An electromyographic comparison of neck conditioning exercises

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By

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USE OF THESIS

ABSTRACT

It is known that sustained muscular contractions can cause muscular pain, which explains the prevalence of neck pain of employees in static and semi-static work such as dentistry, sewing machine and computer operation. Additionally, exposure to high and sustained gravitational forces in high performance combat pilots is another source of neck pain in the workplace. Individuals with neck pain have been found to show decreased neck strength, in particular neck flexor strength has been found to be less than that of the general population. It has been suggested that neck-conditioning exercises may be useful in the prevention and rehabilitation of neck pain. Therefore, the aim of this study was to compare EMG activation levels of selected superficial neck muscles using two neck-training modalities in flexion, extension and lateral bending. The two training modalities were a pin-loaded machine (Cybex) and Thera-Band (T-B). Seventeen subjects (eight males and nine females) each performed six trials. For Cybex the exercise intensities were 50%, 70% and 90% of 3RM and for T-B, three intensities were tested; Green T-B, Blue T-B and Black T-B. In each trial, subjects completed two contractions in flexion, extension and lateral bending while being filmed by a five-camera Motion Analysis system operating at 120Hz and whilst three sites around the neck were monitored bilaterally for EMG activation. Motion analysis data was used to define the concentric and eccentric portions of each exercise and a linear envelope was calculated from the EMG data. EMG data were then normalised to maximum voluntary isometric contraction and the average and peak EMG activation were calculated. A one-way ANOVA with repeated measures was used to compare between exercise modalities/intensities and post-hoc differences were performed via Least Squared Differences. Significant differences ($p<0.05$) were evident when comparing the different intensities of the Cybex modality to each other and also when the Cybex intensities were compared to the T-B in flexion, extension and the majority of variables in lateral bending. There were no significant differences between the differing colours of T-B in the majority of contraction variables. This study demonstrated that the 50% Cybex condition was not a suitable progression from the Black T-B, but appeared to be a reasonable exercise in the strengthening of the neck in high-risk occupations such as high performance combat pilots. Regression equations generated from the EMG data in the Cybex modality revealed that a 30% Cybex condition may "bridge" the gap in intensity between the Black T-B and the 50% Cybex condition. All Thera-Band intensities resulted in low-level EMG activation and is therefore an ideal mode of exercise to be used in injury rehabilitation programs.

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

(i) Incorporate without acknowledgement of any material previously submitted for a degree or diploma in any institution of higher education;

(ii) Contain any material previously published or written by another person except where due reference is made in the text; or

(iii) Contain any defamatory material.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The cervical spine, or neck, consists of seven vertebrae surrounded by passive and active tissue and supports the weight of the head (Winters & Peles, 1990). The active tissue, which is responsible for the movement of the head and neck, can be distinctly separated into two functional divisions; the deeper, intersegmental muscles which provide direct support to the vertebrae and the superficial, more global muscles which move the head as a whole (O'Leary, Falla, & Jull, 2003).

Employees in static and semi-static work such as dentistry, sewing machine and computer operation are known to have an increased predisposition to symptoms of pain, muscular weakness and fatigue in the neck region (Hagberg, 1984; Sommerich, Joines, Hermans, & Moon, 2000). Workers such as these, who spend longer than 70% of their working time with their neck at a minimum of 20° flexion have been found to have a higher risk of neck pain (Ariens et al., 2001). Also, it is known that sustained muscular contraction, (even as low as 5% of maximum voluntary isometric contraction (MVIC)) can cause muscular pain (Sjogaard, Kiens, Jorgensen, & Saltin, 1986; Sogaard, Blangsted, Jorgensen, Madeleine, & Sjogaard, 2003). Additionally, exposure to high and sustained gravitational forces in high performance combat pilots is another source of neck pain in the workplace (Alricsson, Harms-Ringdahl, Larsson, Linder, & Werner, 2004; Alricsson, Harms-Ringdahl, Schuldt, Ekholm, & Linder, 2001; Hamalainen, Heinijoki, & Vanharanta, 1998). Within U.S Marine pilots, 60% of the subjects examined in this study had experienced neck pain during flight, and indicated that pain increased with exposure to high gravitational forces (Knudson, McMillan, Doucette, & Seidel, 1988).

Individuals with neck pain have been found to show decreased neck strength, in particular neck flexor strength has been found to be less than that of the general population (Barton & Hayes, 1996; Silverman, Rodriquez, & Agre, 1991; Vasavada, Li, & Delp, 2001). This may be caused by neural or mechanical factors, or a combination of both these mechanisms (Vasavada et al., 2001). Asymptomatic individuals have been found to also have stronger neck extensors than neck flexors (Alricsson et al., 2004; Garces, Medina, Milutinovic, Garavote, & Guerado, 2002; Kumar, Narayan, & Amell, 2001a; Seng, Lee, & Lam, 2002; Vasavada et al., 2001; Ylinen, Rezasoltani, Julin, Virtapohja, & Malkia, 1999). Several studies have established that in the

healthy population, the neck flexor to extensor isometric strength ratio is approximately 0.7 in both genders (Berg, Berggren, & Tesch, 1994; Garces et al., 2002; Seng et al., 2002; Valkeinen, Ylinen, Malkia, Alen, & Hakkinen, 2002; Vasavada et al., 2001). However, athletes such as wrestlers who regularly perform specific neck exercises, show similar levels of neck extensor and flexor strength (Ylinen et al., 2003a).

It has been suggested that neck-conditioning exercises may be useful in the prevention and rehabilitation of neck pain, and that performing conditioning exercises specific to the neck musculature can increase neck strength and decrease neck pain (Berg et al., 1994; Ylinen et al., 2003b). Further, conditioning of the neck musculature has been shown to elicit muscular strength and endurance increases (Alricsson et al., 2004; Berg et al., 1994; Burnett, Naumann, Price, & Sanders, 2004; Conley, Stone, Nimmons, & Dudley, 1997; Garfinkel & Cafarelli, 1992; Leggett et al., 1991; Ylinen et al., 2003b). In the neck extensors, cross sectional area (CSA) of these muscles has been shown to increase 25% after a 8-12 week neck extension training program (Conley et al., 1997). However, not all increases in strength can be attributed to increases in CSA. An increase in the ability of the neural system to coordinate and recruit motor units may be able to explain the irregularity between muscle CSA and muscular strength (Tsuyama et al., 2001). This would indicate that beneficial improvements in the form of neural control could be realised without concurrent increases in CSA. Furthermore, fatigability of the neck muscles has been shown to decrease with neck conditioning exercises (Portero, Bigard, Gamet, Flageat, & Guezennec, 2001).

Neck strengthening programs have utilised pin-loaded machines, such as the Multi-Cervical Unit (Burnett et al., 2004) and Thera-Band (a device which consists of elastic tubing) (Burnett et al., 2004; Ylinen et al., 2003b) to evoke an increase in neck strength. Pin-loaded machines can readily alter exercise intensity by altering the weight to be resisted and such machines have the added advantage of being able to restrain the body so the neck musculature can be isolated. Thera-Band tubing is available in differing thicknesses, which provides the user with the option to vary the intensity of the exercise. The cost to purchase and operate the Multi-Cervical Unit is very expensive in comparison to the Thera-Band, which provides the advantage of being portable. Both these modalities can train the neck in flexion, extension and lateral bending.

To compare the success of these training modalities, more needs to be known about the training effect on the neck musculature. As the deep muscles of the neck contribute largely the stability of the head and neck, indwelling or needle EMG may appear to be the preferred method of measuring muscle activity. However, such invasive techniques have an inherent risk involved, especially around the anterior structures of the neck. Therefore, surface EMG is the preferred method of examining the function of the neck (Conley et al., 1997).

1.2 Purpose of the Study

The aim of this study was to compare EMG activation levels of selected superficial neck muscles using two neck-training modalities and representative exercise intensities in flexion, extension and lateral bending. The two training modalities were a pin-loaded machine (Cybex) and Thera-Band tubing.

1.3 Significance of the Study

In order to assess the effectiveness of exercises and/or training modalities in the rehabilitation and prevention of neck injuries, the quantification of muscle activation whilst performing selected exercises is essential. Such information has yet to be published in the peer-reviewed literature. The results of this study will quantify the potential training effect one can expect using two common training modalities and their respective intensities that are used in rehabilitation.

1.4 Research Questions

i. Are there significant differences in EMG activation between training modality/exercise intensity in flexion, extension and lateral bending?

1.5 Hypothesis

i. There will be significant differences in EMG activation between training modality/exercise intensity in flexion, extension and lateral bending.

1.6 Definitions of Selected Terms

1RM	Maximum weight lifted for one repetition (kilograms)
3RM	Maximum weight lifted for three repetitions (kilograms)
Cybex	Cybex™ multi-neck machine
CSA	Cross sectional area
ECG	Electrocardiography
EMG	Electromyography
ICC	Intraclass correlation coefficients
Kinematics	The study of the time and space factors of motion of a system
MVIC	Maximal voluntary isometric contraction
T-B	Thera-Band™ elastic resistance

CHAPTER TWO

2.0 REVIEW OF LITERATURE

2.1 Introduction

The paucity of literature available concerning neck pain is surprising, as 40% of the general population will experience pain to this region of the body at some point in their lifetime (Ariens et al., 2001). The majority of studies which have been undertaken have focused on whiplash, which is an acceleration-based injury caused by rear-end and front-end automobile accidents (Sommerich et al., 2000). The following literature review will discuss the findings relevant to the current study in the areas of anatomy, neck disorders in the workplace, muscular strength and strength imbalances in the neck in both the general population and athletes, and the reliability of these neck strength measurements. The literature review will then focus upon the use of neck strengthening exercises in rehabilitation, the use of elastic resistive devices in rehabilitation, the factors that influence force production in the neck muscles and methods of EMG normalisation in the lumbar and cervical spine.

2.2 Anatomy of the Cervical Spine

As the human head provides protection for the sensory apparatus, it is required to be able to operate in such a way so that it can quickly monitor the environment. It achieves this via the construction of the cervical spine, or neck, which attaches the head to the body (Bogduk & Mercer, 2000). The neck is made up of seven vertebrae; the two most superior are termed the atlas (C1) and the axis (C2) respectively. The five vertebrae following distally are known superiorly to distally as C3–C7, and are connected to each other in a column via multiple joints, which allows for movement in three dimensions (Winters & Peles, 1990). The weight of the head is estimated at 7.4% of the weight of the body and is situated at the end of an open kinematic chain, exacerbating any forces applied to distal body segments (Harms-Ringdahl, Ekholm, Schuldt, Nemeth, & Arborelius, 1986).

Ligaments regulate the movements of the neck by limiting unwanted movements, whilst muscles produce movement, as well as antagonising both wanted and unwanted movements (Bogduk & Mercer, 2000). The 20 pairs of neck muscles (Kamibayashi & Richmond, 1998) are functionally divided into the superficial and more global muscles, such as the sternocleidomastoid, that move the head as a whole and the deeper, intersegmental muscles such as the splenius group, which provides direct support to the vertebrae (O'Leary et al., 2003). The

head can move in flexion, extension, lateral bending and rotation, and the individual muscles that cause these movements have been identified through cadaver, MRI and EMG studies. The results of these studies have been summarised by Sommerich and associates (2000) in a recent review paper, and the major muscles of the neck region are presented in Table 1.

Table 1. Summary of Neck Muscle Action as Investigated by EMG.

Action	Muscle Group
Extension	Splenius group, semispinalis group, erector spinae, longissimus cervicis / capitis
Flexion	Longus colli/capitis, sternocleidomastoid
Lateral bending	Sternocleidomastoid, splenius capitis
Rotation	Sternocleidomastoid (contralateral), splenius capitis (ipsilateral)

Adapted from Sommerich et al. (2000).

2.3 Neck Pain in the Workplace

Neck pain is common in occupations such as dentistry, sewing machine and computer operation. In fact, in the general population over one year, 40% of people reported neck pain (Ariens et al., 2001), which manifests itself as myofascial pain or myalgia in the upper portion of the trapezius (Sommerich et al., 2000). Poor office ergonomics, lack of rest breaks, high quantitative job demands, stress and female gender have been determined as risk factors for developing neck pain (Korhonen et al., 2003). However, the most important risk factors for the development of neck pain include flexion of the neck at a minimum of 20° for greater than 70% of the working time, static postures with repetitive movement of the neck in flexion, and static posture with repetitive or forceful movements of the arm (Ariens et al., 2001). To date, a link between neck rotation and pain has not been established (Ariens et al., 2001).

Muscular fatigue resulting from sustained or intermittent contractions at levels as low as 5% MVIC may be associated with neck pain (Sjogaard et al., 1986). Muscles that have a long endurance time tend to have a less pronounced relationship between neck flexion and neck pain, compared to neck muscles that have a relatively short endurance time (Ariens et al., 2001).

High performance combat pilots also experience neck pain. During flying, pilots' necks are placed under multiples of gravitational forces, as well as being held in a combination of rotation, lateral flexion and extension (Hamalainen, Vanharanta, & Kuusela, 1993; Kikukawa,

Tachibana, & Yagura, 1995; Knudson et al., 1988). These high forces can be exacerbated by the use of flight helmets and helmet mounted night vision goggles, which increases the mechanical load upon the neck and moves the head's centre of mass upward and forward (Thuresson, Ang, Linder, & Harms-Ringdahl, 2003). As the head may weigh between 3.5-5kg, and headgear may weigh another 1.8-2.2kg, at +9 Gz, static load equivalents of 471-638N have been generated upon the neck musculature (Schall, 1989). Apart from the more common complaints of muscular pain and strain in the neck, other more serious injuries such as fractures of the cervical vertebrae, stenosis of the spinal canal, cervical disc prolapse and premature spinal degeneration have all been observed in pilots (Alricsson et al., 2004; Hamalainen et al., 1998). The prevalence of acute and chronic neck pain within this occupational group has been reported to vary between 29-89% (Alricsson et al., 2004) and is a common factor reported for a loss of workdays (Hamalainen et al., 1993). It would appear that the structures and muscles of the neck are not designed to withstand the high loads associated with flying under multiple forces of gravity.

2.4 Muscular Strength of the Neck

2.4.1 General Population

Using dynamometry, it has been shown that in the healthy population, the neck flexor to extensor isometric strength ratio was approximately 0.7 for both genders (Berg et al., 1994; Garces et al., 2002; Seng et al., 2002; Valkeinen et al., 2002; Vasavada et al., 2001). This variance of neck flexor to extensor strength can be attributed to the fact that the neck extensors display a much larger cross sectional area (CSA) than the neck flexors (Valkeinen et al., 2002). Neck lateral bending to extensor strength ratio has been shown to be 0.6 (Seng et al., 2002; Vasavada et al., 2001) and neck lateral bending to flexion, 1.2 (Seng et al., 2002). The similarities between the flexion and lateral bending strength of the neck may be explained by the fact that the sternocleidomastoids are the agonists for both movements.

Various studies have shown both gender and age differences when neck strength was investigated (Garces et al., 2002; Valkeinen et al., 2002; Vasavada et al., 2001). Two studies have shown that the average and maximal cervical isometric strength of men is approximately twice as high as in women, even when the subject's physical size differences were accounted for (Garces et al., 2002; Vasavada et al., 2001). Vasavada et al. (2001) believed this indicated that mechanical demands on the neck muscles in women may be closer to the maximum moment generating capacity than in men. A study of healthy subjects showed that older subjects have a

higher level of antagonist coactivation, whilst women have a longer isometric muscular endurance at 60% MVIC (Valkeinen et al., 2002).

In pathological subjects, neck strength has been shown to be decreased (Barton & Hayes, 1996; Berg et al., 1994; Silverman et al., 1991), especially in the neck flexors (Barton & Hayes, 1996). Furthermore, O'Leary et al. (2003) showed a reduction in the EMG activity of the deep neck flexor muscles, paired with an increased activity of the superficial flexors in chronic neck pain patients, which contrasted to the finding of a matched healthy control group (Falla, Jull, & Hodges, 2004). This disturbed coordination of the deep and superficial muscle and presence of pain may decrease the stability of the vertebrae, leading to abnormal mechanical stresses in the neck musculature.

2.4.2 Athletes

Neck strengthening exercises have typically been used to prevent neck injuries in sports such as wrestling and judo (Tsuyama et al., 2001; Ylinen et al., 2003a). Ylinen et al. (2003a) compared the isometric neck strength of high level male wrestlers in rotation, flexion and extension to that of junior wrestlers and a control group. They found that the exercises the wrestlers undertook as part of their routine training, such as pushing their heads against a training partner, resulted in an increase in neck strength, particularly in the neck flexors and rotators, when compared to the control group. The junior wrestlers did not demonstrate the same neck strength as the senior counterparts, but their neck strength was greater than subjects in the control group. Senior wrestlers also showed similar extension and flexion strengths, indicating that neck flexion strength can be improved via neck strengthening exercises, as the general population exhibits a neck flexor to extensor ratio of only 0.7 (Garces et al., 2002; Vasavada et al., 2001).

Wrestlers were again the focus of a study by Tsuyama and colleagues (2001), who examined the neck extension strength and CSA of neck muscles via magnetic resonance imaging (MRI) in college wrestlers and judo athletes. The results demonstrated that wrestlers had greater neck extension strength than the judo athletes, and this was attributed to the fact that wrestlers frequently perform resisted neck extension movements both in training and competition. An interesting finding by the authors was that the wrestlers had a greater CSA than that of the judo athletes, in particular in the deepest layer of the neck extensor muscles as opposed to the superficial layers.

2.5 Reliability of Neck Strength Measurements

A study by Ylinen et al. (1999) measured the reliability of an isometric measurement device and a neck strength testing protocol in neck flexion, extension and rotation. The device consisted of two strain gauges, which were calibrated before testing. Three MVIC's were performed in one direction, with a rest period of 45-seconds between contractions, and five minutes rest between each direction. Retesting was performed 30 minutes later to evaluate within-day reliability, and the entire test was repeated on two separate occasions in order to evaluate the between-days reliability. There were no significant differences in the strength of MVIC's within-days, and intra-class coefficient (ICC) values for measurements between-days ranged from 0.94 to 0.98.

Seng et al. (2002) used an isokinetic dynamometer to measure isometric neck strength in flexion, extension and lateral bending in ten male subjects. MVIC's were determined in each of the four directions during three different sessions. Three exertions with a 45-second break between each effort and a five-minute break between each direction were completed. Two sessions following the above protocol were performed on the same day, three hours apart, and a third session was completed one week later. ICC values for neck extension and flexion strength measurements were both greater than 0.90 for within-day testing, and above 0.80 for between-day testing. Neck lateral bending ICC results were poorer within-day (0.69-0.83), but improved between-days (0.83-0.91).

Leggett et al. (1991) completed a reliability study into isometric neck extension strength in order to establish both within-day and between-day reliability. Seventy-three subjects participated in the study on four days separated by approximately one week. On day one and two, two sessions were completed and were separated by a 20 to 30 minute interval. Neck extension strength was measured for approximately five seconds; with a ten second rest between contractions at different neck flexion angles using a MedX cervical extension machine. The results indicated that this form of neck extension strength testing was highly reliable both within-day and between-day. The authors also suggested that reliable maximal isometric neck extension strength measures are achievable on the first day of testing, and additional days of testing are not required to improve the test score.

2.6 Neck Strengthening Exercises in Rehabilitation and the Prevention of Injury

Papers outlining the use of neck strengthening exercises in therapy and rehabilitation are more numerous when compared to those related to sports. This can be attributed to the relatively large prevalence of neck disorders and pain in the general population. Berg et al. (1994) examined

women working at a laundry plant. These subjects were put through eight weeks of twice-weekly training sessions designed to increase neck strength and decrease neck pain. The authors found that exercising the neck extensors, flexors and rotator muscles through the use of a specially designed hydraulic ergometer resulted in significant increases in neck strength and a reduction in neck pain.

The need for specificity with neck strengthening exercises was established by Conley et al. (1997), who compared a general body weights program to that of a specific neck strengthening program that was tailored to strengthen the neck extensors. The exercises that were examined were prone neck extension exercises against gravity using a specially designed harness. MRI was used to measure the CSA of the neck musculature, and it was found that neck CSA increased by 13%, whilst the average for other limb muscles trained between eight and 16 weeks has been reported previously to be 5-12% (Garfinkel & Cafarelli, 1992). This study showed that for positive gains to be realised, exercises should be specific for the neck musculature, and that training done for other regions of the body do not transfer to the neck.

Burnett et al. (2004) examined isometric neck strength gains over a ten-week training period in Thera-Band and Multi Cervical Unit (MCU) training groups. The training protocol consisted of two 30-minute sessions a week in flexion, extension, left and right lateral flexion and rotation. Stretching in each of the directions was included, and progressive overload was controlled as much as possible between the two groups. Compared to a control group, both training groups exhibited increases in muscular strength, although the MCU elicited larger, although non-significant gains.

Ylinen et al. (2003b) compared intensive isometric neck strength training to that of lighter, endurance training of neck muscles. Their subject cohort was women with chronic, non-specific neck pain, and the study encompassed a year-long training program consisting of five, 45-minute sessions a week in either a strength or endurance training group. The strength-training group used a Thera-Band for a single set of 15 repetitions at 80% of the subject's maximum isometric strength in the anterior, anterolateral and posterior directions. The endurance-training group completed three sets of 20 repetitions of extending the neck from the supine position. Numerous other exercise modalities were included, such as whole body resistance training, massage and aerobic training, which may limit the usefulness of the study. The results of this study showed a reduction in neck pain by 73% in the strength-training group, 59% in the endurance-training group and 21% in the control group. A very small proportion of subjects (3%) reported an increase in neck pain as a result of undertaking these exercises. The strength-training group showed the greatest increases in isometric neck strength, followed by the endurance-training group. The greatest increases for each group were found in neck flexion

in the strength-training group (110%) and neck extension in the endurance-training group (29%). Therefore, a combination of neck strength and endurance training may be appropriate to improve both neck flexion and extension strength with the aim to reduce pain.

Alricsson et al. (2004) investigated isometric neck strength measurements of the flexors and extensors, endurance of the neck extensors and the effect of active encouragement on the above parameters in 40 male fighter pilots over a period of six to eight months. The training program consisted of four sets of ten repetitions of strength and endurance exercises for the neck, using weights attached directly to the head or onto a training helmet. The upper thoracic spine region was also trained using Thera-Band. In addition, stretches for both the neck and upper back were performed. One training group was supervised by a physical therapist and subjects in this group were strongly encouraged to perform the exercises three times a week whilst the other training group was left with written instructions on how to perform the exercises, but no further coaching was received. A significant difference was found between the two groups, with the supervised training group demonstrating a greater increase in isometric strength and endurance than the non-supervised training group.

Only one study has been completed exclusively examining the training of the neck lateral flexors (Portero et al., 2001). The study encompassed eight weeks of isometric training using an isokinetic dynamometer three times per week for seven healthy men. MRI was used to evaluate the CSA of the sternocleidomastoid and trapezius muscles before and after training, whilst EMG was used to assess the rate of fatigue of the muscles again before and after the eight weeks of training. The authors found an increase in the CSA and isometric strength of both muscles, as well as a decreased rate of fatigability of the sternocleidomastoid.

2.7 The Use of Elastic Resistive Devices in Exercise Programs

One disadvantage of elastic resistance as noted by Patterson et al. (2001) is the progressively increasing force required as the material stretches. A consequence of this is that individuals may not be able to complete the desired ROM, as the muscles may be weaker in the shortened position at the end of the contraction where the resistance is greatest.

Of the variations of elastic resistive devices used in therapy and exercise programs today, the most widely studied is the Thera-Band, manufactured by the Hygiene Corporation. The bands are coloured according to their resistance, yellow displaying the least resistance and silver having the greatest resistance. Table 2 shows the amount of force used to stretch each Thera-

Band to a certain length, which was measured using a pull-spring scale by the Hygienic Corporation.

Table 2. Amount of Resistance Generated by Thera-Band at Different Extended Lengths (in Newtons).

Extended length (cm)	Yellow	Red	Green	Blue	Black	Silver
35	3.2	4.5	5.5	6.5	9.0	22.2
40	6.7	9.0	11.0	13.2	17.7	40.0
50	10.0	15.5	19.0	27.7	33.2	53.5
60	11.0	20.0	22.2	33.2	40.0	66.7
70	13.2	24.5	26.7	40.0	44.5	77.2
80	15.5	29.0	31.2	45.5	50.0	89.0
90	17.7	33.2	35.5	53.5	57.75	102.2

The Hygienic Corporation (1996)

Other properties of Thera-Band have been independently assessed. Patterson et al. (2001) tested six colours of the Thera-Band on a standard material testing machine. The variables that were tested were the effect of length on force, the effect of pre-stretching, the loading rate and the effect cyclic loading on force production. There were no differences in resistance due to changing the length of the Thera-Band. Pre-stretching of the Thera-Band approximately 20 times appeared to cause the material to exhibit a more consistent force generating property. The force generating potential was repeatable over at least 5,200 stretch-shorten cycles. The loading rate did not have an effect on the force generation. More force was able to be generated during the concentric part of the exercise, or in other words, when the Thera-Band was being stretched. A major finding of the study was the amount force that was needed to stretch each colour of Thera-Band to a particular percentage of strain. At approximately 50% strain there was 10N difference between the green, blue and black Thera-Bands. At 100% strain there was a 15N difference between the three colours. The authors concluded that the material Thera-Band is made from is very compliant and displayed non-linear behaviour in the initial stretching phase and linear behaviour after 50% elongation.

Matheson et al. (2001) conducted a study on the EMG activation of the quadriceps muscles in eight different seated exercises. The exercises that were performed utilised free weights, Thera-Band, an isokinetic dynamometer and an impulse inertial exercise trainer. Both peak and average normalised EMG activation were recorded. Peak and average EMG activations of Thera-Band exercises were found to be comparable to that of the free weight exercises at a similar resistance. It was found that a higher average EMG activation indicated that the exercise

was more effective in activating the muscle throughout the entire ROM however, a higher peak activation was considered to be inappropriate for people with injuries.

2.8 Factors Influencing Force Production in the Neck Muscles

The CSA of muscle is thought to be related to maximal force production by a constant of approximately 35 $N.cm^{-2}$ (Cholewicki, McGill, & Norman, 1995; Vasavada, Li, & Delp, 1998). Tsuyama and colleagues (2001) examined the relationship between CSA and isometric force production in the neck extensors using MRI and a cervical extension machine in wrestlers and judo athletes. There was a positive correlation between the CSA of the neck extensors and isometric force production however, in some subjects the greater isometric force demonstrated could not be accounted for by the larger CSA. The authors attributed an increase in neural training, such as an increased ability to recruit motor units, to the greater isometric force shown in those subjects.

A greater muscular contraction can be achieved via a greater magnitude of neural drive, either by a larger number of motor units being recruited, or via an increased rate of firing. A larger contraction causes the peak and total power of the EMG signal to increase. In addition, the median frequency increases if there is an increase in the number of motor units being recruited (Kumar, Narayan, & Amell, 2001b).

The relationship between the increases in contraction and EMG activity are not always linearly related to one another and has been shown to be dependant on joint angle (Queisser, Bluthner, Brauer, & Seidel, 1994). Other factors influencing the EMG/force relationship include fatigue level (Harris & Wertsch, 1994; Solomonow, Baratta, Shoji, & D'Ambrosia, 1990), the modulation of the EMG signal caused by the relative motion of the electrodes with respect to the active fibres, possible reflex activity and the change in the instantaneous centre of rotation of the joint and moment arm (Basmajian, 1978; Solomonow et al., 1990). In addition, intersubject variation, muscle variations and variations due to training level impact further on the EMG/force relationship (Basmajian, 1978).

The above considerations indicate that not all muscles are going to show the same EMG/force relationship. A linear EMG-force relationship has been shown to occur in contractions of the interosseus dorsalis muscle (Milner-Brown & Stein, 1975; Woods & Bigland-Ritchie, 1983), whilst non-linear relationships have been found to occur in the biceps brachii (Petrofsky, Glaser, Phillips, Lind, & Williams, 1982; Woods & Bigland-Ritchie, 1983). Alkner et al. (2000) identified a non-linear EMG-force relationship for the vastus medialis and rectus femoris,

however, for the vastus lateralis the relationship was linear. The cervical erector spinae has shown to have a non-linear EMG-force relationship (Mayoux-Benhamou & Revel, 1993; Queisser et al., 1994; Schuldt & Harms-Ringdahl, 1988).

Kumar et al. (2002) undertook a study to examine the relationship between EMG and force in the neck muscles. Using a self-designed testing device, they measured isometric strength and EMG in the sternocleidomastoid, splenii and trapezii muscles in the directions of flexion, extension, lateral bending, anterolateral flexion, and posterolateral extension. All subjects showed the highest force generation in extension and the lowest in flexion, and EMG output was 66% higher in flexion than extension. These results indicate more muscle activity was required in flexion than extension to generate a given force.

Force production by the neck muscles has been found to vary depending upon the position of the neck. Leggett et al. (1991) examined a combination of men and women, and found the highest isometric torque production occurred in neck extension (42Nm) when the neck was at 126° flexion (i.e. the starting position). However, Seng et al. (2002) showed that maximum isometric neck extension strength (52.0 Nm) was found at 20° extension, and this value decreased as the neck was flexed. Neck flexors were strongest at a neutral head position and this value decreased as the neck was flexed or extended. Berg et al. (1994) reported no influence in extension strength (23.2 Nm) in women with previous neck injury when head position was altered, although neck flexion strength was greatest at 30° extension and progressively decreased as the neck was flexed. The method of testing in each of these three studies varied, as did the type of subjects sampled, so direct comparisons cannot be made. However, there is still a discrepancy between the studies as to whether maximal isometric strength occurs when the neck is initially in an antagonistic or agonistic position.

2.9 Methods of EMG Normalisation in the Spine

Normalisation of EMG data is a technique whereby the comparison between studies, subjects, muscles and days can be reliably established (Sommerich et al., 2000). There are few papers that have examined normalisation of EMG in the neck, however, this problem has been previously investigated in the lumbar muscles (Dankaerts, O'Sullivan, Burnett, Straker, & Danneels, 2003; Ng, Kippers, Parnianpour, & Richardson, 2002). Reliability and validity is important in any measurement technique. A small within-day variability when studying EMG indicates a good reliability of the EMG signal, whilst a small between-days variability shows that similar and meaningful results can be repeatedly collected (Elfving, Nemeth, Arvidsson, & Lamontagne, 1999).

The most common form of normalisation is in the form of the maximal voluntary isometric contraction (MVIC), where the maximum muscle activation is determined and used as a reference for further EMG recordings (Nieminen, Takala, & Viikari-Juntura, 1993). This procedure however, does not take into account the non-linear relationship between muscular activation and force, or the differences in muscle length and contractile velocity (Ng et al., 2002). Also, the question of subject motivation or unfamiliarity towards a true MVIC is raised, so it has been suggested that at least three trials are undertaken, with the first trial ignored (Sommerich et al., 2000).

As some authors believe that maximal contractions in the neck region carry an element of discomfort and potential injury, a submaximal voluntary contraction (sub-MVIC) has been suggested in order to normalise EMG data (Sommerich et al., 2000). An additional reason for carrying out a sub-MVIC would be the inability of being able to produce a MVIC in a pathological neck, whether it be due to subconscious protection against further injury or disrupted muscular mechanisms. One method of carrying out a sub-MVIC is to perform the contractions and predict, via a regression equation and the subject's anthropometric measurements, the maximum torque (Ng et al., 2002).

Falla et al. (2002) examined the repeatability and reliability of the EMG mean frequency for the sternocleidomastoid and anterior scalene muscles in nine healthy volunteers. The subjects performed two isometric neck flexion contractions at 50% sub-MVIC over 15 seconds, both 10 minutes apart, and on three non-consecutive days. Within-day and between-days repeatability of the EMG mean frequency was measured by using ICC's and the normalised standard error of the mean. The results indicated that excellent repeatability can be achieved from these muscles at sub-MVIC (50% MVIC) however, the rate of fatigue of the two muscles were not the same, which may demonstrate different ratios of muscle activation in the neck during flexion.

Netto and Burnett (2004) compared the reliability of a MVIC and sub-MVIC (60% MVIC) using an isokinetic dynamometer and a portable cable dynamometer in addition to using manual resistance in five healthy male subjects. The authors found that the MVIC for the two dynamometers had excellent within-day and between-day reliability however, the MVIC for the manual resistance was less reliable, and was attributed to the inconsistency in the point of application of the resistance. Only the dynamometers were compared with the sub-MVIC, and both showed good reliability within-days but poorer results between-days. This may have been caused by the authors using verbal feedback rather than visual feedback. These results indicate that for the neck, EMG normalisation should be performed in the form of a MVIC, using a dynamometer rather than manual resistance.

Dankaerts and co-workers (2003) examined the reliability of the MVIC and sub-MVIC in trunk muscles, both within-day and between-days for healthy subjects and those with chronic low-back pain. The results of the study suggested that there was good within-day reliability for both MVIC and sub-MVIC in both groups of subjects. There was less reliability for both groups between-days for the MVIC compared to the sub-MVIC, indicating that the sub-MVIC was more appropriate to use if the study is to span more than one day.

Ng et al. (2002) outlined the importance of performing normalisation in more than one plane of movement. As they explained in their study, the muscles that cross the joints of the extremities are quite basic compared to those of the trunk that operate in many more degrees of freedom. The authors concluded that MVIC's in at least six directions of the three planes are needed to normalise all the trunk muscles from their study.

2.10 Summary

Neck pain caused by static and flexed positions in the workplace is common, with around 40% of the general population suffering from some form of discomfort in their lifetime (Ariens et al., 2001). People with neck pain experience decreased neck strength, especially in the neck flexors. Neck strengthening exercises have been shown to be effective in reducing pain and increasing neck strength. EMG has shown to be an effective tool in studying muscle activation in the neck region, as long as recommended protocols are adhered to. There is currently a large gap in the literature in the area of quantifying EMG during neck conditioning exercises.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Subjects

Seventeen subjects comprising of eight males and nine females (mean ± (SD) age 23.4 ± 5.1 years, height 171.7 ± 9.7 cms and mass 71.3 ± 14.7 kg) were recruited for this study. Subjects were required to be free of neck injury and neck pain and not suffer from headaches or migraines in order to be considered for inclusion in this study. Ethical approval was obtained from the Edith Cowan University Human Research Ethics sub-committee prior to the commencement of this study. Subjects were required to provide their informed, written consent before testing (Appendix A).

3.2 Experimental Protocol

Subjects performed two different neck exercise-training modalities in flexion, extension and right lateral bending whilst the EMG activation of selected muscles/muscle groups was recorded. The two training modalities that were investigated were; a pin-loaded machine (Cybex) and a portable elastic resistance device (Thera-Band).

For both training modalities three intensities were examined as described below resulting in a total of six separate trials for each subject. For the Cybex the exercise intensities were 50%, 70% and 90% of 3RM (herewith termed 50% Cybex, 70% Cybex and 90% Cybex respectively) and for the Thera-Band modality the intensities were the green, blue and black tubing (herewith abbreviated as Green T-B, Blue T-B and Black T-B). For each trial subjects performed two contractions in flexion, extension and right lateral bending with the speed of contraction set at a count of -one-two- for concentric and -three-four- for the eccentric phase. For all trials subjects were seated in a customised high-backed chair that was fitted with adjustable waist and shoulder straps. This chair restrained the subject and ensured that the neck was isolated. In addition, a testing platform was built firstly, so that the original Cybex chair could be replaced with the customised chair (the original chair did not isolate the neck) and secondly, for device attachment. The platform consisted of a metal frame and a wooden floor. A rigid post was affixed to one end of the platform in order to attach the Thera-Band for the exercises and the cable for the MVIC's. The testing platform is illustrated in Figure 1.

Figure 1. The testing platform.

The Cybex pin-loaded machine contained an attachment, which the head was placed into, and which subjects pushed against, in order to lift the required weight. The headpiece was positioned to allow for full range of movement of the neck, however, it did not allow the subject to lift large weights without the head slipping, so subjects were allowed to guide the headpiece with their hands as shown in Figure 2.

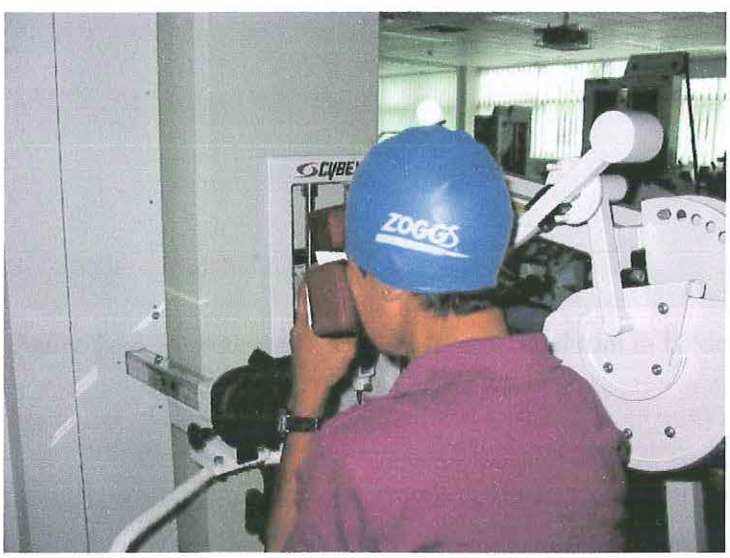

Figure 2. Subject using the Cybex in flexion, showing the headpiece, which was required to be guided during the movement (customised chair not included).

The Thera-Band consisted of a 70cm length of rubber attached to an adjustable head harness via shackles, which was then attached to the post of the testing platform. To attach the Thera-Band to the subject's head a head harness was worn. To avoid the head harness slipping on the head subjects wore a latex swim cap. Figure 3 depicts a subject completing the Thera-Band trial in flexion. The distance from the post of the testing platform to the centre of the chair for all Thera-Band trials was 100cm for both neck flexion and lateral bending, and 107cm for extension. This means that the Thera-Band was already under approximately 42% (flexion and lateral bending) and 53% (extension) strain before the commencement of the contraction. The contraction then increased the length of the Thera-Band by approximately 10cm depending on the subject's ROM and the contraction direction, resulting in approximately 50% strain. The length the Thera-Band was stretched during testing was an important consideration to control, as increased length of the Thera-Band results in an increased resistance to overcome.

Figure 3. A subject completing the Thera-Band trial in flexion.

Subjects undertook testing on two different days. On day one, a familiarisation protocol consisting of sub-maximal contractions in neck flexion, extension and right lateral bending using the Cybex and Thera-Band were performed. All EMG procedures were demonstrated and explained during this time. Furthermore, subjects undertook a three-repetition maximum (3RM) test in each contraction direction using the Cybex. Subjects were also informed about the experimental protocol for day two. The 3RM strength test was performed as described by Maud and Foster (1995) and was carried out as follows:

1) A warm-up of ten repetitions with 50% of the estimated 3RM was completed.
2) A one-minute rest, including stretching was allowed. Three repetitions at 70% estimated 3RM were completed.
3) Step 2 was repeated using 90% of the estimated 3RM.
4) After a two-minute rest and depending upon effort required to complete Step 3, three repetitions at 100% to 105% of the estimated 3RM was completed.
5) A two-minute rest followed Step 4.
   a) If Step 4 was successful, the resistance was increased by 2.5% to 5% and another attempt at three repetitions was made.
   b) If Step 4 was unsuccessful, 2.5% to 5% of the resistance used in Step 4 was subtracted and another attempt at three repetitions was made. If this step was successful, then this was recorded as the subject's 3RM.

On day two, a warm-up, consisting of two sets of 12 repetitions of unloaded contractions in each of the three directions was completed. This was followed by stretching of the neck musculature. For the purposes of EMG normalisation three MVIC's in each of the abovementioned contraction directions was taken after the warm-up using a wire cable attached between the head harness and the post of the testing platform. The first MVIC from each contraction direction was discarded as recommended by Sommerich et al (2000). There was a three-minute rest period allowed between each MVIC to allow full recovery, and verbal encouragement was provided to ensure maximal contractions were generated.

Synchronised EMG and Motion Analysis data were collected for each condition outlined in Table 3. The order of contraction directions and intensities was randomised within each training modality (i.e. subjects completed either the Cybex or Thera-Band protocol in its entirety). To avoid accumulating excessive amounts of fatigue two minutes rest was given between contractions. The average time to complete the entire testing protocol was two and a half hours.

Table 3. Experimental Protocol for Testing Outlining the Type, the Number and Direction of Contractions.

	Flexion	Extension	Lateral bending
MVIC	3	3	3
Cybex			
50% Cybex	2	2	2
70% Cybex	2	2	2
90% Cybex	2	2	2
Thera-Band			
Green T-B	2	2	2
Blue T-B	2	2	2
Black T-B	2	2	2
Total	15	15	15
Total Contractions			45

3.3 Data Collection

3.3.1 Electromyography

Three sites around the neck were monitored bilaterally for EMG activity, namely the anterolateral, posterolateral and posterior aspects of the neck as described in Table 4. The channels shared a common ground over the most bony prominence of the right clavicle.

Ag-AgCl 2.5cm x 7.6 cm disposable surface electrodes (Uni-Patch, Wasbasha, MN), with a conducting gel (Tac Gel, Newark, NJ), were attached in pairs, with an inter-electrode distance of 25mm. An adhesive covering was placed over the paired electrodes to help reduce movement artefact. The skin was prepared firstly by shaving, lightly abrading and cleansing with an alcohol swab. The skin impedance was tested using a multimeter and skin preparation was only considered acceptable if the impedance was less then 5kΩ.

Movement artefact when studying dynamic contractions is a problem when using surface electrodes, as they tend to migrate when the skin is moved from its original position. A pilot study was undertaken which examined this problem and ways to rectify it. Keeping the electrodes attached in pairs and reinforcing the structure with adhesive dressing meant the electrodes would move relative to its pair. This configuration reduced movement artefact to an acceptable level.

Table 4. Sites for EMG Electrode Placement Around the Neck.

Electrode Placement	Vertical Orientation	Intended Muscle Coverage	Anatomical Location
Anterolateral	In line with muscle fibres	Sternocleidomastoid	Approximately in line with C4, over sternocleidomastoid.
Posterolateral	Parallel to muscle fibres	Levator Scapulae/ Posterior Scalenes	Approx. midway between posterior border of sternocleidomastoid and anterior border of upper trapezius.
Posterior	In line with muscle fibres	Cervical erector spinae	2cm laterally from spinous process at C4

From Netto & Burnett (2004).

Raw EMG signals were input into a 16-channel amplifier (Grass Instrument Co. Warwick, RI), connected to a breakout box via BNC connecters, then to the A-D board of the Motion Analysis system described below using a 15-pin ribbon cable. EVa 7.0 Motion Analysis software (Motion Analysis Company, 2002) was used to sample the raw EMG data at 1000Hz.

3.3.2 Motion Analysis

One 25mm diameter retro-reflective marker was placed on the apex of the head. The marker was in constant view of at least two cameras at any one time. To provide known 3-D control points, a calibration frame with dimensions of approximately 52cm x 77cm x 80cm was centred over the area in which the exercises were to occur. This configuration ensured the activity was surrounded with control points to avoid errors associated with extrapolation to unknown points outside the distribution space (Wood & Marshall, 1986).

Subjects were filmed performing all neck muscle contractions for a five second period by a five camera opto-electronic Motion Analysis System (Motion Analysis Company, 2002) operating at 120Hz. Following the identification of markers, video records were automatically digitised and the 3-D points reconstructed using EVa 7.0 software (Motion Analysis Company, 2002). Data was then saved to a file for later analysis.

3.4 Data Analysis

Raw EMG signals and the kinematic data were uploaded onto a personal computer in ASCII format. Both the EMG and kinematic files were analysed in conjunction using a customised LabVIEW V6.1 (National Instruments, Austin, Texas) software program. The raw EMG data was demeaned, full-wave rectified and low pass filtered at 4Hz using a Butterworth fourth order digital filter. Some ECG contamination was noted in a number of different channels. The time period at which ECG contaminated relevant trials was noted in LabVIEW (National Instruments) and the file was manipulated in Excel (Microsoft Corporation) with the relevant data deleted and replaced with adjacent data not affected with ECG. The effect of this approach on EMG activation variables was noted to be minimal in a pilot investigation. A 50Hz notch filter was used to eliminate 50Hz noise due to an unmovable power source located in the lab.

As shown in Figure 4, the raw data and resulting linear envelope were graphed on the same time base to assist in identifying any abnormalities in the EMG signal. The kinematics (z direction) of the apex marker were also graphed on the same time base as the EMG data. EMG data was then sectioned into concentric and eccentric portions based upon the movements of the marker from its starting point through to its finishing point. These data were then time normalised (0-100%) using cubic spline interpolation, and the resulting linear envelopes were displayed on separate graphs.

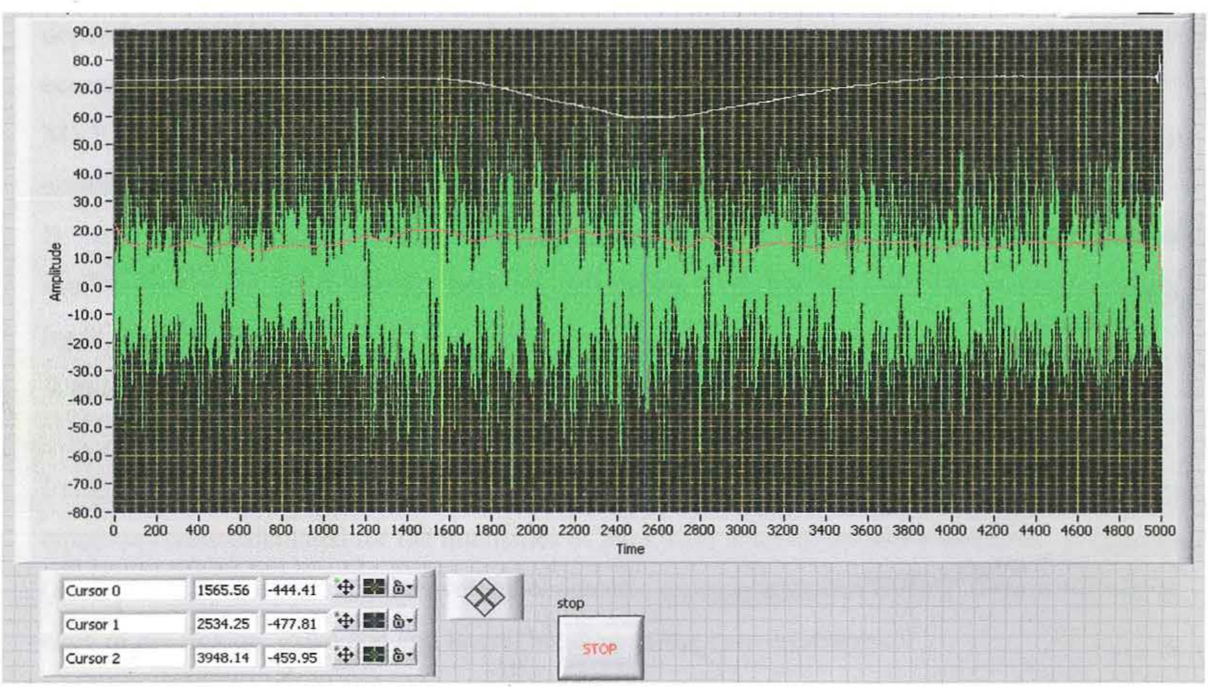

Figure 4. Screen shot of the LabVIEW data analysis program showing kinematics (white trace), raw EMG (green trace) and the corresponding linear envelope (red trace).

Peak EMG activations for all muscles analysed in this study were taken over a 200ms window and the average EMG activation was considered as the average of all points of the linear envelope. These two variables were calculated for both the concentric and eccentric portions of the exercise. The mean of the two contractions for each direction, at each intensity was used in order to reduce within-subject variability.

MVIC's in all contraction directions were analysed using another customised LabVIEW (National Instruments) software program designed to calculate peak activation over a 200ms moving window. Peak activation was recorded and then all data were then expressed as a percentage of the corresponding MVIC.

Only data collected from the agonistic muscles for each contraction was used for analysis. For example, in the extension direction activations collected from the posterior electrode placements was used, for flexion the anterolateral electrodes and lateral bending only the posterolateral electrodes was used.

3.5 Statistical Analysis

For each contraction direction (flexion, extension and lateral bending) there were four dependent variables, they being; peak activation and average activation in the concentric and eccentric portions of the contraction. As explained above these variables were all normalised to MVIC. The independent variable was a combination of training modality and exercise intensity containing six levels. These levels were 50% Cybex, 70% Cybex and 90% Cybex and Green T-B, Blue T-B and Black T-B. Consequently a one-way ANOVA with repeated measures was used to determine the difference between cell means. Post-hoc analysis was conducted using least squares differences. All statistical procedures were conducted using SPSS v11.0 for Windows® with the level of significance set at $p<0.05$.

Furthermore, Pearson product moment correlation coefficients and the associated regression equations were calculated for the intensities of the Cybex training modality and EMG activation (as depicted by the mean of the average concentric and eccentric activation). This was done in each of the flexion, extension and lateral bending contraction directions.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

Four dependent variables which depicted exercise intensity were examined in this study namely; peak and average EMG activation in the concentric and eccentric portions of the selected neck exercises. These variables were examined in extension, flexion and lateral bending for the two exercise modalities. For the three directions in which the neck exercises were performed, all the quantitative variables that depicted exercise intensity showed similar patterns. This has been outlined in the following sections.

Figure 5 illustrates the average EMG activation of the Thera-Band and Cybex modalities for the concentric portion of neck flexion. This figure is typical of the results obtained in this study. This figure shows there was no difference in average EMG activation between the differing grades of Thera-Band examined in this study. There is a step-like increment in EMG activation with increasing intensity from Green T-B to Black T-B however, these increments in average EMG activation were not significant ($p<0.05$). Also from examining this figure there were clearly significant differences ($p<0.05$) evident between the three Cybex intensities due to the difference in means and the relatively small standard deviations. Further, even more marked was the significant difference ($p<0.05$) between the Black T-B and 50% Cybex conditions.

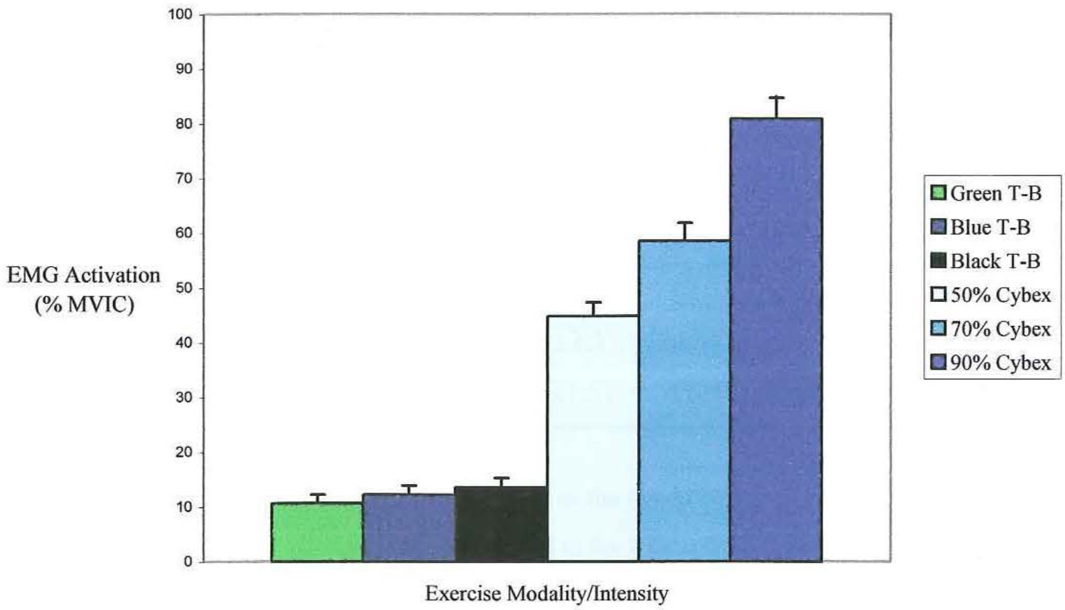

Figure 5. Average EMG activation in the concentric portion of the neck flexion exercise in the Thera-Band and Cybex exercise modalities.

4.2 Flexion

Table 5 presents data for the peak and average EMG activations for the concentric and eccentric portions of the neck flexion exercise using both the Thera-Band and Cybex training modalities. Average EMG activation ranged from 10.6% MVIC using the Green T-B during the concentric portion of the contraction to 80.9% MVIC when performing the 90% Cybex condition also during the concentric portion. Further, peak EMG activation ranged from 18.0% MVIC during the concentric portion of the Green T-B condition to 101.1% MVIC when performing the 90% Cybex condition, again during the concentric portion. Further, significant differences ($p<0.05$) were evident when comparing the different intensities of the Cybex modality to each other and also when comparing to the Cybex intensities to the differing grades of Thera-Band. There were no significant differences ($p<0.05$) between the different grades of Thera-Band, except when comparing Black T-B and Blue T-B to the Green T-B in all variables except peak EMG activation in the concentric portion of the exercise.

Table 5. EMG Related Variables in Flexion for the Thera-Band and Cybex Training Modalities (%MVIC).

	Thera-Band			Cybex			F	p
	Green	Blue	Black	50%	70%	90%		
Peak Concentric	18.0	19.8	20.4	61.6[a,b,c]	78.6[a,b,c,d]	101.1[a,b,c,d,e]	42.7	0.000
Activation	(2.8)	(2.3)	(2.3)	(3.2)	(3.5)	(3.6)		
Peak Eccentric	18.4	24.2[a]	25.6[a]	40.6[a,b,c]	52.4[a,b,c,d]	69.2[a,b,c,d,e]	16.8	0.000
Activation	(1.9)	(1.9)	(2.1)	(2.2)	(2.8)	(3.6)		
Average Concentric	10.6	12.2[a]	13.6[a]	44.9[a,b,c]	58.6[a,b,c,d]	80.9[a,b,c,d,e]	36.2	0.000
Activation	(1.6)	(1.7)	(1.7)	(2.5)	(3.3)	(3.8)		
Average Eccentric	11.1	13.5[a]	13.3[a]	24.4[a,b,c]	38.0[a,b,c,d]	50.2[a,b,c,d,e]	22.8	0.000
Activation	(1.3)	(1.4)	(1.5)	(1.4)	(2.4)	(2.7)		

[a] denotes significantly different when compared to the Green T-B ($p<0.05$)

[b] denotes significantly different when compared to the Blue T-B ($p<0.05$)

[c] denotes significantly different when compared to the Black T-B ($p<0.05$)

[d] denotes significantly different when compared to 50% Cybex ($p<0.05$)

[e] denotes significantly different when compared to 70% Cybex ($p<0.05$)

Figure 6 illustrates the relationship between the three intensities of the Thera-Band modality and the average EMG activation for the entire contraction (the mean of the average concentric and eccentric EMG activation) in addition to the three intensities of the Cybex modality and the average EMG activation for the full contraction in flexion. The correlation coefficient and the line of best fit can be seen for each modality in this figure. There was a strong degree of association evident for both the Thera-Band ($R^2 = 0.91$) and Cybex ($R^2 = 0.99$) modalities. Due to the almost perfect correlation between the Cybex intensities and the related EMG activation, and the large gap between the Black T-B condition and the 50% Cybex condition, the Cybex results were extrapolated to predict the EMG activation from a subject producing a 30% of 3RM contraction. This analysis revealed that a 30% Cybex condition may have produced an average EMG activation of approximately 23% MVIC. The average contraction for the 50% Cybex condition when considered as an average of concentric and eccentric phases of the exercise was approximately 35% MVIC whilst the Black T-B was 13.5% MVIC.

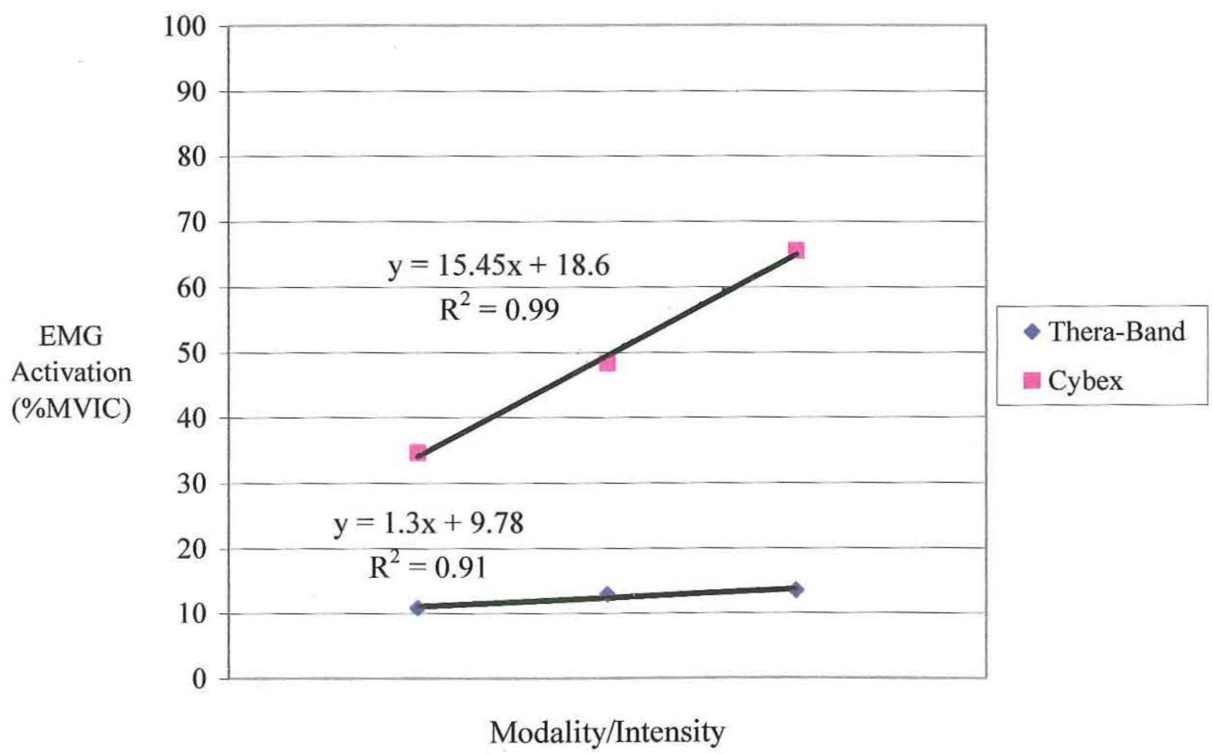

Figure 6. Linear regression of the averaged EMG activations in neck flexion for Thera-Band and Cybex.

4.3 Extension

Table 6 presents data for the peak and average EMG activations for the concentric and eccentric portions of the neck extension exercise using both the Thera-Band and Cybex training modalities. Average EMG activation ranged from 23.0% MVIC using the Green T-B in the eccentric part of the contraction to 94.0% MVIC when completing the 90% Cybex condition in the concentric portion. Peak EMG activation ranged from 34.7% MVIC using the Green T-B in the eccentric portion of the contraction to 112.9% MVIC during the eccentric part. Significant differences ($p<0.05$) were evident when comparing the different intensities of the Cybex modality to each other and also when the Cybex intensities to all grades of the Thera-Band. There were no significant differences ($p<0.05$) between the different colours of T-B, except when comparing Black T-B to Green T-B for both the peak and average EMG activation during the eccentric portion of the exercise.

Table 6. EMG Related Variables in Extension for the Thera-Band and Cybex Training Modalities (%MVIC).

	Thera-Band			Cybex			F	p
	Green	Blue	Black	50%	70%	90%		
Peak Concentric Activation	39.7 (2.9)	40.9 (2.7)	44.0 (2.6)	73.1[a,b,c,d] (3.2)	93.1[a,b,c,d,e] (3.5)	112.9[a,b,c,d,e,f] (4.5)	35.9	0.000
Peak Eccentric Activation	34.7 (2.3)	36.8 (2.0)	38.9[a] (2.1)	59.0[a,b,c,d] (2.9)	80.7[a,b,c,d,e] (3.8)	96.4[a,b,c,d,e,f] (4.2)	39.1	0.000
Average Concentric Activation	33.2 (2.4)	33.8 (2.1)	36.5 (2.3)	59.4[a,b,c,d] (2.5)	79.6[a,b,c,d,e] (3.5)	94.0[a,b,c,d,e,f] (3.7)	47.2	0.000
Average Eccentric Activation	23.0 (1.6)	24.4 (1.3)	27.3[a] (1.7)	38.4[a,b,c,d] (1.7)	51.6[a,b,c,d,e] (2.2)	69.2[a,b,c,d,e,f] (3.0)	48.1	0.000

[a] denotes significantly different when compared to the Green T-B ($p<0.05$)

[b] denotes significantly different when compared to the Blue T-B ($p<0.05$)

[c] denotes significantly different when compared to the Black T-B ($p<0.05$)

[d] denotes significantly different when compared to 50% Cybex ($p<0.05$)

[e] denotes significantly different when compared to 70% Cybex ($p<0.05$)

Figure 7 illustrates the relationship between the three intensities of Thera-Band and Cybex exercises and the average EMG activation in extension. The R^2 values for the Thera-Band and Cybex modalities were 0.93 and 0.99 respectively. Again the almost perfect correlation between the Cybex modality and the EMG activation allowed an investigation of the possible EMG activation in a 30% Cybex condition. The predicted EMG activation from this analysis was approximately 38% MVIC. The average contraction for the 50% Cybex condition when considered as an average of concentric and eccentric phases of the exercise was approximately 49% MVIC whilst the Black T-B was 31.9% MVIC.

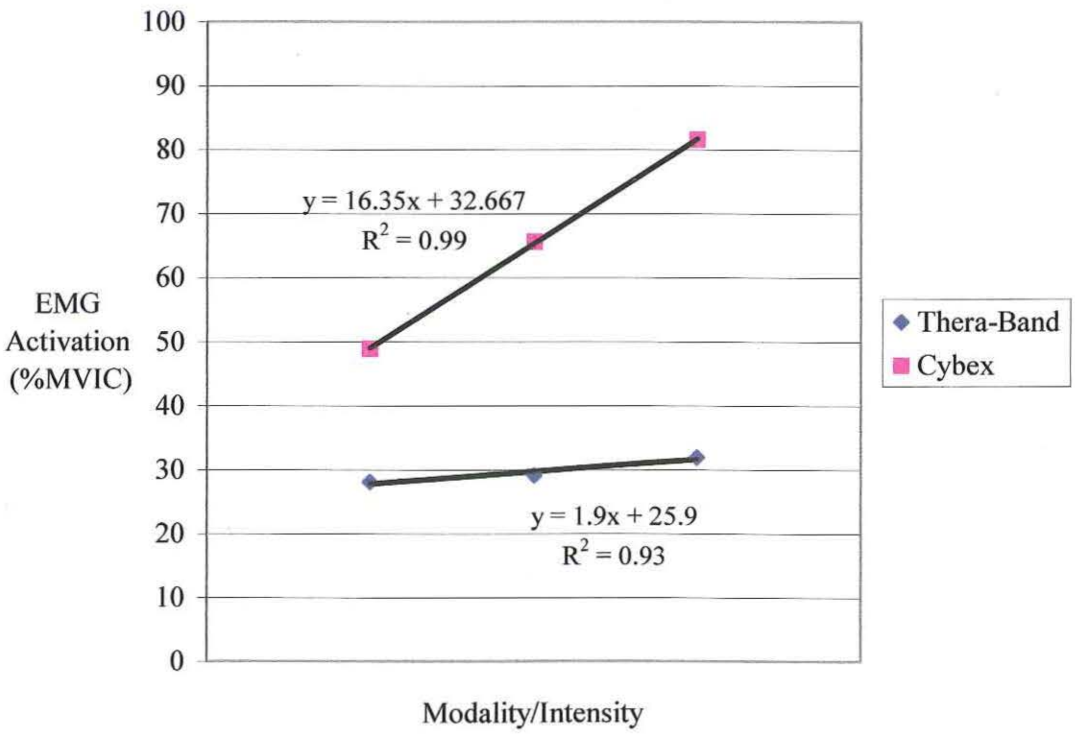

Figure 7. Linear regression of the averaged EMG activations in neck extension for the Thera-Band and Cybex.

4.4 Lateral Bending

Table 7 presents data for the peak and average EMG activations for the concentric and eccentric portions of the neck lateral bending exercise using both the Thera-Band and Cybex modalities. Average EMG activation ranged from 15.7% MVIC using the Green T-B in the eccentric portion of the contraction to 86.2 %MVIC when completing 90% Cybex during the concentric portion. Peak EMG activation ranged from 29.8% MVIC in the eccentric portion of the Green T-B contraction to 104.9% MVIC during the concentric part of the 90% Cybex. There were significant differences (p<0.05) when comparing the majority of different intensities of the Cybex training modality to each other and to the grades of Thera-Band. However, when measuring peak and average EMG activation in the eccentric portion of the exercise, there were no significant differences (p<0.05) between the 70% and 90%, and 70% and 50% 3RM for the peak EMG activation of the Cybex modality. Further, there were no significant differences (p<0.05) between the different grades of Thera-Band.

Table 7. EMG Related Variables in Lateral Bending for the Thera-Band and Cybex Training Modalities (%MVIC).

	Thera-Band			Cybex			F	p
	Green	Blue	Black	50%	70%	90%		
Peak Concentric	30.4	31.7	30.7	63.5[a,b,c]	84.2[a,b,c,d]	104.9[a,b,c,d]	20.6	0.000
Activation	(1.4)	(1.3)	(1.3)	(3.1)	(3.5)	(5.1)		
Peak Eccentric	29.8	36.6	34.4	40.8	61.7[a,b,c,d]	70.9[a,b,c,d]	8.1	0.000
Activation	(1.3)	(1.7)	(2.4)	(2.8)	(2.6)	(3.2)		
Average Concentric	20.7	23.4	23.3	43.9[a,b,c]	68.9[a,b,c,d]	86.2[a,b,c,d,e]	29.6	0.000
Activation	(1.2)	(1.2)	(1.5)	(1.9)	(3.3)	(4.5)		
Average Eccentric	15.7	19.7	20.3	26.5[a]	43.5[a,b,c]	53.2[a,b,c,d]	16.5	0.000
Activation	(0.7)	(0.9)	(1.3)	(1.4)	(1.9)	(3.2)		

[a] denotes significantly different when compared to the Green T-B (p<0.05)

[b] denotes significantly different when compared to the Blue T-B (p<0.05)

[c] denotes significantly different when compared to the Black T-B (p<0.05)

[d] denotes significantly different when compared to 50% Cybex (p<0.05)

[e] denotes significantly different when compared to 70% Cybex (p<0.05)

Figure 8 illustrates the relationship between the three intensities of Thera-Band and Cybex via the average EMG activations in lateral bending. The R^2 value for the Thera-Band was 0.80, whilst the R^2 value for the Cybex modality was 0.98. Extrapolation of the Cybex results to determine the EMG activation using a 30% Cybex revealed that this value would be approximately 24% of MVIC. The average contraction for the 50% Cybex condition when considered as an average of concentric and eccentric phases of the exercise was approximately 35% MVIC whilst the Black T-B was 21.8% MVIC.

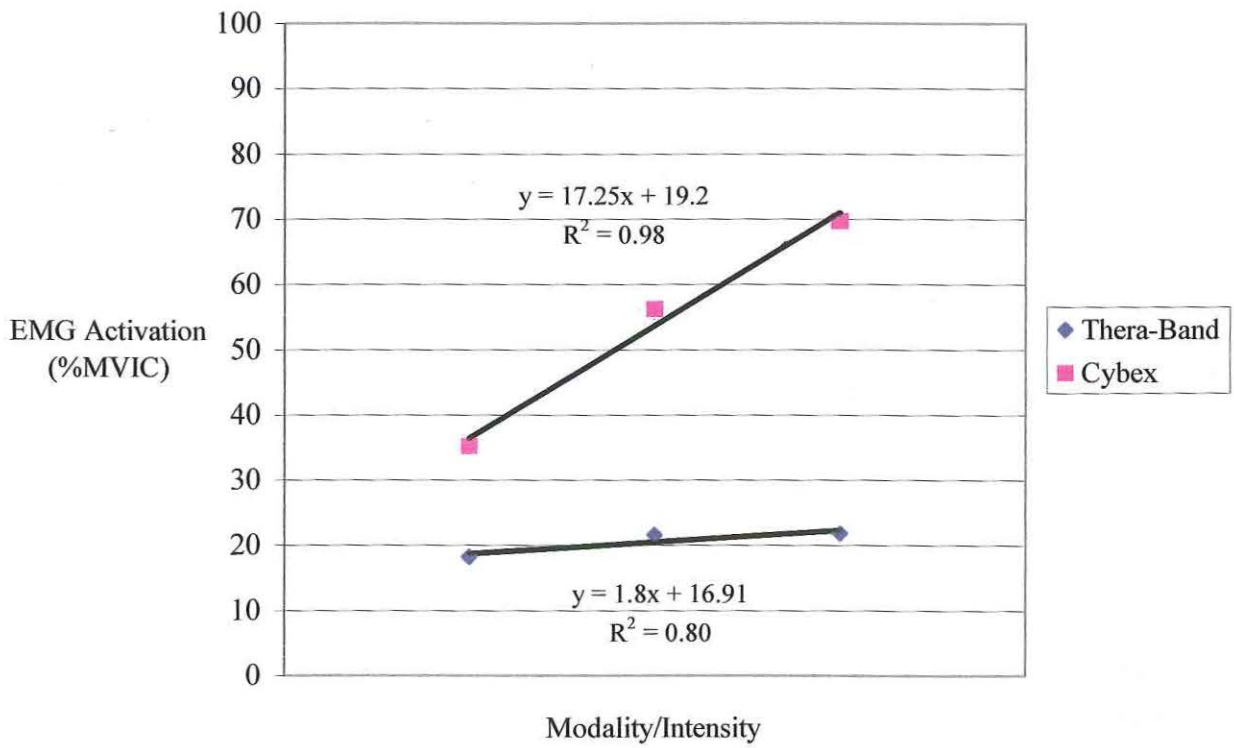

Figure 8. Linear regression of the averaged EMG activations in neck lateral bending for the Thera-Band and Cybex.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Introduction

With the increasing focus on evidence-based practice (Sarig-Bahat, 2003), the quantification of muscle activation during common rehabilitation exercises is an important area of research. This study was designed to examine common neck training modalities and their respective intensities of exercise with the purpose of examining their suitability in the prevention and rehabilitation of neck injuries. In this study only EMG activation of the prime movers was examined therefore, patterns of co-contraction and antagonistic contraction were not considered.

5.2 EMG Activation in Neck Training Modalities

The hypothesis of this study predicted there would be significant differences in EMG activation between training modality and exercise intensity in neck flexion, extension and lateral bending. This study examined these three directions of contraction by investigating peak and average EMG activations over the concentric and eccentric portions of the exercise. All variables showed the same pattern of EMG activation in all three directions over the two exercise modalities. Significant differences were found between the vast majority of Cybex intensities and these intensities were significantly different to the majority of the Thera-Band intensities. However, few differences were found between the Thera-Band intensities. This would lead to the partial rejection of the hypothesis, specifically, there were significant differences between exercise modalities and between intensities for the Cybex, but no significant differences between the intensities for the Thera-Band.

Peak EMG activation reflected the patterns shown in average EMG activation over the intensities for both modalities. Peak EMG activation for the Thera-Band did not exceed 44% MVIC (Black T-B in extension), which would indicate that the exercises utilising the Thera-Band are suitable for clients performing rehabilitation (Hintermeister, Lange, Schultheis, Bey, & Hawkins, 1998). The exercises utilising the Cybex on the other hand recorded peak EMG activity from 40.6% MVIC (50% Cybex in flexion) and up to 112.9% MVIC (90% Cybex in extension), indicating that this exercise may be harmful for post-injury individuals.

Matheson et al. (2001) in a study utilising Thera-Band and free weight exercises in seated quadriceps exercises, found that EMG activation and peak loadings were similar. Although this study and the current study cannot be directly compared due to different muscle groups and EMG processing, subjects performed leg extensions with an ankle weight of 7.9kg and a looped Blue T-B of diameter 32cm. Peak EMG activations in the Thera-Band contractions reached 41.4% MVIC in the concentric portion of the exercise, whilst peak EMG activations for the free weight exercise was 40.5% MVIC, again in the concentric portion. Both these peaks were measured for the vastus lateralis, and were very similar to the peak EMG activations seen for the Blue T-B in the current study of 40.9% MVIC for the concentric portion of neck extension. The peak EMG activations found in the Cybex modality in this study do not compare to those in Matheson and co-workers (2001) study, as they were not designed to match the intensity of the Thera-Band. The authors concluded that Thera-Band was a viable alternative to the use of free weights of a similar resistance.

A study by Patterson et al. (2001) may help to explain the low EMG activations seen in the Thera-band modality in the current study. Their study found that at 50% strain there was less than 10N difference in tensile force between the Green, Blue and Black T-B's. Further, at 100% strain there was only 15N difference between the three grades of tubing. Bearing in mind the EMG-Force relationship it is therefore not surprising that the EMG activation data did not differ between intensities as the resting length of the Thera-band in this study meant that the Thera-band was at a minimum of 50% strain.

5.3 Practical Relevance of Periodisation in Rehabilitation

Periodisation of an exercise program, whether it be elite athletes or in rehabilitation patients, involves manipulating the volume and intensity of the exercise, interspersed with rest periods for the regeneration of the musculature (Kibler & Chandler, 1994). Furthermore, in order to attain a significant improvement in performance, training should follow a cyclic pattern (Matveyev & Zdornykh, 1981). Figure 9 illustrates examples of periodisation, in particular the progressive increase in loading, which could represent either training intensity or volume (shaded columns), and the rest periods (unshaded columns).

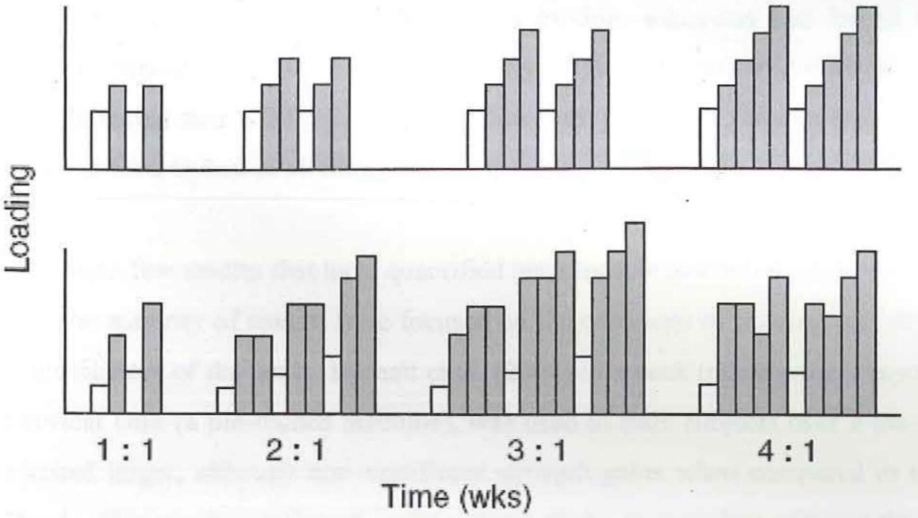

Figure 9. Examples of training cycles (Schmolinsky, 1993).

Periodisation of exercise programs is common in the elite athletic population where optimisation of training time is paramount. In the rehabilitation industry however, training programs are typically not based on well-examined training variables, which may cause hindrance to the rapid progression of the patient in question. An examination of the volume (duration and frequency) of exercise is a relatively straightforward matter. However, quantifying intensity can be more difficult. In this study it was decided to examine two training modalities and intensities; the Cybex at three relative intensities (50%, 70% and 90% of 3RM max), and the Thera-Band, at three absolute intensities (Green, Blue and Black). It is difficult to assess the exact increase in intensity within a training modality (differing loads for the same training modality) and it is particularly difficult to assess decreases/increases in intensity when changing training modalities.

The neck muscles investigated in this study showed a large difference between the Black T-B and 50% Cybex in the four variables that represented EMG activation. These results show that a potential mistake could be made when programming exercise for the patient or worker. For example, a sudden increase in intensity may be provided. The solution to this problem may be twofold. Firstly, the resting length of the Thera-band may be increased prior to the contraction being undertaken (i.e. the resting strain is increased therefore the resistance is increased) or secondly, the percentage of 3RM may be decreased from 50%.

For the Cybex modality in each direction of contraction, the EMG activations increased with an increase in exercise intensity (50%, 70% and 90%) in a linear fashion (flexion R^2=0.99; extension R^2=0.99; lateral bending R^2=0.98). Since there was almost a perfect correlation

between the two variables, the results can be extrapolated to predict EMG activations in a 30% Cybex intensity. This analysis revealed that in flexion, extension and lateral bending the potential EMG activations would be approximately, 23%, 38% and 24% of MVIC respectively. These results reveal that a 30% Cybex condition may provide a suitable bridge between the Black T-B and 50% Cybex in all three directions.

There have been few studies that have quantified neck muscle activation whilst performing neck exercises. The majority of studies have focused on the outcomes of training interventions or the strength imbalances of the neck. Burnett et al. (2004) in a neck training study reported that the Multi Cervical Unit (a pin-loaded machine), was used to train subjects over a ten-week period and it elicited larger, although non-significant strength gains when compared to training with Thera-Band. This result is reflected in the current study, as exercises utilising the Thera-Band showed significantly lower EMG activations than exercises using the Cybex, which would explain the lower training effect experienced by the subjects using the Thera-Band in the study by Burnett and associates. The problem with this study was the fact that none of the exercise intensities had been previously examined, therefore decreasing the chance of achieving significant increase in neck strength.

5.4 Limitations of the Study and Methodological Concerns

There is a risk when using surface electrodes that the signal that is being recorded includes activations other than the muscles being studied (Turker, 1993). This study, rather than monitoring selected muscles, was interested in functional groups defined as the flexors, extensors and lateral benders and corresponded to the anatomical positions of anterolateral, posterolateral and posterior of the neck. This means that if any cross talk did occur, it would be from the muscles in the immediate functional area. Surface electrodes only measure EMG activity from the superficial muscles therefore; the deeper muscles were not examined.

EMG data in this study was normalised using the MVIC method, which whilst has shown to be accurate (Dankaerts et al., 2003; Netto & Burnett, 2004; Ng et al., 2002), does have some inherent problems. It does not take into account the non-linear relationship between muscular activation and force, or the differences in muscle length and contractile velocity (Ng et al., 2002). It was noted that in some of the trials subjects had difficulty in keeping the contraction timing correct, particularly in the 90% Cybex trials. A large number of these trials were discarded. Another problem relating to muscle length was some subject's limited ROM, mostly seen in the lateral bending. The last problem relating to normalisation was the question of subject motivation or unfamiliarity towards a true MVIC. One subject's results were discarded

as EMG activations in excess of 200 %MVIC were recorded. All subjects were free from injury, in addition to receiving verbal encouragement from the investigator and the first MVIC trial from each direction being discarded as suggested by Sommerich et al. (2000). The lack of subject motivation or sub-conscious protection against causing injury may have contributed to the abnormal results produced by this subject.

One point in favour for the normalisation procedures used in this study was the low standard deviations relative to the cell means evident in the results. The weights used in the Cybex modality were normalised to the subject's 3RM and then both the Thera-Band and Cybex EMG activations were normalised to MVIC, making the results relative rather than absolute, which may have contributed towards achieving the low standard deviation values.

CHAPTER SIX

6.0 CONCLUSIONS

6.1 Conclusions

The results of this study revealed that the differing grades of Thera-Band did not produce statistically different increases in muscle activation when compared to one another. However, all three intensities of the Cybex modality displayed significant differences in muscle activation. Furthermore, the Cybex modality showed significantly greater amount of muscle activation when compared to all grades of Thera-Band. Specifically, there was a large difference in EMG activation between the Black T-B and 50% Cybex conditions. From using regression equations generated from the data in this study it was revealed that a 30% Cybex condition may provide a useful "bridge" in intensity between these two conditions. Further research incorporating a 30% Cybex condition is therefore recommended to validate the predicted EMG activations gained from this study.

Results from this study have shown that the use of Thera-Band results in low-level EMG activation and is therefore an ideal mode of exercise to be used in rehabilitation programs. Alternatively, the varying degrees of intensity for the Cybex training modality resulted in significantly higher EMG activations and therefore may not be suitable in rehabilitation. It is suggested that these types of exercises be only used on injury-free neck musculature or on those people that already have increased levels of neck strength. Prehabilitation using the Cybex may be helpful in preventing neck injuries such as those found in high-risk occupations for example, computer and sewing machine operation, dentistry and high performance combat pilots.

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APPENDIX A

INFORMATION FORM

An Electromyographic Comparison of Neck Conditioning Exercises

Summary

The study will investigate the muscle activation in selected neck muscles during two different neck-strengthening modalities. You will be asked to perform two different neck-strengthening training modalities. Eight electrodes (electromyography) will be attached to various sites on your neck. These will measure the muscular activity when you perform the exercises. The entire protocol will take 2.5 hours after a familiarisation session conducted two days prior.

Risk and ethical considerations

As the number of repetitions for each head movement are low, you should not experience any muscle soreness. You will need to be prepared for electromyography by shaving small areas of your neck and slight exfoliation of the skin.

No direct comparisons between different individuals participating in the study will be made at any stage of the testing. Analysis of data will be made on an exercise modality basis, with means and variance between the other exercise modality being compared. You are therefore not in competition with any other individuals in the study and will in no way be made to feel that your results are inadequate or incorrect.

All personal information and test results recorded will remain confidential and will not be used for any purpose other than the current study. Moreover, no data analysis will include your name or information that may identify you specifically as a subject. You will be free to withdraw from this study at any stage and for any reason without prejudice.

Requirements

As the study involves an exercise protocol, it is required that you be healthy at the time of testing. For this reason, you will be asked to complete a medical questionnaire prior to the commencement of testing.

You will also need to wear a tight fitting top with no collar, and no jewellery. Also, shoes with reflective markings on them will need to be removed for the duration of the test.

Should you have any questions relating to any of the information provided above, please feel free to contact me for a further explanation. If you have any concerns about this research, or would just like to speak to an independent person, you may contact Kevin Netto on telephone 9266 3681.

Yours Sincerely,

Jemma Coleman BSc. (Hons candidate)
School of Biomedical and Sports Science, Edith Cowan University
100 Joondalup Drive, Joondalup WA 6027
Phone: 6304 5073 E-mail: jlcolema@ecu.edu.au

Declaration

I ____ have read all of the information contained on this sheet, have completed a medical questionnaire, and have had all questions relating to the study answered to my satisfaction.

I agree to participate in this study realising that I am free to withdraw at any time, for any reason without prejudice.

I agree that the research data obtained from this study may be published, provided I am not identifiable in any way.

I agree to have small areas of my neck shaved with a disposable razor and lightly exfoliated.

Participant ___________________________ Date ___________________

Investigator ___________________________ Date ___________________

MEDICAL QUESTIONNAIRE

The following questionnaire is designed to establish a background of your medical history, and identify any injury and/ or illness that may influence your testing and performance.

Please answer all questions as accurately as possible, and if you are unsure about any thing please ask for clarification. All information provided is strictly confidential.

Personal Details

Name:______________________________ ID number:________________

Date of Birth (D/M/Y):________________

Medical History

Have you ever had, or do you currently have any of the following?

If Yes, please provide details

Do you have or have you had any neck or shoulder pain? Y N

____

Have you recently injured your neck or shoulders? Y N

____

Do you have a history of dizziness or fainting? Y N

____

Do you have an irregular heartbeat? Y N

____

Have you suffered a severe headache that was aggravated by straining? Y N

____

Are you at risk of carotid or coronary artery disease? Y N

____

Do you have high blood pressure? Y N

____

Do you suffer from limited pulmonary function? Y N

____

Is there any other condition not previously mentioned which may affect your participation in this study? Y N

____

Lifestyle Habits

Do you exercise regularly? If YES, what do you do? Y N

____

How many hours per week?

____

Do you smoke tobacco? If YES, how much per day? Y N

____

Do you consume alcohol? If YES, how much per week? Y N

____

Declaration

I acknowledge that the information provided on this form, is to the best of my knowledge, a true and accurate indication of my current state of health.

Name:______________________ Date:____________

Signature:____________________