relationship with the research team.

**What happens to the information?**

All information gathered during the study will be coded immediately so no one can be identified from their results; participants will not be referred to by name in any part of the study. All information will remain confidential and anonymous and will not be passed on to any outside party. At the end of the study information gathered will be statistically analysed using appropriate methods and used as part of a broader
research project. At the end of the study the information will be stored in a locked cabinet in an office in the Health Sciences Building in the University of Limerick.

Who else is taking part?

Approximately 40 participants will be taking part in the study in total. Participants will be male and female and will all be affected by similar chronic mechanical non-specific neck pain.

Could there be any complications?

As procedures included are simple the risk of complications is small. Equipment to be used will have built in safety features and the researcher is trained in the use of this equipment.

What if I have more questions or do not understand something?

If further information is required, you can contact the research team or your physiotherapist at any stage through the contact details below. You will be given sufficient time to consider your participation in the study and as participation is entirely voluntary you are no obligation to participate.

What happens if I change my mind during the study?

As participation is voluntary you are free to withdraw from the study at any time for any reason, with no further consequence.
Contact names:

Cliona O’ Riordan  PhD Researcher, Co-investigator
Cliona.ORiordan@ul.ie

Dr. Amanda Clifford  Principal Investigator, Senior Lecturer University of Limerick, Dept. of Clinical Therapies
Amanda.Clifford@ul.ie

Pepijn Van De Ven  Lecturer, Co-investigator
Pepijn.VandeVen@ul.ie

John Cussen  Product Designer, Co-investigator
johnmcussen@gmail.com

If you have concerns about this study and wish to contact someone independent you may contact:

Cork Teaching Hospitals Research Ethics Committee,
Lancaster Hall,
6 Little Hanover Street,
Cork
Appendix K: Pilot RCT Consent Form

An Investigation into the Functional Rehabilitation of the Deep Neck Flexors using “FLEXOR”

PARTICIPANT CONSENT FORM

I, [PRINT NAME], give consent to my participation in the above-named research project

In giving my consent I acknowledge that:

1. The procedures required for the project and the time involved (including any inconvenience or risk, and their implications) have been explained to me, and any questions I have about the project have been answered to my satisfaction.

2. I have read the Participant Information Sheet and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

3. I understand that I can withdraw from the study at any time, without affecting my relationship with the researchers now or in the future.

4. I understand that my involvement is strictly confidential and no information about me will be used in any way that reveals my identity.

5. I understand that being in this study is completely voluntary – I am not under any obligation to consent.

6. If I agree to participate in an interview, I understand that I can stop the interview at any time if I do not wish to continue, the audio recording will be erased and the information provided will not be included in the study.
7. I consent to: – (please tick the relevant box below)

i) Audio-taping
   YES □ NO

ii) An interview
    YES □ NO

v) Receiving feedback about the study
   YES □ NO

Contact Details:

Name:

..................................................................................................................

Address:.................................................................................................

..........................................................................................................

..........................................................................................................

Email: .................................................................................................

Telephone number: .............................................................................

Signed: Date:
Investigator Contact Details:

Clíona O’Riordan  
PhD Researcher  Principal Investigator  
cliona.orlordan@ul.ie

Dr. Amanda Clifford  
Lecturer, Co-Investigator  
Amanda.Clifford@ul.ie

Pepijn Van DeVen  
Co-Investigator  
Pepijn.VanDeVen@ul.ie

John Cussen  
Product Designer, Co-Investigator  
John.Cussen@ul.ie

If you have concerns about this study and wish to contact someone independent, you may contact:

Cork Teaching Hospitals Research Ethics Committee,  
Lancaster Hall,  
6 Little Hanover Street,  
Cork
An Investigation into the Functional Rehabilitation of the Deep Neck Flexors using “FLEXOR”

Name: __________________________________________________________
Age: _______ years
Weight: _______ kg
Height: _______ m
Currently Employed: Yes______  No______
Occupation: ______________________________________________________
Current Diagnosis: ________________________________________________
Cause of injury/pain: ______________________________________________
Location of Pain: Unilateral____ L  R  Bilateral_________
Duration of pain: _________________________________________________
Current Exercise Level: _____ Low  _____ Moderate  _______ High
Example of exercise currently undertaken:
__________________________________________________________________
__________________________________________________________________
Medications: ______________________________________________________
Cervical ROM:  Flexion: ______  Lateral Flexion: L____ R_____
               Extension: _____  Rotation:  L_____ R_____
Baseline VAS Score: _____  Post 8-Week Intervention VAS Score: _____
Baseline NDI Score: _____  Post 8 Week Intervention NDI Score: _____
Baseline SF 12 Score: _____  Post 8 Week Intervention SF 12 Score: _____
Appendix M: Visual Analogue Scale

An Investigation into the Functional Rehabilitation of the Deep Neck Flexors using “FLEXOR”

Please indicate to your therapist where you rate your pain on a scale of 0-10 today.
Appendix N: Neck Disability Index
Please Read: This questionnaire is designed to enable us to understand how much your neck pain has affected your ability to manage everyday activities. Please answer each Section by circling the ONE CHOICE that most applies to you. We realize that you may feel that more than one statement may relate to you, but Please just circle the one choice which closely describes your problem right now.

**SECTION 1 -- Pain Intensity**
A. I have no pain at the moment
B. The pain is mild at the moment
C. The pain comes and goes and is moderate.
D. The pain is moderate and does not vary much.
E. The pain is severe but comes and goes.
F. The pain is severe and does not vary much.

**SECTION 2 -- Personal Care (Washing, Dressing etc.)**
A. I can look after myself normally but it causes extra pain.
B. I can look after myself normally but it causes extra pain.
C. It is painful to look after myself and I am slow and careful.
D. I need some help, but manage most of my personal care.
E. I need help every day in most aspects of self-care.
F. I do not get dressed, I wash with difficulty and stay in bed.

**SECTION 3 -- Lifting**
A. I can lift heavy weights without extra pain.
B. I can lift heavy weights, but it causes extra pain.
C. Pain prevents me from lifting heavy weights off the floor but I can if they are conveniently positioned, for example on a table.
D. Pain prevents me from lifting heavy weights, but I can manage light to moderate weights if they are conveniently positioned.
E. I can lift very light weights.
F. I cannot lift or carry anything at all.

**SECTION 4 -- Reading**
A. I can read as much as I want to with no pain in my neck.
B. I can read as much as I want to with slight pain in my neck.
C. I can read as much as I want to with moderate pain in my neck.
D. I cannot read as much as I want because of moderate pain in my neck.
E. I cannot read as much as I want because of severe pain in my neck.
F. I cannot read at all.

**SECTION 5 -- Headache**
A. I have no headaches at all.
B. I have slight headaches which come infrequently.
C. I have moderate headaches which come infrequently.
D. I have moderate headaches which come frequently.
E. I have severe headaches which come frequently.
F. I have headaches almost all the time.

**SECTION 6 -- Concentration**
A. I can concentrate fully when I want to with no difficulty.
B. I can concentrate fully when I want to with slight difficulty.
C. I have a fair degree of difficulty in concentrating when I want to.
D. I have a lot of difficulty in concentrating when I want to.
E. I have a great deal of difficulty in concentrating when I want to.
F. I cannot concentrate at all.

**SECTION 7 -- Work**
A. I can do as much work as I want to.
B. I can only do my usual work, but no more.
C. I can do most of my usual work, but no more.
D. I cannot do my usual work.
E. I can hardly do any work at all.
F. I cannot do any work at all.

**SECTION 8 -- Driving**
A. I can drive my car without neck pain.
B. I can drive my car as long as I want with slight pain in my neck.
C. I can drive my car as long as I want with moderate pain in my neck.
D. I cannot drive my car as long as I want because of moderate pain in my neck.
E. I can hardly drive my car at all because of severe pain in my neck.
F. I cannot drive my car at all.

**SECTION 9 -- Sleeping**
A. I have no trouble sleeping.
B. My sleep is slightly disturbed (less than 1 hour sleepless).
C. My sleep is mildly disturbed (1-2 hours sleepless).
D. My sleep is moderately disturbed (2-3 hours sleepless).
E. My sleep is greatly disturbed (3-5 hours sleepless).
F. My sleep is completely disturbed (5-7 hours sleepless).

**SECTION 10 -- Recreation**
A. I am able to engage in all recreational activities with no pain in my neck at all.
B. I am able to engage in all recreational activities with some pain in my neck.
C. I am able to engage in most, but not all recreational activities because of pain in my neck.
D. I am able to engage in a few of my usual recreational activities because of pain in my neck.
E. I can hardly engage in any recreational activities because of pain in my neck.
F. I cannot do any recreational activities all all.

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(with permission from Fairbank J)
Appendix O: Pilot RCT Patient Exercise Diary

Exercise Week; 1  2  3  4  5  6  7  8
(circle as appropriate)

Please indicate on the diary below the days on which you exercised the repetitions and number of sets completed. Please indicate any other forms of exercise undertaken outside of the “FLEXOR” intervention.
<table>
<thead>
<tr>
<th>Monday</th>
<th>Saturday</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuesday</td>
<td>Sunday</td>
</tr>
<tr>
<td>Wednesday</td>
<td>Notes</td>
</tr>
<tr>
<td>Thursday</td>
<td></td>
</tr>
<tr>
<td>Friday</td>
<td></td>
</tr>
</tbody>
</table>
Appendix P: Follow-up Questionnaire Study Ethical Approval Letter (Cork Research Ethics Committee)
25th September 2015

Dr Amanda Clifford  
Senior Physiotherapy Lecturer  
HS2-022  
Health Sciences Building  
University of Limerick

Re: An investigation into the functional rehabilitation of the deep neck flexors using FLEXOR: Part II.

Dear Dr Clifford

Expedited approval is granted to carry out the above study.

The following documents have been approved:

- Application Form
- Consent Form
- Study Protocol
- Study Questionnaires.

We note that the co-investigator involved in this study will be:

- Cliona O’Riordan, Physiotherapist.

Yours sincerely

[Signature]

Professor Michael M M O’Sullivan  
Chairman  
Clinical Research Ethics Committee  
of the Cork Teaching Hospitals

---

The Clinical Research Ethics Committee of the Cork Teaching Hospitals, UCC, is a recognised Ethics Committee under Regulation 7 of the European Communities (Clinical Trials on Medicinal Products for Human Use) Regulations 2004, and is authorised by the Department of Health and Children to carry out the ethical review of clinical trials of investigational medicinal products. The Committee is fully compliant with the Regulations as they relate to Ethics Committees and the conditions and principles of Good Clinical Practice.
An Investigation into the Functional Rehabilitation of the Deep Neck Flexors using “FLEXOR”: Part II

Invitation to Participate

Dear

Thank you for your recent participation in the University of Limerick led research trial on “FLEXOR” and chronic neck pain rehabilitation. Your time, co-operation and participation was most appreciated and your contribution to the overall research study invaluable.

As a follow-up to the study, we invite you to participate in our feedback questionnaire. We are seeking your opinions as a physiotherapist on chronic neck pain rehabilitation and your participation in the “FLEXOR” research trial in general.

It would be greatly appreciated if you could take 10 minutes of your time to read the enclosed questionnaire, follow the detailed instructions and return your completed questionnaire using the stamped addressed envelope (enclosed) at your earliest convenience. Again, as always participation is completely voluntary, however as numbers for the study were quite small, your honest feedback would be gratefully accepted to inform this and future research in the area.

Should you have any queries in relation to the questionnaire please do not hesitate to contact via email Cliona.ORiordan@ul.ie and I will be happy to assist you in any way I can.

Again, on behalf of the research group I wish to sincerely thank you for your co-operation thus far and look forward to receiving your completed questionnaire soon.

Yours Sincerely
Cliona O’Riordan, MISCP,
PhD Researcher, Department of Clinical Therapies,
University of Limerick.
Appendix R: Follow-up Questionnaire Study Patient Invitation Letter

An Investigation into the Functional Rehabilitation of the Deep Neck Flexors using “FLEXOR”: Part II

Invitation to Participate

Dear

Thank you for your recent participation in the University of Limerick led research trial on “FLEXOR” and chronic neck pain rehabilitation. Your time, co-operation and participation was most appreciated and your contribution to the overall research study invaluable.

As a follow-up to the study, we invite you to participate in our feedback questionnaire. We are seeking your opinions on your experience of physiotherapy for your neck pain and participating in the “FLEXOR” research trial in general.

It would be greatly appreciated if you could take 10 minutes of your time to read the enclosed questionnaire, follow the detailed instructions and return your completed questionnaire using the stamped addressed envelope (enclosed) at your earliest convenience. Again, as always participation is completely voluntary, however as numbers for the study were quite small, your honest feedback would be gratefully accepted to inform this and future research in the area.

Should you have any queries in relation to the questionnaire or your individual results from the trial, please do not hesitate to contact me (Clíona) on 087-7798583 or via email Cliona.ORiordan@ul.ie and I will be happy to assist you in any way I can.

Again, on behalf of the research group I wish to sincerely thank you for your co-operation thus far and look forward to receiving your completed questionnaire soon.

260
Yours Sincerely

________________

Cliona O’Riordan, MISCP,
PhD Researcher, Department of Clinical Therapies,
University of Limerick.
Appendix S: Follow-up Questionnaire Study Consent Form

An Investigation in the Functional Rehabilitation of the Deep Neck Flexors using FLEXOR: Part II

PARTICIPANT CONSENT FORM

I, .......................................................... [PRINT NAME], give consent to my participation in the above-named research project.

In giving my consent I acknowledge that:

1. The procedures required for the project and the time involved (including any inconvenience or risk, and their implications) have been explained to me, and any questions I have about the project have been answered to my satisfaction.

2. I have read the Participant Information Sheet and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

3. I understand that I can withdraw from the study at any time, without affecting my relationship with the researchers now or in the future.

4. I understand that my involvement is strictly confidential and no information about me will be used in any way that reveals my identity.

5. I understand that being in this study is completely voluntary – I am not under any obligation to consent.
6. If I agree to participate in an interview, I understand that I can stop the interview at any time if I do not wish to continue, the audio recording will be erased and the information provided will not be included in the study.

7. I consent to: – (please tick the relevant box below)
   i) Audio-taping
      YES ✔ NO
   ii) An interview
       YES ✔ NO
   v) Receiving feedback
      YES ✔ NO
         about the study

Contact Details:

Name:

.......................................................... ..........................................................

Address:______________________________________________________
_____________________________________________________________
________________________________

Email: ______________________________________________________

Telephone number: _________________________________________

Signed: Date:
Investigator Contact Details:

Cliona O’Riordan  
cliona.oriordan@ul.ie  
PhD Researcher  
Principal Investigator

Dr. Amanda Clifford  
Amanda.Clifford@ul.ie  
Lecturer, Co-Investigator

Pepijn Van DeVen  
Pepijn.VanDeVen@ul.ie  
Co-Investigator

John Cussen  
John.Cussen@ul.ie  
Product Designer, Co-Investigator

If you have concerns about this study and wish to contact someone independent, you may contact:

Cork Teaching Hospitals Research Ethics Committee,

Lancaster Hall,

6 Little Hanover Street,

Cork
Appendix T: Follow-up Questionnaire Study – Participant Questionnaire

An Investigation in the Functional Rehabilitation of the Deep Neck Flexors using FLEXOR: Part II

1) Are you: Male ☐ Female ☐

2) Please indicate by ticking the appropriate box your age;
   - 18-24 ☐
   - 25-34 ☐
   - 35-44 ☐
   - 45-54 ☐
   - 55-64 ☐
   - 65+ ☐

3) How long have you been experiencing neck pain?
   - > 3 months- 1 year ☐
   - 1-2 years ☐
   - 2-3 years ☐
   - 3-4 years ☐
   - 5 years + ☐

4) Please indicate on the body chart below, the location of your neck pain before you received physiotherapy treatment.
5) How helpful did you believe physiotherapy treatment could be for your neck pain, from 0 (not helpful at all) to 10 (extremely helpful)? Please indicate by placing an X over the appropriate place on the number line.

6) Please read each of the statements below pertaining to how often you experience neck pain and mark the box most appropriate to you.

<table>
<thead>
<tr>
<th></th>
<th>Always (Daily)</th>
<th>Frequently</th>
<th>Occasionally</th>
<th>Rarely</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>How often did you experience neck pain before your physiotherapy treatment?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How often do you experience pain now post physiotherapy treatment?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7) Please read each of the below statements pertaining to your experience with physiotherapy for your neck pain and indicate by marking in the appropriate box your agreement/disagreement with each of the statements.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither Agree nor Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The treatment I received from my physiotherapist significantly improved my neck pain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I was more physically active following my physiotherapy intervention.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. I am continuing with the exercises</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8) The remainder of the questionnaire contains questions for those who used the “FLEXOR” device as part of their rehabilitation programme. If you were not part of this group, please return your questionnaire with Pages 1 & 2 completed using the stamped addressed envelope.

(For members of the “FLEXOR” exercise group only).

Please read each of the below statements regarding the “FLEXOR” device and exercise intervention and indicate by marking the box most appropriate to you.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither Agree nor Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I understood why I needed to exercise my neck muscles using the “FLEXOR” device.</td>
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<td>2. My neck felt stronger after finishing the “FLEXOR” exercise intervention.</td>
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<td>3. I felt more in control of my own treatment by being able to exercise independently away from the physiotherapist</td>
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<td>4. I followed the “FLEXOR” exercise regime provided fully.</td>
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<td>5. Using “FLEXOR” was time-consuming</td>
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<tr>
<td>6. Having to be assessed twice outside of physiotherapy treatment sessions was inconvenient</td>
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<tr>
<td></td>
<td><strong>Strongly Agree</strong></td>
<td><strong>Agree</strong></td>
<td><strong>Neutral</strong></td>
<td><strong>Disagree</strong></td>
<td><strong>Strongly Disagree</strong></td>
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<td>7.</td>
<td>I felt the device was robust (strong).</td>
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<td>8.</td>
<td>The device was comfortable to wear for the duration of the exercises</td>
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<tr>
<td>9.</td>
<td>The “FLEXOR” device was easy to use.</td>
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<tr>
<td>10.</td>
<td>Overall I had a satisfying experience being involved in the “FLEXOR” trial</td>
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<td>11.</td>
<td>My results provided to me at the end of my exercise program were explained sufficiently</td>
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<td>12.</td>
<td>I felt satisfied with the level of contact from the researchers</td>
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<tr>
<td>13.</td>
<td>Using the “FLEXOR” device helped improve the outcomes of my overall physiotherapy experience.</td>
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<td>14.</td>
<td>I would recommend this device for to friends and family with similar symptoms to me</td>
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</tbody>
</table>
Device Design

9) What was/ were the best feature/s of the device?

_______________________________________________________________________
_______________________________________________________________________

10) What was the worst feature/s of the device?

_______________________________________________________________________

11) What would you change about your experience with the exercise intervention/research participation?

_______________________________________________________________________

Thank you kindly for taking the time to fill in this feedback questionnaire, your participation in this research study is greatly appreciated. Please return this survey at your earliest convenience using the stamped addressed envelope provided.
Appendix U: Follow-up Questionnaire Study – Physiotherapist Questionnaire

An Investigation in the Functional Rehabilitation of the Deep Neck Flexors using “FLEXOR”

**Demographics**

1) Are you:  
- Male [ ]  
- Female [ ]

2) Please indicate by ticking the appropriate box your age:
- 18-24 [ ]
- 25-34 [ ]
- 35-44 [ ]
- 45-54 [ ]
- 55-64 [ ]
- 65+ [ ]

3) How long have you have you worked as a chartered physiotherapist?
- < 5 years [ ]
- 5-10 years [ ]
- 10 + years [ ]

4) Did you participate in the “FLEXOR” trial as a clinician?
- Yes [ ]
- No [ ]

5) Did you refer any patients to participate in the “FLEXOR” trial?
- Yes [ ]
- No [ ]

*If you answered no to questions 4 & 5 please do not proceed to the remaining sections.*
6) If you answered “Yes” to the above Question 5,

What patient characteristics did you feel was most suited to participate in the trial?

<table>
<thead>
<tr>
<th>Gender:</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age:</td>
<td>&lt;45 years</td>
<td>&gt;45 years</td>
</tr>
<tr>
<td>Employed Status:</td>
<td>Employed</td>
<td>Unemployed</td>
</tr>
<tr>
<td>Stage of Chronicity:</td>
<td>&lt;2.5 year</td>
<td>&gt;2.5 year</td>
</tr>
<tr>
<td>Other: (Please State)</td>
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</tr>
</tbody>
</table>

If you answered “No” to Question 6, for what reasons did you not refer any patients to the “FLEXOR” trial?

- Didn’t match inclusion criteria
- Yellow/Red Flags present
- Showed no obvious signs of deep neck flexor involvement
- Adverse reaction to movement/exercise
- Other
  (Please state)

2) On average, how many patients with chronic neck pain do you treat in 1 year?

- < 10
- 10-20
- 20-30
- 30-40
- 40-50
- 50+

3) On average, how many physiotherapy treatment sessions does each of your patients with chronic neck pain receive per treatment block?

- 1-2
- 2-3
- 4-5
- 6-7
- 8+

4) Which outcome measures do you typically use when assessing a patient with chronic non-specific mechanical neck pain? Please tick the appropriate boxes (you may choose more than one)

Subjective feedback on symptoms
Range of Motion;
Using a device
Or observation
Standardised Pain Scales such as NRS (numerical rating scale)/VAS (visual analogue scale)
Neck Disability Index
Health Related Quality of Life Questionnaires
Strength (isometric/isotonic/isokinetic)

5) Below is a list of statements pertaining to the “FLEXOR” study from recruitment and referral of patients to the device itself. Please read each of the statements carefully and indicate by ticking the appropriate box your level of agreement or disagreement with the statement.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither Agree nor Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. All patients with chronic neck pain have weak deep neck flexor muscles</td>
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<tr>
<td>2. Strengthening the deep neck flexor muscles is an important part of a physiotherapy rehabilitation programme for people with chronic neck pain</td>
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<tr>
<td>3. The “FLEXOR” device is beneficial in the care of all patients with chronic neck pain</td>
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</tr>
<tr>
<td>4. It was worthwhile to inform all my patients with chronic neck pain about the “FLEXOR” study</td>
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</tr>
<tr>
<td>5. Referring patients to the “FLEXOR” study was time consuming</td>
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</tbody>
</table>
6. I was adequately informed about the trial; eligibility of participants and steps needed to recruit patients.

7. The inclusion of the “FLEXOR” device aided the recovery of the patients I referred to the trial.

8. Feedback on my patient’s outcomes following the “FLEXOR” intervention was adequate and useful to my treatment plan.

9. The “FLEXOR” device fulfils its intended purpose.

10. The exercise intervention using “FLEXOR” was adequate to ensure strengthening of the deep neck flexor muscles occurred.

11. Overall, I had a satisfying experience being involved in the “FLEXOR” trial.

---

**Device Design**

a) What was/were the best feature/s of the device?

_______________________________________________________________________

_______________________________________________________________________

b) What was the worst feature/s of the device?

_______________________________________________________________________

_______________________________________________________________________

c) What would you change about your experience with the exercise intervention/research participation?

_______________________________________________________________________

_______________________________________________________________________

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*Thank you kindly for taking the time to fill in this feedback questionnaire, your participation in this research study is greatly appreciated. Please return this survey at your earliest convenience using the stamped addressed envelope provided.*

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