PHYSIOTHERAPY FOR PATIENTS WITH HEAD AND NECK CANCER

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A thesis submitted for the degree of PhD (Physiotherapy)

Faculty of Health

University of Newcastle

NSW, Australia

Submitted by 31st October, 2014
Statement of originality

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For the facial lymphoedema study: Emma Johnson, Speech Pathologist, The Calvary Mater Newcastle Hospital, and Judy Holland, Physiotherapist-in-Charge, The Calvary Mater Newcastle Hospital provided information based on their clinical experience to assist in the development of interview questions.

For the case control and comparative electromyography studies: Clayton Reid, Physiotherapist, The Calvary Mater Newcastle Hospital, and Belinda Allen, The Calvary Mater Newcastle Hospital assisted with data collection. Carole James, PhD, University of Newcastle, provided technical assistance; and Suzanne Snodgrass, PhD, University of Newcastle, provided support with study design.

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Statement of Authorship

I hereby certify that the work embodied in this thesis contains a published paper/scholarly work of which I am joint author. I have included as part of the thesis a written statement, endorsed by my supervisor, attesting to my contribution to the joint publication/scholarly work.

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The following thesis is by publication, in accordance with the Rules Governing Research Higher Degrees (Rule 53).

I hereby certify that this thesis is in the form of a series of 6 published papers of which I am a joint author. I have included as part of the thesis a written statement from each co-author, endorsed by Faculty Assistant Dean (Research Training), attesting to my contribution to the joint publications.

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Statements from co-authors

With regards to the publications:

“Lymphoedema following treatment for head and neck cancer: Impact on patients, and beliefs of health professionals”

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Abstract

The management of head and neck cancer is complex and challenging. Treatment frequently results in physical morbidity, such as shoulder pain and dysfunction, and facial lymphoedema. Neck dissection surgery, involving lymph node removal, is the most common treatment for head and neck cancer. Intra-operatively, the accessory nerve can become injured, even when it remains macroscopically intact, causing reduced trapezius muscle activity and weakness. Shoulder pain and dysfunction ensues, impacting on quality of life and function. Facial lymphoedema can result from the surgical removal of cervical lymph nodes and radiation therapy.

The primary aim of this thesis was to investigate accessory nerve injury related to neck dissection surgery, and the effectiveness of a biomechanically specific physiotherapy intervention compared to a control group. The secondary aim was to explore the effects of facial lymphoedema on patients, and the understanding of and management of the condition by treating health professionals.

The qualitative facial lymphoedema study consisted of interviews of both patients with secondary facial lymphoedema as a result of treatment of head and neck cancer, and treating health professionals. The main effect of the condition experienced by patients concerned appearance and body image. The understanding of interviewed health professionals regarding the condition was found to be similar to the patient experience, however patients experiencing facial lymphoedema were generally not referred to physiotherapy. Treating health professionals need to routinely screen for any potential negative psychological and physical effects of facial lymphoedema, and affected patients referred to physiotherapy if required.

Our literature review found that little evidence exists pertaining to the effectiveness of physiotherapy on accessory nerve shoulder dysfunction after neck dissection surgery exists, with only one previous randomised controlled study published. We then undertook a case control electromyography study, to investigate any scapular muscle activity differences following neck dissection surgery in patients with clinical signs of
accessory nerve injury. The upper trapezius and middle trapezius muscles of patients’ operated side were found to have significantly less muscle activity than both a healthy matched control group ($p<0.00$), and their non-operated side ($p=0.001$). There was also significantly less electromyographic activity in the upper trapezius of the non-operated side compared with the healthy matched control group ($p=0.031$). A further comparative electromyography study, investigating scapular muscle activity during specific scapular strengthening exercises, found that overhead strengthening exercises were associated with higher levels of muscle activity. Scapular muscle activity findings from these innovative studies have provided crucial information to maximise the specificity of scapular muscle rehabilitation in this patient population, which then underpinned the development of a specific, graded physiotherapy intervention protocol.

The major study described in this thesis was a blinded, multicentre randomised controlled trial (RCT) to investigate the short and long term effect of progressive scapular strengthening exercises on shoulder pain and dysfunction, compared to usual care in Australia. Per-protocol analysis on 52 participants /53 shoulders demonstrated that the intervention group had statistically significantly higher active shoulder abduction at 3 months compared to the control group (+26.6°; 95% confidence interval [CI] 7.28 to 45.95; $p=0.007$). No significant differences were found between groups for the questionnaires assessing shoulder pain, function and region specific quality of life. At the 6 and 12-month follow-ups, there were no statistical differences between groups. This may reflect either a plateauing of the effect of the intervention in the long term, or the number of participants lost to follow-up. The RCT provided evidence that a progressive scapular strengthening program is more effective than usual care, for patients with accessory nerve injury after neck dissection surgery, that need to rapidly improve their active shoulder abduction.

The second literature review involved the use of, and efficacy for, intra-operative accessory nerve monitoring. It found that there is minimal evidence for its effectiveness in either minimising accessory nerve injury, or as a predictor of shoulder morbidity.
The studies contained in this thesis have provided novel insights which may improve both the multidisciplinary team management, and physiotherapy management, of patients affected with accessory nerve shoulder dysfunction and facial lymphoedema following head and neck cancer treatment. Further studies are required to investigate the effects of physiotherapy intervention in the long-term for accessory nerve shoulder dysfunction, the efficacy of intra-operative accessory nerve monitoring during neck dissection, and management of facial lymphoedema.
Chapter 1  Introduction

The purpose of this thesis was to examine the physical impact of treatment for head and neck cancer, and the potential contribution of physiotherapy to improving shoulder function following neck dissection surgery for cancer. The introduction chapter will describe the oncology treatment typically undertaken by patients with head and neck cancer, and the side effects of these treatments, which pertain to physiotherapy management.

1.1 Background of head and neck cancer

Head and neck malignancy accounts for 3.5% of all cancers in males and 2% in females in New South Wales, Australia, with the highest prevalence occurring in the 55-64 age group for both genders. In NSW, the five-year relative survival for patients diagnosed with head and neck cancer between 1999 and 2003 was 60% for males and 61% for females. Survival rates continue to improve over time, with a fall in mortality rates of 18.4% in males and 18.8% in females from 1998 to 2007. An improvement in survival has meant that more head and neck cancer patients are living with considerable morbidity as a result of treatment. Given that most affected patients are still of working age, there is a large societal effect of head and neck cancer.

Management of these cancers predisposes to significant visible deformity and dysfunction, with a profound impact on the physical and psychological wellbeing of patients. Patients who have undergone surgery for head and neck cancer have significantly worse social functioning and limitations from physical problems compared to healthy people of equivalent age and gender at least one year after surgery.

1.2 Treatment for head and neck cancer

The mainstay of treatment for head and neck cancer is surgery, with or without adjuvant treatment in the form of radiation therapy and/or chemotherapy. Primary tumour site location also influences the management of head and neck cancer. Oropharynx squamous cell carcinoma (SCC) is a more common subset of the head and
neck cancer group, and treatment usually involves surgery followed by radiation therapy if indicated. Hypopharyngeal cancer is often associated with a poorer prognosis and an advanced disease stage presentation compared to other head and neck cancer sites. As such, hypopharynx cancers are frequently managed with multimodal therapy including chemoradiation. Given that surgery and radiation therapy are the more common forms of management in head and neck cancer, the side effects of these treatments will be examined.

### 1.2.1 Surgery for head and neck cancer

Neck dissection surgery is an integral part of the surgical management of head and neck cancer. It involves the comprehensive or selective removal of cervical lymph nodes. Effective lymph node removal aims to reduce the chance of tumour spread and metastases. The removal of tumour and lymph nodes in this region is a challenging surgical procedure given its anatomical complexity, and one in which healthy tissue may inadvertently be negatively affected. Classification of neck dissection involves the neck being divided into five levels based on specific anatomical boundaries and landmarks. Lymph nodes are classified according to these levels.

There are three types of neck dissection. They are defined according to the universally accepted classification developed by the American Head and Neck Society and the American Academy of Otolaryngology Head and Neck Surgery. Radical neck dissection (RND) involves removal of all five levels of lymph nodes (I-V) on one side of the neck with sacrifice of non-lymphatic structures, which includes the spinal accessory nerve, internal jugular vein and sternocleidomastoid muscle. Modified radical neck dissection (MRND) involves the removal of all five levels of lymph nodes (I-V) on one side of the neck with preservation of at least one non-lymphatic structure. Usually the spinal accessory nerve is spared in this procedure. In selective neck dissection (SND), fewer lymph node levels are removed with sparing of all non-lymphatic structures. The ipsilateral sternocleidomastoid (SCM) muscle may or may not be removed with neck dissection.
The spinal accessory nerve exits the skull base through the jugular foramen, together with the glossopharyngeal and vagus nerves. It then variably passes either dorsally or ventrally to the internal jugular vein. The spinal accessory nerve runs along the inner surface of the sternocleidomastoid muscle, penetrating this muscle in 45% of cases, before proceeding on to innervate the trapezius muscle at its upper anterior aspect. The spinal accessory nerve becomes exposed as it crosses both Levels II and V lymph nodes, and thus becomes at risk of injury when undertaking lymphadenectomy in these regions. This takes the form of accessory nerve severing in radical neck dissection, or to traction, skeletonisation and devascularisation of the nerve following nerve-preserving neck dissections.

The undertaking of such surgery is associated with significant morbidity, particularly involving the shoulder and neck. The presence of long term shoulder and arm pain in head and neck cancer patients has been found to be strongly associated with neck surgery, most often resulting from damage to the accessory nerve.

1.2.1.1 Abnormal scapular biomechanics following neck dissection

The neuroanatomical injury from neck dissection and the physical side effect is primarily accessory nerve shoulder dysfunction (ANSD). The accessory nerve is the main motor supply to the trapezius muscle, particularly the upper and middle portions. Several intra-operative electromyographic (EMG) studies undertaken during neck dissection have demonstrated using accessory nerve stimulation that the upper part of the trapezius is innervated by the accessory nerve in all cases, between 85% and 100% of middle trapezius is innervated by the accessory nerve and between 77% and 100% of the lower trapezius receives accessory nerve innervation.

The cervical plexus contribution of the C2, C3 and C4 nerve roots to both the spinal accessory nerve and the trapezius muscle is much more variable. In the majority of patients studied using intra-operative EMG, the C2-C4 branches are involved in trapezius muscle innervation, either directly to the muscle or by joining the spinal accessory nerve. However other EMG studies have found the C2-C4 contribution to trapezius to be inconsistent. Overall, the C2-C4 motor input to trapezius is
debatable, but still requires surgical consideration when aiming for neurological preservation during neck dissection.

Figure 1-1 Anatomy of the accessory nerve and related structures

The trapezius is a large muscle important in stabilising the scapula, both at rest and during shoulder motion. As the insertion of upper and middle trapezius is the acromion and spine of the scapula, impaired trapezius muscle activity leads to impaired scapular biomechanics. The upper portion of trapezius originates on the external occipital protuberance, the medial third of the superior nuchal line and the ligamentum nuchae and inserts onto the posterior border of the lateral third of the clavicle. The distal part of the clavicle is attached to the acromion and coracoid process of the scapula via the acromioclavicular ligament, and the coracoclavicular and coracoacromial ligaments respectively. The primary action of trapezius is to elevate and laterally rotate the scapula as it moves during active shoulder abduction, and to a lesser extent active shoulder flexion. The middle portion of trapezius originates from the seventh cervical and first to third thoracic spinous processes and inserts onto the medial margin of the acromion and the superior lip of the posterior border of the spine of the scapula. Its primary action during active shoulder abduction and flexion is to anchor the scapula onto the chest wall, and prevent elevation of the medial border from the chest wall. Insufficient scapular lateral rotation and elevation during active
shoulder abduction may lead to impingement of structures in the subacromial space, including the subacromial bursa and supraspinatus tendon.

Insufficient ability of the trapezius to support the scapula at rest, leads the scapula to adopt a depressed and medially rotated position with medial scapula border elevation off the chest wall at rest. The weight of the arm can increase the vertical upward force of the anterior structures, such as the sternocostal joint and clavicle, via a torque-like action. Similarly, if patients affected with accessory nerve injury attempt to repeatedly move the shoulder into a restricted abduction range, an increased downward vertical compressive force onto the sternocostal joint and clavicle results. Injury to the sternocostal joint is typically a subluxation of the head of the clavicle in an upward and forward direction. Clavicular injury may take the form of a stress fracture, usually toward the medial end of the bone. There have been several case study reports of injury to this region following neck dissection, affecting patients with both a sacrificed accessory nerve \(^{18, 19}\) and an intact accessory nerve \(^{20}\).

Thus, accessory nerve injury resulting from neck dissection leads to reduced trapezius muscle activity, causing abnormal scapular biomechanics. Patients with ANSD are limited functionally with overhead activities and those that involve active shoulder abduction. This may also negatively impact on their overall quality of life.
1.2.1.2 Facial lymphoedema following neck dissection

The removal of cervical lymph nodes that occurs with neck dissection can affect the functioning of the lymphatic system of the face and neck region, causing secondary regional lymphoedema. The injury to lymphatic structures occurring with neck dissection often leads to persistent oedema and accumulation of lymphatic fluid, which chronically causes inflammatory and fibrotic changes. This causes a considerable negative impact on patients, both physically and psychologically. The understanding of this condition by treating health professionals is unknown.
1.2.2 Radiation therapy for head and neck cancer

The status of cervical nodes after neck dissection is a major determinant of outcome and further management in head and neck cancer. It is not uncommon for patients who have undergone neck dissection to proceed to post-operative radiation therapy. Multiple pathological lymph nodes, an inadequate surgical margin and spread of tumour into peri neural structures are the main indications for post-operative radiation therapy.

Radiation therapy is usually recommended to commence within three to six weeks of surgery. Conventional radiation therapy involves radiation that includes not only the tumour site, but also normal tissue and organs, which often leads to their long-term injury. Adverse effects on quality of life secondary to radiation-induced tissue and organ damage often occur as a result of head and neck tumour control management. Xerostomia (reduced salivary production) and dysphagia (difficulty swallowing) are common negative sequelae following radiation therapy. Reduced neck range of motion frequently occurs following post-operative radiation therapy. Fibrotic tissue as a consequence of surgical scars and radiation therapy are proposed as likely reasons...
for this. The balance between adequate tumour control and maintaining quality of life, through preservation of organ function in the management of head and neck cancer is often difficult and controversial.

The effect of radiation therapy on normal tissue may be classified as acute, during the course of treatment; consequential, appearing later; and late, developing months to years following treatment. Muscle and nerve have a slower cellular turnover, and thus more commonly experience the late effects of radiation-induced damage. In muscle, this manifests as fibrosis, necrosis, atrophy and vascular damage. In nerve tissue, it includes fibrosis of the nerve sheath and demyelination. The development of moderate to severe subcutaneous fibrosis resulting from radiation therapy following breast surgery has been found to be associated with an increased risk of shoulder problems. This has been suggested to be related to fibrotic and atrophic changes in the pectoralis major muscle. However other associated structures may also be involved such as the shoulder joint capsule and ligaments, particularly inferiorly where scar tissue may form as a result of lymphadenectomy. Increased tissue fibrosis occurring with radiation therapy patients with extremity soft tissue sarcoma has been found to be associated with significantly lower patient function in a recent multi-centre randomised study. In patients who have undergone neck dissection surgery for cancer, the radiation field includes the anterolateral neck and thus this portion of trapezius. Consequently, the muscle is likely to experience the adverse tissue changes of radiation therapy, further compounding the manifestation of ANSD. Additionally, the accessory nerve is also included in the radiation field. Therefore, there may be subsequent injury to the accessory nerve due to the adverse effects of radiation therapy.

1.2.2.1 The effect of radiation therapy on shoulder pain

Studies of the effect of radiation therapy following neck dissection surgery suggest that radiation therapy does not appear to have a significant effect on long term outcome relating to shoulder pain, function or quality of life. A prospective study that measured shoulder pain, shoulder function and quality of life in 139 neck
dissection patients found that undergoing radiation therapy was not a significant predictor of shoulder dysfunction at four months following surgery. It could be argued that this follow up time period is inadequate to assess whether radiation therapy had an effect on these outcomes given that the effects on muscle and nerve tissue are often late, and in some cases years later. A retrospective study of 137 patients one year after surgery found that having radiation therapy had no significant effect on shoulder pain and disability. Other studies with smaller samples support findings that radiation therapy has no significant effect on shoulder pain, shoulder range of motion and quality of life in neck dissection patients at least six months following surgery. Overall, prevalence studies of ANSD following neck dissection surgery indicate radiation therapy does not affect long-term outcomes of shoulder pain and disability. In contrast, studies at a cellular level suggest there is potential for radiation therapy to affect muscle and nerve tissue adversely. This may further contribute to trapezius muscle weakness, particularly of the upper fibres, and accessory nerve injury, both of which are included within the radiation field. As many neck dissection patients also undergo adjuvant radiation therapy, this was an important factor considered in this thesis.

1.2.2.2 The effect of radiation therapy on facial lymphoedema

Patients with head and neck cancer may undergo radiation therapy as a primary treatment, or following neck dissection surgery. This can lead to inflammatory changes in blood vessels as well as the lymphatic channels in the region. Blockages to lymphatic flow occur, which may result in impaired lymphatic system functioning. Consequently, head and neck cancer patients are at risk of developing secondary lymphoedema.

1.3 Research aims

The primary purpose of this thesis was to determine the most common physical impact of treatment for head and neck cancer, and the potential role of physiotherapy contributing to the management of such disorders. With respect to commonly described shoulder dysfunction following neck dissection surgery, the aim was to
investigate the role of biomechanically specific scapular exercises on shoulder pain, function and quality of life in patients affected by accessory nerve related shoulder dysfunction following neck dissection.

The aims of each study conducted as part of the research underpinning this thesis are:

• **Study 1**

To assess the impact of facial lymphoedema on affected head and neck cancer patients, and the understanding and management of the condition by treating health professionals.

• **Study 2**

To determine the level of evidence for physiotherapy management of accessory nerve related shoulder dysfunction following neck dissection.

• **Study 3**

To investigate the electromyographic differences of the scapular muscles on the side demonstrating clinical signs of accessory nerve injury resulting from neck dissection surgery, compared to their unaffected side and a group of healthy age and gender-matched controls.

To investigate the effect of various scapular muscle strengthening exercises on scapular muscle activity in neck dissection patients with clinical signs of accessory nerve injury.

• **Study 4**

Assess the short and long term effects of an early progressive scapular strengthening physiotherapy program compared to usual care on patients affected with accessory nerve shoulder dysfunction following neck dissection.
• Study 5

To review the evidence for the use of intra-operative physiological nerve monitoring of the accessory nerve in affecting prevalence of post-operative shoulder morbidity and as a predictor of functional outcome.

1.4 Thesis outline

There are eight chapters that comprise this thesis. Following the Introduction chapter, there are six chapters that consist of published papers in peer-reviewed academic journals. There were five studies conducted as follows: Study 1) A qualitative study exploring the effects of facial lymphoedema on head and neck cancer patients experiencing this condition and the understanding of facial lymphoedema by treating health professionals titled “Lymphoedema following treatment for head and neck cancer: impact on patients, and beliefs of health professionals”. This paper was published in European Journal of Cancer Care 2014; 23(3):317-327; Study 2) A literature review to assess the level of evidence for physiotherapy in the management of accessory nerve shoulder dysfunction, titled “Physiotherapy for accessory nerve shoulder dysfunction following neck dissection surgery: A literature review” (published in Head and Neck 2011; 33(2):274-280); Study 3) i. A case controlled study comparing the scapular muscle activity of a series of neck dissection patients affected by accessory nerve injury compared to healthy matched controls: “Impact of neck dissection on scapular muscle function: A case controlled study” published in Archives of Physical Medicine and Rehabilitation 2013; 94(1):113-119), ii. A comparative study exploring the effect of scapular muscle exercises on scapular muscle activity in neck dissection patients with clinical signs of accessory nerve shoulder dysfunction titled “Scapular muscle exercises following neck dissection surgery for head and neck cancer: A comparative electromyographic study” published in Physical Therapy 2013; 93(6):786-797; Study 4) The multicentre randomised controlled trial including the methods, results, discussion of findings with 3, 6 and 12 month follow-up: “Maximising shoulder function following accessory nerve injury after neck dissection surgery: A multicentre randomised controlled trial”. Published online in Head and
Chapter 2  Lymphoedema following treatment for head and neck cancer: impact on patients, and beliefs of health professionals

This chapter contains the published manuscript as titled above, published in European Journal of Cancer Care, 2014;23(32):317-327.

The authors of this publication are Aoife McGarvey, Peter Osmotherly, Gary Hoffman and Pauline Chiarelli.

The chapter does not differ from the published paper apart from the tables and references that have been renumbered to maintain consistency throughout the thesis.

2.1 Abstract

Cervicofacial lymphoedema is a recognised side effect that may result following treatment for head and neck cancer. This study aimed to investigate the perspectives of affected patients and the beliefs that treating health professionals hold about head and neck lymphoedema. Ten patients with head and neck lymphoedema and 10 health professionals experienced in the treatment of head and neck cancer patients agreed to participate in semi-structured face to face interviews. Interviews were recorded, audio files were transcribed and coded and then analysed for themes. Themes of experiences of patients with head and neck lymphoedema and the beliefs of health professionals largely overlapped. Given its visible deformity, the main effect of lymphoedema in head and neck cancer patients is on appearance. In some cases this lead to negative psychosocial sequelae such as reduced self-esteem, and poor socialisation. Clinicians need to be aware of those patients more likely to experience lymphoedema following treatment for head and neck cancer, and how they are affected. Understanding how patients with facial lymphoedema are affected psychologically and physically, and the importance of prompt referral for lymphoedema treatment, might ultimately improve outcomes and ensure optimal management.
2.2 Introduction

2.2.1 Lymphoedema in head and neck cancer patients

Lymphoedema is the persistent swelling and accumulation of protein rich fluid that results from either obstruction of lymphatic vessels, removal or damage to lymphatic structures. Chronic lymph stasis may eventually lead to inflammation, fibroplasia, and resultant induration of tissue. Neck dissection is a common treatment for head and neck cancer. Cervical lymphadenectomy as a consequence of neck dissection can lead to lymphoedema in the face and neck region, as a result of disruption to or removal of lymphatic drainage. Contracture of scar tissue following neck dissection may also interrupt lymphatic flow. Oedema may resolve in the post-operative phase of neck dissection. However it may persist, progressing to secondary lymphoedema in this region.

Radiation therapy is a common primary or adjuvant treatment for head and neck cancer. Inflammatory changes to blood vessels and lymphatic channels in the face and neck that can occur during or following radiation therapy, may further impair lymphatic system function, possibly contributing to lymphoedema. Additionally, the mobility of the jaw, face and neck is often reduced as a side effect of treatment, restricting the ability to chew and swallow. The resultant reduction in regional muscle activity is likely to further impair the lymphatic system. Thus, head and neck cancer patients are at risk of developing secondary lymphoedema due to the effects of treatment on the lymphatic system.

2.2.2 Prevalence, prognosis and risk factors of facial lymphoedema

Patients undergoing treatment for head and neck cancer often experience “internal” oedema, (within the upper aero digestive tract), “external” oedema or lymphoedema (visible swelling in the soft tissue of the head or neck), or mixed oedema (a combination of both oedema types). Information on the prevalence of facial lymphoedema is conflicting in published literature. This is likely due to difficulties with accurate measurement of lymphoedema in this anatomical region, and differences
in patient cohort in relation to tumour stage and types of cancer treatment received. A retrospective review of 264 head and neck squamous cell carcinoma patients found 12.1% of people had persisting facial oedema following treatment. However there was no distinction made in the study between lymphoedema and other forms of oedema. European studies have reported that 36% to 48.4% of head and neck cancer patients experience lymphoedema following treatment. A more recent prevalence study of 81 patients at a single centre in the USA found 75.3% of patients with head and neck cancer had some form of either internal oedema, external oedema or mixed oedema. As acknowledged by the authors, the higher prevalence rate may relate to the sample being predominately of a higher tumour stage, with over 80% of patients being either stage III or IV. Longitudinal studies examining how head and neck lymphoedema progresses over time have not been reported. Prevalence studies provide insights limited to one point in time. While retrospective chart reviews have been published, these approaches fail to track the progression of this condition.

Causes of regional oedema, but not specifically lymphoedema, that occur after treatment for head and neck cancer, have been reported. These include internal jugular vein thrombosis, local infection, cervical lymphadenectomy, flap reconstruction and the presence of tumour or metastatic lymph nodes. Persisting facial oedema was found to be an indicator of poor prognosis. Oedema delayed in onset has been suggested to relate to recurrent disease with more advanced lymph node involvement, and would need to be excluded as a possible cause of facial oedema prior to a diagnosis of lymphoedema being made.

### 2.2.3 Sequelae of secondary lymphoedema

The impact of lymphoedema on affected head and neck cancer patients is generally reflective of its anatomical location and severity, with the most common being the neck and submental area. Significant associations between the severity of external lymphoedema and reduced neck rotation as well as difficulties in swallowing and compromised nutritional intake have been found. Lymphoedema affecting the tissue surrounding the eyes and lips is less common, but is likely to have a greater impact on
function as it affects the ability to open the eyelids, verbally communicate and masticate. Most affected patients experience some impact upon their body image, which may lead to psychological sequelae such as anxiety and depression.

The effect of lymphoedema on patients may vary, depending on differences in patient demographics, tumour stage, and length of time since treatment completion. Thus, this qualitative study carried out on a small cohort aimed to explore the sequelae of secondary lymphoedema in head and neck cancer patients.

2.2.4 Management and treatment of secondary lymphoedema

Few scientifically robust studies have explored the management of secondary lymphoedema in head and neck cancer patients. Smith and Lewin conducted a narrative literature review of relevant studies that included nine articles and two abstracts. Only three of the considered articles were related to treatment for lymphoedema in the head and neck region. This included manual lymphatic drainage and customised compression garments, two of which related to head and neck cancer patients. Since these two studies had small sample sizes, it is difficult to conclude the benefit of these treatment modalities. Underpowered investigations and lack of randomised controlled trials contribute to a lack of evidence-based treatment of lymphoedema in head and neck cancer patients. Therefore, current management protocols appear likely to be based on reasonable clinical opinion alone. Lack of research in this area may be due to logistical difficulties associated with undertaking intervention studies, or may reflect the idea that while secondary lymphoedema may be a negative treatment sequelae for head and neck cancer patients, this is possibly not considered by health professionals as a high priority compared with other more immediate concerns, such as cure. A deeper understanding of the impact of lymphoedema on affected patients might allow health professionals to offer better support and management. Investigating if similarities or disparities exist between the experiences of head and neck cancer patients with secondary lymphoedema, and the beliefs of treating health professionals, may identify if multidisciplinary teams...
understand the condition, and are meeting the needs of affected patients. Knowledge of common factors associated with developing secondary lymphoedema, and being aware of how patients with lymphoedema are affected, might improve the likelihood of early screening and referral on to a lymphoedema therapist for management. The collective clinical opinion of health professionals experienced in treating patients with head and neck cancer may allow for the development of a framework to underpin the identification and management of this under-reported condition, thus reducing its associated negative sequelae.

### 2.3 Aims of the study

Using face-to-face interviews, this study aimed to explore the relationships between:
1. how lymphoedema affects head and neck cancer patients;
2. beliefs of medical and health professionals regarding which patients might be more at risk of developing lymphoedema,
3. how it affects patients,
4. how lymphoedema might be effectively managed.

### 2.4 Methods

#### 2.4.1 Participants

Semi-structured one-on-one interviews were used to explore relevant issues. The interviews were underpinned by a series of pre-developed questions that allowed the interviewer to further explore themes and clarify responses provided.

Two separate participant groups took part in the interviews, with a convenience sample of 20 participants. The first group consisted of 10 patients who had experienced lymphoedema as a result of treatment for head and neck cancer, and had been identified by a treating physiotherapist, speech pathologist or doctor. The second group included 10 health professionals involved in the treatment of head and neck cancer patients at a large regional tertiary referral hospital.

Head and neck cancer patients who had been treated either by physiotherapy and/or speech pathology and who demonstrated clinical signs of lymphoedema were
invited to participate. Eligibility criteria included: (1) minimum of 3 months since completion of treatment for head and neck cancer, which is the accepted time frame for external lymphoedema; (2) age 18 years and over and (3) English speaking. Exclusion criteria were: (1) presence of metastatic disease; (2) currently undergoing radiation therapy and/or chemotherapy and (3) inability to give informed consent. The professional group was invited from members of the regional multidisciplinary head and neck cancer team, and lymphoedema therapists working at the hospital.

2.4.2 Ethical Consideration

Ethical approval to conduct the study was granted by the Hunter New England Health Research Ethics and Governance Unit and the University of Newcastle Ethics Committee. Informed consent was obtained from all participants, with audio files allocated a study number for anonymity. Participants’ names were not included on the recording. Participants were informed they could cease the recording at any time, or ask for a section of recording to be deleted if they wished.

2.4.3 Data Collection

All interviews were undertaken in a private room at the hospital. The interviews were recorded and the same interviewer conducted all the interviews, in order to maintain consistency with questioning style. The interviews were conducted by the chief investigator who is a physiotherapist experienced in treating patients with head and neck cancer. During the interview, leading and closed style questions were avoided. The questions developed to explore the aims were based on a combination of clinical experience and review of the current literature (in Thesis Appendices). Both patients and health professionals were invited to add any other comments at the end of the interview. One interview was recorded for each participant. Sampling continued until the point where data saturation was reached.

2.4.4 Data Analysis

The recorded interviews were transcribed and analysed. The first author extensively reviewed all audio files and their hard copy transcripts. Codes were developed based
on initial observations of the transcripts, and applied to textual data. Common themes were then generated by indexing common categories and triangulation of converging perspectives of participants to aid study validity. Frequency of coding was recorded, which was then utilised to determine importance of the sample’s responses (Table 2-2). A second researcher independently reviewed coding and coding frequency to ensure consistency and improve reliability. Any differences in coding and coding frequency between the researchers were then discussed to clarify and promote agreement.

2.5 Results

2.5.1 Participants

Eighty per cent of interviewed patients were male with a mean age of 60.1 years (range 32 to 75 years). Seven of the ten patients had undergone bilateral treatments for cancer. The time from the completion of cancer treatment to interview ranged from 10 to 18 months (Table 2-1). The duration of each interview ranged from 3 minutes to 30 minutes in length, with a median duration of 8 minutes per interview.

2.5.2 Identified themes

Major themes emerging from patients’ experience of lymphoedema were grouped into the following areas: (1) Physical effects of lymphoedema; (2) Psychosocial issues associated with lymphoedema; (3) Management strategies found to be helpful.

Major themes of health professionals’ beliefs of lymphoedema were: (1) Clinical features, including their perceptions of common risk factors and the prevalence of such; (2) How it is perceived to affect patients; (3) Management strategies commonly recommended.
2.5.3 Patient experiences

2.5.3.1 Physical effects of lymphoedema

Altered appearance

Interview codes indicated a large variation in how having secondary lymphoedema affects patients; physically, psychologically and socially. The predominant effect of lymphoedema was the impact on patients’ appearance. Unlike limb lymphoedema, which can be covered by clothing, overt swelling around the face and neck more obviously affects appearance more than limb lymphoedema, as it is unable to be hidden.

A male patient who underwent bilateral radiation therapy and chemotherapy reported:

It’s certainly affecting (me) the fact that I have a much thicker and fatter neck, so it’s affecting my appearance … now with this big fat neck it looks more like a bullfrog in family photos. My general appearance has been altered quite considerably… And all of a sudden to have a big bulbous neck like a cane toad.

Another male patient mentioned:

I think I was just self-conscious. It just looked strange. I’d never had that before and I was more conscious about it than anything.

Diurnal pattern

While half of the participants reported that the degree of swelling had lessened over time, all patients reported that the lymphoedema was still present. A diurnal pattern was evident in three patients, with an increase in facial swelling during the night and for the initial morning period. This pattern was associated with patients who reported being limited in their ability to lie flat on their back during sleep.

Tightness and reduced cervical spine range of motion

The majority of interviewees reported experiencing facial lymphoedema in the submandibular region and described sensations such as: thick, hard, feels like lead, and tight. The two patients who had lymphoedema in the neck reported feeling restrictions to their range of motion.
Mucus secretions and swallowing

Half of the patients reported the presence of mucous or thick viscous secretions in the throat that seemed to be linked with facial lymphoedema (FL). Often improvement of FL was associated with a reduction in the amount of mucus, but there was no apparent causal link between these two features. Because the majority of patients reported dysphagia related to damage to internal structures as well as external oedema, it was difficult for patients to isolate the specific effect of lymphoedema on swallowing. Some patients reported the presence of lymphoedema meant they were unable to lay supine, in order to perform exercises prescribed to improve dysphagia. Many patients reported both mucus and lymphoedema being worse in the morning, often making breakfast a more challenging meal in terms of swallowing.

2.5.3.2 Psycho-social aspects of facial lymphoedema

There was a large variation in how the change in appearance affected the patients, both emotionally and socially. Most men indicated they felt no lasting psychological effect from the change in their appearance. They were not bothered by it and accepted it, once they knew it was a normal and expected side effect of the treatment:

… Having gone through the rest of it (treatment for cancer), it wasn’t an issue… You know, it was all part and parcel of it … there’s still a little bit (facial lymphoedema) there, just that little bit… they (surgeons) actually said that the swelling might not go down… it doesn’t bother me because I’ve accepted it…

Another male said:

The swelling itself was a real concern. I’m not a vain person so it looked a bit funny but didn’t worry me…
<table>
<thead>
<tr>
<th>Participant number</th>
<th>Age</th>
<th>Area of Cancer</th>
<th>Tumor Stage (TMN)</th>
<th>Treatment</th>
<th>Time since treatment completion</th>
<th>Oedema Location</th>
<th>Lymphoedema Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>61</td>
<td>Bilateral SCC(^a) tonsils</td>
<td>T3N2M0</td>
<td>Bilateral radiation therapy, chemotherapy</td>
<td>18 mo</td>
<td>Bilateral: Cheek, Submandibular Neck</td>
<td>MLD(^d) Exercises</td>
</tr>
<tr>
<td>2</td>
<td>58</td>
<td>Unilateral submandibular SCC(^a) lymph node</td>
<td>Unknown primary</td>
<td>Unilateral MRND(^b), bilateral intensity-modulated radiation therapy</td>
<td>14 mo</td>
<td>Unilateral: Cheek, Submandibular</td>
<td>MLD(^d) Exercises</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>Unilateral SCC(^a) base of tongue</td>
<td>T3N0M0</td>
<td>Bilateral radiation therapy, chemotherapy</td>
<td>11 mo</td>
<td>Bilateral: Submandibular Neck</td>
<td>MLD(^d) Exercises</td>
</tr>
<tr>
<td>4</td>
<td>64</td>
<td>Unilateral tonsil SCC(^a)</td>
<td>T3N0M0</td>
<td>Bilateral radiation therapy, chemotherapy</td>
<td>12 mo</td>
<td>Bilateral: Submandibular</td>
<td>MLD(^d) Exercises</td>
</tr>
<tr>
<td>5</td>
<td>63</td>
<td>Bilateral SCC(^a) tongue</td>
<td>Malignant neoplasm</td>
<td>Bilateral MRND(^b), bilateral radiation therapy, chemotherapy</td>
<td>13 mo</td>
<td>Bilateral: Neck</td>
<td>Nil</td>
</tr>
<tr>
<td>6</td>
<td>75</td>
<td>Unilateral SCC(^a) tongue</td>
<td>T2N0M0</td>
<td>Unilateral SND(^c)</td>
<td>10 mo</td>
<td>Unilateral: Submandibular Neck</td>
<td>MLD(^d) Exercises</td>
</tr>
<tr>
<td>7</td>
<td>63</td>
<td>Unilateral SCC(^a) tonsil</td>
<td>T1N2M0</td>
<td>Bilateral radiation therapy and chemotherapy</td>
<td>3 mo</td>
<td>Bilateral: Face, Submandibular Neck</td>
<td>MLD(^d) Exercises</td>
</tr>
<tr>
<td>8</td>
<td>62</td>
<td>Unilateral oropharynx</td>
<td>T2N2M0</td>
<td>Bilateral radiation therapy and chemotherapy</td>
<td>11 mo</td>
<td>Bilateral: Submandibular Neck</td>
<td>MLD(^d) Compression</td>
</tr>
<tr>
<td>9</td>
<td>63</td>
<td>Unilateral buccal SCC(^a)</td>
<td>T1N1M0</td>
<td>Unilateral SND(^c) and radiation therapy</td>
<td>10 mo</td>
<td>Unilateral: Face, Submandibular Neck</td>
<td>MLD(^d) Exercises</td>
</tr>
<tr>
<td>10</td>
<td>32</td>
<td>SCC lower lip</td>
<td>T4N0M0</td>
<td>Bilateral SND(^c)</td>
<td>13 mo</td>
<td>Bilateral: Submandibular</td>
<td>MLD(^d)</td>
</tr>
</tbody>
</table>

\(^a\) SCC squamous cell carcinoma, \(^b\) MRND modified radical neck dissection, \(^c\) SND selective neck dissection, \(^d\) manual lymphatic drainage
However, for one male patient with significant lymphoedema in the neck, face and submental region, the change in appearance had pronounced negative effects on self-esteem, self-image and ability to socialise:

If we could get rid of the appearance as I think it affects me mentally and emotionally... No one likes to think they have four or five chins unless you’ve managed to drink a lot of wine and eat a lot of pizza, which I haven’t done either for the past two years... Certainly it has caused me to step out of photos just with the family in the last 12 months because I know the image or the photo isn’t going to come out very good.

Negative body image issues were also more noticeable in the two interviewed females, with one reporting:

I was talking about covering the disfigurement somehow wearing a mask... when I was in the street... I feel like if I meet someone new, the look of my face is the elephant in the room... I wear skivvies most of the time, or a scarf to cover it up so I wasn’t worried about the look of it in public.

The other female, with mild lymphoedema, reported that she no longer felt comfortable being included in photographs, due to the effect of the swelling on her appearance.

2.5.3.3 Strategies to assist with facial lymphoedema

Lymphoedema massage techniques had been taught to several patients by a physiotherapist (Table 2-2). They reported these techniques helped with swelling and mucus, leading to improved ability to sleep at night, and improvement of lymphoedema experienced particularly first thing in the morning.

Performing cervical spine range of motion exercises were also perceived to relieve lymphoedema, with one male patient reporting:

Within a couple of days of doing all those different exercises it was freeing it (lymphoedema) up. Particularly for the sleeping... I found that if I was doing it a few times a day and if I did it before I went to sleep at night it certainly eased it.
### Table 2-2 Themes, sub themes and coding frequencies emerging from interviewed patients

<table>
<thead>
<tr>
<th>Physical Effects (frequency of emergence)</th>
<th>Psychological and Social Effects (frequency of emergence)</th>
<th>Helpful Management Strategies (frequency of emergence)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altered appearance (10)</td>
<td>Acceptance (6)</td>
<td>Massage (MLD) (8)</td>
</tr>
<tr>
<td>Diurnal pattern (4)</td>
<td>Negative body image (4)</td>
<td>Neck ROM exercises (2)</td>
</tr>
<tr>
<td>Neck tightness and/or reduced neck ROM (4)</td>
<td>Reduced socialisation (3)</td>
<td>Lymphoedema garment (3)</td>
</tr>
<tr>
<td>Mucus secretions (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chewing, swallowing problems (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty lying flat (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altered clothing (3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MLD, Manual lymphatic drainage; ROM, Range of motion

#### 2.5.4 Health Professional experiences

Health professionals participating in an interview were all members of the head and neck cancer multidisciplinary team, apart from the lymphoedema therapists, who each had at least 5 years' experience managing head and neck cancer patients. The interviewees consisted of two consultant radiation oncologists, two consultant maxillofacial surgeons, one dietician, and one speech pathologist, two physiotherapists trained in lymphoedema management, a radiation therapy nurse and a head and neck cancer care co-ordinator.

#### 2.5.4.1 Clinical Features

This theme describes the beliefs of health professionals related to lymphoedema incidence in head and neck cancer patients, possible causes or common factors associated with its development and its progression over time (Table 2-3). The majority of health professionals reported the incidence of lymphoedema to be common after treatment for head and neck cancer. Treatment type, and multiplicity or combinations of modalities (neck dissection surgery; radiation therapy; chemotherapy) were believed to have the strongest relationship with development of lymphoedema. The greater the number of combined treatment modalities the patients received and the higher the dosage of treatments, the greater the chance of developing lymphoedema. Almost all health care professionals reported that bilateral treatment modalities and chemo radiation to the region was associated with a higher incidence of lymphoedema, with incidence estimates between 40% and 80%. Reports of delayed oral intake, and
associated impaired mastication and swallow, with reduced regional mobility, was another perceived contributor to development of lymphoedema. Most health care professionals interviewed believed that lymphoedema improves, but usually does not fully resolve.

### 2.5.4.2 Beliefs about effects of secondary lymphoedema on patients

The healthcare professionals were asked to describe the physical, functional and psychological effects they believe lymphoedema to have on affected patients. Nearly all interviewees reported that the greatest effect of lymphoedema was on their appearance.

For those with mild oedema it was widely believed by healthcare professionals that this would not impact on patients’ function:

> Most commonly lymphoedema is actually more cosmetic than functional. They just don’t like the look of a double chin rather than anything interfering with them.

However healthcare professionals believed there to be negative functional consequence of lymphoedema, specifically related to its severity. Other commonly reported main adverse effects caused by localised swelling included difficulties with mastication, swallowing and speech. Again, the mixed picture of internal and external oedema made it difficult to define specific associations:

> If they’re feeling quite swollen, manipulation of food and drink in the oral cavity can sometimes be impaired. If it was just facial lymphoedema isolated it’d have to be … quite significant to have that impact. But generally it’s not just limited to facial lymphoedema and they’re also presenting with lymphoedema in their throat as well.

There was wide variation in healthcare professionals’ perception of psychological effects of lymphoedema on patients. Two believed that most patients aren’t concerned about lymphoedema, once they know it’s not cancer recurrence and is an expected side effect of treatment for their cancer. This belief supports the suggestion that the effect of lymphoedema is not generally functional. Without a functional deficit three health professionals reported that patients tend to be less concerned by treatment side effects.
However seven health professionals felt there was a link between the physical effect on appearance and a negative psychological impact:

Having any operation around the face by definition is cosmetically challenging, so it’s (lymphoedema) going to be difficult in regards to the way that they look, that is psychologically. They may know the disease has gone but psychologically it’s (lymphoedema) going to affect them…and their friends will notice it.

A lymphoedema therapist stated:

If you’ve already got facial disfigurement and then you end up with pockets of swelling in odd places, I think it just adds to the overall picture.

The effect of swelling on negative body image can also negatively affect socialisation, and the ability to improve levels of deconditioning, with patients being “so self-conscious that their joining of society in normal things suffers badly as well”.

Table 2-3 Themes, sub themes and coding frequencies emerging from interviewed health professionals regarding secondary lymphoedema

<table>
<thead>
<tr>
<th>Clinical features (frequency of emergence)</th>
<th>Physical effects (frequency of emergence)</th>
<th>Psychological and Social Effects (frequency of emergence)</th>
<th>Helpful management strategies (frequency of emergence)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common (7)</td>
<td>Altered appearance (9)</td>
<td>Acceptance/Not concerned (3)</td>
<td>Refer if indicated (6)</td>
</tr>
<tr>
<td>Treatment multiplicity increases risk (9)</td>
<td>Neck Tightness and/or reduced Neck ROM (3)</td>
<td>Negative Body Image (6)</td>
<td>Reassurance/Education (6)</td>
</tr>
<tr>
<td>Improves, rarely fully resolves (8)</td>
<td>Mucus secretions (0)</td>
<td>Reduced Socialisation (2)</td>
<td>MLD (6)</td>
</tr>
<tr>
<td></td>
<td>Chewing, Swallowing Problems (10)</td>
<td></td>
<td>Neck or jaw ROM exercises (3)</td>
</tr>
<tr>
<td></td>
<td>Dysphasia (3)</td>
<td></td>
<td>Compression garments (0)</td>
</tr>
</tbody>
</table>

MLD, Manual lymphatic drainage; ROM, Range of motion

**2.5.4.3 Management strategies**

This theme explored what health professionals recommend or implement once a patient has lymphoedema. Strategies were closely linked to both the severity of lymphoedema and perception of how patients may be affected by it. Health professionals were more likely to refer those patients with severe and noticeable lymphoedema who were having difficulties with mastication and swallowing (i.e.
functional deficits) for physiotherapy for management of lymphoedema. However, the mainstay of health professional management was reassurance that lymphoedema is a common treatment side effect, education that it is likely to improve but not fully resolve, and advice to accept it. Referral of head and neck cancer patients for lymphoedema management was neither routine nor common. This differed to referral processes for breast cancer patients.

One lymphoedema therapist reported:

Everyone thinks that a breast cancer patient needs physio, it’s absolutely automatic… whereas I think there’s not so much of a recognition that physiotherapy can be helpful to the head and neck person… somebody should be aware that we’ve got a bit more to offer, whether it’s speech pathologists or doctors.

A nurse reported:

The resources and information about this topic (facial lymphoedema in head and neck cancer patients) is almost non-existent I think. Looking at breast cancer surgery, they have a lot of input as to lymphoedema and what to expect after surgery: they get automatic referrals. But I find in the head and neck (cancer) world that there’s not much information at all.

There was an awareness of the lack of evidence underpinning the management of lymphoedema and most health professionals consequently directed management on a case-by-case basis. In terms of physical treatments, the majority reported they give advice on local massage if it was required. Compression garments were believed to be less useful in treatment of head and neck or facial lymphoedema compared to lymphoedema of the limbs, and was therefore usually not recommended to patients. Given the obvious nature of wearing the garment, compliance was reported as likely to be an issue.

One of the important treatments for lymphoedema is compression and putting compression on the face is pretty difficult for a person to wear…it’s almost too much to bear on top of what they’ve already had…The treatment is worse than the condition.
2.6 Discussion

This is the first study to investigate the experiences of a small cohort of patients who developed lymphoedema following treatment for head and neck cancer, and to explore the related beliefs of health professionals involved in their management. Head and neck cancer is more prevalent in men \(47\), and the study sample is reflective of this. Despite varying reports regarding the effect of gender on perception of appearance \(48\), \(49\), it is recognised that the majority of patients in this study were male, which is likely to affect findings. The two included women reported greater negative psychosocial impact of visible oedema, so the effect of lymphoedema on appearance perception in a sample with a greater proportion of females may yield a different result.

There was a large overlap and commonality between reports of the lived experiences of head and neck cancer patients with lymphoedema and the clinical opinions of health professionals. Three key themes emerged that were common across the two groups.

2.6.1 Common features of FL

The belief of treating health professionals is that the greater the extent and multiplicity of treatment, then the greater the negative effect on lymphatics and likelihood of lymphoedema. This appears to fit with the majority of patients interviewed who had bilateral procedures. While this may be a coincidental finding given the small sample size, it appears physiologically reasonable and consistent with the mechanisms of the regional lymphatics, and the effect of combined treatments.

Lymphoedema, by definition, is a chronic condition. All patients interviewed still had oedema, although half noted an improvement over time. Most healthcare professionals also reported this to be their experience, a fact that many then used to reassure patients as a management tool. The regional lymphatics of the face and neck are rich with lymph nodes, with reports documenting an average of 150 to 300 \(50\). There is both marked collateral flow and considerable variability in this region’s lymphatic anatomy, particularly in terms of number of nodes and drainage patterns. A recent lymphoscintigraphy study found a lymphatic pattern variability of 75% in 24
melanoma patients and collateral flow above the 30% variability normally expected.\textsuperscript{51} Overlap of lymphatic vessels, together with the vast number of lymph nodes, are likely to improve the natural resolution of lymphoedema in the head and neck region compared to the limbs. Effects of gravity will influence natural oedema pooling mechanisms, leading to the submandibular region being the main affected area in FL. Most patients demonstrated lymphoedema in this region, which is consistent with previously published research.\textsuperscript{35}

2.6.2 Impact of lymphoedema

The effect of lymphoedema on appearance was the overriding theme from the interviews, given its visibility. Most patients’ fears and concerns regarding lymphoedema were alleviated by reassurance from healthcare professionals. Overall, the male patients felt it was a minor side effect of treatment and felt able to accept it as part of the treatment process. Female patients in this study emphasised aspects or issues pertaining to body image. This correlated closely with beliefs of health professionals. A previous study of 280 patients with head and neck cancer that underwent surgery indicated that a large majority were concerned or embarrassed about the associated bodily changes at some stage following diagnosis, with over 17% of patients having the presence of swelling as a body image concern.\textsuperscript{52} Concerns about body image were found at various stages of survivorship, including prior to surgery.\textsuperscript{52}

The anticipation of disfigurative surgery has been found to influence overall distress, anxiety and coping effectiveness, with pre-operative coping ability predicting the post-operative behavioural response.\textsuperscript{53} The presence of lymphoedema may be a part of the physical changes that patients with head and neck cancer surgery experience.

Potential for altered appearance to impact on patients’ psychological wellbeing was recognised by health professionals. Psychological conditions such as anxiety and depression are often influenced by stage of cancer and cancer treatment.\textsuperscript{34} The potential link between the presence of facial lymphoedema as a result of head and neck cancer treatment and anxiety levels mean that it is crucial that these patient concerns are addressed by treating health professionals.
Eating, particularly in the early phases of return to a normal diet following cancer treatment, can stimulate both lymphoedema and mucus. It is recognised that while the presence of mixed oedema makes investigation of the relationship between external oedema and swallowing difficult, our findings are consistent with those of a recent study which reported statistically significant associations between lymphoedema and problems with mucus and swallowing. If the presence of lymphoedema limits certain positions required to perform dysphagia exercises, this then further compounds the problem of poor swallowing ability. Some exercises to improve dysphagia may not be able to be performed if lymphoedema is present, as they involve movements such as chin tucks lying supine. It is suggested that the presence of lymphoedema contributes to dysphagia arising by reduced contractility of muscles and poor soft tissue compliance.

2.6.3 Implications for management

Findings of this study related to the physical and psychological side effects of lymphoedema correlate with other anecdotal reports, clinical opinion and prevalence studies. Altered appearance associated with lymphoedema in this region can adversely affect body image, self-esteem, socialisation and as a consequence predispose to anxiety and distress. The number of body image concerns and body image dissatisfaction are significant predictors of poorer quality of life outcomes. Negatively perceived changes to appearance also adversely affect self-esteem and socialisation. Patients who are self-conscious about appearance following surgery are likely to have social avoidance. An alteration in body image has been found to link with high levels of anxiety.

Physical side effects of facial lymphoedema may include difficulty with speech and swallowing and difficulties with breathing in more severe cases. The extent of facial lymphoedema has been found to be significantly related to swallowing difficulties and nutritional problems, with this association more due to the severity of external rather than internal lymphoedema. Thus, early and prompt management of
lymphoedema may then positively influence these physical and psychological quality of life factors.

Common factors associated with the development of lymphoedema in head and neck cancer patients may include neck dissection surgery; bilateral and radical dose radiation therapy and multi-modality treatment. Treating health professionals need to have awareness of potential risk factors for head and neck lymphoedema and an understanding of the importance of timely referral for physiotherapy, if the impact on a patient’s appearance is affecting them psychologically or functionally. It is essential that patients be routinely questioned by health professionals about their feelings towards any lymphoedema that may be present, and are screened for anxiety or socialisation issues. Consideration of any secondary lymphoedema, and specific questioning of affected patients to determine if the oedema is bothering them, is mandatory to meet the needs of patients more effectively. Patients may not raise the issue of lymphoedema, as it may be perceived as unimportant compared to the goals of curative treatment. Thus, as health professionals, we need to be more pro active in screening for signs of lymphoedema, assessing its effect on patients, and referring on for lymphoedema management if indicated. The awareness of referral to physiotherapy for management of lymphoedema in the head and neck region may be less common than in lymphoedema affecting the limbs. Indeed, in contrast to head and neck cancer patients, some health professionals in this study reported that patients with breast cancer tend to be more routinely referred to physiotherapy for lymphoedema management. It is uncertain as to why this is the case, but awareness of the role of physiotherapy appears to be greater for limb lymphoedema than lymphoedema affecting the face region.

Dysphagia is a common side effect experienced by patients undergoing treatment for head and neck cancer, requiring assessment by a speech pathologist. A physiotherapist may also treat patients with swallowing difficulties and facial lymphoedema. Improved communication between physiotherapists and speech pathologists is warranted in this patient population, because of the overlap of professional treatment
goals of reducing lymphoedema and improving dysphagia. Encouragement of lymphoedema patients to attend available head and neck cancer support groups, and/or physical conditioning classes may assist with issues of poor body image and in turn enhance greater socialisation. Results of this study might, taken together with outcomes of previous studies, reasonably underpin the development of a region specific lymphoedema questionnaire for head and neck cancer survivors, including the dimensions of appearance, ability to lie supine, and effect on socialisation. Further studies to investigate the effectiveness of physiotherapy treatment modalities for lymphoedema might include such outcome measures as a barium swallow assessment before and after manual lymphatic drainage, or other lymphoedema management interventions. These may potentially provide a direction for intervention in this patient group.

2.6.4 Study Limitations

There are limitations to this study, that impact on its findings. Firstly, the sample size is small. Although interviews were performed to a point where saturation of themes became evident, a larger sample size would potentially expand the resource pool and improve the validity of the study results. This would also have allowed a more mixed sample population, in terms of both gender and stages of recovery after cancer treatment. Additionally some interviews lasted for a short period of time, which may have limited the depth of information obtain. The patient cohort was at a later stage of lymphoedema onset, and most had received some form of lymphoedema management at the time of the interview. This may lead to greater levels of acceptance compared to patients where oedema is of a more recent onset. Consideration could be given to compare this study’s results with patients experiencing lymphoedema in a group demonstrating more acute onset of oedema.

2.7 Conclusion

Facial lymphoedema frequently impacts negatively on a patient’s appearance and body image, which may then reduce their self-esteem and socialisation. Patients experiencing facial lymphoedema may also have functional issues such as dysphagia.
Health professionals, despite being aware of these effects, may not explore this in-depth with patients who are experiencing facial lymphoedema, and tend not to routinely refer them on to physiotherapy for further management. Thus, there needs to be improved communication between treating health professionals and a change to current referral patterns, with prompt referral to physiotherapy for patients experiencing facial lymphoedema. This may ultimately improve the quality of life of patients with facial lymphoedema.

2.8 Implications of the findings for physiotherapists

Lymphoedema in the cervicofacial region may occur after surgical and radiation therapy treatment for head and neck cancer. This can have a profoundly negative impact on affected patients, both physically and psychologically. Cervicofacial lymphoedema is one of the conditions that may present to physiotherapy for assessment and management. Affected patients may benefit from physiotherapy treatment, and education focusing on self-management strategies. Given that compression garments are infrequently utilised in the facial region, given its challenges, most physiotherapists working with oncology patients could perform the physiotherapy techniques of manual lymphatic drainage and prescription of facial, jaw and neck exercises.

However, health professionals may not be aware of the potential benefit that physiotherapy has to offer to patients with facial lymphoedema. To improve this concept, physiotherapists may need to be more pro-active in communicating the potential benefit of physiotherapy management to other health and medical professionals. Greater routine screening of cervicofacial lymphoedema needs to occur within the head and neck cancer multidisciplinary team. If lymphoedema is present, and is affecting patients physically or psychologically, prompt referral on to physiotherapy for assessment and management is required.
Chapter 3 Physiotherapy for accessory nerve shoulder dysfunction following neck dissection surgery: A literature review

Shoulder pain and dysfunction is yet another condition that can be encountered by patients following neck dissection surgery for head and neck cancer. Typically, this is the result of intra-operative accessory nerve injury leading to shoulder pain, and reduced shoulder range of motion and function. The role of physiotherapy in the assessment and management of this post-operative condition has not been clearly defined. Therefore, the following chapters are based on a combination of literature reviews and studies, to investigate the physiotherapy management of accessory nerve shoulder dysfunction in this patient population.

This chapter contains the published manuscript as titled above, published in Head and Neck 2011; 33(2):274-280.

The authors of this publication are Aoife McGarvey, Peter Osmotherly, Gary Hoffman and Pauline Chiarelli.

The chapter does not differ from the published paper apart from the tables and references that have been renumbered to maintain consistency throughout the thesis.

3.1 Abstract

Background: Neck dissection is an operation that can result in accessory nerve injury. Accessory nerve shoulder dysfunction (ANSD) describes the pain and impaired range of motion that may occur following neck dissection. The aim of this review was to establish the level of evidence for the effectiveness of physiotherapy in the post-operative management of ANSD.
**Methods:** A literature search of physiotherapy and ANSD using Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Physiotherapy Evidence Database (PEDro) and Cochrane library databases was undertaken.

**Results:** Physiotherapy has been shown to be well tolerated in this patient group following surgery. However, few studies exist as to the effect of physiotherapy on ANSD.

**Conclusions:** There is a need for research to investigate the effects of early, appropriate physiotherapy on the development of ANSD following neck dissection surgery. Such a study has the potential to improve the functional outcome and quality of life in this patient group, and ultimately to promote best practice guidelines for management.

### 3.2 Background

Neck dissection is an integral part of the surgical management of head and neck cancer. The presence of long-term post-operative shoulder and arm pain, identified in patients after head and neck surgery, has been found to be strongly associated with cervical lymphadenectomy that can result in damage to the accessory nerve.

Most epidemiological studies have shown that radical neck dissection, with accessory nerve resection, leads to the highest prevalence of shoulder pain and dysfunction. However, up to 67% of patients also reportedly experience similar symptoms, in accessory nerve sparing procedures (modified radical and selective neck dissection). Indeed, studies have shown that there may be no significant difference in either the prevalence or the severity of pain according to surgery type. Even when the continuity of the accessory nerve is maintained, microtrauma in the form of traction, skeletonisation and devascularisation to the nerve may still occur. This will impair its ability to effectively conduct.

Accessory nerve injury causes trapezius muscle weakness, which results in the scapula being positioned in depression, abduction and medial rotation. Impaired scapula position at rest and during arm elevation leads to reduced active shoulder abduction.
and flexion 58, 59. The trapezius muscle also has motor nerve contributions from the C2, C3 and C4 branches of the cervical plexus. However this nerve contribution to trapezius has been found to be much less compared to the accessory nerve motor supply 13, 15.

The presence of accessory nerve shoulder dysfunction (ANSD) is a common sequelae of neck dissection 9. This secondarily affects scapular muscle strength and the associated biomechanics of scapula movement during arm elevation 60. ANSD results in impaired shoulder function 61, pain and diminished quality of life 62.

A recent review of the role of post-operative physiotherapy in the management of shoulder dysfunction following neck dissection highlights the distinct lack of scientific rigour for both the implementation and the effectiveness of physiotherapy intervention 63. Although the 5 included studies investigated the effect of various physiotherapy modalities on shoulder pain and disability following neck dissection surgery, the methodology of the review was not defined, and studies in the review were not systematically or critically appraised.

### 3.3 Review Aims and Methods

The purpose of this review was to establish the level of evidence for the effectiveness of physiotherapy and the types of physiotherapy that may be implemented in the management of accessory nerve shoulder dysfunction following neck dissection. A search of Cumulative Index to Nursing and Allied Health Literature (CINAHL), Physiotherapy Evidence Database (PEDro) and Cochrane library databases to May 2009 was undertaken. For Medline and CINAHL databases, the keywords “head and neck cancer”, “spinal accessory nerve”, “neck dissection surgery” and “neck dissection” were combined with the keywords ”physiotherapy”; “physical therapy”, “exercise”, “quality of life and shoulder”; and “shoulder pain”, “shoulder disability” and “shoulder syndrome”. For the physiotherapy related PEDro database, the keywords “head and neck cancer”, “spinal accessory nerve”, “neck dissection surgery” and “neck dissection” were searched individually.
3.3.1 Study selection criteria

Titles of all the articles that were identified from the search strategy were reviewed. If the title contained the keywords “physiotherapy”, “physical therapy”, “rehabilitation”, or “conservative treatment” together with the words “shoulder pain”, “shoulder dysfunction”, “neck dissection”, “head and neck cancer” or “spinal accessory nerve injury”, then the entire article was retrieved and reviewed. If reviewed articles mentioned other articles pertaining to rehabilitation of the shoulder following neck dissection, they were also included.

Each article was then rated according to Sackett’s levels of evidence 44. Systematic reviews and randomised controlled trials were ranked as level 1, cohort studies ranked as level 2, case control studies ranked as level 3, case series ranked as level 4 and expert opinion and discussion papers ranked as level 5. To limit anecdotal evidence, those articles that were ranked at the two lowest levels of evidence - levels 4 and 5 - were excluded from review. Articles that included patients that had not undergone neck dissection were excluded.

The search was limited to published studies derived from the English-language literature, in addition to those studies translated into English from the non-English-language literature.
3.4 Review study results

Twenty articles were retrieved using the above-mentioned search strategy. Of these 20 articles, 11 were excluded. Of the excluded articles, 5 were discussion papers, 4 were case reports, 1 was a conference abstract, and 1 was a before-after study that was not based on neck dissection patients. Figure 3-1 shows the study selection process, with studies excluded listed. Of the 9 included articles, 5 were before- after studies, 1 was a conference abstract, 1 was a prospective study, 1 was a retrospective cohort study, 1 was a pilot study of a randomised controlled trial, and 1 was a randomised controlled trial. The findings of these articles are summarised in Table 3-1 and Table 3-2.

The majority of earlier physiotherapy studies focused on intervention following radical neck dissection (accessory neurotmesis). A change to functional or more selective surgery is reflective of efforts to reduce post-operative shoulder morbidity.
Evidence related to the type and effectiveness of physiotherapy following accessory nerve neurotmesis is inconclusive from the literature. Various physiotherapy modalities after radical neck dissection surgery have been suggested and described. Uses of a scapula orthotic support 77, 79, soft tissue therapy 70, 72, 75, 81 and electrotherapy 74, 75 have been proposed. Other modalities used such as infrared heat 76 are questionable in terms of safety, given that cervical skin sensory loss occurs post operatively, and biological plausibility given the pathological mechanisms underlying the condition 85. Two before-after studies demonstrated subjective improvements in patients’ reporting of pain following the use of a passive scapula orthotic support after radical neck dissection 77, 79. However, both studies lacked a comparison control group, and used no objective outcome measures. Overall, there is little foundation for evidence-based guidelines or recommendations for these modalities following accessory neurotmesis.

Exercise-based physiotherapy following neck dissection, with or without accessory neurotmesis, involves several types of regimens that target various muscle groups. Active and active-assisted cervical spine and shoulder exercises have been assessed 66, 72, 74, 81. The aim of these exercises is to maintain or improve the range of motion of the cervical spine, maintain passive glenohumeral joint range of motion and prevent secondary pathologies such as adhesive capsulitis 86, 87. A non-randomised prospective study investigating the effect of passive elevation exercises and active internal and external rotation exercises examined outcomes, as assessed by the degree of shoulder pain, range of motion, electromyography of involved muscles, and patients’ self-rated functional ability 80. These authors proposed that active movement would recover spontaneously once passive restriction was restored. Results indicated a significant difference in passive and active shoulder elevation range of motion, pain scores and functional measures in favour of the exercise group 6 months after surgery. However, the study lacked randomisation and the large number of treatment sessions described in the paper, on average 97 days, is not feasible in most public hospital systems.
<table>
<thead>
<tr>
<th>Reference</th>
<th>Study type</th>
<th>No. of participants</th>
<th>Outcome measures</th>
<th>Treatment modality</th>
<th>Findings</th>
<th>Level of evidence</th>
<th>Methodological issues</th>
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<tr>
<td>Fialka and Vinzenz 75</td>
<td>Before-after</td>
<td>43</td>
<td>VAS pain</td>
<td>Faradic current</td>
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<td>Scapula position</td>
<td>STT</td>
<td>Physiotherapy did not worsen participants</td>
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<td></td>
<td></td>
<td></td>
<td>AROM abduction</td>
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<tr>
<td>Johnson et al 76</td>
<td>Before-after</td>
<td>16</td>
<td>Subjective reports of improvement</td>
<td>Infrared heat</td>
<td>Relief of pain reported in all participants</td>
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<td>Kizilay et al 79</td>
<td>Before-after</td>
<td>28</td>
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<td>72% were pain-free at 3 months</td>
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<td>AROM shoulder</td>
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<td>82% returned to previous function</td>
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<td>No description of measurement methods</td>
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<td>Self-reports of function</td>
<td>Orthosis may improve levels of pain and disability</td>
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<tr>
<td>Shimida et al 81</td>
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<td>29</td>
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<td>3</td>
<td>Lacked randomization</td>
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<td>Relaxation techniques</td>
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<td>The shoulder orthosis reduces pain from improving scapula alignment</td>
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<td>No description of measurement methods</td>
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<td></td>
<td></td>
<td>Small sample size</td>
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</table>

VAS= Visual Analog Scale, EMG=Electromyography, AROM=active range of motion, STT=soft tissue therapy, AAROM=active assisted range of motion
Generalised strengthening exercises which target those muscles surrounding the glenohumeral joint, such as the rotator cuff group, are not specific to ANSD pathology because they are muscles that are not directly affected by an injury to the accessory nerve. One before-after study with only 9 participants provides very limited evidence for the effectiveness of including such non-specific strengthening exercises. Another before-after study involved generalised strengthening exercises in 43 patients who had radical neck dissection. There was no reported improvement in shoulder abduction, lateral scapula displacement or trapezius muscle atrophy after several months of exercises. This may suggest lack of effectiveness of strength training when the accessory nerve has been resected.

From a pathophysiological and biomechanical perspective, it would seem reasonable to direct exercises toward strengthening the trapezius muscle and other scapular muscles that work synergistically with trapezius, since accessory nerve injury affects trapezius muscle strength. The theoretical benefits of progressive resisted scapular muscle strengthening exercises on ANSD were documented as early as 1975, and later in a before-after study undertaken by the same researchers.

Recent studies investigating the effectiveness of progressive resisted scapular muscle strengthening are more methodologically robust. However, these studies also have acknowledged limitations. In the first single-blinded, randomised controlled study to evaluate the effect of a progressive resistance exercise training regimen on shoulder dysfunction relating to accessory nerve injury following neck dissection surgery, McNeely et al investigated the efficacy and safety of performing low intensity strengthening exercises in this patient population. Adherence rates were promising, with 93% of patients in the intervention group completing the 12-week supervised program, and an 83% overall completion rate. Both groups received weekly supervised scapular and rotator cuff muscle strengthening exercises, with the intervention group receiving resistance exercises that were progressed. Differences in pain and shoulder function were evident in favour of the intervention group, but the study lacked sufficient power to report any real significant statistical differences with only 17
participants, and a lack of detail regarding the intervention specifics. The exercises chosen were more generalised in nature, so not biomechanically specific to accessory nerve-related shoulder dysfunction. Patients who had neurotmesis of the accessory nerve during surgery that are not likely to recover trapezius muscle function were included in the trial, which potentially lowered the measured effectiveness of the study intervention.

In a subsequent randomised trial, control and intervention groups received the respective exercises described in the previous study, with both retrospective and prospective participant recruitment. Outcome measures of upper body muscular strength and endurance were included, as well as the Neck Dissection Impairment Index, a condition-specific quality of life questionnaire. Assessment of 53 participants demonstrated a statistically significant improvement in pain and disability scores in the intervention group at the 12-week follow-up. Unfortunately no long-term follow up measures were taken. Given the long recovery time of a nerve-related pathology, and the potential for latent radiation therapy effects on muscle and nerve, such data would provide valuable insight. A major limitation of this randomised controlled trial, acknowledged by the authors, was that the study sample included a large number of patients with neck dissection whose surgery preceded the intervention by a substantial period of time. The median time since surgery for 44% of participants was greater than 18 months prior to the commencement of the intervention, and for some participants as long as 15 years previously. The clinical relevance of the study result is vastly compromised by the inclusion of patients who underwent surgery many years before, without any attempts at rehabilitation.
<table>
<thead>
<tr>
<th>Study</th>
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<th>Level of evidence</th>
<th>Outcome Measures</th>
<th>Treatment Modality</th>
<th>Results</th>
<th>Conclusions</th>
<th>Methodological Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>McNeely et al</td>
<td>Randomised Pilot</td>
<td>17</td>
<td>2</td>
<td>VAS pain AROM shoulder SPADI FACT-H &amp; N</td>
<td>Progressive scapular muscle strengthening 3x/week for 12 weeks</td>
<td>93% adherence in SPADI in favour of intervention group</td>
<td>Potential for resisted exercise to be feasible and improve function</td>
<td>Small sample size</td>
</tr>
<tr>
<td></td>
<td>study</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lacked assessor blinding</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No stratification of surgery type</td>
</tr>
<tr>
<td>McNeely et al</td>
<td>RCT</td>
<td>52</td>
<td>1</td>
<td>VAS pain AROM shoulder SPADI NDII Muscle endurance</td>
<td>Progressive scapular muscle strengthening 3x/week for 12 weeks</td>
<td>Significantly reduced pain and disability in favour of intervention group</td>
<td>Post-operative physiotherapy should include progressive scapular muscle strengthening</td>
<td>Retrospective recruitment Control group received supervised strengthening Large number of treatment sessions</td>
</tr>
<tr>
<td>Remmler et al</td>
<td>Before-after</td>
<td>90</td>
<td>3</td>
<td>AROM shoulder EMG Manual muscle tests</td>
<td>Physiotherapy to maintain AROM not described</td>
<td>Increase in EMG in modified radical neck dissection</td>
<td>MRND leads to a shoulder dysfunction that improves over time. This does not occur in RND.</td>
<td>Large drop out rate of 75% at 12 months No control group</td>
</tr>
<tr>
<td>Salerno et al</td>
<td>Prospective</td>
<td>60</td>
<td>3</td>
<td>Constant scale Passive and active shoulder exercises</td>
<td>Improved pain, function and shoulder range of motion scores in exercise group</td>
<td>Passive exercise leads to recovery in active shoulder movement</td>
<td>Method of group selection unclear Large number of treatment sessions</td>
<td></td>
</tr>
</tbody>
</table>
3.5 Discussion

ANSD is a common sequelae following neck dissection. The prognosis and time taken for accessory nerve recovery is largely dependent on the type of neck dissection performed, and thus the type of injury sustained by the nerve. Neurotmesis occurs when a nerve has been completely divided, resulting in complete injury. Neurotmesis has the poorest potential for recovery, which may or may not continue for up to 24 months. Axonotmesis is the result of nerve fibre damage. Although the sheath overlying the nerve fibre is still intact, it leads to complete peripheral degeneration of the muscle supplied by the nerve. This is often caused with stretch injuries and focal ischemia of the nerve. There are varying degrees of axonal injury dependent upon the number of motor axons involved, with extensive axonal injury taking up to 18 months for recovery. Neuapraxia results in short-term dysfunction of the nerve, often attributed to nerve fibre demyelination with motor fibres predominantly affected. Recovery from neuapraxia occurs by remyelination and has the quickest recovery, usually taking six to eight weeks.

Some studies attribute accessory nerve injury during nerve-sparing neck dissection to a neuapraxia. However impaired trapezius muscle activation noted in electromyographic (EMG) studies is evident more than eight weeks after surgery in patients with nerve-sparing neck dissection. This would seem to indicate axonotmesis. Accessory nerve axonotmesis that occurs following neck dissection may not necessarily lead to the immediate signs of nerve injury in the innervated trapezius muscle, such as muscle atrophy and weakness. This is ascribed to the axoplasmic flow that may exist distal to the nerve injury, providing temporary muscle tone. As a result, these signs of nerve injury may not be present until weeks later. Clinically this is an important point, in that the majority of patients with post-operative neck dissection are unlikely to demonstrate shoulder movement deficits prior to discharge from the hospital because of the latent effects on trapezius muscle innervation that follows axonotmesis. A slower nerve recovery process also has important implications for post-
operative management. It could be argued that physiotherapy rehabilitation following axonotmesis will take at least three months to have any potential effect.

Overall there appears to be minimal direct evidence in the current literature that physiotherapy is effective in the treatment of ANSD following neck dissection surgery. Further, the timing and type of physiotherapy that may be effective in this group of patients is inconclusive. There are several possible reasons for this. First, in several countries, patients with neck dissection routinely receive physiotherapy following surgery, so ethically it would not be possible to undertake a level 1 trial in these countries. Second, prospective recruitment in this patient group may be challenging to undertake, given that many patients are often undergoing adjuvant treatment, such as radiation therapy.

Despite this, physiotherapy following ANSD aimed at progressive strengthening of the trapezius muscle and other scapular muscles that perform a similar function is a treatment regimen with a strong anatomical basis. The effectiveness of strengthening exercises largely depends on the severity of nerve injury. A very early study showed no functional recovery in muscle function when more than 80% of motor units were lost. There is limited benefit to be gained by performing resisted strength training where muscles are extremely weak from a more permanent nerve injury. Since there is limited nerve recovery following neurotmesis, there is reduced ability for measurable increase in muscle strength. Potentially, strengthening exercises will be far less effective in patients with radical neck dissection where the accessory nerve is severed.

The premise of progressive resisted strength training in peripheral nerve injuries where the nerve remains intact is that the muscle must be overloaded to both overcome disuse atrophic changes and enhance neural adaptation.

The inclusion of strengthening exercises following a peripheral nerve injury has been advocated in previously published literature, with modest evidence for moderate improvement in muscle strength in a recent Cochrane review. A prospective
randomised controlled trial in this review investigated the effectiveness of performing a progressive resisted strengthening program in patients with 2 different peripheral neuropathy conditions. One group had Charcot-Marie tooth disease, a condition that leads to demyelination of the affected nerves. In this group, a progressive resisted strengthening program had a beneficial effect. However, no changes were found in the myotonic dystrophy patient group, suggesting little or no benefit of strength training where there is little physiological potential for improvement.

3.6 Conclusion

Shoulder pain and reduced shoulder movement together with their deleterious effects on shoulder function and quality of life are common sequelae following neck dissection, secondary to accessory nerve injury. Early physiotherapy targeted at facilitating nerve recovery and increasing scapular muscle strength may help to reduce the effects of ANSD. Indirectly, there is some evidence supporting the effectiveness of physiotherapy following a nerve injury where there is potential for the nerve to recover.

This review demonstrates there is a lack of evidence in the literature to support the effectiveness of physiotherapy on ANSD. Furthermore, it is inconclusive with respect to the type and timing of physiotherapy intervention that may be effective. This is possibly the result of potential challenges and barriers faced when conducting a prospective randomised controlled trial investigating early physiotherapy intervention in this patient group. As such, there is a need to establish whether early, appropriate physiotherapy management has a positive effect on shoulder pain, function and quality of life in this patient cohort. The outcome of such a study has the potential to improve functional outcomes and quality of life in this patient group, and ultimately develop best practice guidelines for management.
3.7 Implications of findings for the following study

Selection of a potentially effective physiotherapy intervention requires knowledge of the extent and activation of scapular muscle activity that is associated with an accessory nerve injury following neck dissection surgery. As the systematic review of published literature has highlighted, an optimum exercise intervention for these patients remains undefined.

The aims of the following study were to assess the scapular muscle activity differences in patients with accessory nerve dysfunction following neck dissection surgery of both their affected and unaffected sides compared to healthy controls. This knowledge could then potentially be used to underpin the design of an intervention group rehabilitation strengthening exercise program for a subsequent randomised controlled trial.
Chapter 4 Impact of Neck Dissection on Scapular Muscle Function: A case controlled EMG study

This chapter contains the published manuscript as titled above, published in Archives of Physical Medicine and Rehabilitation 2013; 94:113-9.

The authors of this publication are Aoife McGarvey, Peter Osmotherly, Gary Hoffman and Pauline Chiarelli.

The chapter does not differ from the published paper apart from the tables and references that have been renumbered to maintain consistency throughout the thesis.

4.1 Abstract

Objectives: To assess the dynamic activity of scapular muscles in patients with accessory nerve dysfunction following neck dissection surgery, compared to both their unaffected side, and to age and gender matched controls.

Design: A case control investigation.

Setting: The study was conducted at the Physiotherapy department at the Calvary Mater Newcastle Hospital, Australia.

Participants: Two groups of 10 participants were recruited. One group consisted of neck dissection patients with demonstrated clinical signs of accessory nerve injury. The second group was composed of matched healthy individuals.

Intervention: Surface electromyographic activity of the upper trapezius, middle trapezius, rhomboid major and serratus anterior muscles were compared dynamically during scapular strengthening exercises.

Main Outcome Measure: Electromyographic activity comparisons were made between the neck dissection affected side, the neck dissection unaffected side, and the matched
healthy control side. Raw data and data expressed as percentage of maximal voluntary isometric contraction were compared.

Results: The neck dissection affected side demonstrated significantly less upper trapezius and middle trapezius muscle activity compared to the neck dissection unaffected side and matched control group. The neck dissection unaffected side had significantly less upper trapezius muscle activity than the matched control group.

Conclusion: Trapezius muscle activity is significantly reduced in accessory nerve shoulder dysfunction as a result of neck dissection, both in the affected and unaffected sides. This needs to be considered in the rehabilitation of this patient group.

Keywords: Neck dissection, Accessory nerve, Shoulder pain, Electromyography

4.2 Introduction

Accessory nerve shoulder dysfunction (ANSD) is a debilitating and painful condition that can result from neck dissection surgery that is undertaken in the management of cancer. Accessory nerve injury can occur during cervical lymphadenectomy, even when the nerve is preserved. As the accessory nerve is the main motor supply to the trapezius muscle, its neural impairment leads to reduced trapezius muscle strength, causing the scapula to be depressed, abducted and medially rotated at rest. Dynamically, trapezius muscle weakness leads to reduced active shoulder abduction and flexion, due to reduced scapular lateral rotation and elevation during these movements. The resultant abnormal scapular biomechanics, causes mechanical overload of the scapular complex, leading to shoulder pain and reduced regional function.

Patients who undergo neck dissection may require adjuvant radiation therapy over the lateral aspect of the neck. The radiation field includes both the accessory nerve and the trapezius muscle. Radiation therapy causes fibrosis of muscle fibres and the neural sheath, as well as nerve demyelination. This ultimately results in muscle atrophy, compounding trapezius muscle weakness. Additionally, treatment for head and
neck cancer often causes significant weight loss, and therefore likely global loss of muscle mass. Reduced physical activity levels in head and neck cancer patients are yet another factor compounding muscle weakness. More than half of patients are classified as sedentary following treatment, which may be further exacerbated by cancer-related fatigue.

Accessory nerve conduction has been investigated after neck dissection by using needle intramuscular electromyographic (EMG) activity of the trapezius muscle on the operated side. Such studies indicate reduced trapezius electromyographic activity. However, they fail to inform about trapezius electromyographic activity under dynamic conditions, or about the electromyographic activity of other accessory scapular muscles. These studies also fail to compare scapular muscle electromyographic activity in the affected side with either the unaffected side, or healthy individuals.

The primary aim of this study was to measure the surface electromyographic (SEMG) dynamic activity of scapular muscles resulting from strengthening exercises that may be prescribed for patients with ANSD after neck dissection, compared with the SEMG of scapular muscles on their unaffected side and with the SEMG of scapular muscles in healthy age- and sex-matched controls. Improved appreciation of the levels of scapular muscle activity in patients with ANSD compared with the patients’ unaffected arm and compared with healthy individuals would provide valuable insight into the nature of the muscle activity differences between these groups, thereby enlightening exercise prescription in rehabilitation for patients with ANSD.

4.3 Method

The investigation was designed as a case-control study. The first muscle group to be electromyographically studied was that in participants who demonstrated the clinical signs of ANSD after neck dissection (i.e. scapula depression, reduced active shoulder abduction, and scapula winging at rest and/or on active shoulder abduction), labeled “neck dissection affected” (NDA). The second group of electromyographic-studied
muscles was that of the unaffected side of the same neck dissection participants, labeled “neck dissection unaffected” (NDU). A control group of muscles was studied in healthy individuals; age and sex matched to the neck dissection participants. The level of SEMG activity was recorded from bilateral scapular muscles (upper trapezius, middle trapezius, rhomboid major, serratus anterior) of all participants. All data was maintained in a de-identified form using assigned participant numbers.

Neck dissection participants were recruited from the Calvary Mater Newcastle Hospital via a letter of invitation. Inclusion criteria for neck dissection participants were: (1) neck dissection surgery for cancer that occurred within the last 2 years; (2) shoulder pain on the operated side, with onset after neck dissection; (3) clinical signs of ANSD demonstrated on the operated side; and (4) age greater than 18 years. Criteria for exclusion from the study included patients who had: (1) accessory nerve sacrifice; (2) a history of shoulder or neck pain, or both, in the past 6 months prior to neck dissection surgery; (3) signs of adhesive capsulitis (reduced shoulder external rotation, abduction and internal rotation); (4) the presence of residual locoregional cancer or distant metastases to other regions; or (5) a preexisting medical condition with an inability to repeatedly lift a 2.0 kilogram weight, or perform exercise against resistance.

Healthy volunteers were sex and age matched to within one year of the neck dissection participants. The healthy control participants were recruited from the Hunter Medical Research Institute Volunteer Register. Volunteers were excluded if they had (1) a history of shoulder or neck pain, or both, within the past 6 months; (2) previous neck dissection surgery; (3) existing cancer in any area of the body; or (4) a preexisting medical condition with an inability to repeatedly lift a 2.0 kilogram weight, or perform exercise against resistance. Baseline participant characteristics were recorded as described in Table 4-1.
<table>
<thead>
<tr>
<th>Neck dissection participant number</th>
<th>Gender</th>
<th>Age</th>
<th>Tumour Site and Stage (TMN*)</th>
<th>Radiation therapy</th>
<th>Surgery type (Levels Dissected)</th>
<th>Time since Surgery</th>
<th>Hand dominance</th>
<th>Occupation</th>
<th>Healthy Control Age</th>
<th>Healthy Control Hand dominance</th>
<th>Healthy Control Occupation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>60</td>
<td>T1N1M0 neck node</td>
<td>Yes</td>
<td>Right MRND‡ (I-V)</td>
<td>10 weeks</td>
<td>Right</td>
<td>Cleaner</td>
<td>59</td>
<td>Right</td>
<td>Fitter</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>57</td>
<td>T2N1M0 mandible and floor of mouth</td>
<td>No</td>
<td>Bilateral MRND‡ (I-V)</td>
<td>4 weeks</td>
<td>Right</td>
<td>Unemployed</td>
<td>57</td>
<td>Right</td>
<td>Unemployed</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>61</td>
<td>T4N0M0 SCC† ear</td>
<td>Yes</td>
<td>Left SND§ (I-IV)</td>
<td>8 weeks</td>
<td>Right</td>
<td>Machinery inspector</td>
<td>61</td>
<td>Right</td>
<td>Retired</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>55</td>
<td>T4N0M0 SCC† suborbital region</td>
<td>Yes</td>
<td>Right SND§</td>
<td>13 months</td>
<td>Right</td>
<td>Pest controller</td>
<td>55</td>
<td>Left</td>
<td>Machine Operator</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>64</td>
<td>T1N0M0 oral tongue</td>
<td>No</td>
<td>Left SND§ (I-IV)</td>
<td>20 months</td>
<td>Right</td>
<td>Retired, 63</td>
<td>63</td>
<td>Right</td>
<td>Engineer</td>
</tr>
<tr>
<td>6</td>
<td>Male</td>
<td>57</td>
<td>N2M0 unknown primary metastatic SCC† forehead</td>
<td>No</td>
<td>Left SND§</td>
<td>8 weeks</td>
<td>Right</td>
<td>Teacher</td>
<td>58</td>
<td>Right</td>
<td>Technical Assistant</td>
</tr>
<tr>
<td>7</td>
<td>Male</td>
<td>75</td>
<td>T2N0M0 SCC† forehead</td>
<td>No</td>
<td>Left MRND‡ (I-V)</td>
<td>7 weeks</td>
<td>Left</td>
<td>Retired</td>
<td>75</td>
<td>Right</td>
<td>Retired</td>
</tr>
<tr>
<td>8</td>
<td>Male</td>
<td>57</td>
<td>T4N0M0 SCC† mandible</td>
<td>Yes</td>
<td>Bilateral SND§</td>
<td>14 months</td>
<td>Right</td>
<td>Retired</td>
<td>57</td>
<td>Right</td>
<td>Educator</td>
</tr>
<tr>
<td>9</td>
<td>Female</td>
<td>62</td>
<td>T2N0M0 buccal SCC†</td>
<td>Yes</td>
<td>Left SND§ (I-III)</td>
<td>9 weeks</td>
<td>Right</td>
<td>Retired</td>
<td>63</td>
<td>Right</td>
<td>Retired</td>
</tr>
<tr>
<td>10</td>
<td>Female</td>
<td>50</td>
<td>T1N0M0 oral tongue</td>
<td>No</td>
<td>Right SND§ (I-IV)</td>
<td>8 weeks</td>
<td>Right</td>
<td>Nurse</td>
<td>50</td>
<td>Left</td>
<td>Unemployed</td>
</tr>
</tbody>
</table>

TNM*, tumor, nodes, metastasis; SCC†, squamous cell carcinoma; MRND‡, modified radical neck dissection; SND§, selective neck dissection
The study conformed to the Declaration of Helsinki, and was approved by Hunter New England Health Human Research Ethics committee and the University of Newcastle Human Research Ethics Committee. Written informed consent was obtained from all participants.

Ten electrodes were placed over four muscles (active electrodes) as summarised in Table 4-2, with two bony prominences being earth electrodes (the spinous process of C7 and the ipsilateral clavicle). Electrode location was standardised according to anatomic and SEMG human studies, and accepted procedures for SEMG sensor placement were followed. Collection of SEMG recording occurred with the use of the ADI Power Lab 8SP (ML 785) and two dual bio amplifiers (ML135).

SEMG signals were amplified and filtered with a low-pass filter of 50Hz, with data acquired at a sampling rate of 2 kHz and a recording range of 0-2 mV. Raw electromyographic signals were then transmitted from the electrodes to a computer for processing (Lab Chart v7 for Windows XP operating system) and storage for future analysis.

Neck dissection participants were asked to perform a series of 10 maneuvers, first on the affected arm and then on the unaffected arm. The healthy participants performed the maneuvers on the left arm first, and then the right arm. Each maneuver performed was sequentially ordered (Table 4-3). Practice of each maneuver occurred prior to testing to maximize correct performance. Three repetitions were performed for each maneuver, with at least a 30 second rest between each repetition. A minimum of 60 seconds rest occurred between different maneuvers. The maneuvers involved seven dynamic scapular strengthening exercises with a 2.0 kg weight, and four maximum voluntary isometric contractions (MVIC) for each muscle being tested.
### Table 4-2 Anatomical Landmarks of Scapular Muscles for Electrode Placement and Maximal Voluntary Isometric Contraction (MVIC)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Electrode Placement</th>
<th>MVIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper trapezius</td>
<td>Three centimetres superior to lateral one third clavicle and directed to ligamentum nuchae</td>
<td>Scapula elevation in sitting. Resistance applied into shoulder depression and cervical spine contralateral flexion</td>
</tr>
<tr>
<td>Middle trapezius</td>
<td>Four centimetres proximal to acromion towards C7 spinous process</td>
<td>As for upper trapezius</td>
</tr>
<tr>
<td>Rhomboids</td>
<td>Three centimetres from junction of middle and lower third of scapula border and T2 spinous process</td>
<td>Prone, head rotated ipsilaterally. Scapula adducted and elevated. Elbow fully flexed, shoulder extended and adducted. Resistance applied into shoulder abduction and depression</td>
</tr>
<tr>
<td>Serratus anterior</td>
<td>Superior aspect 8th rib mid axillary line directed anteriorly</td>
<td>Supine, shoulder at 90° flexion, elbow fully extended. Resistance applied into shoulder retraction.</td>
</tr>
</tbody>
</table>

### Table 4-3 Dynamic manoeuvres performed

<table>
<thead>
<tr>
<th>Dynamic manoeuvres</th>
<th>Muscles targeted</th>
<th>Exercise description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder shrug</td>
<td>Upper trapezius</td>
<td>In standing, tested arm by side and elbow fully extended, holding onto dumbbell. Scapula in neutral position of elevation/depression. Elevate scapula to maximum height maintaining position of elbow and glenohumeral joint, then return to start position.</td>
</tr>
<tr>
<td>Overhead press</td>
<td>Upper trapezius</td>
<td>In standing, shoulder abducted to 90 degrees so humerus at horizontal level, and elbow flexed to 90 degrees, holding onto dumbbell. Extend elbow fully, so weight moves up towards ceiling, then return to start position.</td>
</tr>
<tr>
<td>Single-arm row in standing</td>
<td>Rhomboids</td>
<td>In standing, contralateral hand on plinth, and trunk flexed to approximately 45 degrees, with contralateral leg in front in a lunge position. Ipsilateral hand holding onto dumbbell, with elbow fully extended. Ipsilateral shoulder flexed in line with contralateral knee, holding onto dumbbell with elbow fully extended. Retract scapula and flex elbow, pulling dumbbell toward ipsilateral lower rib region.</td>
</tr>
<tr>
<td>Single-arm row in prone</td>
<td>Rhomboids</td>
<td>In prone holding dumbbell. Contralateral hand under forehead to maintain neck in neutral position. Ipsilateral glenohumeral joint just clear of plinth. Ipsilateral shoulder in approximately 90 degrees flexion with elbow fully extended, and end range scapula protraction as gravity allows. Retract scapula and flex elbow, pulling dumbbell toward ipsilateral lower rib region. No shoulder abduction permitted.</td>
</tr>
<tr>
<td>Horizontal adduction/flexion</td>
<td>Serratus anterior</td>
<td>In sitting. Start position is wrist in line with shoulder and elbow flexed. Raise arm towards midline and upwards, combining shoulder adduction and flexion.</td>
</tr>
<tr>
<td>Bilateral arm wall press up</td>
<td>Serratus anterior</td>
<td>Both hands positioned on wall placed shoulder width apart, and shoulders flexed to 90 degrees. Start position is full scapula retraction with sternum depressed towards wall, elbows fully extended. End position is maximum scapula protraction, shoulders and elbows remain in starting position.</td>
</tr>
<tr>
<td>Scapula protraction in supine</td>
<td>Serratus anterior</td>
<td>In supine, shoulder at 90°degrees flexion holding dumbbell, elbow fully extended, ipsilateral scapula fully on plinth surface. Protract scapula fully, so scapula lifts off plinth, then return to starting position. Shoulder and elbow remain in same position as at the start. No trunk rotation permitted.</td>
</tr>
</tbody>
</table>
The MVICs for each muscle were based on normalisation studies for the muscles under investigation, which would also be feasible for participants to perform \(^{104,108,109}\) (see Table 4-3). For the MVIC, the same researcher applied maximal manual pressure, and participants held the contraction in the isometric position for a period of three seconds.

For the dynamic strengthening exercises, three seconds was counted to reach the end point of the exercise, and then three seconds to return to the starting position. If the maneuver was incorrectly performed, the maneuver was repeated with feedback provided to correct the participant’s performance. If a participant experienced pain or was physically unable to correctly perform the maneuver, then the maneuver was ceased and the trial was then excluded from subsequent data analysis.

### 4.3.1 Data reduction

All raw electromyographic data were filtered with a high pass filter of 1Hz, and then smoothed using root mean square (RMS). All data that included noisy signals with artifacts such as electrocardiogram activity, movement error, and insufficient resting baseline electromyographic activity were excluded. For all three trials of each maneuver, or those clean trials remaining, a three second total time period either side of the maximum RMS electromyographic activity was selected for subsequent numerical data analysis. The average RMS electromyographic of the trials was calculated for each of the 10 maneuvers, including the MVICs, to represent the mean muscle activity. Two data sets were collected for each participant. One data set consisted of raw electromyographic averages for each dynamic exercise maneuver for each muscle. The second data set consisted of the first data set expressed as a percentage of the MVIC for each respective muscle.

### 4.3.2 Data Analysis

As groups of participants were age and sex matched, and no participants appeared particularly overweight or obese, it was assumed that both groups were similar, permitting comparison of RMS electromyographic data. Between-group comparisons
of raw RMS dynamic exercise/ MVIC (%MVIC) data were additionally performed for normalisation purposes. To examine if there was a difference between the three groups, a generalised linear mixed model was fit to the data, using STATA 12.0 statistical software (Stata Corporation, Texas) to perform the analysis, with a level of significance set at $P < 0.05$. The outcome was electromyographic activity in millivolts, and the main predictor was by group with a dummy variable for exercise included in the model. The generalised linear mixed model included a random effect for participant and was used to take account of the repeated measurement within participants.

### 4.4 Study Results

#### 4.4.1 Sample characteristics

The sampling frame consisted of 19 potential neck dissection participants with suspected ANSD. Four were unable to be contacted, one had pre-existing medical co-morbidities that prevented performance of the maneuvers, two had metastatic disease, one declined and one had no ANSD on assessment. The final sample consisted of 10 neck dissection participants and 10 healthy matched control participants, with baseline characteristics described in Table 4-1. For the bilateral neck dissection participants, both demonstrated only one side that was affected by ANSD. Participant 2 had the right shoulder affected by ANSD, and participant 8 had the left shoulder affected by ANSD. Three neck dissection participants had surgery on their dominant side shoulder. Seven of the healthy control participants had the same hand dominance as the matched neck dissection participants.

#### 4.4.2 Electromyographic activity

Upper trapezius raw EMG was significantly lower in the NDA group compared to the NDU group ($P=0.001$), and in the NDA group compared to the control group ($P=0.000$). There was also significantly less raw electromyographic activity in the upper trapezius of the NDU group compared with the control group ($P=0.031$).
Middle trapezius raw electromyographic activity between groups demonstrated a similar pattern, with less muscle activity in the NDA group compared with both the NDU group \((P =0.000)\) and the control group \((P =0.000)\). However there was no significant difference in middle trapezius raw electromyographic activity between NDU and control groups.

Rhomboid raw electromyographic activity demonstrated no significant differences between all three groups, with NDA group rhomboid electromyographic activity equaling the rhomboid electromyographic activity of the control group exactly, and the NDU group producing the highest rhomboid electromyographic compared with the other two groups.

Serratus anterior raw electromyographic activity was highest in the NDA group compared with both the NDU and the control groups, which was not a significant difference, with the lowest serratus anterior electromyographic activity occurring in the control group.

Percentage MVIC data indicated that the NDA group demonstrated higher electromyographic scores than the control group for all muscle groups except for the rhomboids. The NDU group had higher %MVIC than the control group for all muscle groups except for the middle trapezius. Both raw and % MVIC data are summarised in Table 4-4.
Table 4-4 Raw EMG and % MVIC scapular muscle differences by group

<table>
<thead>
<tr>
<th>Muscle tested</th>
<th>Mean EMG (mV)</th>
<th>Mean Difference (mV)</th>
<th>Std Error</th>
<th>95% CI</th>
<th>% MVIC*</th>
<th>Mean difference %</th>
<th>Std Error</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>UT*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDU†</td>
<td>0.073</td>
<td></td>
<td></td>
<td></td>
<td>0.727</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDA‡</td>
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<td>0.015</td>
<td>.005</td>
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<td>0.769</td>
<td>-0.033</td>
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<tr>
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<tr>
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<tr>
<td>NDU†</td>
<td>0.067</td>
<td>-0.008</td>
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<td>-0.497</td>
<td>0.162</td>
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</tr>
</tbody>
</table>

UT*, upper trapezius; NDU†, Neck dissection unaffected arm; NDA‡, Neck dissection affected arm; MT§, middle trapezius; RH†, rhomboids; SA¶, serratus anterior; MVIC*, maximum voluntary isometric contraction; Control, Control healthy matched arm

Mean difference (mV) is the EMG difference between the group listed first compared to the group listed underneath.

4.5 Discussion

To our knowledge, this is the first study to investigate the dynamic electromyographic activity of scapular muscles in the neck dissection population. Previous electromyographic studies of accessory nerve function in neck dissection patients have involved motor conduction of the accessory nerve 32, 103. These studies are useful for information about the degree of trapezius muscle denervation under static conditions, but they fail to account for dynamic activity, which arguably has greater clinical relevance for rehabilitation purposes. Furthermore, results of this data provide novel
information crucial to understanding the extent of trapezius and scapular muscle activity in ANSD-affected sides compared with unaffected sides, and also compared with a healthy population, during dynamic exercise conditions.

Twenty participants were recruited, with 10 participants in each group. This number of participants was based on sample sizes in other descriptive SEMG studies involving the shoulder \textsuperscript{111,112}. Most of the sample were men, with a mean age of approximately 60 years of age, which reflects the sex and age distribution of the head and neck cancer population \textsuperscript{47}. The differences in range of time from surgery to electromyographic assessment may have affected study findings, with overall higher electromyographic activity demonstrated in participants with a longer time since surgery. Scapular muscle strengthening exercises when the accessory nerve is intact are physiologically more likely to be effective, since there is minimal nerve recovery after neurotmesis from radical neck dissection \textsuperscript{113}. Hence, only those neck dissection patients with an intact accessory nerve were included. This study measured the EMG electromyographic activity during one assessment. A reassessment of measures in 12 months would be a useful comparison.

\textbf{4.5.1 Study Limitations}

SEMG was theorised to be the most feasible method of electromyography for the study participants, because it is non-invasive. The order of maneuvers was not randomised, either within or across participants. The exercise sequence was chosen based on the order of exercises currently being investigated as part of a randomised controlled study by the authors. As such, there is a possibility of muscle fatigue or motor learning affecting the muscles during both the latter exercises and the arm that was secondarily tested. This may have impacted on the differences in scapular muscle activity found between the affected and unaffected sides in neck dissection participants.

Raw electromyographic data comparisons between participants have limitations because of individual anatomic differences such as muscle fibre composition and adipose tissue \textsuperscript{110}. Consequently, %MVIC is frequently used as an attempt to normalise
these differences and allow comparisons between people. However, using %MVIC as a normalisation method to compare data between groups is potentially misleading in this study, since the overall raw MVIC electromyographic activity was higher in the unaffected side and in healthy controls, which lowers the %MVIC score. Although %MVIC is a normalisation method to account for structural differences between participants, raw data comparison is useful for patient populations that experience a painful condition \(^{114}\), and a more accurate reflection of electromyographic differences in this study.

Both upper and middle sections of the trapezius muscle demonstrate significantly lower dynamic muscle activity in ANSD after neck dissection compared with both unaffected arms and healthy controls. Reduced trapezius electromyographic levels in the operated side following neck dissection are likely to be a result of a combination of intra-operative axonotmesis of the accessory nerve, exacerbated by the side effects of radiation therapy, which causes both muscle atrophy \(^{100}\) and nerve demyelination \(^{27}\).

The trapezius is a large and crucial muscle that aids in scapula elevation and lateral rotation to allow normal glenohumeral joint movement. Importantly, it would appear that rehabilitation in patients with ANSD and an intact accessory nerve following neck dissection should include some form of upper and middle trapezius muscle strengthening, as an attempt to increase trapezius muscle activity. Although electromyographic muscle activity is not a measure of strength, strengthening exercises are prescribed to enhance muscle activity, since there is an association between these outcomes \(^{115}\).

The upper trapezius was also found to have significantly lower electromyographic activity in the NDU group compared to the control group. This result may indicate reduced muscle activity attributable to deconditioning, and as a result of undergoing treatment for cancer with associated weight and muscle loss. However, the reduction in electromyographic activity was not found in the other scapular muscles under study in the NDU group. Contralateral reductions in electromyographic activity of the upper trapezius on the unaffected side may be caused by degenerating ventral horn cell
mechanisms within the spinal cord, which animal studies have shown to occur in peripheral motor nerve injuries. Clinically, it would potentially be of benefit for exercises in ANSD patients to include strengthening of the upper trapezius muscle not only on the affected side, but on the unaffected side as well.

A further interesting finding in this study was the higher muscle activity in the serratus anterior in the NDA group compared with both other groups. Although this difference was not statistically significant, it may suggest a compensatory scapular muscle mechanism occurring in the serratus anterior in patients with ANSD to balance the trapezius muscle deficit. Promotion of accessory muscle use, particularly the serratus anterior muscle, may aid scapula rotation and subsequently improve glenohumeral abduction, reducing shoulder pain.

Rehabilitation of patients with ANSD is not currently tailored to the muscle activity findings of this study. Inclusion of bilateral upper trapezius and unilateral middle trapezius strengthening exercises that are directed towards assessment findings should be included as standard treatment of ANSD. In addition, it would seem sensible to include exercises to enhance synergistic serratus anterior muscle activity, during any possible neural recovery mechanisms of the accessory nerve when the upper trapezius has less muscle activity. Specific scapular muscle rehabilitation, based on demonstrated muscle activity patterns, has the potential to limit the development of painful secondary shoulder conditions in patients with ANSD, such as impingement syndrome and adhesive capsulitis.

4.6 Conclusion

Neck dissection patients affected by ANSD demonstrate significantly lower levels of upper and middle trapezius muscle dynamic electromyographic activity compared with both their unaffected side and healthy controls. Upper trapezius dynamic electromyographic activity is also significantly lower on the unaffected arm compared to healthy controls. A trend towards higher dynamic serratus anterior muscle activity is evident in the ANSD arm, which may suggest a compensatory accessory muscle
strategy. These scapular muscle activity differences experienced in patients with ANSD following neck dissection should be considered with their rehabilitation. Specific exercises tailored to the scapular muscle deficit demonstrated with ANSD need to routinely include bilateral upper trapezius muscle, unilateral middle trapezius muscle and unilateral serratus anterior muscle strengthening. This may possibly reduce the sequelae of painful secondary shoulder disorders.

4.7 Suppliers

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Bella Vista NSW 2153
NSW AUSTRALIA
PH: +61(2) 88183400

4.8 Implications of findings for the following study

The scapular muscle activity differences found in this study in patients demonstrating the signs of accessory nerve shoulder dysfunction after neck dissection identify the scapular muscles that need to be more specifically targeted with rehabilitation. There are various strengthening exercises that aim to predominantly target a specific scapular muscle. Ideally, strengthening exercises that maximise targeted muscle activity are more likely to be most effective. Understanding which particular strengthening exercises are associated with maximal scapular muscle activity, especially in the upper trapezius muscle of this patient group, will guide the type of physiotherapy rehabilitation exercises selected to comprise the optimal intervention for this patient group.

The effectiveness and feasibility of scapular muscle strengthening exercise selection is investigated in the following study in this patient group.
Chapter 5 Scapular muscle exercises following neck dissection surgery for cancer: A comparative electromyographic study

This chapter contains the published manuscript as titled above, published in Physical Therapy. 2013; 93(6):786-797.

The authors of this publication are Aoife McGarvey, Peter Osmotherly, Gary Hoffman and Pauline Chiarelli.

The chapter does not differ from the published paper apart from the tables and references that have been renumbered to maintain consistency throughout the thesis.

5.1 Abstract

Background: Shoulder pain and dysfunction can occur following neck dissection surgery for cancer. These conditions often are due to accessory nerve injury. Such an injury leads to trapezius muscle weakness, which, in turn, alters scapular biomechanics.

Objective: The aim of this study was to assess which strengthening exercises incur the highest dynamic activity of affected trapezius and accessory scapular muscles in patients with accessory nerve dysfunction compared with their unaffected side.

Design: A comparative design was utilised for this study.

Methods: The study was conducted in a physiotherapy department. Ten participants who had undergone neck dissection surgery for cancer and whose operated side demonstrated clinical signs of accessory nerve injury were recruited. Surface electromyographic activity of the upper trapezius, middle trapezius, rhomboid major and serratus anterior muscles on the affected side was compared dynamically to that of the unaffected side during 7 scapular strengthening exercises.
Results: Electromyographic activity of the upper and middle trapezius muscles of the affected side was shown to be lower than that of the unaffected side. The neck dissection side affected by surgery demonstrated higher levels of upper and middle trapezius muscle activity during exercises involving overhead movement. The rhomboid and serratus anterior muscles of the affected side demonstrated higher levels of muscle activity compared with the unaffected side.

Limitations: Exercises were repeated 3 times on one occasion. Muscle activation under conditions of increased exercise dosage should be inferred with caution.

Conclusions: Overhead exercises are associated with higher levels of trapezius muscle activity in patients with accessory nerve injury following neck dissection. However, pain and correct scapular form must be carefully monitored in this patient group during exercises. Rhomboid and serratus anterior accessory muscles may have a compensatory role, and this role should be considered during rehabilitation.

5.2 Introduction

Cancer that develops in the head and neck is able to metastasise to the cervical lymph nodes. Neck dissection surgery is undertaken as part of the management of these cancers and involves removal of the relevant draining lymph nodes. The spinal accessory nerve is encountered during various types of neck dissection on its path to penetrate and supply the sternocleidomastoid and trapezius muscles. The accessory nerve is at operative risk from either a direct or indirect injury during several types of neck dissection, even if remaining macroscopically intact 11. Such injuries result in a reduced motor input to, and therefore weakness of, the trapezius muscles. Dysfunction in these muscles is typified at rest by a dropped, winged and medially rotated scapula. Dynamically, reduced scapular elevation and rotation motion results in decreased glenohumeral abduction and flexion, when the trapezius muscle is most active 59. Abnormal scapular biomechanics cause mechanical overload to the shoulder joint complex, leading not only to reduced regional function, but also pain and negative effects on quality of life 61. Neck dissection has become increasingly focused on
preserving the accessory nerve, in an attempt to limit post-operative shoulder morbidity. Despite this trend, shoulder dysfunction has been reported in up to 67% of patients with a spared accessory nerve. The high incidence of shoulder morbidity remains a pertinent and debilitating post-operative issue.

Physiologically, there is an argument for addressing this biomechanical dysfunction by including strengthening exercises that maximize trapezius muscle activity, to subsequently improve scapular elevation and lateral rotation. Electromyography (EMG) is a tool that can be used to monitor muscle activity and, therefore, a method to aid exercise selection. Strengthening exercises associated with the highest levels of upper and middle trapezius muscle activity measured through EMG are likely to be the most beneficial in patients experiencing trapezius muscle weakness resulting from accessory nerve injury.

Following neck dissection, patients may experience not only the direct impact of accessory nerve injury causing reduced trapezius muscle activity but also the sequelae of secondary scapular and glenohumeral muscle imbalances. As such, the term “accessory nerve shoulder dysfunction” (ANSD) is utilised to describe the overall observed muscle imbalances in this patient group.

The effectiveness of strengthening exercises for the trapezius muscle and other accessory scapular muscles has been studied using surface electromyography (SEMG) in individuals who were healthy. However, these studies examined participants without either shoulder pain or restriction in shoulder movement. Patients experiencing ANSD after neck dissection are unlikely to have sufficient shoulder elevation movement to perform commonly recommended scapular strengthening exercises such as horizontal abduction, scaption and bench press. Consequently, scapular strengthening exercises may need to be modified in order to be feasible for patients with ANSD. Which specific exercises are most effective, in terms of scapular muscle activity and particularly trapezius muscle activation, is unknown in the ANSD population.
Patients who develop ANSD frequently undergo post-operative radiation therapy and chemotherapy. Radiation therapy typically is directed over the lateral aspect of the neck, predisposing the patient to further demyelination of the accessory nerve neural sheath and causing fibrosis of the trapezius muscle.

Treatment of head and neck cancer often leads to loss of muscle mass resulting from significant weight loss. Cancer related fatigue and reduced physical activity occurs in as much as 50% of patients with head and neck cancer following treatment. This is a further factor compounding both muscle weakness and the capacity to exercise. Factors in patients with head and neck cancer, such as daily alcohol consumption, lower levels of education, radical neck dissection surgery, depression and anxiety also have been found to significantly reduce exercise adherence. It is crucial for exercise selection to be maximised in patients with ANSD, given there are a multitude of factors reducing their overall capacity to exercise. Maximising the impact of scapular muscle strengthening exercise selection is likely to augment effectiveness of rehabilitation in this patient group.

The effectiveness of progressive scapular muscle strengthening exercises have been investigated in patients with ANSD. However, the exercises selected in this study consisted of general upper body strengthening, rather than targeted, biomechanically specific exercises. In addition, patients with accessory neurotmesis, which arguably would not benefit from strengthening exercises as the potential for trapezius muscle recovery is minimal, were included in the sample. Neither that study, nor any other examination of this patient group since, has recorded the EMG activity of trapezius or accessory scapular muscles in neck dissection patients under dynamic conditions. Intramuscular needle EMG activity of the trapezius muscle has been used to explore accessory nerve conduction on the operated side after neck dissection. These studies have provided information regarding the levels of trapezius muscle activity in patients who are affected. However, when considering rehabilitation exercises, dynamic SEMG studies are likely to be more clinically informative in establishing those exercises associated with higher levels of trapezius muscle activity.
The primary aims of this study were (1) to investigate which exercises suitable for prescription for patients with ANSD following neck dissection have the highest dynamic SEMG activity of the trapezius muscle and (2) to explore coexisting patterns of muscle activity in other scapular accessory muscles. A secondary aim was to assess any differences in relevant muscle activity between the affected and unaffected sides of the participants following neck dissection. Gaining an understanding of which exercises are associated with higher levels of trapezius muscle activity will maximize effective exercise selection by physiotherapists in the rehabilitation of patients with ANSD following neck dissection. Insight into scapular muscle patterns in this patient population has potential to provide further specificity in directing rehabilitation.

5.3 Methods

5.3.1 Participants

Participants who had undergone neck dissection surgery were recruited from the hospital via a letter of invitation. Written informed consent was obtained from all participants.

Participants were eligible for inclusion if they had: (1) neck dissection surgery for cancer within the previous 2 years; (2) shoulder pain on the operated side, with onset after neck dissection; (3) clinical signs of ANSD demonstrated on the operated side (scapular depression; reduced active shoulder abduction; and scapular winging at rest or on active shoulder abduction); (4) no previous experience with the exercises performed; and (5) age over 18 years. Potential participants were excluded if they had: (1) accessory nerve sacrifice; (2) history of shoulder or neck pain in the 6 months prior to neck dissection surgery; (3) signs of adhesive capsulitis (reduced shoulder external rotation, abduction and internal rotation); (4) the presence of residual loco-regional cancer or distant metastases to other regions; or (5) a pre-existing medical condition with an inability to repeatedly lift a 2.0 kg weight, or perform exercise against resistance. The aim of recruitment was to include 10 participants, which is comparable to sample sizes in other descriptive SEMG studies involving the shoulder.
Baseline participant characteristics recorded were sex, age, hand dominance, current occupation, date and type of neck dissection surgery, cancer location and staging, and whether radiation therapy or chemotherapy occurred following surgery.

5.3.2 Design

A comparative design was utilised for this study. Patients who had undergone neck dissection and whose operated side demonstrated clinical signs of ANSD were the first group studied and were labeled the “neck dissection affected” (NDA) group. In a comparison group, the EMG activity of the muscles of the unaffected arm of the same participants was studied (NDU group). Bilateral scapular SEMG activity of the upper trapezius, middle trapezius, rhomboid major and serratus anterior muscles was recorded. Assigned participant numbers ensured that all data was maintained in a de-identified form.

5.3.3 Procedure

Ten electrodes were placed over 4 muscles (active electrodes) and 2 bony prominences (reference electrodes), as summarised in Table 5-1. Electrode location was standardised according to anatomical and SEMG human studies \(^{104-106}\), and accepted procedures for SEMG sensor placement were followed \(^{107}\), to maximise reliability of the EMG data. All active electrodes were placed parallel to the muscle fibres. The inter-electrode distance for all active electrode placement points was 3.0 cm. One reference electrode was placed on the spinous process of seventh cervical vertebra, with the second reference electrode placed on the ipsilateral clavicle. Surface electrodes were connected to leads that linked to amplifiers. Collection of SEMG recording was done using ADI Power Lab 8SP (ML 785) and 2 dual bio amplifiers (ML135) (ADInstruments Pty Ltd, Bella Vista, Australia).
### Table 5-1 Anatomical Landmarks of Scapular Muscles for Electrode Placement and Maximal Voluntary Isometric Contraction (MVIC)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Electrode Placement</th>
<th>MVIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper trapezius</td>
<td>Three centimetres superior to lateral one third clavicle and directed to ligamentum nuchae</td>
<td>Scapula elevation in sitting. Resistance applied into shoulder depression and cervical spine contralateral flexion</td>
</tr>
<tr>
<td>Middle trapezius</td>
<td>Four centimetres proximal to acromion towards C7 spinous process</td>
<td>As for upper trapezius</td>
</tr>
<tr>
<td>Rhomboid Major</td>
<td>Three centimetres from junction of middle and lower third of scapula border and T2 spinous process</td>
<td>Prone, head rotated ipsilaterally. Scapula adducted and elevated. Elbow fully flexed, shoulder extended and adducted. Resistance applied into shoulder abduction and depression</td>
</tr>
<tr>
<td>Serratus anterior</td>
<td>Superior aspect 8th rib mid axillary line directed anteriorly</td>
<td>Supine, shoulder at 90° flexion, elbow fully extended. Resistance applied into shoulder retraction.</td>
</tr>
</tbody>
</table>

Surface EMG signals were amplified and filtered with a low-pass filter of 50Hz, with data acquired at a sampling rate of 2 kHz and a recording range of 0 to 2 mV. Raw EMG signals then were transmitted from the electrodes to a computer for processing (Lab Chart version 7 for Windows XP operating system), and storage for future analysis (Figure 5-1). Electromyographic data were collected simultaneously from upper trapezius, middle trapezius, rhomboid and serratus anterior muscles for each exercise performed. All raw EMG data were visually inspected during testing. If there was doubt as to the validity of EMG data recorded, or the signal had noise artifact, the exercise was repeated and labeled accordingly.

![Figure 5-1 Visual EMG display of muscle activity](image-url)
Participants were asked to perform a series of 7 sequentially ordered dynamic strengthening exercises with a 2.0 kg weight (Figure 5-2), first with the affected arm (NDA group) and then with the unaffected arm (NDU group). Each exercise was performed in a standardised manner with maximum displacement taking place over a 3-second period followed by 3 seconds to return to the starting position. Three repetitions were performed for each exercise, with at least a 30-second rest between each repetition, and 60 seconds rest between different exercises. To maximise the correct performance of each exercise, practice occurred prior to testing, and visual and verbal feedback were given to the participants. If the exercise was incorrectly performed, the exercise was repeated with feedback provided to correct their performance. If a participant experienced pain or was physically unable to correctly perform the exercise, then the exercise was ceased and data were labeled “Participant unable to complete due to pain/inability to perform/incorrectly performed”. The trial then was excluded from subsequent data analysis.

Electrodes were removed from the rhomboid major muscle for exercise 7, as the exercise required participants to be positioned supine. Therefore, no data were collected for the rhomboid major muscle for exercise 7.

**5.3.4 Data Reduction**

All raw EMG data were filtered with a high pass filter of 1Hz, then smoothed using root mean square (RMS). A visual inspection of EMG data obtained was undertaken to maximise signal validity. All data that included noisy signals were excluded. Noisy signals included artifacts such as electrocardiogram activity, movement error, and insufficient resting baseline EMG activity. For all 3 trials of each exercise, or those clean trials remaining, a 3-second total time period either side of the maximum raw RMS EMG activity was selected for subsequent numerical data analysis. The average RMS EMG of the trials was calculated for each of the 7 exercises to represent the mean muscle activity. The resultant data set consisted of raw RMS EMG averages for each dynamic exercise for each muscle.
Figure 5-2 Dynamic manoeuvres performed

<table>
<thead>
<tr>
<th>Dynamic exercise number</th>
<th>Muscles targeted</th>
<th>Exercise description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Shoulder shrug</td>
<td>Upper trapezius</td>
<td>In standing, tested arm by side and elbow fully extended, holding onto dumbbell. Scapula in neutral position of elevation/depression. Elevate scapula to maximum height maintaining position of elbow and glenohumeral joint, then return to start position.</td>
</tr>
<tr>
<td>2. Overhead press</td>
<td>Upper trapezius</td>
<td>In standing, shoulder abduced to 90 degrees so humerus at horizontal level, and elbow flexed to 90 degrees, holding onto dumbbell. Extend elbow fully, so weight moves up towards ceiling, then return to start position.</td>
</tr>
<tr>
<td>3. Single-arm row in standing</td>
<td>Rhomboid Major</td>
<td>In standing, contralateral hand on plinth, and trunk flexed to approximately 45 degrees, with contralateral leg in front in a lunge position. Ipsilateral hand holding onto dumbbell, with elbow fully extended. Ipsilateral shoulder flexed in line with contralateral knee, holding onto dumbbell with elbow fully extended. Retract scapula and flex elbow, pulling dumbbell toward ipsilateral lower rib region.</td>
</tr>
<tr>
<td>4. Single-arm row in prone</td>
<td>Rhomboid Major</td>
<td>In prone holding dumbbell. Contralateral hand under forehead to maintain neck in neutral position. Ipsilateral glenohumeral joint just clear of plinth. Ipsilateral shoulder in approximately 90 degrees flexion with elbow fully extended, and end range scapula protraction as gravity allows. Retract scapula and flex elbow, pulling dumbbell toward ipsilateral lower rib region. No shoulder abduction permitted.</td>
</tr>
<tr>
<td>Dynamic exercise number</td>
<td>Muscles targeted</td>
<td>Exercise description</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>5. Horizontal adduction/flexion</td>
<td>Serratus anterior</td>
<td>In sitting. Start position is wrist in line with shoulder and elbow flexed. Raise arm towards midline and upwards, combining shoulder adduction and flexion.</td>
</tr>
<tr>
<td>6. Bilateral arm wall press up</td>
<td>Serratus anterior</td>
<td>Both hands positioned on wall placed shoulder width apart, and shoulders flexed to 90 degrees. Start position is full scapula retraction with sternum depressed towards wall, elbows fully extended. End position is maximum scapula protraction, shoulders and elbows remain in starting position.</td>
</tr>
<tr>
<td>7. Scapula protraction in supine</td>
<td>Serratus anterior</td>
<td>In supine, shoulder at 90° degrees flexion holding dumbbell, elbow fully extended, ipsilateral scapula fully on plinth surface. Protract scapula fully, so scapula lifts off plinth, then return to starting position. Shoulder and elbow remain in same position as at the start. No trunk rotation permitted.</td>
</tr>
</tbody>
</table>

### 5.3.5 Data Analysis

Data were compared in raw RMS format, as the data comparison was within-subjects. Additionally, participants had a painful condition that may reduce the ability to perform a maximal voluntary contraction (MVC) for normalisation purposes. To examine differences between the NDA and NDU groups, a generalised linear mixed model was fitted to the data, using STATA 12.0 statistical software.
College Station, Texas), with a level of significance set at $P < 0.05$. The outcome variable was EMG activity in millivolts, and the main predictor was by group with a dummy variable for exercise included in the model. The generalised linear mixed model included a random effect for participant and was used to account for repeated measurements within participants.

5.4 Results

The sampling frame consisted of 19 potential participants with neck dissection and suspected ANSD. Four potential participants were unable to be contacted: 1 had pre-existing medical co-morbidities that prevented performance of the exercises, 2 had metastatic disease, 1 declined to participate, and 1 had no ANSD upon assessment. The final sample consisted of 10 participants with neck dissection. Baseline characteristics of the individual participants are shown in Table 5-2. The mean age of the final sample was 59.8 years (range = 50-75 years). Eighty percent of the participants were male. Half of the participants were receiving or had previously received adjuvant radiation therapy, with a mean treatment time of 24.2 weeks (range = 4 weeks- 20 months) from date of surgery to the study assessment date. Two participants had undergone a bilateral neck dissection. Both of these participants demonstrated only one side that was affected by ANSD, which was subsequently classified as the NDA side. Three neck dissection participants had surgery on their dominant side shoulder.
<table>
<thead>
<tr>
<th>Neck dissection participant number</th>
<th>Gender</th>
<th>Age</th>
<th>Tumour Site and Stage (TNM)</th>
<th>Radiation therapy</th>
<th>Surgery type (Levels Dissected)</th>
<th>Time between Surgery and Assessment</th>
<th>Hand dominance</th>
<th>Occupation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>60</td>
<td>T1N1M0 neck node</td>
<td>Yes</td>
<td>Right MRND (I-V)</td>
<td>10 weeks</td>
<td>Right</td>
<td>Cleaner</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>57</td>
<td>T2N1M0 mandible and floor of mouth</td>
<td>No</td>
<td>Bilateral MRND (I-V)</td>
<td>4 weeks</td>
<td>Right</td>
<td>Unemployed</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>61</td>
<td>T4N0M0 SCC† ear</td>
<td>Yes</td>
<td>Left SND (I-IV)</td>
<td>8 weeks</td>
<td>Right</td>
<td>Machinery inspector</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>55</td>
<td>T4N0M0 SCC† suborbital region</td>
<td>Yes</td>
<td>Right SND (I-IV)</td>
<td>13 months</td>
<td>Right</td>
<td>Pest controller</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>64</td>
<td>T1N0M0 oral tongue</td>
<td>No</td>
<td>Left SND (I-IV)</td>
<td>20 months</td>
<td>Right</td>
<td>Retired</td>
</tr>
<tr>
<td>6</td>
<td>Male</td>
<td>57</td>
<td>N2M0 unknown primary metastatic SCC†</td>
<td>No</td>
<td>Left SND (I-IV)</td>
<td>8 weeks</td>
<td>Right</td>
<td>Teacher</td>
</tr>
<tr>
<td>7</td>
<td>Male</td>
<td>75</td>
<td>T2N0M0 SCC forehead</td>
<td>No</td>
<td>Left MRND (I-V)</td>
<td>7 weeks</td>
<td>Left</td>
<td>Retired</td>
</tr>
<tr>
<td>8</td>
<td>Male</td>
<td>57</td>
<td>T4N0M0 SCC mandible</td>
<td>Yes</td>
<td>Bilateral SND (I-IV)</td>
<td>14 months</td>
<td>Right</td>
<td>Retired</td>
</tr>
<tr>
<td>9</td>
<td>Female</td>
<td>62</td>
<td>T2N0M0 buccal SCC</td>
<td>Yes</td>
<td>Left SND (I-IV)</td>
<td>9 weeks</td>
<td>Right</td>
<td>Retired</td>
</tr>
<tr>
<td>10</td>
<td>Female</td>
<td>50</td>
<td>T1N0M0 oral tongue</td>
<td>No</td>
<td>Right SND (I-IV)</td>
<td>8 weeks</td>
<td>Right</td>
<td>Nurse</td>
</tr>
</tbody>
</table>

TNM, tumor, nodes, metastasis; SCC, squamous cell carcinoma; MRND, modified radical neck dissection; SND, selective neck dissection.
5.4.1 EMG activity

Results of raw EMG activity in smoothed RMS form by muscle group and exercise performed are summarised in Table 5-3. Data for exercise 6 were collected for only 3 participants, either because of inability to perform the exercise correctly due to pain or inability to maintain the exercise position (4 participants), or because the signals were noisy either from movement artifact (1 participant) or ECG artifact (2 participants). As there was a large amount of missing data for exercise 6, this exercise was excluded from subsequent data analysis.

For the NDA group, upper trapezius muscle EMG activity was highest for exercises 2 and 7, respectively. Middle trapezius muscle EMG activity was maximised for exercises 2 and 5. Exercises 2 and 5 had the highest EMG activity for combined upper and middle trapezius muscles in the NDA group. In the NDU group, although a similar pattern for upper and middle trapezius muscles was observed, the peak levels of activity were observed in exercises 1 and 5 for both muscle parts. Overall, trapezius muscle activity was greatest in exercises 2, 5 and 1 respectively for NDA and NDU combined.

The NDA group demonstrated lower levels of EMG activity compared to the NDU group for the upper trapezius muscle in all exercises, with EMG activity for exercises 1 and 7 being statistically significantly lower. Middle trapezius muscle activity was statistically significantly lower for all exercises, other than exercise 7, in the NDA compared with the NDU group.

For accessory scapular muscles in the NDA group, exercises 4 and 3 demonstrated the highest levels of rhomboid major muscle EMG activity, and exercises 1 and 2 were associated with highest levels of serratus anterior muscle activity. Three out of 5 exercises for the rhomboid major muscle in the NDA group had higher levels of EMG activity compared to the NDU group; however, this pattern was the reverse for exercises 2 and 5, with significantly higher rhomboid muscle activity in the NDU group. A similar pattern was observed in the serratus anterior muscle, with higher
muscle activity in the NDA group for 4 out of 6 exercises and with muscle activity for exercise 4 being significantly higher in the NDA compared with the NDU group.

Table 5-3 Raw Electromyographic (EMG) scapular muscle differences by group and exercise

<table>
<thead>
<tr>
<th>Muscle group</th>
<th>Exercise performed</th>
<th>NDU Mean EMG (mV)</th>
<th>NDA Mean EMG (mV)</th>
<th>Mean Difference (mV)</th>
<th>95% CI for the difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>UT*</td>
<td>1 (Shoulder shrug)</td>
<td>0.084</td>
<td>0.054</td>
<td>0.030*</td>
<td>0.008 – 0.051</td>
</tr>
<tr>
<td></td>
<td>2 (Overhead press)</td>
<td>0.073</td>
<td>0.065</td>
<td>0.008</td>
<td>-0.016 – 0.032</td>
</tr>
<tr>
<td></td>
<td>3 (Row standing)</td>
<td>0.066</td>
<td>0.054</td>
<td>0.012</td>
<td>-0.010 – 0.033</td>
</tr>
<tr>
<td></td>
<td>4 (Row prone)</td>
<td>0.057</td>
<td>0.044</td>
<td>0.013</td>
<td>-0.007 – 0.033</td>
</tr>
<tr>
<td></td>
<td>5 (Adduction/flexion)</td>
<td>0.083</td>
<td>0.063</td>
<td>0.020</td>
<td>-0.004 – 0.044</td>
</tr>
<tr>
<td></td>
<td>6 (Wall press up)</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>7 (Protraction supine)</td>
<td>0.078</td>
<td>0.068</td>
<td>0.011*</td>
<td>0.012 – 0.035</td>
</tr>
<tr>
<td>MT†</td>
<td>1 (Shoulder shrug)</td>
<td>0.261</td>
<td>0.071</td>
<td>0.190*</td>
<td>0.067 – 0.314</td>
</tr>
<tr>
<td></td>
<td>2 (Overhead press)</td>
<td>0.235</td>
<td>0.097</td>
<td>0.138*</td>
<td>0.053 – 0.223</td>
</tr>
<tr>
<td></td>
<td>3 (Row standing)</td>
<td>0.222</td>
<td>0.073</td>
<td>0.149*</td>
<td>0.067 – 0.230</td>
</tr>
<tr>
<td></td>
<td>4 (Row prone)</td>
<td>0.128</td>
<td>0.054</td>
<td>0.074*</td>
<td>0.024 – 0.125</td>
</tr>
<tr>
<td></td>
<td>5 (Adduction/flexion)</td>
<td>0.241</td>
<td>0.090</td>
<td>0.151*</td>
<td>0.070 – 0.231</td>
</tr>
<tr>
<td></td>
<td>6 (Wall press up)</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>7 (Protraction supine)</td>
<td>0.031</td>
<td>0.041</td>
<td>-0.008</td>
<td>-0.015 – -0.001</td>
</tr>
<tr>
<td>RH‡</td>
<td>1 (Shoulder shrug)</td>
<td>0.056</td>
<td>0.092</td>
<td>-0.035</td>
<td>-0.075 – -0.004</td>
</tr>
<tr>
<td></td>
<td>2 (Overhead press)</td>
<td>0.123</td>
<td>0.042</td>
<td>0.082*</td>
<td>0.040 – 0.123</td>
</tr>
<tr>
<td></td>
<td>3 (Row standing)</td>
<td>0.075</td>
<td>0.110</td>
<td>-0.035</td>
<td>-0.071 – -0.002</td>
</tr>
<tr>
<td></td>
<td>4 (Row prone)</td>
<td>0.100</td>
<td>0.113</td>
<td>-0.013</td>
<td>-0.063 – -0.036</td>
</tr>
<tr>
<td></td>
<td>5 (Adduction/flexion)</td>
<td>0.077</td>
<td>0.041</td>
<td>0.035*</td>
<td>0.017 – 0.053</td>
</tr>
<tr>
<td></td>
<td>6 (Wall press up)</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>7 (Protraction supine)</td>
<td>0.031</td>
<td>0.041</td>
<td>-0.008</td>
<td>-0.015 – -0.001</td>
</tr>
<tr>
<td>SA§</td>
<td>1 (Shoulder shrug)</td>
<td>0.034</td>
<td>0.151</td>
<td>-0.117</td>
<td>-0.332 – -0.099</td>
</tr>
<tr>
<td></td>
<td>2 (Overhead press)</td>
<td>0.114</td>
<td>0.110</td>
<td>0.004</td>
<td>-0.036 – 0.043</td>
</tr>
<tr>
<td></td>
<td>3 (Row standing)</td>
<td>0.045</td>
<td>0.062</td>
<td>-0.017</td>
<td>-0.061 – 0.026</td>
</tr>
<tr>
<td></td>
<td>4 (Row prone)</td>
<td>0.040</td>
<td>0.071</td>
<td>-0.032*</td>
<td>-0.061 – -0.003</td>
</tr>
<tr>
<td></td>
<td>5 (Adduction/flexion)</td>
<td>0.110</td>
<td>0.101</td>
<td>0.009</td>
<td>-0.013 – -0.031</td>
</tr>
<tr>
<td></td>
<td>6 (Wall press up)</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>7 (Protraction supine)</td>
<td>0.059</td>
<td>0.068</td>
<td>-0.008</td>
<td>-0.018 – -0.001</td>
</tr>
</tbody>
</table>

UT*, upper trapezius; MT†, middle trapezius; RH‡, rhomboids; SA§, serratus anterior; NDU#, Neck dissection unaffected arm; NDA#, Neck dissection affected arm; *** Missing data, insufficient for analysis; Mean difference (mV), EMG difference of NDU group compared with NDA group. Asterisk indicates statistically significant difference.

5.5 Discussion

This is the first study to examine dynamic SEMG activity of scapular muscles in the neck dissection population, which arguably has greater clinical relevance for rehabilitation purposes than preceding static EMG studies. Although EMG muscle activity is not a measure of strength, strengthening exercises are prescribed to enhance muscle activity, as there is association between these outcomes.
Both the upper and middle sections of the trapezius muscle in patients affected with ANSD following neck dissection surgery demonstrated less dynamic EMG activity compared with their unaffected side. Patients with radical neck dissection and accessory neurotmesis were excluded, as there is no potential for nerve recovery and trapezius muscle strengthening exercises, therefore, are physiologically likely to be ineffective. Reduced trapezius EMG levels in the operated side primarily result from intra-operative nerve injury of the accessory nerve. Post-operative radiation therapy and overall physical deconditioning further compound the trapezius muscle activity loss. However, other factors may also influence the SEMG results found. Soft tissue scarring and fibrosis in the ipsilateral neck region resulting from both neck dissection and radiation therapy may further reduce measured muscle activity in the upper and middle trapezius muscles (which are contained in the lateral neck area). Radiation therapy causes soft tissue fibrosis, which reduces muscle fibre contractility.

Additionally, the tissue composition between the surface electrode and the electrical activity of the muscle under study influences SEMG activity. Scar tissue is likely to affect the impedance of the SEMG signal. Although the factors of tissue composition are unavoidable in this patient group, it potentially influences the SEMG differences found between the operated and unaffected sides.

The greater differences found between the NDA and NDU groups in middle trapezius muscle activity, compared with upper trapezius muscle activity, may be related to the surface electrode location used. Many EMG studies report using the insertion points of the spinous process of the seventh cervical vertebra and the angle of the acromion for upper trapezius muscle location. However, anatomical studies reveal that these insertion points are in fact those for middle trapezius muscle fibres. This study based electrode placement for trapezius muscle parts on anatomical studies. Thus, the middle trapezius muscle electrode location we utilised was that for upper trapezius muscle in several other studies. These different electrode locations may explain the greater differences in the middle trapezius muscle compared with the upper trapezius muscle found between groups in this study.
Collectively, exercises 2, 5, and 1 demonstrate the highest levels of EMG activity for upper and middle trapezius muscles of the NDA and NDU groups. These findings suggest that overhead strengthening exercises are likely to more effectively recruit trapezius muscle fibres. These exercises, therefore, should be prioritised in the exercise selection for patients with ANSD, given that the main rehabilitation focus is to maximize trapezius muscle activity to correct the biomechanical scapular deficit. However, patients with ANSD exhibit restricted active shoulder flexion and abduction because of abnormal scapular biomechanics resulting from trapezius muscle weakness. Therefore, performing exercises in an overhead direction may not always be feasible in this patient group due to regional pain resulting from subacromial impingement and glenohumeral joint restriction. The effect of repeated exercise on muscle activity or pain was not investigated, as the study protocol included one assessment only with 3 repetitions of each exercise. Performing exercises over a longer time period may yield different results, not only in terms of muscle activity, but also practicality. Overhead activity exercises may worsen shoulder pain, so caution needs to be used when prescribing exercises into a restricted movement direction. Exercises 1 and 3 are associated with the next highest levels of upper and middle trapezius activity, and do not involve movement in an overhead direction. Thus, if patients are reporting pain with exercises 2 and 5, it is suggested that exercises 1 and 3 should be prescribed as an alternative.

The higher EMG activity found in the serratus anterior muscle, and to a lesser extent, in the rhomboid accessory muscles, in the NDA group compared with the NDU group, was an interesting finding. This finding is suggestive of compensatory muscle activity in the accessory scapular muscles of patients affected with ANSD, in particular the serratus anterior muscle, working to balance the trapezius muscle deficit. The conflicting results for rhomboid muscle activity indicate that its role in ANSD is uncertain. Although the trapezius and serratus anterior muscles often are considered to work as a force couple to control scapular external rotation, direct reciprocal muscle activity does not exist. Both synergistic and antagonistic activity of serratus anterior occurs. This force couple assists the trapezius muscle to laterally rotate the scapula.
and anchor the scapula onto the ribs; however, it also is antagonistic to the upper trapezius muscle in that it abducts the scapula. A similar conflicting force couple exists with the rhomboid muscle 121, which works synergistically with the trapezius muscle to adduct the scapula, but antagonistically to downwardly rotate it.

Whether this observed increased scapular accessory muscle activity in patients with ANSD should be encouraged or avoided is certainly arguable. Peripheral nerve lesions are linked with central nervous system reorganisation, with plasticity mechanisms resulting in either beneficial adaptive changes, or deleterious maladaptive changes if abnormal movement patterns are promoted 122, 123. Knowledge as to the prognosis for accessory nerve recovery is likely to guide rehabilitation decisions related to whether to actively promote serratus anterior and rhomboid muscle activity. For those patients with longer recovery anticipated of the accessory nerve due to greater levels of nerve injury, such as with axonotmesis or neurotmesis, it would seem feasible to encourage accessory muscle use for functional purposes. Promotion of accessory muscle use, particularly the serratus anterior muscle, may aid scapula rotation and subsequently improve glenohumeral abduction, reducing shoulder pain. The challenge is that often the degree of nerve injury is unknown, other than with radical neck dissection when the nerve is severed.

Accessory nerve function following neck dissection can be assessed through the use of continuous intra-operative nerve monitoring. This procedure involves stimulation of the accessory nerve throughout surgery with measurement of trapezius muscle output. It allows the identification and preservation of the nerve during surgery 124 and, importantly, gives an indicator if there are any differences in accessory nerve function between the start and the completion of surgery. Therefore, any patient who demonstrates reduced motor output of the trapezius muscle after neck dissection can be identified and referred for physiotherapy management. Participants in this study did not undergo intra-operative accessory nerve monitoring. The presence of abnormal muscle imbalances was established by the demonstrated typical clinical signs (scapular depression, reduced active shoulder abduction, and scapular winging at rest and on
active shoulder abduction). The inclusion of intra-operative accessory nerve monitoring would be a useful tool to consider for further study to establish definitive levels of accessory nerve injury, which then could be related to EMG findings.

Exercise order was based on those currently being investigated as part of a randomised controlled study by the authors. Sequence of exercises performed may have affected muscle activity results, as the order of exercises was not randomised. Therefore, there was a possibility of muscle fatigue affecting the muscles both during the latter exercises and the unaffected arm that was secondarily tested. Raw EMG data comparisons have limitations due to individual anatomical differences such as muscle fibre composition and adipose tissue.

Muscle activity levels during exercise expressed as a percentage of maximal voluntary contraction (%MVC) typically are utilised as a normalisation technique to address this measurement issue. However, if a participant is experiencing a painful condition, it is likely to reduce the validity of the %MVC normalisation method. Another commonly used EMG normalisation technique is to utilise a submaximal reference voluntary contraction, thereby avoiding the limitations associated with a maximal muscle contraction. A submaximal reference voluntary contraction typically occurs in the mid range of movement, and in the shoulder, this often is in 125 degrees of shoulder scaption while holding a weight for several seconds. The feasibility of participants in this study being able to reliably perform this normalization technique is low due to the reduced glenohumeral joint range of flexion and abduction by virtue of having an accessory nerve injury. As such, neither normalisation technique was performed. Given that comparisons were within participants, no participants were obese or particularly overweight, and raw data comparison is a more accurate reflection of patient populations that experience a painful condition, these comparisons were considered acceptable.

The trapezius is a large and crucial muscle that aids in scapular elevation and lateral rotation to allow normal glenohumeral joint movement. Patients with ANSD demonstrate muscle activity deficits in both upper and middle sections of the trapezius
muscle, affecting scapular biomechanics and causing restricted shoulder movement and pain. Physiotherapy rehabilitation of patients with ANSD and an intact accessory nerve following neck dissection should include some form of upper and middle trapezius muscle strengthening, to maximize trapezius muscle activity. The roles of the serratus anterior and rhomboid major muscles are less clear in relation to exercise prescription. Both nerve recovery stage and potential need to be considered if including accessory muscle strengthening exercises in scapular rehabilitation.

5.6 Conclusion

Lower levels of middle and upper trapezius muscle dynamic EMG activity were demonstrated in patients who have undergone neck dissection surgery and are affected by ANSD compared to their unaffected side. A trend towards higher dynamic serratus anterior muscle activity is evident in the ANSD-affected arm, which may suggest a compensatory accessory muscle strategy. Consideration should be given to scapular muscle activity differences following neck dissection and the potential for regaining accessory nerve function when treating patients with ANSD. Physiotherapy in patients after neck dissection surgery is challenging because of the morbidity in treatment of cancer, which places limitations on patients’ ability to exercise. It is crucial that exercise prescription be specific to maximise rehabilitation gains and capitalise on recovery processes. Exercises shown in this study to maximise trapezius muscle activity should guide physiotherapists’ exercise selection and should be used with careful monitoring to avoid any painful symptoms and ensure correct scapular stabilisation.
5.7 Implications of findings for the following study

Neck dissection patients, with clinical signs of accessory nerve shoulder dysfunction, demonstrated greater levels of upper and middle trapezius muscle activity in their affected side, with the overhead exercises being overhead press and combined horizontal adduction and flexion. However, if these exercises were unable to be performed due to shoulder pain or limited elevation range of motion, then exercises shoulder shrug and single arm row in standing were the next effective for upper and middle trapezius muscle activity.

These study findings, enable a graded approach to specific physiotherapy exercise selection for patients with accessory nerve shoulder dysfunction following neck dissection surgery, allowing consideration of exercise feasibility and effectiveness of muscle activity. Selection of a particular scapular muscle strengthening exercise needs to consider maximisation of upper trapezius muscle and other accessory scapular muscle activity, the patient’s active shoulder range of motion, pain, and if they are undergoing any adjuvant treatment.

The muscle activity findings may be effective in the rehabilitation of accessory nerve dysfunction following neck dissection surgery, with overhead exercises not being prescribed until active shoulder flexion and abduction is pain free and greater than 90 degrees, with correct scapula control. However, despite these novel findings, it is unknown if an intervention study based on the muscle activity results of this study, may be beneficial.

The effectiveness of an intervention based on these scapular muscle activity findings, compared to usual care, is explored in the next study.
Chapter 6  Maximising shoulder function following accessory nerve neurapraxia after neck dissection surgery: A multicentre randomised controlled trial

This chapter contains the published manuscript as titled above, published in Head and Neck 2014 DOI 10.1002/hed.237129.

The authors of this publication are Aoife McGarvey, Peter Osmotherly, Gary Hoffman and Pauline Chiarelli.

The chapter does not differ from the published paper apart from the tables and references that have been renumbered to maintain consistency throughout the thesis.

6.1 Abstract

Background: Shoulder pain and dysfunction following neck dissection may result from injury to the accessory nerve. The effect of early physiotherapy in the form of intensive scapular strengthening exercises is unknown.

Methods: A total of 59 neck dissection participants were prospectively recruited for this study. Participants were randomly assigned to either the intervention (n= 32), consisting of progressive scapular strengthening exercises for 12 weeks, or the control group (n= 29). Blinded assessment occurred at baseline, and at 3, 6 and 12 months.

Results: Three-month data were collected on 52 participants/53 shoulders. Per-protocol analysis demonstrated that the intervention group had statistically significantly higher active shoulder abduction at 3 months compared to the control group (+26.6°; 95% confidence interval [CI] 7.28 to 45.95; p= 0.007).

Conclusion: The intervention is a favourable treatment for maximising shoulder abduction in the short term. The effect of the intervention compared to usual care is uncertain in the longer term.

Key Words: Accessory nerve, shoulder dysfunction, neck dissection, physical therapy
6.2 Introduction

Accessory nerve injury can occur following neck dissection performed in the management of head and neck cancer. Modified and selective neck dissections have been popularised as they avoid the accessory neurotmesis that is associated with “classic” radical neck dissection. Despite recent surgical attempts to limit the post-operative morbidity seen with accessory nerve compromise, injury to the accessory nerve can still occur in up to 67% of patients, in spite of these nerve sparing dissections. Microtrauma to the accessory nerve can occur through intra-operative neural manipulation and traction, leading to focal or segmental demyelination and devascularisation, even with an intact neural sheath.

The accessory nerve is the primary motor supply to the large trapezius muscle. There are also known but much lesser contributions from C2, C3 and C4 branches of the cervical plexus. When neural input to the trapezius is impaired, weakness of the muscle results. This has a major detrimental effect on scapula position. At rest, the scapula becomes dropped and winged with reduced trapezius muscle activity. Abnormal scapular biomechanics leads to significantly reduced active glenohumeral abduction and flexion compared to pre-operative levels. Reduced active glenohumeral abduction and flexion resulting from accessory nerve shoulder dysfunction has pronounced negative effects on regional shoulder pain, function and quality of life, which are well-documented.

Neck dissection status has been found to significantly influence levels of disability. The burden of this affects not only patients, but has a larger societal impact. Given that most head and neck cancer patients are men and still of working age, the presence of accessory nerve shoulder dysfunction impacts greatly on their ability to return to work. Although the prevalence of accessory nerve shoulder dysfunction has been reported, there is large variation in the reports how the dysfunction progresses over time. Consequently, there is no definitive prognostic information for medical and health professionals to provide to affected patients, further adding to the challenge of occupational planning.
Post-operative care of accessory nerve shoulder dysfunction following neck dissection may vary based on setting, location and opinions of treating professionals. Optimal evidence-based management of accessory nerve shoulder dysfunction is inconclusive. The only randomised controlled trial with sufficient sample size investigating the effect of physiotherapy in patients with accessory nerve shoulder dysfunction found a 12-week supervised progressive upper limb strengthening exercises to be superior to upper limb strengthening exercises without load progression. However, as the authors acknowledge, the study lacked prospective recruitment, with a median time since surgery > 18 months for 44% of the participants. Patients with accessory neurotmesis, in which nerve recovery mechanisms are unlikely, were also included. No follow-up measures were undertaken beyond 12-weeks. Both groups received physiotherapy three times a week for 12 weeks, which is resource intensive and costly. The effect of advice only compared to regular physiotherapy has been recently investigated. However, with the analysed sample size being only 24 participants, and a high risk of bias resulting from methodological flaws, the study outcome is considered to be of limited value. This review highlights the need for further studies with long-term follow-up in this patient population, with physiotherapy conducted during the early post-operative phase and radiation therapy period.

The main purpose of this study was to investigate the effect of early specific intensive rehabilitation in patients with accessory nerve shoulder dysfunction after neck dissection, compared to usual care in Australia (primarily a brochure of self-directed home-based exercises) during a 12-month period. The secondary purposes were to investigate the prevalence of accessory nerve shoulder dysfunction after neck dissection in the included study sites, how accessory nerve shoulder dysfunction progresses over a 12-month period, and the feasibility of performing intensive strengthening exercises during adjuvant treatment for head and neck cancer. Results of the study may improve the evidence-based physiotherapy management of patients affected by accessory nerve shoulder dysfunction after neck dissection, thereby improving consistency of care and maximising the efficient use of resources.
6.3 Materials and Methods

6.3.1 Participants
The trial was conducted from April 2009 to December 2012 at three study sites within NSW, Australia: The Calvary Mater Newcastle, Liverpool and Westmead Hospitals. Participants were recruited from these hospitals, or as private patients of a collaborative surgeon attending the study site hospitals. All participants were diagnosed with carcinoma of the head and neck region and had undergone a neck dissection, with accessory nerve preservation, within the past 8 weeks prior to study entry, with demonstrated clinical signs of accessory nerve shoulder dysfunction after surgery. Shoulder dysfunction as a result of accessory nerve injury was assumed if participants presented with at least 2 of the following clinical signs: a dropped and winged scapula at rest, scapula winging on active shoulder abduction and reduced active abduction range of motion. Eligibility criteria also included a fully healed neck dissection scar, ≥18 years of age, and ability to sufficiently communicate in the English language. Exclusion criteria were medical comorbidities or psychiatric illness that would affect the ability to perform the intervention, illness as a result of post-operative complications, the presence of distant metastases, and a previous history of shoulder pain or known shoulder pathology within 6 months before neck dissection. Ethical approval to conduct the trial was obtained from the Human Research Ethics Committees of the University of Newcastle, Hunter New England Area Health Service, South Western Sydney Local Health District, and Western Sydney Local Health District. Informed written consent was obtained from all participants that agreed to participate.

6.3.2 Study Design and Randomisation
The study was a single blind prospective, randomised controlled trial. A physiotherapist assessor, blinded to the study, initially screened potential participants at each study site. Those participants included were then randomly assigned to either the control group or the intervention group after the baseline assessment. Randomisation was via a block design stratified by the study site and neck dissection
type (modified radical neck dissection versus selective neck dissection), with codes generated separately for each hospital with treatment allocation balanced in blocks of size four. An independent statistician generated the codes using the Proc Plan procedure in the SAS statistical software package. Allocation codes were inserted by an independent person in sealed, opaque envelopes for concealment, and labeled with sequential study numbers. After participant consent, the treating physiotherapist selected the next available envelope to determine into which treatment group the patient was allocated to.

6.3.3 Outcome Measures

Outcome measures were assessed at baseline, 3 months, 6 months and 12 months for the operated side affected by accessory nerve shoulder dysfunction. Participants who underwent a bilateral neck dissection had outcome measures obtained for either one or both shoulders, depending upon the demonstrated post-operative signs of accessory nerve shoulder dysfunction.

6.3.3.1 Primary Outcome Measures

The Shoulder Pain and Disability Index (SPADI) is a validated questionnaire measuring shoulder pain and impairment, which has been shown to demonstrate good test-retest reliability and high levels of internal consistency. It is a more responsive scale than other, more general, health-related quality of life scales. The SPADI consists of scoring 5 items relating to shoulder pain, and 8 items relating to functional activity of the shoulder, which are summated to give a total score of up to 100 (with a higher score reflective of greater shoulder pain and disability).

Active shoulder range of motion on the affected side was assessed using a gravity-dependent digital inclinometer, which has good intrarater reliability. Positions of testing and procedures, such as order of testing, were standardised. Active shoulder abduction was considered the primary outcome measure of interest, as it is the movement most affected by an accessory nerve injury.
6.3.3.2 Secondary Outcome Measures

The Neck Dissection Impairment Index (NDII) \(^{89}\) is a validated and reliable treatment-specific quality of life score that measures shoulder and neck impairment as a result of cancer treatment of the neck. It consists of a Likert scale of 10 questions with five response items of how, in the last four weeks, either neck or shoulder pain has bothered them and if their ability to perform functional, social, and work activities has been affected.

A Global Perceived Effect Scale (GPES) was developed based on similar scales utilised in intervention studies \(^{138}\). The scale consisted of four questions, which aimed to measure participants’ perceived overall effect of either the control or intervention treatment on levels of pain and satisfaction. The GPES gave a total score out of four, with a score of four reflective of the highest perceived effect of treatment received. It was collected at the 3-month follow up period only.

6.3.3.3 Prevalence of accessory nerve shoulder dysfunction

The prevalence of signs of accessory nerve shoulder dysfunction following neck dissection with accessory nerve preservation was calculated by dividing the number of patients with subjective and/or objective signs of signs of accessory nerve shoulder dysfunction by the number of neck dissection patients that were assessed subjectively and/or objectively. Because of the large number of patients being unable to attend for an objective assessment, subjective assessment of signs of accessory nerve shoulder dysfunction consisted of questioning if they had developed new shoulder pain since neck dissection and if they were limited in activities of daily living that involved abduction movement. All patients were encouraged to attend for objective assessment of their shoulder if possible, to confirm whether or not signs of accessory nerve shoulder dysfunction was present.

6.3.3.4 Treatment Factors and Demographical Data

Baseline demographic information was recorded as summarized in Table 6-1. Details pertaining to participants’ tumour stage based on the universal TNM classification
system and adjuvant treatments received (radiation therapy and chemotherapy) were obtained from self-report and data via medical records and clinical information systems (Table 6-1). Analgesia logs were issued for participants to self-record pain medication taken from baseline for 12 weeks. The type and frequency of medication was recorded weekly.

6.3.4 Interventions

Both interventions were delivered by a physiotherapist with at least 6 years of clinical experience. The primary investigator (AM) trained each treating physiotherapist with regard to the intervention protocol.

6.3.4.1 Control Group

Participants randomised to the control group received what is considered to be current usual physiotherapy care in Australia after neck dissection surgery. The control group received a combination of general advice and a brochure of generalised shoulder and neck exercises. The brochure consisted of instructions and photographs of active-assisted glenohumeral joint exercises, active cervical spine range of movement exercises and advice about scar tissue massage, correct posture and encouraging functional use of the upper limb. If control group participants wished to receive further physiotherapy, they were free to do so at a location other than the study site. The treating physiotherapist at the follow up time periods recorded the physiotherapy that control group participants may have received, in terms of the number of sessions. It was not possible to control for the type of physiotherapy they may have received elsewhere.
<table>
<thead>
<tr>
<th>Table 6-1 Baseline Demographic and Disease Profile Details of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of participants</strong></td>
</tr>
<tr>
<td><strong>Demographic profile</strong></td>
</tr>
<tr>
<td>Mean age y (range)</td>
</tr>
<tr>
<td>Men</td>
</tr>
<tr>
<td><strong>Disease profile</strong></td>
</tr>
<tr>
<td>Tumour location</td>
</tr>
<tr>
<td>Oral Cavity/Oropharynx</td>
</tr>
<tr>
<td>Hypoparanyx/Larynx</td>
</tr>
<tr>
<td>Nasopharynx/Nasal Cavity</td>
</tr>
<tr>
<td>Salivary glands</td>
</tr>
<tr>
<td>Melanoma neck/SCC neck</td>
</tr>
<tr>
<td>Unknown primary</td>
</tr>
<tr>
<td>Other*</td>
</tr>
<tr>
<td>Disease stage (TNM classification)</td>
</tr>
<tr>
<td>I (T1N0)</td>
</tr>
<tr>
<td>II (T2N0)</td>
</tr>
<tr>
<td>III (T3N1, T3N1, T1N1, T2N1)</td>
</tr>
<tr>
<td>IV (T2N2, T4N0)</td>
</tr>
<tr>
<td>IVA (T4N0-2, T1-4N2, TXN2)</td>
</tr>
<tr>
<td>IVB (TXN3)</td>
</tr>
<tr>
<td>IVC (TXN1, T3N2)</td>
</tr>
<tr>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Bilateral neck dissection</strong></td>
</tr>
<tr>
<td>Neck dissection type</td>
</tr>
<tr>
<td>MRND (Level I-V)</td>
</tr>
<tr>
<td>SND (Level 5 not dissected)</td>
</tr>
<tr>
<td>Free flaps</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Scapula</td>
</tr>
<tr>
<td>Radial ipsilateral</td>
</tr>
<tr>
<td>Radial contralateral</td>
</tr>
<tr>
<td>Fibula</td>
</tr>
<tr>
<td>Operated side is dominant side</td>
</tr>
<tr>
<td>Radiation Therapy</td>
</tr>
<tr>
<td>During intervention</td>
</tr>
<tr>
<td>Prior to intervention</td>
</tr>
<tr>
<td>Not received</td>
</tr>
<tr>
<td>Chemotherapy</td>
</tr>
<tr>
<td>Cisplatin</td>
</tr>
<tr>
<td>Interferon</td>
</tr>
<tr>
<td>Not received</td>
</tr>
<tr>
<td>Analgesia (≥2x/week for ≥ 6/52)</td>
</tr>
<tr>
<td>Paracetamol/Panadeine</td>
</tr>
<tr>
<td>Opioid</td>
</tr>
<tr>
<td>Paracetamol and NSAID</td>
</tr>
<tr>
<td>Paracetamol and Opioid</td>
</tr>
<tr>
<td>Paracetamol and NSAID and Opioid</td>
</tr>
<tr>
<td>Nil</td>
</tr>
<tr>
<td>No data available</td>
</tr>
</tbody>
</table>
**6.3.4.2 Intervention Group**

The intervention took place for 12 weeks, and consisted of one supervised session and two home sessions per week. Additional home sessions were only undertaken if deemed appropriate and safe. The intervention group protocol primarily consisted of supervised progressive scapular strengthening exercises (Table 6-2) of the upper trapezius, rhomboid and serratus anterior muscles, utilizing hand weights, with the lowest possible weight being 0.5kg. The treating physiotherapist selected 1 type of exercise for each muscle group, based on the participant’s ability to perform the exercise with correct form without producing/increasing shoulder pain, discomfort or fatigue 8-12 times (8-12 repetition maximum), for 2 to 3 sets. At least a 1-minute rest occurred between consecutive sets. A weekly home exercise diary was utilised to maximise compliance of unsupervised sessions, with the exercise frequency and dosage determined by the supervised session. Participants were advised not to upgrade the exercise parameters at home. If participants experienced an increase in shoulder or neck pain or worsening of fatigue during a session, they were advised to modify or cease the particular exercise and any pain or post-exercise muscle soreness was recorded at the subsequent supervised session. Weights were increased by 0.5 kg when the treating physiotherapist deemed a participant could safely perform the exercise after at least a week on the prescribed weight. If pain and shoulder limitation deemed a hand weight not suitable, then a theraband exercise band was utilised as an alternative until a weight could be safely used.

In addition to the scapular-strengthening program, the intervention group participants performed active cervical spine range of motion exercises in all directions (10-15 repetitions, 1-2 sets), active-assisted shoulder range of motion exercises (10-15 repetitions, 1-2 sets), cervical spine and pectoralis major stretches (30 second hold, 3 repetitions). Advice about self-administered scar tissue massage of the neck region was given if the participant was not undergoing radiation therapy or had treatment-related skin changes deeming massage not appropriate. Addition of therapist-applied manual
therapy was only performed on intervention participants if it was deemed a necessary adjunct in order to complete prescribed exercises.

Adherence to the intervention was recorded each week by the treating physiotherapist, consisting of attendance at the supervised session and whether or not the participant performed the two home sessions as prescribed. Reasons for intervention participants not attending a supervised session or not performing the prescribed exercises were noted, as were any adverse effects. An adherence rate of at least 70% was considered to be a feasible and acceptable level of compliance with the intervention protocol.

Table 6-2 Intervention group exercises

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Muscles targeted</th>
<th>Exercise description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder shrug</td>
<td>Upper trapezius</td>
<td>In standing, tested arm by side and elbow fully extended, holding onto dumbbell. Scapula in neutral position of elevation/depression. Elevate scapula to maximum height maintaining position of elbow and glenohumeral joint, then return to start position.</td>
</tr>
<tr>
<td>Overhead press</td>
<td>Upper trapezius</td>
<td>In standing, shoulder abducted to 90 degrees so humerus at horizontal level, and elbow flexed to 90 degrees, holding onto dumbbell. Extend elbow fully, so weight moves up towards ceiling, then return to start position.</td>
</tr>
<tr>
<td>Single-arm row in standing</td>
<td>Rhomboids</td>
<td>In standing, contralateral hand on plinth, and trunk flexed to approximately 45 degrees, with contralateral leg in front in a lunge position. Ipsilateral hand holding onto dumbbell, with elbow fully extended. Ipsilateral shoulder flexed in line with contralateral knee, holding onto dumbbell with elbow fully extended. Retract scapula and flex elbow, pulling dumbbell toward ipsilateral lower rib region.</td>
</tr>
<tr>
<td>Single-arm row in prone</td>
<td>Rhomboids</td>
<td>In prone position, holding dumbbell. Contralateral hand under forehead to maintain neck in neutral position. Ipsilateral glenohumeral joint just clear of plinth. Ipsilateral shoulder in approximately 90 degrees flexion with elbow fully extended, and end range scapula protraction as gravity allows. Retract scapula and flex elbow, pulling dumbbell toward ipsilateral lower rib region. No shoulder abduction permitted.</td>
</tr>
<tr>
<td>Horizontal adduction/flexion</td>
<td>Serratus anterior</td>
<td>In sitting position. Start position is wrist in line with shoulder and elbow flexed. Raise arm towards midline and upwards, combining shoulder adduction and flexion.</td>
</tr>
<tr>
<td>Bilateral arm wall press up</td>
<td>Serratus anterior</td>
<td>Both hands positioned on wall placed shoulder width apart, and shoulders flexed to 90 degrees. Start position is full scapula retraction with sternum depressed towards wall, elbows fully extended. End position is maximum scapula protraction, shoulders and elbows remain in starting position.</td>
</tr>
<tr>
<td>Scapula protraction in supine</td>
<td>Serratus anterior</td>
<td>In supine, shoulder at 90° degrees flexion holding dumbbell, elbow fully extended, ipsilateral scapula fully on plinth surface. Protract scapula fully, so scapula lifts off plinth, then return to starting position. Shoulder and elbow remain in same position as at the start. No trunk rotation permitted.</td>
</tr>
</tbody>
</table>
6.4 Analysis

The study-blinded assessor at each site performed data entry into the study database. A sample size of approximately 60 participants was required in order to detect a moderate to large standardised difference in the primary outcome measure, the SPADI. This sample size was calculated based on the mean difference in the SPADI scores of 14.5 with a SD of 20 between groups from an earlier pilot study in the same patient population. The level of significance chosen was a $p$ value < 0.05 with a power of 80%.

A generalised linear mixed model was fitted to the data separately for each of the outcomes. The $p$ value associated with the interaction term was used to determine if there was a statistically significant difference in change from baseline to the time point of interest between groups. The model included a random intercept term for the participant to account for the repeated measurements on individuals.

An additional per-protocol analysis was performed, excluding those intervention group participants that did not fulfil the protocol criteria, as outlined in Figure 6-1.

6.5 Results

A total of 59 participants were recruited with 60 affected shoulders (1 participant with both shoulders affected by signs of accessory nerve shoulder dysfunction), from a total of 348 of those potentially eligible (see Figure 6-1). Recruitment occurred from April 2009 until January 2012. The main reasons for exclusion were participants’ verbal reporting of no signs of accessory nerve shoulder dysfunction (29.4%) and living out of the study site. Fifty potential study participants declined to participate.

Three month follow-up data were collected on 52 participants/53 shoulders (88% of included participants) with 7 participants lost to follow up. Participant loss did not differ between groups (2 were deceased; 3 were unable to be contacted; and 2 had developed metastases or were unwell). A total of 10 participants (11 shoulders) in the intervention group were excluded from the per-protocol analysis with reasons provided in Figure 6-1.
Figure 6-1 Consolidated Standards of Reporting Trials (CONSORT) flow diagram
At 6-month follow-up, a further 7 participants were lost, with 5 of the participants in the control group (3 were living out of area; 1 had deceased; 1 did not attend assessment; 1 was unable to be contacted and 1 control group participant electively withdrew). Twelve-month data were collected on a total of 39 participants (40 shoulders) with a further 6 participants lost to follow-up, 4 of these in the intervention group (2 were deceased; 2 were unable to be contacted; and 2 were unwell).

6.5.1 Baseline Characteristics
Baseline participant demographics and disease and treatment characteristics were similar between groups (Table 6-1). There were a slightly higher proportion of participants randomised to the intervention group (54%). The majority of participants were men (73%), with a mean overall age of 58.4 years (range 18-80).

6.5.2 Prevalence of accessory nerve shoulder dysfunction
Overall, the prevalence of accessory nerve shoulder dysfunction was 36.86% across all study sites. There was a large number of potential participants (81) who were not contacted based on being of non-English speaking background, poor cognitive function or who lived out of the study area. Of the 59 included participants, 33 had undergone a selective neck dissection, and 26 had undergone a modified radical neck dissection. The type of surgery was unknown in 81 potential participants.

6.5.3 Intervention Group Exercise adherence
Out of the 32 participants (33 shoulders) allocated to the intervention group, 22 participants (22 shoulders) received the protocol intervention. Five intervention participants developed or had pre-existing exclusion criteria that were unknown at time of study entry, with the remaining participants not receiving at least 70% of the protocol (see Figure 6-1). The overall percentage of sessions attended by the intervention group was 76.6%. The percentage of sessions attended by those participants included in the per-protocol analysis (excluding participants that developed metastases, died, or did not attend to start protocol) was 82.2%. The most
common reason for not attending sessions was work or other commitment (41.9%), followed by side effects from radiation therapy and cancer-related fatigue (27.4%).

The overall percentage of home sessions correctly performed was 74.2%. The percentage of home sessions correctly performed by those participants analysed as completing the intervention (excluding participants that developed metastases, died, or did not attend to start protocol) was 81.8%. The most common reasons were side effects from radiation therapy and cancer-related fatigue (38%), followed by participants increasing the dosage parameters of home exercise beyond that which was prescribed (19.0%). One intervention participant died in the intervention period. One intervention participant, with 2 affected shoulders, developed increasing shoulder pain at 3 weeks. The treating physiotherapist ceased administering the protocol at this point in contravention of agreed management guidelines.

6.5.4 Control group
Seven control group participants received additional physiotherapy elsewhere, for a total of 36 sessions. The majority of these participants (4 of 7) sought physiotherapy and had most sessions (21 out of 36) in the first 3 months of the study period.

6.5.5 Response to treatment
The outcome measures of active shoulder abduction, flexion, the SPADI and the NDII showed improvements over time. No improvements over time were shown for active shoulder external rotation or internal rotation.

6.5.5.1 Primary outcome measures
Both groups demonstrated an improvement in the SPADI score over the study period. The SPADI score did not significantly differ between groups at any follow-up time point (Table 6-3 and Table 6-4). The increase in active shoulder abduction was significantly higher in the intervention group at 3 months, being 26.6° (95% confidence interval (CI) 7.3 to 46) greater than the control group for the per protocol analysis. There were no statistical differences between groups for abduction at any other follow-up. There were no statistical differences in any of the primary outcome measures of
abduction, flexion, the SPADI or the NDII based on neck dissection type (modified radical neck dissection or selective neck dissection) at any of the follow-up time points. Analysis on the basis of hand dominance did not reveal any association with measured outcomes.

Table 6-3 Effect of intervention on outcome measures for intent to treat analysis

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>Mean (SD)</th>
<th>Mean change between group differences (95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>3 months</td>
</tr>
<tr>
<td><strong>Abduction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>61.2 (34.0)</td>
<td>81.9 (31.5)</td>
</tr>
<tr>
<td>Intervention</td>
<td>62.3 (29.9)</td>
<td>98.2 (41.6)</td>
</tr>
<tr>
<td><strong>Flexion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>105.7 (28.6)</td>
<td>120.67 (21.9)</td>
</tr>
<tr>
<td>Intervention</td>
<td>116.8 (28.6)</td>
<td>130.1 (30.5)</td>
</tr>
<tr>
<td><strong>SPADI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>43.0 (29.3)</td>
<td>28.0 (26.7)</td>
</tr>
<tr>
<td>Intervention</td>
<td>38.8 (25.4)</td>
<td>28.6 (25.6)</td>
</tr>
<tr>
<td><strong>NDII</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>45.2 (27.9)</td>
<td>63.5 (25.7)</td>
</tr>
<tr>
<td>Intervention</td>
<td>48.8 (22.0)</td>
<td>62.3 (21.1)</td>
</tr>
</tbody>
</table>

SPADI, Shoulder Pain and Disability Index; NDII, Neck Dissection Impairment Index
### Table 6-4 Effect of intervention on outcome measures for per-protocol analysis

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>Baseline</th>
<th>3 months</th>
<th>6 months</th>
<th>12 months</th>
<th>3 months</th>
<th>6 months</th>
<th>12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abduction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>61.16</td>
<td>81.92</td>
<td>107.80</td>
<td>116.69</td>
<td>26.62</td>
<td>11.45</td>
<td>9.59</td>
</tr>
<tr>
<td>Intervention</td>
<td>61.43</td>
<td>111.43</td>
<td>118.49</td>
<td>126.87</td>
<td>107.80</td>
<td>118.49</td>
<td>126.87</td>
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<tr>
<td>(34.04)</td>
<td>(31.46)</td>
<td>(38.64)</td>
<td>(41.16)</td>
<td>(42.76)</td>
<td>(38.83)</td>
<td>(38.64)</td>
<td>(41.16)</td>
</tr>
<tr>
<td><strong>Flexion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>105.7</td>
<td>120.67</td>
<td>128.25</td>
<td>137.51</td>
<td>7.42</td>
<td>0.31</td>
<td>1.42</td>
</tr>
<tr>
<td>Intervention</td>
<td>117.43</td>
<td>141.02</td>
<td>139.14</td>
<td>148.52</td>
<td>128.25</td>
<td>139.14</td>
<td>148.52</td>
</tr>
<tr>
<td><strong>SPADI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>43.03</td>
<td>27.98</td>
<td>18.57</td>
<td>14.90</td>
<td>-5.05</td>
<td>0.41</td>
<td>6.21</td>
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<td>Intervention</td>
<td>48.95</td>
<td>67.73</td>
<td>73.88</td>
<td>74.17</td>
<td>18.85</td>
<td>13.18</td>
<td>14.36</td>
</tr>
<tr>
<td><strong>NDII</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>45.19</td>
<td>63.54</td>
<td>72.63</td>
<td>79.56</td>
<td>-0.56</td>
<td>-1.51</td>
<td>-8.43</td>
</tr>
<tr>
<td>Intervention</td>
<td>48.95</td>
<td>67.73</td>
<td>73.88</td>
<td>74.17</td>
<td>18.85</td>
<td>13.18</td>
<td>14.36</td>
</tr>
<tr>
<td>(27.87)</td>
<td>(25.75)</td>
<td>(19.61)</td>
<td>(14.93)</td>
<td>(17.21)</td>
<td>(17.21)</td>
<td>(21.11)</td>
<td>(17.21)</td>
</tr>
</tbody>
</table>

SPADI, Shoulder Pain and Disability Index; NDII, Neck Dissection Impairment Index
6.5.5.2 Secondary outcome measures

There were no significant differences between groups for active shoulder flexion (Table 6-3 and Table 6-4), GPES (mean of 3.4 for both groups), external rotation (in 0\(^\circ\), 60\(^\circ\) and 90\(^\circ\) of abduction) or internal rotation (in 60\(^\circ\) and 90\(^\circ\)).

6.6 Discussion

This is the first prospective randomised controlled trial to investigate the effect of early intensive physiotherapy on accessory nerve shoulder dysfunction after neck dissection. Over the 12-month study period, both the control and intervention groups demonstrated improved outcome measures for active shoulder abduction and flexion, shoulder pain, and disability. This is a promising prognostic indicator for this patient population. The results favoured the intervention group per-protocol analysis for active shoulder abduction at the 3-month follow up, with a significantly greater increase compared to the control group. There were, however, no significant differences between the intervention and control groups for shoulder pain, function and quality of life outcome measures. Several possible reasons may explain this result. First, the intervention may not improve shoulder pain or quality of life, despite shoulder abduction being observed to improve to a greater extent. Second, 41% of participants were undergoing adjuvant radiation therapy, which is likely to greatly reduce the validity of those outcome measures assessing pain and function, namely the SPADI and NDII. This is particularly the case at the 3-month follow up, when the side effects of radiation therapy are likely to be greatest. Despite randomisation, radiation therapy is a large extraneous variable, which is likely to impact on participants’ responses to these measures independent to the intervention.

There were no significant differences in measured outcomes between the groups at 6 and 12 months. This may be because there is no long-term additional benefit of the intervention, which suggests that a brochure of generalised exercises and advice has a similar outcome to intensive rehabilitation beyond a 3-month time period. The evidence for the effect of strengthening exercises on muscles affected from a peripheral
motor nerve injury is limited because of a lack of studies. Physiologically, it is theorised that resisted exercise improves peripheral motor nerve injury via muscle hypertrophy, and the neural mechanisms of remyelination, axonal sprouting, and regeneration. Given that collateral sprouting and axonal regeneration occur at 2 to 6 months after nerve injury, it would seem reasonable that the effects of exercise may plateau with time. This is consistent with our findings.

Alternatively, it may reflect that the study lacked power at the 6-month and 12-month time points. The available sample size had reduced to 45 participants at 6 months, and to 37 for the per-protocol analysis at 12 months. Loss to follow-up has been reported in another study, which investigated a similar intervention in the same patient population. This is reflective of the challenges faced with conducting prospective physiotherapy research with long-term follow-up in head and neck cancer patients. With both groups improving over time, the most optimal type of physiotherapy appears yet to be defined in the longer term.

Randomisation was stratified for neck dissection type, as it was theorized that the selective neck dissection group may have a better outcome, given that the levels of lymph nodes dissected do not include level 5. However, in modified radical neck dissection in which level 5 lymph nodes are included in the dissection, the accessory nerve becomes exposed, so is therefore at risk of injury. Other studies have reported a difference in shoulder outcomes based on neck dissection type, with selective neck dissection demonstrating better outcomes compared to modified radical neck dissection. Our study outcomes did not change based on neck dissection type. Further studies with larger sample size may give further insight as to the effect of neck dissection type on shoulder function related to accessory nerve injury.

There were some challenges with compliance of the intervention protocol. A per-protocol analysis was conducted as 32% of participants either did not meet the criteria following study inclusion, or did not meet 70% adherence required for the intervention. Many neck dissection patients were experiencing the side effects of radiation therapy, so the intervention, at times, may not be feasible. The complexities
associated with undertaking regular physiotherapy during radiation therapy may be why other randomised physiotherapy studies of neck dissection patients required radiation therapy to be completed prior to study inclusion 82, 83.

Overall, there is a distinct lack of evidence regarding the physiotherapy management of accessory nerve shoulder dysfunction in neck dissection patients 113, 130. First, head and neck cancer is not as common as other cancer types 47, making sufficient recruitment of participants challenging. Second, adherence to rehabilitation can be challenging in patients with head and neck cancer 118. General exercise levels are vastly lower than normal 102, often because of patients experiencing the side effects of adjuvant treatment. Third, some countries may not offer self-management exercises as standard management of accessory nerve shoulder dysfunction: therefore, ethically, this is unable to be studied. A previous study has reported significant improvements in the SPADI with progressive scapular strengthening exercises, compared to non-progressive scapular strengthening exercises 83. However the size of improvement in the SPADI of the intervention group compared to the control group in this study 83 was small, being only 9.6 points different. It is questionable as to whether this difference constituted a magnitude to be considered clinically important. Given the intensity associated with this particular study’s intervention of 3 times per week for 12 weeks, there would need to be a clinically important difference in order to justify the intensity not only for the patient, but the resources required with its delivery. Physiotherapy in the form of self-directed home-based exercises may be more feasible in patients experiencing cancer and their treatment effects, and may yield a similar outcome to more demanding rehabilitation programs. Previous physiotherapy studies 129 investigating the effect of self management prior to our study have been greatly underpowered and lack detail pertaining to the intervention protocol.

There were some limitations to this study. As mentioned, it was likely to be underpowered at the 6 and 12-month follow-up, with a substantial drop out rate. This is, unfortunately, not uncommon with the head and neck cancer population, who have a reasonably high mortality rate 128. Second, ethically, it was not possible to deny
control group participants physiotherapy at another site if they so wished, because this is current usual care following neck dissection in Australia. Physiotherapy was independently performed in the control group, so the compliance with the brochure recommendations was unknown. As such, the control group was somewhat heterogeneous, as some participants received additional physiotherapy, whereas others did not. Third, there are some limitations of the outcome measures used. There have been reports that the SPADI may not sufficiently measure recreational and occupational disability \(^{134}\), or account for volume or change in activity. The NDII is specific to the neck cancer population, however, it does not separate shoulder symptoms from neck symptoms. The GPES was a modified scale, and not directly replicated from other studies, so it has questionable validity and reliability. Despite these acknowledged limitations, both the SPADI and NDII are the most utilised and rigorously tested region-specific quality of life instruments in head and neck cancer survivors \(^{143}\). Fourth, the method of collecting prevalence data meant that a large number of neck dissection patients were not assessed, or were only assessed subjectively. This may have had an impact on the accuracy of the prevalence data obtained. It also meant that prevalence based on surgery type was not calculated. Analgesia logs were self-reported. The completion rates by participants for this record was low, resulting in a limited ability to draw inferences from the medication data. Analgesia type and dosage is likely to influence the pain that is reported. Further studies need to ensure that compliance with pain medication logs is upheld, in order to factor this into the outcomes obtained.

A recent surface electromyography study by the authors demonstrated significantly less upper and middle trapezius dynamic muscle activity in patients affected with accessory nerve shoulder dysfunction without accessory neurotmesis after neck dissection, compared to their unaffected side \(^{144}\). For this reason, the basis of our intervention was progressive trapezius, and accessory scapular muscle strengthening exercises. One of the exclusion criteria of this study were those patients who had undergone radical neck dissection with accessory neurotmesis, as there is no potential
for nerve recovery, and, therefore, trapezius muscle strengthening exercises are physiologically likely to be ineffective 113.

Reduced trapezius electromyography levels in the operated side are likely to mainly result from intra-operative nerve injury of the accessory nerve. However, adjuvant radiation therapy and poor levels of physical deconditioning following neck dissection further reduce trapezius muscle activity. Radiation therapy causes soft tissue scarring and fibrosis, so it would physiologically seem plausible that this would reduce trapezius muscle fibre contractility as well as negatively impact on accessory nerve structure, as both are likely to be included in the radiation field. Indeed, the effect of radiation therapy on accessory nerve function and shoulder symptoms following neck dissection is conflicting, with some studies reporting radiation therapy to increase shoulder morbidity 61 and worsen spinal accessory nerve function 145, whereas other studies show no additional effect of radiation therapy 11, 32, 146. Unfortunately, the sample size was inadequate to effectively sub analyse the effect of radiation therapy on shoulder outcomes.

The intervention group was associated with greater shoulder abduction range of motion compared to the control group at the 3-month follow up. However, the intervention may not be feasible for all patients to undertake, given the commitment involved, particularly for those patients undergoing radiation therapy. If immediate improvement in shoulder abduction range of motion is not required, then a brochure of shoulder and neck exercises with appropriate advice is potentially of similar benefit as to intensive progressive scapular strengthening exercises.

6.7 Conclusion

Accessory nerve shoulder dysfunction may occur after neck dissection, even when the nerve is intact. The prognosis of the dysfunction is good over time, with gradual improvement of shoulder pain, function, and region-specific quality of life over a 12-month period. This study illustrates a benefit for the performance of progressive scapular strengthening exercises for the improvement in abduction range of motion in the short term. The effect of the intervention in the longer term is uncertain, mostly
because of the number of participants lost at the 6 and 12-month follow-up time points. Progressive scapular strengthening is recommended for those patients who need the return of shoulder elevation range of motion as soon as possible, for occupational or recreational purposes. Further physiotherapy studies may investigate the feasibility and effectiveness of performing progressive scapular strengthening exercises following radiation therapy, compared to during radiation therapy.

6.8 Acknowledgements

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6.10 Implications of findings for the following study

The main aim of the study was to assess the effectiveness of an intervention based on progressive scapular muscle strengthening compared to what is currently usual care in Australia on active shoulder abduction range of motion, shoulder pain and function and regional quality of life.

Patients with demonstrated clinical signs of accessory nerve injury following neck dissection surgery with an intact accessory nerve were included in this study. Those patients with a sacrificed accessory nerve were excluded, as it was theorised that the intervention would likely be of limited benefit for the latter group. It is apparent when considering participants in this study that there are a substantial proportion of patients following neck dissection with accessory nerve injury despite an intact nerve.
Presentation of these findings at numerous conferences led to frequent discussions, particularly amongst surgeons, at the higher than expected percentage of accessory nerve shoulder dysfunction occurring in neck dissection patients despite nerve preservation. Many surgeons at these conferences admitted to being unaware that accessory nerve injury could occur with nerve preservation. This raised debate amongst attending surgeons as to why routine intra-operative monitoring of the accessory nerve is not utilised, and whether it would be of use in reducing nerve injury. Indeed, minimisation of any accessory nerve injury is the ultimate outcome for neck dissection patients.

The following paper aimed to investigate the evidence for intra-operative nerve monitoring of the accessory nerve in patients during neck dissection surgery.
Chapter 7  Intra-operative monitoring of the spinal accessory nerve: a systematic review

7.1 Abstract

Objectives: To investigate the evidence that of intra-operative nerve monitoring of the spinal accessory nerve affects the prevalence of post-operative shoulder morbidity and predicts of functional outcome.

Methods: A search of MEDLINE, Scopus and Cochrane databases from 1995 to October 2012 was undertaken, using the search terms “monitoring, intra-operative” and “accessory nerve”. Articles were included if they pertained to intra-operative accessory nerve monitoring undertaken during neck dissection surgery and included a functional shoulder outcome measure. Further relevant articles were obtained by screening the reference list of retrieved articles.

Results: Only three articles met the inclusion criteria of the review. Two of these included studies suggesting that intra-operative nerve monitoring shows greater specificity than sensitivity in predicting post-operative shoulder dysfunction. Only one study, with a small sample size, assessed intra-operative nerve monitoring in neck dissection patients.

Conclusion: It is unclear whether intra-operative nerve monitoring is a useful tool for reducing the prevalence of accessory nerve injury and predicting post-operative functional shoulder outcome in patients undergoing neck dissection. Larger, randomised studies are required to determine whether such monitoring is a valuable surgical adjunct.

Key Words: Neck dissection, Accessory nerve, Intra-operative nerve monitoring

7.2 Introduction

Accessory nerve injury is an unfavourable outcome that can result from the clearance of cervical lymph nodes during the surgical management of head and neck cancer. Varying degrees of accessory nerve injury can occur during neck dissection. This can
range from neurotmesis from radical neck dissection, to neurapraxia or axonotmesis following selective or modified radical neck dissections. Injury to the accessory nerve results in trapezius muscle weakness, leading to abnormal scapular biomechanics and, in turn, reduced shoulder mobility and pain. In an attempt to limit the post-operative shoulder morbidity associated with accessory nerve sacrifice in radical neck dissection, more conservative approaches to neck dissection surgery have become increasingly common. However, even with a macroscopically intact accessory nerve, microtrauma caused by traction, skeletonisation and devascularisation of the nerve may still occur during surgery. This can impair nerve function for prolonged periods of time.

The prevalence of shoulder dysfunction following accessory nerve-sparing neck dissection is reported to be as high as 67%. A recent electromyography (EMG) study consisting solely of neck dissection patients with an intact accessory nerve demonstrated significantly reduced trapezius muscle activity in both the operated and non-operated sides compared with healthy controls. Despite the trend in neck dissection surgery towards accessory nerve preservation, shoulder morbidity remains a relatively common and debilitating post-operative issue.

Lower cranial nerves are also at risk of injury during head and neck cancer surgery because surgical dissection or local tumour masses may compromise the course of normal neural anatomy. The use of intra-operative nerve monitoring has been reported since 1986. Intra-operative nerve monitoring is a convenient and readily available tool for minimising peripheral nerve injury and limiting post-operative morbidity associated with surgery. It typically involves continuously monitoring bursts and trains of motor unit potential activity during surgery, as well as electrically stimulating the nerve while recording a compound muscle action potential from the innervated muscle. A requirement for a higher degree of nerve stimulation to induce a compound muscle action potential at the end of surgery compared with the beginning of surgery may indicate nerve injury.
Immediate auditory and visual feedback regarding both nerve location and mechanical stimulation of motor axons may direct the surgical procedure to avoid potential nerve injury. Motor cranial nerves typically at risk of iatrogenic damage during neck dissection are the facial, superior laryngeal and recurrent laryngeal (RLN), hypoglossal, and spinal accessory nerves. Nerve selection for monitoring during head and neck surgery depends on which nerves are likely to be at risk of iatrogenic injury. The facial nerve is typically monitored during parotidectomy, the superior laryngeal nerve and RLN during thyroidectomy and the spinal accessory nerve during neck dissection. However, as noted by Witt et al., although there is abundant literature regarding the use of intra-operative nerve monitoring to reduce nerve injury prevalence and help predict post-operative functional outcomes in the facial nerve and the RLN, there are fewer reports regarding its use for the spinal accessory nerve.

The primary aim of this systematic literature review was to establish the level of evidence for the use intra-operative accessory nerve monitoring in predicting the prevalence of nerve injury and resultant post-operative shoulder morbidity.

7.3 Method

7.3.1 Search Strategy
A search of the MEDLINE, Scopus and Cochrane databases from 1995 to October 2012 was undertaken. The keywords and MeSH search terms were “monitoring, intra-operative” and “accessory nerve”. The review search was limited to studies published in the English language and conducted on adult humans. An author (ACM) screened the titles and abstracts for eligibility for inclusion in the review.

7.3.2 Study Selection Criteria
If the abstract pertained to intra-operative accessory nerve monitoring or accessory nerve monitoring that may have been undertaken during surgery, then the entire article was retrieved and reviewed. Studies that were descriptive, did not involve nerve monitoring during surgery, lacked outcomes related to shoulder function, or
included cranial nerve monitoring not involving the accessory nerve were excluded. The reference lists of retrieved articles were screened and further articles with titles pertaining to intra-operative accessory nerve monitoring were retrieved. These papers were included in the review if exclusion criteria were absent. An author (PGO) assessed the eligibility of studies, and consensus was reached by discussion with ACM.

7.4 Study Results

7.4.1 Literature Search

The initial literature search identified twenty studies. All abstracts were screened, and study inclusion and exclusion criteria were applied (outlined in Figure 7-1). Of the 20 articles, 9 were excluded: 4 were not in English \textsuperscript{154-157}; 2 were based on intra-operative monitoring of the facial nerve \textsuperscript{158,159}; 2 were descriptive reviews \textsuperscript{160,161}; and 1 was a letter to the editor \textsuperscript{162}. A remaining 11 articles were retrieved in full. The reference list of each article was screened, and a further six articles containing the initial search term “intra-operative” and either “cranial nerve” or “accessory nerve” in the article title were retrieved \textsuperscript{153,163-167}. Of the total of 17 articles retrieved, 11 were excluded because 5 were descriptive reviews \textsuperscript{149,167-170}, 4 did not describe accessory nerve monitoring in the intra-operative period \textsuperscript{163,164,171,172}, 1 did not describe any outcomes pertaining to shoulder morbidity \textsuperscript{14}, and 1 was not in English \textsuperscript{173}. A total of six articles were then reviewed for possible inclusion in the systematic review \textsuperscript{153,165,166,174-176}. Of these, three were excluded because one was a preliminary study for which the data were subsequently included in a later, larger study \textsuperscript{153}, one cranial nerve study lacked EMG data pertaining to the accessory nerve \textsuperscript{165} and another did not document either EMG or functional shoulder outcomes \textsuperscript{175}. A remaining three articles were included in the systematic review \textsuperscript{166,174,176}.
Abstracts retrieved and screened for inclusion (n=20)

Studies excluded (n=9)
- Not English language (n=4)
- Facial nerve monitoring (n=2)
- Descriptive review (n=2)
- Letter to Editor (1)

Studies retrieved for more detailed evaluation (n=11)

Further abstracts screened for inclusion based on references (n=6)

Studies excluded (n=11)
- Descriptive review (n=5)
- Not intraoperative monitoring (n=4)
- No shoulder outcomes (n=1)
- Not English language (n=1)

Potentially appropriate studies to be included in the literature review (n=6)

Studies excluded (n=3)
- Duplicate data in other study (n=1)
- No data available on accessory nerve (n=1)
- No EMG data reported or functional outcomes (n=1)

Studies included in meta-analysis (n=3)

Studies excluded (n=3)
- Duplicate data in other study (n=1)
- No data available on accessory nerve (n=1)
- No EMG data reported or functional outcomes (n=1)

Studies withdrawn, by outcome, with reasons (n=0)

Studies with usable information, by outcome (n=3)

Figure 7-1 CONSORT Diagram of Literature Review
7.4.2 Study Characteristics

The characteristics of the three included studies are described in Table 7-1.

Table 7-1 Characteristics of Included Studies

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Type</th>
<th>Number of participants monitored</th>
<th>Persistent shoulder dysfunction</th>
<th>Clinical Assessment Parameters of SAN injury</th>
<th>Follow up date</th>
<th>Surgery Type</th>
<th>Electrical Stim Parameters</th>
<th>Country, Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Witt et al, 2007</td>
<td>Randomised Prospective, Single site, Single surgeon</td>
<td>22</td>
<td>4</td>
<td>VAS of maximum pain (0-10)</td>
<td>2 months</td>
<td>Selective and Modified Radical Neck Dissection</td>
<td>Threshold EMG change end to start of surgery &gt;0.4mA</td>
<td>USA Not mentioned</td>
</tr>
<tr>
<td>Karlikaya et al, 2008</td>
<td>Single arm case series, Prospective Single site, Multiple surgeons</td>
<td>11</td>
<td>0</td>
<td>Mention that SAN dysfunction was evaluated clinically. No specific detail.</td>
<td>24 hours</td>
<td>Posterior fossa</td>
<td>Threshold EMG change end to start of surgery &gt;0.5mA</td>
<td>Turkey 2006-2007</td>
</tr>
<tr>
<td>Topsakal et al, 2008</td>
<td>Single arm case series, Retrospective, Single site, Single surgeon</td>
<td>118</td>
<td>9</td>
<td>Atrophy and weakness of SCM and trapezius</td>
<td>Between 0.2 and 54 months (mean of 13.87 months)</td>
<td>Skull base</td>
<td>Constant stimulation. No exact values given.</td>
<td>USA 1994-1999</td>
</tr>
</tbody>
</table>

VAS, Visual Analog Scale; ROM, Range of motion; SAN, Spinal accessory nerve; SCM, sternocleidomastoid; EMG, electromyographic
Each study described a single-arm case series: one in a neck dissection patient group; one consisting of patients undergoing posterior fossa surgery; and one related to surgery at the skull base. The prevalence of post-operative accessory nerve shoulder dysfunction ranged from 0 % to 18 %, with the highest morbidity reported in the study involving neck dissection patients. The time of post-operative assessment of shoulder function varied, from immediately post-operative to 54 months after surgery. The study with the largest sample size was related to skull base surgery, and had a large range of follow-up periods (0.2-54 months). The other two studies had shorter follow-up periods of up to 7 days and 2 months, respectively, following surgery.

The threshold EMG change from the start of to the end of surgery considered to be important was greater than 0.4mA for one study and greater than 0.5mA for another, while the third study (with the largest sample size) did not record a threshold difference. The only study of a neck dissection population found that only two of the four patients (50 %) with demonstrated shoulder dysfunction had significant threshold EMG changes. This suggests that EMG sensitivity for detecting shoulder dysfunction is low. However, the same study found that 17 out of 19 patients (89 %) without a significant EMG change did not demonstrate shoulder dysfunction, suggesting that the specificity of intra-operative nerve monitoring is better. Nevertheless, the small sample size and lack of a comparison group limits the reliability of such inferences.

The larger study, with a sample size of 118 skull base surgeries, found that EMG had a higher rate of specificity than sensitivity in detecting shoulder dysfunction, with a true negative rate of 66.9 % and a true positive rate of 44.4 %.

### 7.5 Discussion

Evidence in the literature for the usefulness of intra-operative nerve monitoring in potentially reducing injury to the accessory nerve and for predicting post-operative function in neck dissection patients is minimal and contradictory. Only one article included in this systematic literature review pertains to its use in a neck dissection patient group. The lack of a sample size calculation in this small study (with only 22 patients), and the lack of a control group, result in insufficient statistical strength to
reliably conclude whether intra-operative nerve monitoring of the accessory nerve during neck dissection is useful.

In contrast, many studies have assessed the effect of intra-operative nerve monitoring for the facial nerve and RLN. While the facial nerve is commonly monitored during parotid surgery, some reports suggest that intra-operative nerve monitoring does not improve post-operative facial nerve function \(^{151,177}\). Although these studies had moderate sample sizes of 100 and 53, respectively, both lacked a sample size calculation based on the incidence rate of facial nerve injury. Transient facial paresis was found in 17% of patients in one study, all of which resolved in three months \(^{177}\). The second study reported transient facial paralysis in 41% of patients immediately post-operatively, with persistent facial dysfunction in 6%. This study had a variable follow-up period of 0.2-7.9 months \(^{151}\).

The low prevalence rates of nerve injury require a larger study sample size to detect possible differences in nerve injury rates and functional outcomes between groups that do and do not utilise intra-operative nerve monitoring. Indeed, this was recently highlighted in a large meta-analysis evaluating the efficacy of intra-operative monitoring of 64,699 RLNs during thyroidectomy in reducing nerve injury and predicting post-operative outcomes \(^{178}\). The largest randomised controlled study in this meta-analysis included 1000 nerves in each study arm \(^{179}\). It found that the RLN monitoring group had a significantly lower prevalence of temporary paresis of the RLN compared with the control group, where the nerve was visualised. However, despite the positive result of this randomised study \(^{179}\), the pooled results of the meta-analysis \(^{178}\) indicate no difference in the rate of true vocal fold palsy between groups. Such contradictory reports mean that the use of intra-operative nerve monitoring of facial nerves and RLNs is controversial. However, this may simply reflect variations in nerve monitoring outcomes in different types of surgery performed by different surgeons using different EMG monitoring settings, protocols and functional outcome measures.
The prevalence of accessory nerve injury appears to be greater than that of facial nerve injury, with reports that up to 67% of neck dissections are associated with accessory nerve injury despite an intact nerve. It is therefore surprising no further research has been done into its use. However, this may result from the controversy surrounding the clinical usefulness of intra-operative nerve monitoring. The nerve monitor signal may not always be reliable, with false positive and false negative alarm signals occurring during surgery. In the largest study included in this systematic review, a false positive rate was found in 33% of cases, and false negatives were found in 55.5% of cases. Concern has been raised regarding possible over-reliance on nerve monitoring by surgeons, which may preclude the use of keen visual observation and anatomical nerve identification, and may lead to inferior surgical technique.

Several articles have investigated the use of needle EMG to establish possible links between post-operative nerve monitoring, and functional shoulder outcomes. However, there are limitations in the clinical usefulness of this tool in the post-operative setting. Post-operative use of needle EMG is invasive and less feasible owing to patient discomfort and lack of accessibility. It may also be more resource intensive, and therefore costly, than intra-operative nerve monitoring.

Therefore, intra-operative nerve monitoring might be a useful adjunct method for identifying and monitoring at-risk nerves during surgery. The motor contribution to the trapezius muscle has variable anatomy. Although the spinal accessory nerve is the primary motor innervation to the trapezius, there are varying contributions from the C2-C4 cervical plexus. This was demonstrated by study of needle EMG during supraomohyoid or modified neck dissections. Thus, it would be prudent to identify and monitor the deep cervical plexus contributions to the trapezius muscle intra-operatively. Furthermore, the “Suarez manoeuvre”, an eponym describing the manoeuvre to mobilise the accessory nerve during delivery to level 2b, may cause sufficient microscopic injury via skeletonisation and devascularisation to affect the integrity of the accessory nerve. Intra-operative monitoring of the accessory nerve may help to limit injury in the form of neurapraxia and axonotmesis. Any differences
between pre-operative and post-operative accessory nerve firing may then predict post-operative functional outcome. This may limit the development of post-operative shoulder morbidity after neck dissection, which may improve post-operative symptomatic outcomes by reducing pain and improving shoulder function and quality of life.

There is a distinct lack of intra-operative nerve monitoring studies involving the accessory nerve that are randomised and include a control group. Randomised controlled trials, with one group of patients receiving intra-operative nerve monitoring and the other not, are necessary to explore the efficacy of intra-operative nerve monitoring. Such trials should include a pre-determined sample size calculation to provide adequate power for data analysis, and utilise blinded assessors to measure functional outcomes at specific, clinically reasonable time points (ideally more than one) after surgery. Given the slow rate of neural recovery following injury, follow up should continue for at least up six months post-operatively. Clinically useful outcome measures in neck dissection patients are those focused on shoulder morbidity associated with accessory nerve injury.

Active shoulder abduction range of motion is a pertinent outcome of interest because this movement is most limited following accessory nerve injury. The aim of active shoulder abduction would be restoration of the pre-operative range of motion. Other outcome measures may include questionnaires to assess shoulder pain, regional function and quality of life. Any difference in scores between groups with and without intra-operative nerve monitoring should reflect the minimally important clinical change. The Neck Dissection Impairment Index \(^{127}\) is one such measure, a region-specific quality of life questionnaire focused on the neck dissection patient population. Although the Neck Dissection Impairment Index has been found to be a valid and reliable instrument, what constitutes a meaningful clinically important difference is still unclear. The Shoulder Pain and Disability Index \(^{134}\) is also a validated and reliable tool to assess shoulder pain and function. The minimal important difference reported to be clinically meaningful is a change in score of more than 13 points \(^{181}\). Thus, a mean
difference between intra-operative nerve monitoring and no intra-operative nerve monitoring groups of 13 points in the Shoulder Pain and Disability Index scores would indicate a clinically important change.

Differences in nerve monitor output (i.e. the EMG threshold difference) between pre- and post-operative levels would also need to be recorded, to assess correlations with the presence or absence of shoulder dysfunction. In accessory nerve monitoring studies, an EMG threshold difference of more than 0.4mA between the start and end of surgery is reported to be significant 166.

7.6 Conclusion

Evidence for the usefulness of intra-operative nerve monitoring in limiting the prevalence of accessory nerve injury or as a method of predicting post-operative shoulder dysfunction outcomes following neck dissection is inconclusive. Limitations of this literature review include heterogeneity in the included studies, the small sample size of the only study based on accessory nerve monitoring during neck dissection 166; and the lack of sample size calculations in all three studies. There is a therefore a need to accurately determine the clinical usefulness of intra-operative nerve monitoring of the accessory nerve neck dissection patients using scientifically robust methods, including a larger cohort size and inclusion of a control group.

7.7 Summary

- Intra-operative nerve monitoring (IONM) may be a useful tool, to monitor the spinal accessory nerve during neck dissection surgery
- The effectiveness of IONM is affecting prevalence of spinal accessory nerve injury, and as a predictor of functional outcome of the shoulder is uncertain due to lack of evidence in the literature
- Larger, randomised studies are required to determine if IONM of the accessory nerve is a useful surgical adjunct during neck dissection


7.8 Financial Support

This research received no specific grant from any funding agency, commercial or not-for-profit sectors.
Chapter 8  Discussion

8.1 Overview

The key research findings of each study are described in detail in Chapters 2 to 7. Section 8.2 outlines the overall research findings of each study and relates them back to each study objective and the current literature. The strengths and limitations of the research are discussed in Section 8.3. Section 8.4 describes the implications of the research findings for management of patients with accessory nerve shoulder dysfunction and facial lymphoedema, (as a result of treatment for head and neck cancer), and directions for clinical practice. The recommendations for future research (Section 8.5) are outlined before the concluding remarks in Section 8.6.

8.2 Summary of the research findings

Evidence for rehabilitation in patients with accessory nerve shoulder dysfunction following neck dissection surgery has been minimal, prior to our publications. The series of studies that comprise this thesis has lead to the development and assessment of a targeted rehabilitation program, based on a systematic examination of the shoulder function of patients after neck dissection surgery. Our SEMG study results have provided original findings to develop rehabilitation specificity. Evidence now exists for scapular muscles that require targeting with strengthening exercises, and exercises that maximise upper and middle trapezius muscle activity in patients with accessory nerve shoulder dysfunction following neck dissection surgery. Our randomised controlled study was the first prospective study to utilise a specific intervention in this patient group, based on the findings from our SEMG study. Both short and long-term follow-up was undertaken in the RCT, which has not been performed previously. The statistically significant improvement in active shoulder abduction in the intervention group compared to the control group at the three-month follow-up demonstrates the effectiveness of a specific intervention in the short term.
8.2.1.1 Facial lymphoedema: impact on patients and beliefs of health professionals

The aims of this qualitative study were focused on

- How facial lymphoedema impacts affected patients; and

- The beliefs of health professionals around this theme and if this is consistent with the experiences of patients

- Management strategies for facial lymphoedema that are utilised or recommended

Analysis of the coding resulting from the semi-structured interviews found that the main effect of facial lymphoedema on affected patients were body image concerns resulting from a change in appearance. Lymphoedema was also described as part of the facial disfigurement resulting from head and neck cancer treatment. This lead to anxiety and reduced socialisation in some affected patients. This finding is consistent with another study of patients that underwent surgery for head and neck cancer which reported that over 17% of patients were concerned or embarrassed about body image due to facial swelling 52.

Overall, results of the interviews of health professionals involved in the care of patients with head and neck cancer indicated that their perceptions of the effects of facial lymphoedema were consistent with the experiences described by affected patients. The coding frequency indicated that the greatest impact on patients psychosocially was on appearance, which could lead to body image issues and reduced socialisation. The collective opinion was that functional problems might be associated with facial lymphoedema, such as difficulty with mastication and swallowing, if the degree of lymphoedema was large. However, the existence of mixed oedema was believed to make a causal link between external oedema and functional effects difficult to conclude. Screening for the presence of facial lymphoedema, or referral to physiotherapy, was reported to be uncommon. Reassurance and manual lymphatic drainage were found to be the two most common management strategies.
8.2.2 Literature review: Physiotherapy for accessory nerve shoulder dysfunction after neck dissection surgery

The purpose of this review was to:

- Establish the level of evidence for the effectiveness of physiotherapy, and the types of physiotherapy that have been described in the literature in the management of accessory nerve shoulder dysfunction following neck dissection.

Overall there was little evidence for the effectiveness of physiotherapy. Intervention consisting of progressive scapular strengthening rehabilitation was found to have the highest level of evidence. Progressive scapular strengthening rehabilitation has been investigated in two previous studies; the earlier study being a pilot study before the larger randomised controlled trial. The control group in these studies still consisted of a scapular strengthening intervention, but without load progression. Both groups involved supervised physiotherapy sessions for three times per week. The randomised controlled trial found that the intervention group had significantly better pain and less disability than the control group at the three-month follow up.

8.2.3 Scapular muscle activity case control study

This case control study assessed the dynamic scapular muscle activity of patients after neck dissection affected by accessory nerve injury (without neurotmesis) to healthy matched controls. The aims were to:

- Compare scapular muscle activity differences between affected (NDA) and unaffected (NDU) sides, and compared to healthy matched controls; and

- To investigate which suitable exercises have the highest dynamic SEMG activity of the trapezius muscle.

The upper and middle sections of the trapezius muscle in the NDA group demonstrated significantly lower dynamic muscle activity compared to both the NDU and healthy control groups. The NDU group had significantly lower electromyographic activity of the upper trapezius muscle compared to the healthy.
control group. Serratus anterior muscle activity was higher in the NDA group compared with both other groups, however this difference was not statistically significant.

Collectively, overhead exercises were (overhead press and combined shoulder adduction and flexion) found to have the highest levels of SEMG activity for upper and middle trapezius muscles of the NDA and NDU groups.

8.2.4 Multicentre randomised controlled trial

The study participants were patients with clinical signs of accessory nerve shoulder dysfunction following neck dissection surgery. Study aims were to investigate:

- The effect of early progressive scapular muscle rehabilitation compared to a brochure consisting of neck and shoulder exercises and advice
- The prevalence of accessory nerve shoulder dysfunction, with an intact accessory nerve, in three different study sites
- How accessory nerve shoulder dysfunction progresses over a 12-month period
- The feasibility of performing intensive strengthening exercises during adjuvant treatment for head and neck cancer

The intervention was found to be statistically significantly better than the control group in terms of active shoulder abduction at the three month follow up, being 26.6° (95% confidence interval (CI) 7.3 to 46) greater than the control group for the per protocol analysis. Clinically, this difference between groups is functionally relevant. However, the questionnaires investigating shoulder pain and disability (the SPADI), and region specific quality of life (the NDII) found no significant difference between groups at any time point.

Accessory nerve shoulder dysfunction was found to be present in 36.86% of patients who underwent an accessory nerve-sparing neck dissection, across all study sites.
However, given that 81 potential participants were not contacted, the prevalence figure may be inaccurate.

Both groups of participants demonstrated improvement in the primary and secondary outcome measures over time, compared to baseline levels. Prognostically, it would seem that there is a positive outcome for accessory nerve shoulder dysfunction after neck dissection.

The intervention was overall found to be feasible. Adherence to the intervention protocol was overall at a good level, given the patient population under study, and the high percentage of participants simultaneously undergoing radiation therapy. Participants included in the per-protocol analysis had an overall supervised session attendance rate of 82.2%. Work or other commitment (41.9%), followed by side effects from radiation therapy and cancer-related fatigue (27.4%), were the most common barriers to attendance. The percentage of participants who completed the intervention was 81.8%, with adjuvant treatment side effects (38%) the greatest barrier.

### 8.2.5 Systematic review: Intra-operative monitoring of the accessory nerve

The aim of this systematic review was to:

- Investigate the evidence as to whether intra-operative nerve monitoring of the spinal accessory nerve affected either the prevalence of post-operative shoulder morbidity or could predict of functional outcome.

The review only produced three relevant studies, with only one small study based on a neck dissection patient population. Therefore the usefulness of intra-operative nerve monitoring for the above-mentioned goals was found to be inconclusive.

### 8.3 Research Strengths and limitations

The three studies and two literature reviews constitute an important and original contribution in the physiotherapy management of head and neck cancer patients. To our knowledge, there are no scientifically rigorous publications that precede either the
physiotherapy literature review or the intra-operative nerve accessory nerve monitoring systematic review.

The facial lymphoedema study highlighted the need for health professionals to take a more pro-active role in the management of this condition, and improve both multidisciplinary communication and current referral patterns. However, the small sample size meant it lacked participant heterogeneity and had reduced validity of the results. The interviews were of short duration, and so the information gained may have been limited.

Surface electromyography of scapular muscles in patients affected by accessory nerve shoulder dysfunction has not been studied previously. Innovative and valuable information has been gained as to the muscle activity patterns of scapular muscles on the affected side. Dynamic exercises, which maximise trapezius muscle activity, have now been identified as a direct consequence of the study’s results. Assessment of the effect of various scapular muscle exercises has provided a framework for rehabilitation specificity. The lack of any previous studies investigating muscle activity in this patient population in order to guide rehabilitation means that the outcomes of this research were unique. The main limitation of the study was that there was one assessment, which involved only three repetitions of each exercise. Investigation of muscle activity, which occurs over a longer period of rehabilitation, may lead to a different outcome.

The randomised controlled trial investigating the effect of progressive scapular strengthening on accessory nerve shoulder dysfunction following neck dissection showed a moderately large positive short-term result for the primary outcome of active shoulder abduction. The intervention group had a highly statistically and clinically significant improvement in active shoulder abduction of 26.6° (95% confidence interval (CI) 7.3 to 46) greater than the control group for the per protocol analysis at the three-month follow up. Our study had several strengths compared to the only other prior randomised study. 

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The main differences were that our study involved:

- Early, prospective recruitment post neck dissection surgery
- Exclusion of patients with accessory nerve sacrifice
- Intervention based on biomechanical deficits
- Supervised sessions only once a week for the intervention
- A brochure of mobility neck and shoulder exercises and advice for the control group, which is less resource intensive than a 12 week program
- Long term follow-up – both at 6 and 12 months

The main limitations were:

- The lack of statistical power at the 6 and 12 month follow-up due to participants lost to follow-up
- Heterogeneity of the control group
- A limited ability to confidently report the prevalence rate of accessory nerve shoulder dysfunction following neck dissection surgery
- Insufficient participant numbers to sub analyse the effect of neck dissection type and radiation therapy on outcomes

8.4 Implications for management

Negative physical side effects resulting from head and neck cancer treatment are common, with several conditions being pertinent to physiotherapy assessment and management. However, physiotherapy is not a routine part of the multidisciplinary team management for patients undergoing treatment for head and neck cancer in Australia. Results from the series of studies presented in this thesis demonstrate that physiotherapy referral for appropriate management of these conditions has the potential to improve patient outcomes and meet both patient needs and standards for evidence-based practice.

Improved communication between health professionals involved in the management of patients with facial lymphoedema secondary to treatment for head and neck cancer, and physiotherapists, is likely to improve current referral patterns to physiotherapy.
Multidisciplinary team awareness of the impact of facial lymphoedema on affected patients, both psychologically and physically, will improve holistic care. Patients that report issues that are possibly linked to facial lymphoedema, such as negative body image and reduced socialisation, or swallowing problems with external oedema, potentially will benefit from physiotherapy management.

As demonstrated by the RCT, a substantial proportion of patients following neck dissection surgery will have accessory nerve injury despite nerve preservation. This may not be apparent in the immediate post-operative inpatient setting. Therefore, routine screening for shoulder pain and for the three clinical signs of accessory nerve shoulder dysfunction needs to occur six to eight weeks following any type of neck dissection. If accessory nerve shoulder dysfunction is present, then patients need to be referred to physiotherapy for management.

Physiotherapy management of accessory nerve shoulder dysfunction needs to consider patient factors such as:

- Short and long-term functional goals
- Ability to comply with a 12-week supervised program based on side effects from adjuvant treatment, motivation, and location
- Age

Evidence-based physiotherapy management now exists for accessory nerve shoulder dysfunction following neck dissection surgery. Results from the RCT indicate that if a patient’s goal is to maximise active shoulder abduction, then the best physiotherapy management is a 12-week supervised and home program of progressive scapular rehabilitation. However, if patients do not require maximisation of abduction at 3 months following neck dissection surgery, then a brochure consisting of shoulder and neck mobility exercises with advice may be as effective as an intensive program at 6 and 12-months.
Significant differences for muscle activity imbalances of patients with ANSD compared to healthy controls from the SEMG case control study means that progressive scapular strengthening rehabilitation for patients with ANSD needs to target:

- Upper and middle trapezius of the operated side
- Upper trapezius of the non-operated side
- Serratus anterior, while the trapezius muscle activity is reduced

Specificity of scapular muscle exercise selection is now established following results of the comparative SEMG study. Based on the muscle activity findings, exercises that are most effective are scapular exercises that are performed overhead. However, repeated overhead strengthening exercises may not be possible in this patient group due to shoulder pain and restricted shoulder range of motion. Therefore, a shoulder shrug and a standing row should be prescribed in these cases.

### 8.5 Recommendations for future research

The findings of the work contained in this thesis have revealed other potential areas for further research.

#### 8.5.1 Facial lymphoedema

Facial lymphoedema has been found both in our study and in previous research to negatively affect appearance, body image, socialisation, and the ability to lie supine. Development of a validated region specific lymphoedema questionnaire for head and neck cancer patients, including these dimensions, would allow for the quantitative assessment of the associated psychological and physical impact of facial lymphoedema.

A recent literature review found only two articles related to treatment for lymphoedema in the head and neck region. One study investigated the effectiveness of manual lymphatic drainage and compression garments on 11 patients. No control group was used in this investigation. The other article was a case series on two patients...
using manual lymphatic drainage. Therefore, little evidence exists regarding the possible benefit of physiotherapy for these patients, and if these patients are treated with physiotherapy techniques, which type of physiotherapy is most successful. The effectiveness of physiotherapy treatment modalities, including manual lymphatic drainage, compression, facial and neck exercises and self-management education needs to be further investigated with methodologically robust studies. The possible link between facial lymphoedema and swallowing problems has not been clearly investigated. Utilisation of an outcome measure to assess swallowing ability, such as a barium swallow test before and after a selected physiotherapy intervention aimed to improve external oedema, may indicate intervention effectiveness. Results from these future studies would provide a direction for evidence-based physiotherapy intervention in this patient group.

8.5.2 Physiotherapy for accessory nerve shoulder dysfunction

Further studies are needed to assess the prevalence of ANSD by the objective shoulder assessment of all patients that undergo accessory nerve preserving neck dissection surgery, and whether surgery type (SND compared to MRND) has an influence on the prevalence of this disorder.

Larger physiotherapy intervention studies would allow for sub analysis of outcomes based on patient factors such as adjunct radiation therapy, neck dissection type (SND compared to MRND) and age. Results of such studies may provide valuable data as to whether there are subgroups of patients with ANSD that are “responders” or “non-responders” to progressive scapular rehabilitation. A greater sample size in further research would also allow for the investigation of the longer-term effects of targeted exercise intervention.

Physiotherapy intervention for patients who have undergone radical neck dissection surgery, with accessory neurotmesis has not been adequately investigated. An RCT to investigate the potential effectiveness of supportive measures, such as an orthosis, may be warranted in future.
Overall, the literature supports the relationship between occurrence of subcutaneous and muscle fibrosis and radiation therapy dose. Secondly, the presence of fibrosis as a long-term result of radiation has a deleterious effect on local joint movement. Thus, the effect of radiation therapy on participants under study, and their response to exercise requires consideration.

8.5.3 Intra-operative monitoring of the accessory nerve during neck dissection

Whether or not intra-operative monitoring of the accessory nerve reduces shoulder morbidity resulting from accessory nerve injury during neck dissection surgery, or can be utilised, as a predictor of post-operative shoulder morbidity, is an area for future research.

8.6 Conclusion

Facial lymphoedema is a side effect that may occur following treatment for head and neck cancer. The psychological and physical effects need to be considered by treating health professionals, and affected patients referred to physiotherapy if required.

A 12-week supervised and home program of progressive scapular rehabilitation in patients with ANSD following neck dissection has been shown to be effective in increasing active shoulder abduction at 3 months. Scapular muscles that need to be targeted include the operated side upper trapezius, middle trapezius and serratus anterior, and the non-operated side upper trapezius. Overhead exercises are associated with the highest scapular muscle activity, but should be prescribed with caution.


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68. Olson ML, Shedd DP. Disability and rehabilitation in head and neck cancer patients after treatment Head and Neck Surgery 1978;1:52-8


70. Courtney-Koro S. Rehabilitation following partial glossectomy and neck dissection for tongue cancer Rehabilitation Oncology 2004;22:15-20


77. Villanueva R. Orthosis to correct shoulder pain and deformity after trapezius palsy Archives of Physical Medicine and Rehabilitation 1977;58:30-4


135


84. Scott B, Lowe D, Rogers SN. The impact of selective neck dissection on shoulder and cervical spine movements Physiotherapy 2007;93:102-9


90. Quan D, Bird S. Nerve conduction studies and electromyography in the evaluation of peripheral nerve injuries The University of Pennsylvania Orthopaedic Journal 1999;12:45-51


93. Edds MV. Hypertrophy of nerve fibres to functionally overloaded muscles Journal of Comparative Neurology 1950;93:259


105. Mercer SR. Surface electrode placement and upper trapezius Advances in Physiotherapy 2002;4:50-3


111. Boettcher C, Cathers I, Ginn KA. The role of shoulder muscles is task specific Journal of Science and Medicine in Sport 2010;13:651-6


167. Dillon F. Electromyographic neuromonitoring in otolaryngology- Head and neck surgery Anesthesiology 2010;28:423-42


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181. Schmitt JS, Di Fabio RP. Reliable change and minimum important difference (MID) proportions facilitated group responsiveness comparisons using individual threshold criteria J Clin Epidemiol 2004;57:1008-18
Thesis Appendices