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A comparison of training methods to increase neck muscle strength [thesis]

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A COMPARISON OF TRAINING METHODS TO INCREASE NECK MUSCLE STRENGTH

by

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USE OF THESIS

ABSTRACT

The purpose of this study was to determine if increases in isometric cervical muscle strength and range of movement (ROM) generated from ten weeks of training on the Multi-cervical unit (MCU) is significantly greater than the increase gained by training with the dynaband. The high rate of neck injury in the Air Force from pilots exposed to high +Gz force has instigated this research. 32 healthy subjects were split into three groups, with one group as the control, one group training on the MCU and one group training on the dynaband. Training groups completed ten weeks of resistance training in their specified mode. Pre and post testing was performed on the MCU to measure changes in isometric strength and ROM. Comparisons were made using a one way ANOVA ($p<0.05$) with Scheffe post-hoc comparisons. The MCU group displayed the greatest increase in isometric strength with increases in flexion of 64.4%, extension 62.9%, left lateral flexion 53.3% and right lateral flexion 49.1%, but differences were only statistically significant from the control group. The increases seen from the dynaband group were somewhat lower, flexion 42.0%, extension 29.9%, left lateral flexion 26.7% and right lateral flexion 24.1%. Power calculations revealed small subject numbers prevent a significance being found between the two training groups. Additionally the MCU group displayed the only significant change in ROM, right side lateral flexion increase of 32.3%. This study proves the efficacy of the training methods to increase isometric cervical muscle strength and highlights the fact that strengthening programs need to be integrated into the training programs of people exposed to high +Gz forces.

DECLARATION

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

(i) *incorporate without acknowledgement 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.*

Signature:

Date: 2/7/02

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Symptoms of neck disorders are becoming more prominent in Western countries with neck complaints being reported as one of the major causes for long-term sick leave (Berg, Berggren & Tesch, 1994; Highland, Dreisinger & Russell, 1992). Individuals exposed to the extreme positive acceleration forces produced by current high performance aircraft are also at substantial risk of injury, which is a major concern in aviation medicine (Hamalainen & Vanharanta, 1992; Oksa, Hamalainen, Rissanen, Myllyniemi & Kuronen, 1996). A pilot's neck can be required to cope with gravitational forces of up to nine times that of gravity (+9Gz) and usually whilst moving their heads to look around the cockpit and over their shoulders. Since pilots require their neck's to be mobile and have full range of cervical movement the use of a neck brace, effective enough to eliminate injury, would be too restrictive.

Clinical cases of spondylosis and spondylarthrosis have been revealed on X-rays from numerous pilots who have reported acute in-flight neck pain. (Hamalainen, Toivakka-Hamalainen & Kuronen, 1999). Concurrent analysis with magnetic resonance imaging (MRI) also revealed narrowing of the cervical disc spaces. These radiological signs have been linked to restricted and painful range of motion and also pose a major threat to a pilots health since cervical spinal stenosis left untreated can exclude them from safely returning to normal flying status (Hamalainen et al., 1999).

The above neck injuries are a frequent problem among fighter pilots of high performance aircraft. Eighty-five percent of F/A-18 pilots in the Royal Australian Air Force (RAAF) have reported experiencing acute G-induced neck pain during their career (Newman, 1997). Similarly 85% of pilots in the U.S. Air Force had experienced at least one acute neck pain episode during their career with the yearly prevalence of neck pain for all pilots being 56.6% (Albano & Stanford, 1998). This is a markedly higher incidence than the 5.7 to 16.6% yearly prevalence of neck pain for men in the general population (Oksa et al., 1996).

Furthermore, as Leggett, Graves, Pollock, Shank, Carpenter, Holmes, & Fulton (1991) state, numerous articles in the athletic training and coaching literature refer to the importance of strengthening the neck musculature to reduce the risk of injury however, the field of aviation and aerospace medicine seem to be neglecting this area as Newman (1997) found that only 23% of RAAF pilots performed any specific neck strengthening exercises.

It is the sustained high positive Gz forces that these aircraft are capable of that increases the potential for pilots to sustain an injury. The link between occurrence of injury and the high level of gravitational forces that the pilots of these aircraft are exposed to has come under inquiry. Hamalainen and Vanharanta (1992) have found as sustained +Gz force increases, strain on the cervical erector spinae increases. At +4Gz muscular strain was 2.4 times that at +1Gz level flight and under +7Gz was 5.9 times as high. Additionally another documented cause of neck pain was seen to

be the length of the individual pilots accumulated fight time. An increase in flight time increased the opportunity to sustain an injury and more injuries could be expected (Albano & Stanford, 1998). The low participant rates in cervical muscle exercise coupled with the high risk of injury during +Gz flight means that neck injuries will be more likely and loss of workdays and +Gz restricted flights will increase unless methods to increase +Gz-tolerance are found and instigated.

Clinical research on strength training of the cervical muscles has been proven as an effective way to increase neck strength and decrease perceived pain (Berg et al., 1994; Jordan, Mehlsen, Bulow, Ostergaard & Danneskiold-Samsoe, 1992; Leggett, et al., 1991). Several articles (Albano et al., 1998; Hamalainen et al., 1998) have extrapolated the results from these types of studies to aviation medicine for preventative strategies for in-flight neck pain in pilots. The lack of research however, prohibits an effective training program and training mode to be identified for effective use. This was the impetus for the current study. Current physiotherapy rehabilitation programs are using a machine called the Multi-Cervical Unit (MCU), which can accommodate specific cervical movement patterns to train for recovery from such injuries as whiplash. The objective of these programs is to utilize a resistance-training program to see the patients level of neck strength return to normal functioning. It will be valuable to determine if these programs could be adapted to carry healthy subjects to a stronger level of functioning and at the same time not impinge on their cervical flexibility, since some research indicates that combining different forms of training on the same musculature could possible limit performance in both areas (Schmitt, Pelham &

Holt, 1998). Additionally there is the notion that strength training may restrict the development and maintenance of flexibility (Greippe, 1985). The MCU can quantify isometric cervical muscle strength and range of movement (ROM).

To accompany the MCU the Nexerciser protocol was developed to provide patients with a cheaper more convenient method to continue their rehabilitation by using dynabands as resistance against muscle contraction. The Nexerciser is currently one of the only methods designed to specifically strengthen the muscles of the neck. It allows the participant to exercise in both a concentric and eccentric manner against resistance and through range of movement. It consists of a length of flexible rubber tubing (dyna-band), which is available in four different colours representing different resistances. This is attached at one end to a doorframe or stationary object and at the other the head brace which consists of a padded head strap, adjustable in size by a Velcro strip. This method of training is being used in physiotherapy rehabilitation for neck injuries in conjunction with the MCU treatment so patients can continue their recovery. This makes rehabilitation more affordable since the dynaband can be purchased relatively cheaply and used anywhere since it is portable and lightweight.

The Nexerciser was developed from other physiotherapy protocols that use dynaband to provide resistance for training a muscle group and is a relatively new method for training the neck. This study will attempt to validate its use as an effective way to train the cervical musculature.

1.2 Significance of the Study

Studies to date have identified that there is a high prevalence of neck injury in pilots (Albano et al., 1998; Hamalainen et al., 1992; Hoek van Dijke, G.A., Snijders, C.J., Roosch, E.R., & Burgers, P.I., 1993) and that specific cervical muscle exercises can increase strength, range of movement (ROM) and decrease pain (Berg et al., 1994; Hamalainen et al., 1998; Highland et al., 1992; Jordan et al., 1992; Leggett et al., 1991) but little exists about structured training programs and what type of intervention is most effective.

The results from a study that identifies an effective mode of training and a program that elicits a substantial increase in cervical muscle strength will aid professionals involved in exercise prescription to select appropriate training methods for pilots to prevent neck injuries by increasing pilots baseline isometric strength and endurance levels. The results could also be used to help athletes in sports where neck injuries may occur or where neck strength is integral to the sport, such as Rugby or Soccer and aid in the best provision of rehabilitation of neck strength in clinical patients.

The selection and use of the MCU and Dynaband modalities in this study reflect their current use in rehabilitation programs and their specificity to training for the neck. Additionally, the expense of both modalities is vastly different. The cost of the MCU hardware and software is around AU$70,000 with physiotherapy appointments being $30 per session. Whilst each Dynaband set would cost AU$80, is portable and can be operated anywhere.

1.3 Purpose of the Study

The purpose of this study is to determine if increases in isometric cervical muscle strength and ROM generated from ten weeks of training on the MCU is significantly greater than the increase gained by training with the Dynaband. Thus, this study will endeavour to answer these key research questions

i) Does training on the Multi-Cervical Unit elicit greater changes in isometric cervical muscle strength than training with Dynaband?

ii) Does the training protocol impinge on the subjects' ability to retain full range of cervical movement?

This will help determine whether the MCU's efficacy outweighs the Dynabands cost effectiveness and portability.

1.4 Hypotheses

The hypotheses for the study

i) Greater isometric strength increases will be seen in cervical flexion, extension and lateral flexion with those subjects training on the Multi-Cervical-Unit as opposed to the dynaband.

ii) ROM will increase in both the MCU and dynaband training groups.

CHAPTER TWO

2.0 REVIEW OF LITERATURE

2.1 The Clinical Relationship Between Cervical Musculature Training and Strength, ROM and Pain.

There has been a few studies conducted on healthy subjects and patients with degenerated or herniated discs, or cervical muscle strain, to determine if cervical musculature training can increase strength and ROM of neck muscles whilst decreasing perceived pain (Berg et al., 1994; Maeda, A., Nakashima, T., & Shibayama, 1994; Highland et al., 1992; Leggett et al., 1991). In these studies subjects commonly performed eight to ten weeks of training, one to two times per week executing extension, flexion and occasionally rotation exercises.

Maeda et al. (1994) found highly significant gains in isometric strength of the cervical musculature in just eight weeks. These researchers observed the effect of concentric and eccentric training on the strength of cervical muscle. Even though they did not find any significant differences between the concentric and eccentric training groups they did find significant ($p<0.001$) increases in isometric strength, of 37.8% and 39.6% respectively.

Berg et al. (1994) examined 17 women laundry workers who suffered from cervical muscle disorders. They showed that 12 minutes of specific neck-strengthening exercise twice weekly for eight weeks significantly increased muscular strength and brought about a reduction in perceived neck pain. It is postulated that the changes in strength and perceived pain are inter-related, though the exact mechanism of this

relationship has not been identified. Nevertheless, these results are supported by other similar studies. Highland et al. (1992) used 90 patients with degenerated disc (n=6), herniated disc (n=4) and cervical strain (n=70), who participated in an eight-week strength training rehabilitation program on a MedX Cervical Extension Machine (MedX Corp., Ocala, Fl). They found that all groups showed significant increases in strength and range of movement along with the decrease in perceived pain.

Only one study by Highland et al. (1992) found patients who did not make a recovery back to normal functioning as determined by returning to work. Highland and co-workers explained this by citing that these patients had similar absolute gains to all other groups but were initially much weaker and therefore did not reach a satisfactory healthy level at the end of training.

Similarly Greenwood and DeNardis (2000) found highly significant improvements in strength and range of movement using the MCU. The subjects of Greenwood's study were patients at the Melbourne Whiplash Centre participating in rehabilitation on the MCU. All had experienced some sort of accident that required clinical treatment. As a group the subjects experienced percentage increases of 69.7 - 71.0% in strength and 12.6 - 23.7% in ROM.

Leggett et al. (1991) measured isometric cervical extension strength over ten weeks of dynamic variable resistance cervical extension training. Increases in isometric strength ranged from 6.3% to 14.3%, which were lower than other studies on neck

strength (Greenwood & DeNardis, 2000; Maeda et al., 1994). However, Leggett et al. (1991) only provided a frequency of training of one day per week, which may not be enough of a stimulus for optimal improvements (McArdle, Katch & Katch, 1996).

All these studies conduce that good results can be achieved if an optimal amount of training and frequency is selected. The challenge is whether these types of programs can be successfully adapted to obtain similar results from healthy subjects.

2.2 Importance of Flexibility During Strength Training.

In the course of all exercise prescription the resultant performance factors need to be reviewed. That is to say consideration to what the final outcome one will want as a result of training will need to be incorporated into the training programs. This is well documented in studies comparing training designed to develop such things and muscular endurance versus muscular power and many other athletic combinations. These types of studies will show that combining different forms of training on the same musculature can limit performance.

Results from a study by Schmitt et al. (1998) indicate that athletes combining flexibility and resistance training however can gain in both areas. They demonstrated that soccer players combining both flexibility and strength training observed gains in flexibility no different than those isolated to flexibility training only.

Schmitt et al. (1998) points out a study by Greippe (1985) who in his research paper on swimmers shoulder found that swimmers doing high intensity resistance training experienced more pain during a flexibility test and those who experienced more pain were less flexible than those who experienced no pain. This study may point out that strength training may restrict the development and maintenance of flexibility yet is unsubstantiated in his study.

Another study by Wang, Whitney, Burdett & Janosky, (1993) found posterior muscle tightness in the lower extremities in long distance runners when compared to non-runners and correlated this with their involvement with running. These studies highlight the need to assess range of movement throughout the undertaking of resistance or high intensity training.

2.3 Comparison of Training Methods and Isometric Cervical Muscle Strength.

Studies identifying the positive effects of resistance training are readily available. Many have quantified the amount of strength increase in pretest, posttest research designs similar to studies by Welch and Rutherford (1996) on the effects of two isometric training protocols on quadriceps strength. They found 9.1 % – 11.3 % increases in quadriceps strength in over 55 year olds. Klinge, Magnusson, Simonsen, Aagaard, Klausen and Kjaeron (1997) elicited a 43% increases in isometric strength of the hamstrings after 13 weeks of training with 12 of their subjects.

More have even compared protocols such as Moss, Refsnes, Abildgaad, Nicolaysen, and Jensen (1997) who found a statistically significant difference between training groups training three times per week using 90% RM for 2 reps to a group training 15% RM for 10 reps.

DeMichele, Pollock, Graves, Foster, Carpenter, Garzarella, Brechue, and Fulton (1997) compared training once a week, twice a week and three times per week to a no training control group for increase in isometric torso strength throughout rotation. They found training two and three times a week elicited significantly greater increases in strength than training once a week but found no extra benefit in training three times per week when compared to two.

Many of these types of studies have transpired from what Morrissey, Harman, and Johnson (1995) call a considerable demand for information on the effectiveness of various resistance exercises for increasing physical performance, and whilst there is much research in this area the amount of literature directly related to strength training for the cervical musculature is limited. Some studies have endeavored to cover this area of research.

Conley, Stone, Nimmons & Dudley (1997) conducted research on human cervical neuromuscular adaptation to 12 weeks of resistance training using three groups: a control group; conventional whole body resistance training; and conventional plus a weighted head extension exercise. The conventional exercises consisted of 3 sets of 10 repetitions for parallel squats push press, bench press and crunches on Sunday

and Wednesdays, pulls from mid-thigh, shrugs, Romanian dead lifts, bent rows on Monday and Thursdays. The weighted head extension exercise used a head harness that provided gravity dependant resistance (Conley et al., 1997). Results from this study found that only the weighted head extension exercise group demonstrated a training effect suggesting that specific cervical exercise was required to establish a neuromuscular adaptation.

As in any type of physical training the rule of specificity states that the more specific the exercise the more direct and positive the results will be. Studies such as that by Conley and associates (1997) proved that neuromuscular adaptations to training require specific cervical exercise. So with the introduction of a specific cervical muscle exercise machine to the field of rehabilitation, Hamilainen and Vanharanta, (1992) and Highland et al. (1992) conducted studies to determine if specific cervical exercise was safe to perform on clinical patients. Not only did these studies find it a safe and reliable method, but also for sufficient stimulation of the cervical musculature and thus successful rehabilitation, training requires a considerable resistance to be applied during each exercise. Thus, for a significant training effect to occur it can be assumed that training needs to be speci : and sufficient resistance needs to be applied in a manner that produces progressive overload.

2.4 Reliability of the MCU

The MCU is currently being used in rehabilitation centres to treat patients with cervical muscle disorders or injury pertaining from such accidents as whiplash. It has the ability to restrain the body and isolate the cervical musculature during exercise. Furthermore, it has the ability to provide resistance during exercise for all angles of movement. Literature written on the reliability of the MCU has proven it has an excellent inter and intra-observer reliability (Greenwood, 2000).

Greenwood's study examined 26 subjects with no neck problems who were assessed using the Melbourne Protocol on the Hanoun MCU by three therapists in turn with five minutes rest between each. Two test days for each subject were taken exactly one week apart. Systematic differences between therapists were low, indicating a good degree of agreement between therapists, also the order of testing had no significant effect on measurement. However, Greenwood highlighted the importance of having trained and experienced therapists who adhered to the testing protocol. Correlations and ICC's between the therapist's scores were all high (approaching 1.0) and standard errors of measurements (SEM) were low representing good inter-observer reliability. For test-retest reliability no significant differences were found over time. Minimum detectable change (MDC) show that it is able to detect meaningful clinical change, i.e. the therapist can be 90% confident that increases in measurements of >10 degrees indicate genuine gains in ROM and are not a chance occurrence. Similarly strength gains of 4 lbs for flexion and 10 lbs for extension allow for 90% confidence in concluding that there has been a strength gain. (Keating, DeNardis & Bedlington, 2000)

A similar machine to the Hanoun MCU is the MedX (Ocala, FL) used by Leggett et al. (1991). Leggett evaluated the reliability and variability of repeated measurements on this unit over four separate testing days. The results showed that isometric measurements of cervical extension strength are highly reliable and associated with low variability. Jordan et al. (1992) used a Neck Exercise Unit (Follo, Norway) and a reliability study undertaken over three separate days to reveal good intra- and inter-day reliability with correlation coefficients and ICC's for isometric strength extension of 0.96, 0.90, 0.94 and 0.92, respectively. These validation studies demonstrate these cervical exercise units are effective measures of test, re-test values.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Subjects

Thirty-six male subjects agreed to participate after receiving oral and written information of the details of the study. Subjects needed to be free of prior cervical injury including whiplash, neurological impairment or neck pain lasting for more than seven days. Additional exclusion criteria included subjects who suffer from headaches or migraines or muscular disorders that may be aggravated by exercise. The use of a health questionnaire aided in the collection of height and weight details and the identification of any prior injuries that would indicate exclusion from the study (Appendix A). Subjects were divided into three groups of 12 best matched by their pre-strength values however, consideration to their ability to travel to the different training venues for the different groups had to be accounted for. The groups were named as follows: -

i) MCU training group

ii) dynaband training group

iii) no training control group

Three subjects, two from the dynaband group and one from the control group, failed to complete the training due to personal reasons. One other subject from the dynaband group had to discontinue training after five weeks due to an unrelated injury, which prevented him from attending the training sessions.

The anthropometric data for the final cohort of subjects who completed all ten weeks of training and the post-training test is displayed in Table 1.

Table 1: Anthropometric Data (mean(SD)) for The Three Training Groups.

	MCU (n=12)	Dynaband (n=9)	Control (n=11)
Age (yr)	23.3 (4.0)	21.7 (3.1)	22.6 (4.4)
Height (cm)	182.1 (4.0)	181.3 (7.2)	181.6 (4.3)
Mass (kg)	78.8 (13.2)	75.8 (13.6)	76.4 (7.3)

Application to undertake research involving human subjects was cleared by the Edith Cowan University Committee for the Conduct of Ethical Research. Written consent was collected from all subjects prior to testing (Appendix B).

3.2 Training Equipment

The MCU (Figure 1) was located at the Lifecare Whiplash Centre of Western Australia. Physiotherapists at the Centre can assess a patient's cervical function on the machine and also treat them by using the MCU as a rehabilitation training tool. The MCU is designed to incorporate 180 degrees of rotation and a full range of lateral flexion and extension. For movement specificity the head brace has a 35-degree angle tilt and horizontal plane movement allowing the unit to accommodate training in dynamic multi-axis direction training. This study only utilised movements for neutral position forward flexion, left and right lateral flexion from neutral and backwards extension also from neutral. All movements travelled through the subject's range of motion. The MCU also has the ability to record angle specific maximum voluntary isometric contraction.

Figure 1: The Hanoun Multi Cervical Unit

The dynaband training group used the Nexerciser head brace as originally designed at the Western Australian Whiplash Centre to provide patients with a more convenient and cheaper method of rehabilitation from injury. Start and contraction positions can be seen in Figure 2, Figure 3 and Figure 4 for flexion, extension and lateral flexion respectively. The ability to change the dynaband density makes it useful to provide progressive overload in training. Training with the dynaband took place on the Edith Cowan University campus. An adjustable soft padded head strap is secured around the subjects' forehead and is attached to a length of flexible dynaband 70 cm long. The dynaband is securely attached to a stationary object at its extremity.

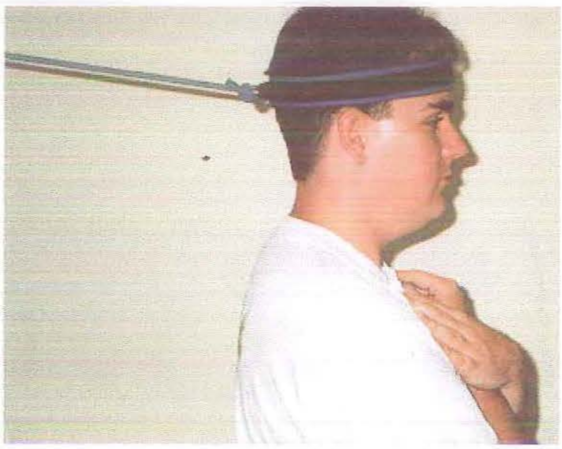

Figure 2: Flexion with the Dynaband.

Figure 3: Extension with the Dynaband.

Figure 4: Lateral Flexion with the Dynaband.

3.3 Testing Procedure

Prior to recording test values all subjects were able to familiarize themselves with the testing procedure on the MCU. Practice measures were taken to establish reliable strength values (a covariance of less than 15%) in the aim to eliminate over estimation of training induced strength gains.

The baseline test for all subjects was conducted on the MCU. It recorded range of movement (ROM) for flexion, extension and left and right lateral flexion (Figure 5, Figure 6 & Figure 7). Subjects were seated in the machine's chair and restricted with two seatbelt harnesses in order to isolate the cervical musculature and negate the use of torso strength. Seat height was electronically adjusted so that the padded head brace was positioned correctly. Once the head brace is fastened firmly to the subject's crown, movement of the head activates the pulley system to record range of movement on the attached computer software. The average of the three peak values for ROM became the variable.

Maximal cervical isometric strength was recorded by placing a force transducer in the head brace (Figure 8). Each measurement aimed to establish an isometric strength value by instructing the subject to apply force after hearing a prompt. This force was then held for three seconds before relaxing. Each measurement was repeated three times with a ten second-rest period between contractions. The average of the three trials became the main variable. Again a covariance of less than 15% was employed. A post-training test was conducted in the same manner between 72 and 96 hours after the last training session had concluded, therefore subjects were fully recovered from their last training session.

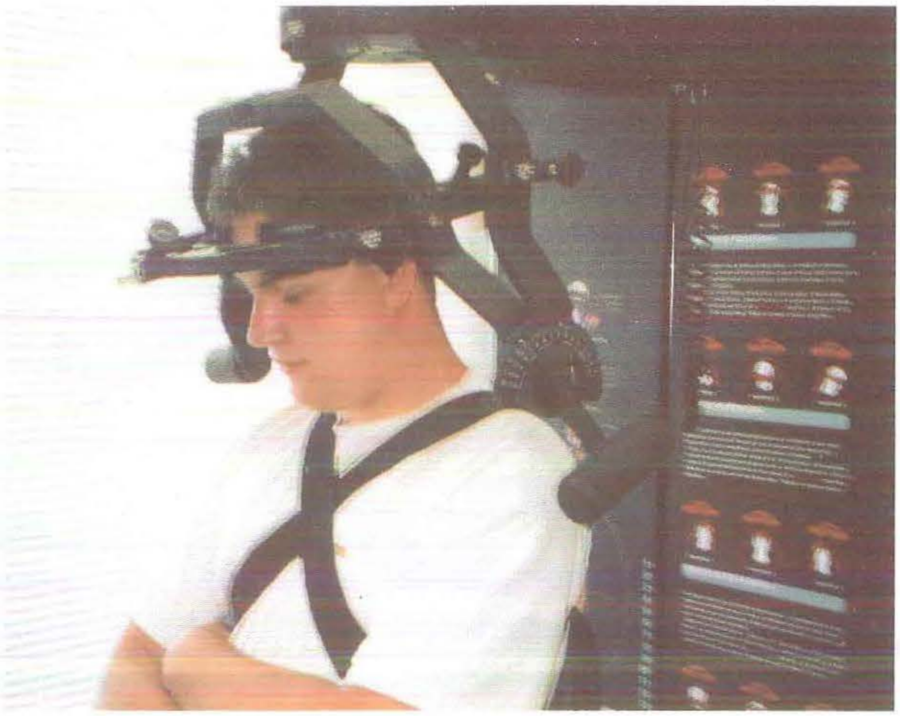

Figure 5: Flexion on the MCU.

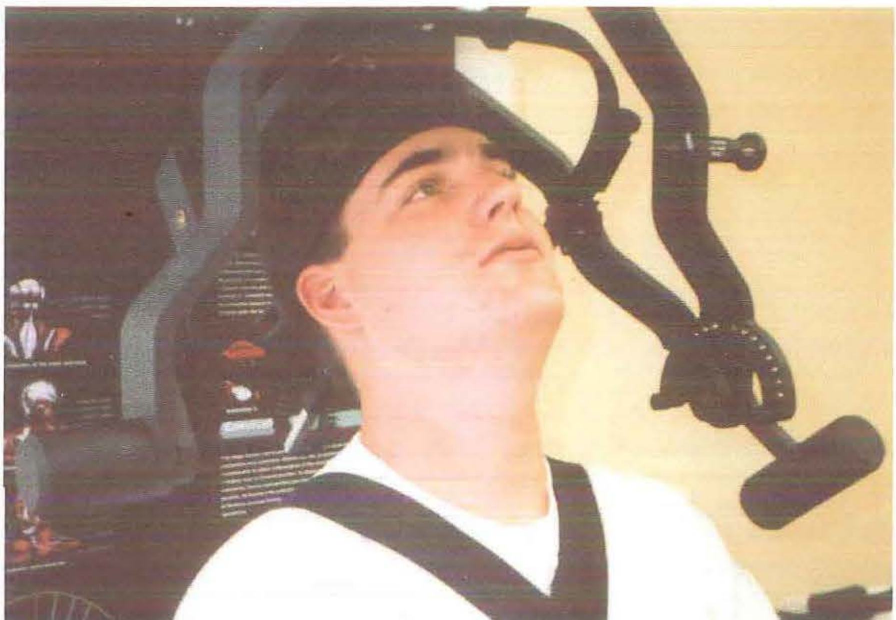

Figure 6: Extension on the MCU.

Figure 7: Lateral Flexion on the MCU.

Figure 8: Isometric Testing for Neutral Flexion using the Force Plate.

3.4 Training Procedures

Each group performed ten weeks of resistance training in their specified mode comprising two sessions per week, for approximately 30 minutes per session. This included 15 minutes for warm-up and cool down and 15 minutes for training in the subject's specified mode. For both groups warm-up consisted of active range of motion for flexion, extension, lateral flexion (left/right) and rotation (left/right), followed by stretches for the equivalent areas (Appendix C).

The number of sets and repetitions for exercises remained constant between the two training groups. Each set commenced one minute fifteen seconds after the previous had commenced and the speed of both eccentric and concentric phases remained constant during the ten weeks with a count of -one-two- for contraction and -three-four- for the eccentric phase. Subjects completed two or three sets of ten repetitions for each exercise depending on the weekly progression displayed in Table 2.

3.4.1 MCU training

MCU training commenced with light loads for all subjects since everyday life does not activate the neck muscles as fully as the MCU does. Generally, all subjects increased exercise intensity by one plate on the machine's pin loaded weight stack every session (Table 2). Towards the last weeks of training this progression proved to be too difficult so the workout was increased to three sets per exercise for one week before progressing again in weight.

3.4.2 Dynaband training

Training with the dynaband commenced with the red dynaband at two sets of ten repetitions. The red dynaband was used to provide light resistance whilst the subjects learned the movements. This was level 1: 70cm red dynaband. Level two was the 70cm green dynaband, level three the 70cm blue dynaband, level four used the 55cm blue dynaband, level five used the 70cm black and level six the 55cm black dynaband. Table 2 displays the week-by-week progression for the training groups.

Table 2: MCU & Dynaband Weekly Progressions for Training Intensity

Week	Sets	Reps	MCU %max	Dynaband Level
1	2	10	24	1
2	2	10	33	2
3	3	10	46	2
4	2	10	60	3
5	3	10	74	3
6	2	10	88	4
7	3	10	96	4
8	2	10	102	5
9	3	10	106	5
10	3	10	114	6

3.5 Statistical Analysis

Statistical analysis was performed using SPSS version 10.0 for Windows. Firstly, a one-way ANOVA was performed to determine if pre-training cervical isometric strength differed between the groups.

Difference in isometric strength and ROM changes between the three groups (i.e. MCU, Dynaband & Control) from pre to post training were then analysed using a one way ANOVA. The accepted level of significance was set at $p < 0.05$. Scheffe post-hoc comparisons were performed to identify which groups the differences occurred between. Since the study could only accommodate small subject numbers power calculations were performed on the MCU and Dynaband groups. An Independent-samples t-test was completed between these two groups with specific note of the t value so the effect size (d) could be given by

$$d = \frac{2t}{\sqrt{df}}$$

By rearranging the above formula and using a table of critical values for t distribution (Appendix D) the degrees of freedom could be calculated by

$$df = \left(2\text{x}\left(\frac{t_{crit}}{d}\right)\right)^2$$

To acquire the difference between the means of the MCU group and Dynaband group that would have revealed a statistically significant change the following formula was used:

$$\triangle \text{M} = \sigma \times t_{crit}$$

CHAPTER FOUR

4.0 RESULTS

4.1 Isometric Strength

Statistical analysis found no difference ($p>0.05$) between any group for pre-training cervical isometric strength. Means for average isometric strength differences between post-training and pre-training are presented in Table 3 along with the corresponding standard deviations. Raw results for means of all subjects and the percentage increases between pre and post-tests are shown in Table 4.

Table 3 shows the control group displayed minimal increase in isometric strength as would be expected. Changes in strength in this group was limited to 2.4 lbs which is less than Greenwood & DeNardis (2000) Minimum Detectible Change (MDC) criteria of 4 lbs for flexion movements and 10 lbs for extension. Table 3 also illustrates that there was a statistically significant change ($p<0.05$) in isometric flexion strength for both the MCU group (8.6 lbs) and Dynaband group (7.1 lbs) when compared to the control group. These increases were on average 64.4 % for the MCU group and 42.0 % for the Dynaband group (Table 4). The MCU group also exhibited significant ($p<0.05$) mean increases in strength for extension and left lateral flexion of 62.9 % and 53.3 % respectively. Improvements from the MCU group were between 22.4 % and 33.0 % greater than those found on the Dynaband however, were not statistically different.

With the help of Cohen's (1977) effect size conventions for what he categorized as 'small' (0.20), 'medium' (0.50) and 'large' (0.80) effects, the d index for extension strength in the MCU group is perceived as a large effect (Table 3). The effect size for flexion movements reflect medium effect sizes (Table 3).

Table 3: Mean(SD) Isometric Strength Differences Between Post-Training and Pre-Training for Training and Control Groups.

VARIABLE (lbs)	MCU (n=12)	DYNABAND (n=9)	*d*	CONTROL (n=11)	p value
Flexion	8.6 (3.3) *	7.1 (4.3) *	0.43	2.1 (3.9)	0.001
Extension	12.3 (8.8) *	6.1 (6.8)	0.80	0.2 (6.2)	0.002
Left Lateral Flexion	8.7 (7.2) *	4.6 (5.0)	0.68	1.9 (5.1)	0.034
Right Lateral Flexion	7.9 (7.5)	4.4 (5.1)	0.55	2.4 (4.8)	0.111

* denotes significantly different (**$p<0.05$**) when compared to control group

Table 4: Percentage Increases(SD) for Raw Data of Average Isometric Strength from Pre-Training to Post-Training for Training & Control Groups.

VARIABLE (lbs)	MCU (n=12)			DYNABAND (n=9)			CONTROL (n=11)		
	Pre	Post	Increase	Pre	Post	Increase	Pre	Post	Increase
Flexion	13.4 (6.8)	22.0 (9.2)	64.4 %	16.9 (8.1)	23.9 (8.1)	42.0 %	16.9 (7.9)	19.0 (8.8)	12.6 %
Extension	19.5 (7.3)	31.8 (10.3)	62.9 %	20.5 (7.8)	26.6 (9.0)	29.9 %	24.0 (12.0)	24.2 (12.7)	0.7 %
Left Lateral Flexion	16.3 (6.9)	25.0 (9.5)	53.3 %	17.1 (6.6)	21.6 (6.0)	26.7 %	17.1 (5.8)	19.0 (9.2)	11.1 %
Right Lateral Flexion	16.0 (7.5)	23.8 (7.4)	49.1 %	18.2 (5.8)	22.6 (7.6)	24.1 %	17.7 (7.1)	20.1 (9.1)	13.6 %

4.2 Range of Movement

Means and SD's for average range of movement differences between post-training and pre-training and pre/post percentage increases are presented in Tables 5 and 6.

Table 5 shows no statistically significant change in ROM for extension or left side lateral flexion in all groups. However, the table does show that flexion for the MCU group and Dynaband group were significantly different to the control group. This change is not indicative of a gain in ROM from the training groups but rather a decrease in ROM from the control group of 10.7 degrees. This could be attributed to the fact that all the control subjects were students who at the time of the post test were in their two week study break before final exams and thus were more than likely sitting looking down over books for long periods of time thus causing some tightness in the posterior neck muscles consequently making it hard to perform the flexion movement. The only significant increase in ROM came from the MCU group for right side lateral flexion (Table 5).

All groups demonstrated an imbalance in pre-training values for left to right side lateral flexion ROM with tightness to the right side (Table 6). The MCU group was the only group to improve equilibrium between left and right sides during the ten weeks of training by increasing their mean right lateral flexion ROM by 32.3 % (Table 6).

Table 5: Mean(SD) Range of Movement Differences Between Post-Training and Pre-Training for Training and Control Groups.

VARIABLE (degrees)	MCU (n=12)	DYNABAND (n=9)	*d*	CONTROL (n=11)	p value
Flexion	4.2 (6.2) *	1.0 (4.5) *	0.59	-10.7 (12.1)	0.001
Extension	3.1 (6.1)	1.0 (4.0)	0.40	-0.2 (6.1)	0.376
Left Lateral Flexion	9.6 (5.1)	2.8 (8.4)	1.06	7.8 (7.5)	0.097
Right Lateral Flexion	12.7 (5.0) *	5.7 (8.2)	1.11	4.4 (10.1)	0.039

* denotes significantly different ($p<0.05$) when compared to control group

Table 6: Percentage Increases(SD) for Raw Data of Average Range of Movement from Pre-Training to Post-Training for Training and Control Groups.

VARIABLE	MCU (n=12)			DYNABAND (n=9)			CONTROL (n=11)		
(degrees)	Pre	Post	Increase	Pre	Post	Increase	Pre	Post	Increase
Flexion	64.1 (8.3)	68.2 (6.2)	6.5 %	70.3 (6.3)	71.3 (5.0)	1.5 %	74.3 (7.0)	63.6 (12.6)	-14.4%
Extension	53.8 (7.9)	56.9 (7.8)	5.7 %	56.5 (8.9)	57.5 (7.7)	1.8 %	56.8 (6.0)	56.6 (8.8)	-0.4 %
Left Lateral Flexion	48.6 (6.5)	58.3 (7.0)	19.8 %	53.9 (8.5)	56.7 (8.0)	5.3 %	43.6 (4.4)	51.4 (6.9)	17.9 %
Right Lateral Flexion	39.4 (8.4)	52.1 (9.0)	32.3 %	40.7 (7.6)	46.4 (10.1)	14.0 %	39.9 (5.0)	44.3 (9.0)	10.9%

CHAPTER FIVE

5.0 DISCUSSION

5.1 Isometric Strength

The current study can prove the efficacy of muscular strengthening programs for increasing a subject's cervical isometric strength values significantly when compared to a non-training control group. The major question this study posed was whether the MCU or dynaband produced a more desirable change in cervical isometric strength and thus in deliberation the first hypothesis stated that greater isometric strength increases would be seen at all directions of contraction from those training on the MCU. The results show that the MCU group displayed improvements in all four isometric strength tests and that these increases exceeded the MDC values by up to 200% (120% - 200%) whilst the dynaband group only exceeded them by 40% to 75%. However, the difference in the increases between the two groups was not recorded as being statistically significant. The failure to attain statistical significance can more than likely be attributed to the low number of subjects, which would limit the ability of the study to detect differences between the groups at statistically significant levels. These two training groups were subject to an independent t-test to attain each variable's effect size. Power calculations revealed that for extension, group numbers of 15 would have revealed a statistical significance between the MCU and Dynaband. Conversely, further increases of just 1.27 lbs from the MCU group would have also revealed a statistical significance. This increase (1.27 lbs) is only small and in comparison to MDC criteria is much less than the 10 lbs significance level thus indicating that it is only a small way from indicating significance between the two groups. However, this is still speculative since the

preliminary analysis of the current study found that the Dynaband training was as effective as the MCU training. This argument is supported by the failure to find a statistically significant difference between the two training groups. In fact the Dynaband could be more effective than the results show considering the advantage the MCU training group had in testing. As Morrissey et al. (1995) point out, when different modes of strength training are compared, the most improvement is usually observed from the mode that matches the testing routine. This is to say the MCU group should have displayed an increased training effect over the Dynaband group in testing. This may have been evident in the results, however, it still did not produce a significant difference between the two groups which suggests the Dynaband is just as effective as the MCU.

Table 3 displays that the average isometric strength difference for extension in the Dynaband group lagged behind the flexion increases and was the only variable that did not reach the MDC criteria for the dynaband group. This can be attributed to some restrictions in the equipment. Since it is hard to isolate the deep neck extensors because the larger posterior muscles, such as the trapezius, can be incorporated into the extension movement, it was noticed that more weight could be lifted as compared to flexion movements. The adaptability the MCU offers meant the weight pin could be quickly relocated so the weight for extension could be a few plates heavier than that of flexion movements. This allowed the extensor muscle group to keep increasing week by week, where as in the dynaband group the equipment prohibited this adaptation for the extension movement so subjects found extension easy when compared to flexion exercises.

The Review of Literature revealed mixed results and considerable variation in studies that found an isometric strength increase from cervical training. The current study's findings are a marked increase in strength when compared to most other similar studies. The adaptation to this training mode and frequency certainly establishes the effectiveness of its specificity to the muscles of the neck. This successful adaptation is conditional on an adequate training stimulus and the values obtained in the current study underscore the fact that the cervical musculature can demonstrate large improvements in a short amount of time for the reason that the cervical musculature is generally relatively untrained in subjects limited to daily activities. However, this is also conditional on the mode of training being highly specific to the cervical musculature since general whole-body strengthening programs have not produced comparable gains in cervical strength. This is comparable to the fact that in subjects who undertake physical conditioning such as sports or weight training the muscles of the cervical region remain generally inactive since their main role is for stabilizing actions (Conley et al., 1992). The ability for those starting such a specific resistance-training program to quickly accommodate to an increasing resistance could correspond with a sudden decrease in the prevalence of neck injuries in people exposed to +Gz forces if such strengthening programs were incorporated into their training.

5.2 Range of Movement

Changes in ROM were assessed to ensure subjects did not loose range of movement after undertaking the strength-training program as this is sometimes a concern since increasing muscle mass can cause restrictions to movement or may become sore or tight from incorrect training progression or lack of warm-ups and cool-downs. Aircraft pilots rely heavily on their ability to rotate their heads during combat manoeuvres so the issue of ROM is of extreme importance. Consequently, careful consideration to the intensity of each session and the implementation of a warm-up and cool-down protocol was formulated. Our second hypotheses thus stated ROM would increase in both the MCU and dynaband training groups. Neither of the training groups experienced a loss in ROM, which is what the study aimed for by prescribing an effective warm up, and cool-down protocol that all subjects adhered to. Although all group variables show minimal changes in ROM (apart from flexion control group) left lateral flexion and right lateral flexion for the MCU are considerably higher.

The greater increase in lateral flexion from the MCU may have resulted since subjects on the machine are restricted by a seatbelt harness, this minimises lateral torso movement or dropping of the shoulder. The dynaband has more error for such movement to occur. Auxiliary movement would effectively take work off the cervical musculature as the head reaches its furthest flexion point, thus decreasing the ROM the muscles would work through.

It is also interesting to note that all groups demonstrated a left and right imbalance in pre-training lateral flexion. All groups had restricted ROM to the right side. This was thought to be attributed to muscular tightness or restriction from greater muscle mass to the right side since an oral survey revealed most subjects were right handed, threw right handed and played racket and bat sports right handed. Interestingly the role of the MCU in correcting this imbalance can actually be seen from viewing pre- and post-test values in Table 6. The MCU group exhibited a vast increase in right side lateral flexion of 32.3%. Right side lateral flexion increased so to be more even with the left side by the post-training test. The dynaband group also seem to exhibit this response but to a much lesser degree nevertheless this mild response is still better than the control group whose imbalance actually became worse.

5.3 Recommendations

This study has been able to assess the application of effective resistance training to the cervical musculature and has documented important statistical significant changes in isometric strength and ROM. The importance of strengthening the neck is apparent from past research on the high risk and high prevalence of injury in high performance fighter pilots and also the noticeable speed at which subjects in the current study were able to respond to training.

This study was essentially performed to validate a training mode that would increase cervical isometric muscle strength. It appears that the dynaband is as effective as the MCU in the pursuit to increase cervical isometric strength. Further study with larger subject numbers would be required before a more definitive statement can be

made concerning this observation. Nevertheless, this study has been unique in its purpose and ability to quantify training responses for the cervical muscles through the full range of movement. The ability to do so was greatly aided by the excellent compliance rates with all subjects successfully completing all sessions. Subjects were able to make good gains quickly and it is hypothesised that this diligent attendance was necessary to achieve such a result from training. Additionally subjects would require to be disciplined enough to continue the program to ensure maintenance of a strong and healthy neck. The results provide an encouraging outlook concerning the contention with the high prevalence of injury in today's Air Force and the value of increasing strength to over come injury.

These results reveal that the incorporation of a specific neck strengthening program into the pilots training schedule would be recommended as the best way to decrease injury rates in the Air Force. Acquiring a MCU would be seen as necessary since it is a valid assessment tool for measuring neck strength and thus flight status. The MCU could also be used in rehabilitation for those who have already sustained a neck injury and to assess recovery from injury as well as record pre-training strength values and increases in strength during the course of their training.

Currently the dynaband would be valuable in a neck strengthening program for pilots and more importantly practical since all pilots can be issued with a dynaband kit, this being especially useful for pilots who are not posted where a MCU is stationed. Additionally a neck-strengthening program should be in place for those returning to service after a break to develop neck strength back to functional strength. Some

changes may need to be made to the methodology since in the current study subject's matched attributes of the pilot's population, but excluded subjects with prior neck injuries. In actual fact past research will confirm that many pilots will already have sustained a neck injury. Training may also be impaired by simultaneous +Gz exposure during training sorties. Thus application of these programs would require greater care in periodising training so that the development of cervical strength does not impede the current training and activities of the participants.

Although it is attractive to attribute an increase in neck strength with the prediction of a decrease in neck injury future studies need to incorporating pilots and the issues discussed above in a longitudinal study to determine whether actual decreases in injury rates occur as a direct result of an applied strength-training program.

5.4 Conclusions

The major obstacle for programs designed to increase cervical muscle strength has been the lack of equipment, with no specific mode of exercise that targets the muscles of the neck. In the early stages of training gains in strength are attributable mainly to neurological adaptations, which are specific to the movement pattern. This study has been able to quantify training with two new cervical muscle-training modes, which are specific to this movement pattern.

The results have supported the fact that the application of an intensive cervical musculature resistance-training program carried out over 10 weeks can increase cervical muscular strength significantly when compared to a non-training control

group. The study also reveals that training on the MCU did not elicit significantly greater changes in isometric cervical muscle strength than training with the dynaband, thus rejecting our first hypotheses. The Nexerciser is a valid tool in its use to train the cervical musculature and the increases in strength seen from the dynaband group are just as effective as MCU training. These strength increases are achievable but required diligence to achieve these levels of improvements. Additionally, subjects will require discipline to continue the program to ensure the maintenance of a strong and healthy neck.

It was also found that neither training mode impinged on the subjects ability to retain full range of cervical movement but rather increased their ROM in most instances thus supporting our second hypotheses. Consequently, pilots commencing either program can be assured they will not be sacrificing their ability to operate in the cockpit.

Essentially, the low participant rates in cervical muscle exercise need to be reviewed and Air Force pilot's need to assume some degree of preventative action to decrease the prevalence of neck injuries. Increasing neck strength seems to be the best way to combat the impending deleterious effects of exposure to +Gz forces and is a large step in the right direction to decrease neck injuries and loss of workdays due to the effects of high +Gz forces.

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APPENDIX A

PARTICIPANT HEALTH QUESTIONAIRE

A Comparison of Training Methods to Increase Neck Muscle Strength

Please fill out the following health questionnaire, as it will ensure the risk of injury to you is minimized and will also provide us with the details we need to compare results between subjects, and a means to contact you. Thank you.

Name:____________________________

Age:_______ Height:___________ Weight:___________

Phone:_________________ Mobile:______________________

e-mail:____

- Tick the box that matches the total time you spend in <u>physical activity</u> per week

☐	Sedentary	
☐	Light	up to 3 hrs per week
☐	Light-Mod	4-6 hrs per week
☐	Moderate	7-10 hrs per week
☐	Heavy	10-15 hrs per week
☐	Very Heavy	up to 20 hrs per week

- What sports are you currently participating in?______________________

____

- Are you currently participating in a weight training program, if so how often?

____

- If you are not currently weight training, have you previously taken part in weight training, if so how long ago and how often would you go? ______________
____

Have you ever experienced any of the following?

Yes	No	
☐	☐	Cervical/Neck injury
☐	☐	Whiplash
☐	☐	Migraines
☐	☐	Muscular disorder that is aggravated by exercise
☐	☐	Acute <u>neck</u> pain lasting longer than seven days, if so describe the injury:

____

____

THANK YOU FOR COMPLETING THIS QUESTIONAIRE

APPENDIX B

EDITH COWAN
UNIVERSITY

PERTH WESTERN AUSTRALIA

INFORMATION SHEET FOR PARTICIPANTS
A Comparison of Training Methods to Increase Neck Muscle Strength

Aims of the Study

This study aims to monitor the neck strength response to a neck resistance-training program using two different modes of exercise, and identify which mode (if any) produces significantly greater improvements in neck strength. Studies to date have verified that specific neck exercise increases cervical muscle strength (Berg et al., 1994; Maeda et al., 1994; Highland et al., 1992; Leggett et al., 1991) but none have identified which type of training is more beneficial. Furthermore, new expensive methods of training that have commonly been used for neck rehabilitation for such things as whiplash have not yet been justifiably proved a superior way of training as apposed to more economical options.

Additionally the study aims to obtain electromyography (EMG) action potentials from the cervical musculature during muscle contractions at maximum voluntary contraction and during training. This information will be used to compare training loads to the stress loads the neck can withstand under the +Gz forces that Royal Australian Air Force pilots are exposed to.

You can expect an improvement in neck strength and possibly reduce the change of injury or pain during movements that place strain on the neck. A fully qualified physiotherapist will perform all tests plus all sessions are free to you.

The concept of this study is to provide preventative strategies for pilots exposed to +Gz forces in order to avoid injury, training to help athletes in sports where neck injuries may occur, such as Rugby and information to aid in the best provision of rehabilitation of neck strength in clinical patients.

Requirements of you as a subject

- This study is voluntary and you may withdraw from the study at any time.
- You will be required to:
  - Sign a consent form
  - Complete a health questionnaire
  - Attend three neck strength tests at Lifecare Wembley on a machine called a multi cervical unit (MCU). Each session will take approximately 20 minutes.
  - Participate in a resistance-training program with the dynaband and counterweighted helmet protocol two times per week on-campus between October 29th and January 21st.
  - Duration of training sessions will not exceed 30 minutes.

Risk of Participating in the Study

All participants will perform neck strength assessments on the multi-cervical unit. These tests will be performed by a fully qualified physiotherapist and offers minimal risk to the participant. Following the test, you may experience some muscular discomfort in the neck.

Training also offers minimal risk of muscular strains or neck soreness however preventative strategies are in place to reduce the likelihood of subjects experiencing such side effects. As with the commencement of any resistance-training program some short-term muscular discomfort and fatigue can be expected.

Project Details

All information gathered during the course of this study will remain confidential and will be stored in locked filing cabinets only accessible by the principal researchers.

Any questions concerning the study can be directed to

Ryan Price

Or

Fiona Naumann
Edith Cowan University
School of Biomedical & Sports Science
100 Joondalup Dve, Joondalup, WA 6027
Telephone: 9400 5012 email: f.naumann@cowan.edu.au

CONSENT FORM For: A Comparison of Training Methods to Increase Neck Muscle Strength

I ______________________________ have read the information for participants for the study "A comparison of training methods to increase neck muscle strength" and any questions I have asked have been answered to my satisfaction.

I agree to participate in this activity, realising I may withdraw at any time.

Also if I am enrolled in a BSc award at ECU I understand that participation or non-participation will have no bearing on my academic progress.

Option 1

☐ I am available for training at Lifecare Wembley

Option 2

I am available for training at ECU Joondalup;
☐ 11:00am Mon & Fri,
☐ 5:30 pm Mon & Wed or,
☐ 7:30 pm Tue & Thu

If these days do not suit you please indicate the most appropriate days below.

(times)

☐ Monday ______________________________
☐ Tuesday ______________________________
☐ Wednesday ______________________________
☐ Thursday ______________________________
☐ Friday ______________________________
☐ Saturday ______________________________
☐ Sunday ______________________________

I agree that the research data gathered for this study may be published provided I am not identifiable.

Signature: ______________ Date: ______________

Researcher: ______________ Date: ______________

APPENDIX C

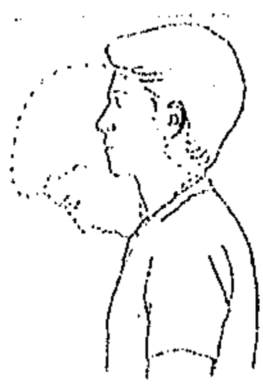
NECK STRENGTH SESSION WARM-UP AND COOL DOWN

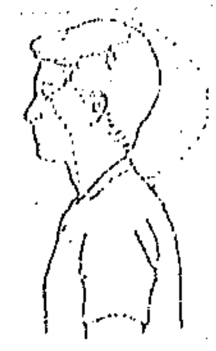
WARM-UP

Before beginning your exercise session, it is IMPORTANT to do a WARM-UP and STRETCHES to prevent muscle soreness. Your warm-up will be as follows:

1. Shoulder shrugs and shoulder rolls (between 5 - 10 each)

ACTIVE RANGE OF MOVEMENT (ROM) EXERCISES





2. Bend head forward slowly and breath in, then bend head slowly backwards and shrug shoulders.

3. Tilt head slowly towards left shoulder and push opposite shoulder down. Repeat in other direction.

4. Turn head slowly to look over left shoulder, then turn to look over right shoulder.

STRETCHES

5. Gently grasp side of head while reaching behind back with other hand. Tilt head away until a gentle stretch is felt. Repeat each side.

6. Place hand on same side shoulder blade. With other hand gently stretch head down and away. Repeat other side

7. Repeat stretches this time using your hand to resist tilting your head back up for 5 sec, then relax and continue stretch for a further 10 seconds.

COOL DOWN

After finishing your exercise session repeat the exercises and stretching you did in the warm-up.

APPENDIX D

TABLE D. CRITICAL VALUES OF STUDENT'S *t* DISTRIBUTION

The values listed in the table are the critical values of t for the specified degrees of freedom (left column) and the alpha level (column heading). For two-tailed alpha levels, t_{crit} is both + and −. To be significant, $|t_{obt}| \geq |t_{crit}|$.

df	*Level of significance for one-tailed test*					
	.10	*.05*	*.025*	*.01*	*.005*	*.0005*
	Level of significance for two-tailed test					
	.20	*.10*	*.05*	*.02*	*.01*	*.001*
1	3.078	6.314	12.706	31.821	63.657	636.619
2	1.886	2.920	4.303	6.965	9.925	31.598
3	1.638	2.353	3.182	4.541	5.841	12.941
4	1.533	2.132	2.776	3.747	4.604	8.610
5	1.476	2.015	2.571	3.365	4.032	6.859
6	1.440	1.943	2.447	3.143	3.707	5.959
7	1.415	1.895	2.365	2.998	3.499	5.405
8	1.397	1.860	2.306	2.896	3.355	5.041
9	1.383	1.833	2.262	2.821	3.250	4.781
10	1.372	1.812	2.228	2.764	3.169	4.587
11	1.363	1.796	2.201	2.718	3.106	4.437
12	1.356	1.782	2.179	2.681	3.055	4.318
13	1.350	1.771	2.160	2.650	3.012	4.221
14	1.345	1.761	2.145	2.624	2.977	4.140
15	1.341	1.753	2.131	2.602	2.947	4.073
16	1.337	1.746	2.120	2.583	2.921	4.015
17	1.333	1.740	2.110	2.567	2.898	3.965
18	1.330	1.734	2.101	2.552	2.878	3.922
→ 19	1.328	1.729	2.093	2.539	2.861	3.883
20	1.325	1.725	2.086	2.528	2.845	3.850
21	1.323	1.721	2.080	2.518	2.831	3.819
22	1.321	1.717	2.074	2.508	2.819	3.792
23	1.319	1.714	2.069	2.500	2.807	3.767
24	1.318	1.711	2.064	2.492	2.797	3.745
25	1.316	1.708	2.060	2.485	2.787	3.725
26	1.315	1.706	2.056	2.479	2.779	3.707
27	1.314	1.703	2.052	2.473	2.771	3.690
28	1.313	1.701	2.048	2.467	2.763	3.674
29	1.311	1.699	2.045	2.462	2.756	3.659
30	1.310	1.697	2.042	2.457	2.750	3.646
40	1.303	1.684	2.021	2.423	2.704	3.551
60	1.296	1.671	2.000	2.390	2.660	3.460
120	1.289	1.658	1.980	2.358	2.617	3.373
∞	1.282	1.645	1.960	2.326	2.576	3.291

APPENDIX E

RAW TEST DATA

Pre training Isometric Strength				Pre training ROM				Post training Isometric Strength				Post training ROM		
Flexion	Extension	Left Lat Flx	Right Lat Flx	Flexion	Extension	Left Lat Flx	Right Lat Flx	Flexion	Extension	Left Lat Flx	Right Lat Flx	Flexion	Extension	Left Lat Flx
15.3	27	20.1	21.3	78.7	60.8	59.1	58.93	28.9	48.1	34.2	30.2	79.1	71.8	75.1
18.3	22.9	28.9	29.9	67.3	53.5	44.3	38.97	30.7	43.4	43.3	40.6	73.7	54.7	58.8
11	10.4	9.7	9.5	55.1	42.2	45.5	42.03	19.9	23.3	20.6	22.7	55.9	50.2	50.6
7.2	14.9	7.1	6.9	59.7	64.9	54	38.33	14.5	22.5	15	14.6	60.8	64	52.5
4.7	13.3	7.9	7.8	65.9	62.1	48.4	37.7	14.3	29.2	20.8	17.2	73.3	67.5	60.7
16	17.8	15.6	12.4	69.7	48.5	52.1	47.53	23.3	24.6	23.2	20.1	64.6	60.9	60
9.4	18	13.7	9.2	67.5	48.6	44.3	37.07	15.1	19.7	14.7	14.4	67.5	45.1	52.3
11.1	18.5	15.8	16.5	56.7	42.3	45.8	31.5	15.9	18.4	13.1	13.1	65.4	51.8	53.1
11.9	17.8	19.2	19.6	58.8	61.6	42	31.7	16.6	32	26.4	22.8	70.2	54.7	57
17.5	26	19.5	22.2	75.6	57	37.5	26.6	25.3	36	20.9	19.3	71.8	56.9	52.3
30.3	35.7	26.8	24.8	51.4	47.8	54.8	38.03	44.6	41.7	32.6	33.9	66.6	50.1	63.2
8.1	11.8	11.7	11.7	62.2	56.7	55.7	44.03	15.2	42.4	35.6	37.1	69.5	55.2	63.6
22.6	24.6	22.3	20	66.9	64.7	46.7	43.67	32.2	42.2	30.3	29.3	67.2	62.5	45.3
11.7	16.6	15.3	16	61.3	58.5	52.8	32.33	21.9	21.8	25.7	24.4	65.4	61.2	64.2
16.3	29.4	25.9	28.7	63.6	56	51.8	44.53	23.1	38.6	30.7	36.8	71.4	49.4	53.9
18.5	19.7	18.6	18.5	73.8	51	61	34.67	20	22.8	18	19.4	69.8	53.4	50.6
13.2	12.4	11	15.6	71.7	62.8	44	31.2	16.8	21.8	18.6	20.2	65.5	65.7	53.4
10.8	14.4	12.9	12.7	76	62.2	58.2	46.6	21.1	17.1	16.8	10.8	77.2	65.3	71.6
12.5	16.6	10.2	14	64.8	38.1	48.1	37	14.6	17.1	14	14.8	71	43.3	53.4
35.7	35.5	27	25.9	74.8	65.4	71.4	54.47	41	30.5	21.4	23.7	74.8	62.2	62.9
10.5	14.9	10.6	12.2	79.4	50.1	51.2	41.8	24.8	27.3	19.3	23.6	79.3	54.8	55.4
15.1	19.3	15.3	15.3	79.9	52	41.3	42.67	22.1	23.2	18.8	22.5	38.7	49.1	46.5
17.5	20.5	24.2	26.4	59.1	61.1	42.7	35.43	25.8	22.1	28.7	32.5	54.3	64.1	51.3
16.2	13.5	8.6	6.6	66.3	49.4	49.4	38.8	10.9	16.3	8.7	11.5	55.6	41.1	49.3
29.9	37	19.5	19	79.3	63.4	43.4	40.6	32.5	47.7	31.8	29.8	79.1	70.4	51.7
14.8	29.7	16.6	23	74.9	64	50.6	51.43	15.1	18.5	16.9	20.9	61.9	63.4	49
26	29.2	23.8	21.9	79.1	55.4	39.8	31.37	27.4	21.2	21.1	20	56.5	54.5	43.8
7.6	12.6	12.1	10.1	68	63	46.4	38.23	8.4	13.1	9.9	8.3	59.1	63	54.8
15.1	19.3	15.3	15.3	79.9	52	41.3	42.67	14.9	21	13.3	12.6	79.5	45.2	64.5
27.1	51.2	26.8	29.9	76.4	62.9	46.9	39.77	30.3	50.3	35.5	35.3	76.6	54.4	62.5
11.2	20.2	15.3	16.3	80.1	50.4	35.4	39.9	10.4	15.5	11.5	13.6	72.8	59.1	49.4
5	11.5	10.9	11.1	74.4	51.7	42.5	38	11.1	16.9	13.2	14.5	65.4	58.5	42.7

	Pre/Post difference for Strength				Pre/Post difference for ROM			
Right Lat Flx	Flexion	Extension	Left Lat Flx	Right Lat Flx	Flexion	Extension	Left La Flx	Right Lat Flx
69.8	13.6	21.1	14.1	8.9	0.4	11	16	10.87
56.43	12.4	20.5	14.4	10.7	6.4	1.2	14.5	17.46
50.87	8.9	12.9	10.9	13.2	0.8	8	5.1	8.84
47.87	7.3	7.6	7.9	7.7	1.1	-0.9	-1.5	9.54
57.4	9.6	15.9	12.9	9.4	7.4	5.4	12.3	19.7
52.6	7.3	6.8	7.6	7.7	-5.1	12.4	7.9	5.07
44.67	5.7	1.7	1	5.2	0	-3.5	8	7.6
41.83	4.8	-0.1	-2.7	-3.4	8.7	9.5	7.3	10.33
45.13	4.7	14.2	7.2	3.2	11.4	-6.9	15	13.43
38.87	7.8	10	1.4	-2.9	-3.8	-0.1	14.8	12.27
59.03	14.3	6	5.8	9.1	15.2	2.3	8.4	21
60.43	7.1	30.6	23.9	25.4	7.3	-1.5	7.9	16.4
35.37	9.6	17.6	8	9.3	0.3	-2.2	-1.4	-8.3
44.77	10.2	5.2	10.4	8.4	4.1	2.7	11.4	12.44
44.77	6.8	9.2	4.8	8.1	7.8	-6.6	2.1	0.24
32.07	1.5	3.1	-0.6	0.9	-4	2.4	-10.4	-2.6
40.17	3.6	9.4	7.6	4.6	-6.2	2.9	9.4	8.97
61.53	10.3	2.7	3.9	-1.9	1.2	3.1	13.4	14.93
45.37	2.1	0.5	3.8	0.8	6.2	5.2	5.3	8.37
57	5.3	-5	-5.6	-2.2	0	-3.2	-8.5	2.53
56.67	14.3	12.4	8.7	11.4	-0.1	4.7	4.2	14.87
43.9	7	3.9	3.5	7.2	-41.2	-2.9	5.2	1.23
46.6	8.3	1.6	4.5	6.1	-4.8	3	8.6	11.17
32	-5.3	2.8	0.1	4.9	-10.7	-8.3	-0.1	-6.8
48.83	2.6	10.7	12.3	10.8	-0.2	7	8.3	8.23
34.8	0.3	-11.2	0.3	-2.1	-13	-0.6	-1.6	-16.63
34.3	1.4	-8	-2.7	-1.9	-22.6	-0.9	4	2.93
43.8	0.8	0.5	-2.2	-1.8	-8.9	0	8.4	5.57
54.63	-0.2	1.7	-2	-2.7	-0.4	-6.8	23.2	11.96
60.73	3.2	-0.9	8.7	5.4	0.2	-8.5	15.6	20.96
48.97	-0.8	-4.7	-3.8	-2.7	-7.3	8.7	14	9.07
38.27	6.1	5.4	2.3	3.4	-9	6.8	0.2	0.27