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A comparison of training methods to increase neck muscle strength

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Abstract. *Objective:* To compare two neck strength training modalities.

Background: Neck injury in pilots flying high performance aircraft is a concern in aviation medicine. Strength training may be an effective means to strengthen the neck and decrease injury risk.

Methods: The cohort consisted of 32 age-height-weight matched participants, divided into two experimental groups; the Multi-Cervical Unit (MCU) and Thera-Band tubing groups (THER), and a control (CTRL) group. Ten weeks of training were undertaken and pre-and post isometric strength testing for all groups was performed on the MCU. Comparisons between the three groups were made using a Kruskal-Wallis test and effect sizes between the MCU and the THER groups and the THER and CTRL groups were also calculated.

Results: The MCU group displayed the greatest increase in isometric strength (flexion 64.4%, extension 62.9%, left lateral flexion 53.3%, right lateral flexion 49.1%) and differences were only statistically significant ($p < 0.05$) when compared to the CTRL group. Increases in neck strength for the THER group were lower than that shown in the MCU group (flexion 42.0%, extension 29.9%, left lateral flexion 26.7%, right lateral flexion 24.1%). Moderate to large effect sizes were found between the MCU and THER as well as the THER and CTRL groups.

Conclusions: This study demonstrated that the MCU was the most effective training modality to increase isometric cervical muscle strength. Thera-Band tubing did however, produce moderate gains in isometric neck strength.

Keywords: Neck, strength training, isometric, +Gz force, high performance pilots

1. Introduction

Neck pain and injuries are becoming more prominent in Western countries, with neck complaints being reported as one of the major causes for long-term sick leave [3,12]. Individuals exposed to the extreme positive acceleration forces produced by current high performance aircraft are also at a substantial risk of injury. This is a major concern in aviation medicine [9–11,21,

25]. Eighty-five percent of F/A-18 pilots in the Royal Australian Air Force (RAAF) reported experiencing acute G-induced neck pain during their career [20]. Similarly, 85% of pilots in the US 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 approximately 57% [1]. This figure is a markedly higher incidence than the 5.7% to 16.6% yearly prevalence of neck pain for men reported in the general population [21].

Strengthening the cervical musculature has been used to decrease pain in clinical patients [3,12,13,17,28,31] in addition to being suggested as a method to prevent neck complaints in high performance pilots [2,

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15,24]. Neck strength may be increased through activities that make a high demand on the neck musculature such as wrestling [30] and may also be increased in a non-significant manner through flying high performance aircraft [4,24]. However, there may be a period of time prior to this activity-specific adaptation where the spinal structures are injured due to the exposure to excessive external forces.

To date, there has been little research conducted into the use of neck strengthening exercises in asymptomatic individuals. To increase neck strength it is known that area-specific training is required [2,7,22,31] and that supervision of individuals during training will increase the potential of a training effect [2]. The magnitude of neck strength is known to be direction dependent, for example, it has been found in previous research studies that cervical muscle strength in extension is greater than that found in flexion [2,3,16,23,27,29] which can be explained by the relationship between muscle cross sectional area and strength [14,26].

This study compared two diverse neck strength training modalities, one being the multi-cervical unit (MCU) [6,8] as illustrated in Fig. 1, the other being Thera-Band tubing (Pro-Med Products, Inc.) (Fig. 2). The MCU is a pin-loaded machine that utilizes a mechanical pulley arrangement and has the ability to restrain the body and isolate the cervical musculature during specific exercise. The neck can be trained in flexion, extension and lateral flexion using this device and the intensity of muscular contraction can be adjusted by altering the pin-loaded weight stack. Thera-Band tubing consists of a stretchable latex rubber. This tubing is able to be attached to a stationary structure and can be attached to the head via a Velcro head band. The tubing then offers resistance to head movement in flexion, extension and lateral flexion. Resistance can be adjusted by increasing either the thickness or length of the tubing. Both training methods are currently used in rehabilitation centres to treat patients with neck injury such as whiplash associated disorders. The cost of a MCU is expensive and requires a trained therapist to supervise the session. In comparison, Thera-Band tubing is inexpensive, lightweight and portable, which makes accessibility to training much easier.

The purpose of this study was to compare the isometric cervical muscle strength changes in response to a supervised ten week training program using the MCU and Thera-Band tubing. Information obtained from this study may assist in identifying an effective mode of training cervical muscle strength. This will aid professionals involved in exercise prescription to select



Fig. 1. The Multi-Cervical Unit (MCU) training modality.



Fig. 2. The Thera-Band tubing training modality.

appropriate training methods to increase neck strength, with the long term goal of possibly preventing neck injuries in pilots.

2. Methods

2.1. Subjects

The initial subject cohort in this study consisted of thirty-six male subjects. These subjects were randomly divided into three groups: the MCU training group ($n = 12$); the Thera-Band tubing (THER) training group ($n = 12$); and a non-training control (CTRL) group ($n = 12$). Subjects were free of prior cervical injury including whiplash, neurological impairment or neck pain lasting for more than seven days. Additional exclusion criteria included; subjects who suffered from headaches or migraines, or muscular disorders that may be aggravated by exercise, or subjects that were currently engaged in neck strengthening programs. 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. The study protocol was approved the Edith Cowan University Human Research Ethics Committee. Written, informed consent was obtained from all subjects prior to testing.

Four subjects, three from the dynaband group and one from the control group, failed to complete the neck training program due to personal reasons. Therefore, the final cohort consisted of; the MCU training group ($n = 12$), THER training group ($n = 9$) and CTRL group ($n = 11$).

2.2. Experimental protocol

The MCU was used to measure both pre-and post isometric cervical muscle strength for all subjects in flexion, extension and lateral flexion in the neutral position. All strength tests were performed in a blinded manner by an experienced physiotherapist and subject data was not identifiable through name. Measurement of isometric neck strength using the MCU has previously been found to possess very good to excellent reliability [6]. Subjects were strapped into the MCU in an upright position, to minimize any movement other than that of the cervical area. Subjects were instructed to press maximally against a force pad for three seconds with either the forehead, side or back of the head depending upon the direction being tested. Three tests were performed consecutively for each procedure with an average measurement in pounds (lbs) being recorded. The force pad was positioned immediately above the eyebrows for the flexion tests, directly above the occipital protuberance for the extension tests and under the top of the ear in

Table 1
Multi-Cervical Unit (MCU) and Thera-Band Tubing (THER) 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

Table 2
Anthropometric data for the Multi-Cervical Unit (MCU), Thera-Band tubing (THER) and control (CTRL) groups (mean \pm SD)

	MCU ($n = 12$)	DYN ($n = 9$)	CTRL ($n = 11$)
Age (yrs)	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)

alignment with the subject's ear for the lateral flexion tests.

Both the MCU and THER training groups performed ten weeks of resistance training comprising two sessions per week, each separated by 3–4 days, 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 training groups warm-up consisted of the active range of motion for flexion, extension, lateral flexion (left/right) and rotation (left/right), followed by stretches for the neck muscles. The training protocol (sets x reps) remained constant between the two training groups and was based upon an intensive-interval strength-endurance model (Table 1). Each set commenced one minute fifteen seconds after the previous had commenced and the speed of eccentric and concentric phases remained constant during the ten weeks with a count of -one- for contraction and -two-three- for the eccentric phase. These two strength training modalities could not be recounted to the same denomination as they have varying methods of increasing intensity.

For training sessions on the MCU, the subjects were strapped into the MCU in an upright position, to minimize any movement other than the cervical area. Subjects were instructed to adjust the pin loaded weight stack and lift the weight stack with either the forehead, side or back of the head. The principle of progressive overload was employed to ensure that training loads continued to challenge the subjects. This was achieved

Table 3
Mean (\pm SD) for isometric strength (lbs) measured pre-and post-training for Multi-Cervical Unit (MCU), Thera-Band tubing (THER) and Control (CTRL) groups

	Time	Flexion	Extension	L/L Flexion	R/L Flexion
MCU (n = 12)	pre	13.4 (6.8)	19.5 (9.2)	16.3 (6.9)	16.0 (7.5)
	post	22.0 (9.2)	31.8 (10.3)	25.0 (9.5)	23.8 (7.4)
	difference	8.6 (3.3)*	12.3 (8.8)*	8.7 (7.2)*	7.9 (7.5)
THER (n = 9)	pre	16.9 (8.1)	20.5 (7.8)	17.1 (6.6)	18.2 (5.8)
	post	23.9 (8.1)	26.6 (9.0)	21.6 (6.0)	22.6 (7.6)
	difference	7.1 (4.3)*	6.1 (6.8)	4.6 (5.0)	4.4 (5.1)
CTRL (n = 11)	pre	16.9 (7.9)	24.0 (12.0)	17.1 (5.8)	17.7(7.1)
	post	19.0 (8.8)	24.2 (12.7)	19.0 (9.2)	20.1 (9.1)
	difference	2.1 (3.9)	0.2 (6.2)	1.9 (5.1)	2.4 (4.8)
<i>p</i> value		0.003	0.005	0.046	0.189
<i>d</i> value	MCU/ THER	0.40	0.79	0.62	0.52
<i>d</i> value	THER/ CTRL	1.20	0.90	0.54	0.40

*Denotes significantly different ($p < 0.05$) when compared to the CTRL group.
d value denotes effect size between MCU and THER and between the THER and CTRL groups.

by either increasing the number of repetitions, the number of sets, or the weight lifted.

In the THER training group, four distinct colours of Thera-Band tubing (red, green, blue then black) representing differing resistances were used to allow progressive overload in training. Training progressed weekly in a manner pre-determined by the researchers, through increasing the density of the Thera-Band tubing. Sessions utilising the blue and black dynaband included an extra week of training where the length of the theratube which was previously standardised at 70 cm was decreased by 15 cm (i.e. 55 cm) in order to provide another method of progression. The level of resistance progressed as such; level one on the red dynaband, level two the green dynaband, level three the blue dynaband, level four used the shorter blue dynaband, level five used the black and level six the short black dynaband.

2.3. Statistical analysis

Statistical analysis was performed using SPSS V10.0 for Windows. Comparisons between the three training groups for age, height and weight, and pre-training isometric neck strength at baseline, in addition to the differences in isometric strength from pre-to post training, were analyzed using a Kruskal-Wallis test. The level of significance was set at $p < 0.05$. Effect size (*d*) was calculated for all variables between the MCU/THER and THER/CTRL groups as the sample size was small [5]. An effect size of 0.2 was considered small, 0.5 moderate and 0.8 as large [5].

3. Results

There were no significant differences between the two experimental groups (MCU and THER) and the CTRL group for age, height or weight. The anthropometric data for the final subject cohort are detailed in Table 2.

There were no significant difference in baseline cervical isometric strength between the training and control groups. The values recorded for pre-and post training and the differences between these values are presented in Table 3.

There was a statistically significant increase in isometric flexion strength for both the MCU group and THER group when compared to the CTRL group. These increases were 64.4% for the MCU group and 42.0% for the THER group, respectively. The MCU group also exhibited significant increases, when compared to the CTRL group, in isometric extension strength and isometric left/right lateral flexion of 62.9% and 53.3%/49.1%, respectively.

4. Discussion

This study established that there was a trend towards the MCU being the more effective training modality in producing increases in isometric neck strength when compared to the THER training group. Effect size calculations indicated that with larger subject numbers in each group, there may have been significant differences found between the MCU and THER training groups.

Consequently, the MCU would be recommended as an effective training methodology to increase isometric neck strength in asymptomatic subjects.

Previous research has mainly focussed on re-training an injured neck back to a basic functional state. Greenwood and DeNardis [8], studied rehabilitation patients and found highly significant improvements in neck strength when training with the MCU. Subjects in Greenwood's study experienced increases in cervical strength, ranging from 69.7 to 71.0%. Maeda et al. [18] also found highly significant gains in isometric strength of the neck musculature of injured subjects in eight weeks. They found significant increases in isometric strength, of between approximately 38%–40%. To our knowledge there have been few studies however, to document isometric strength gains in non-injured necks.

In this study the THER training group showed non-significant increases in isometric neck strength however, these strength gains were less than what was achieved with the MCU. This was an important finding considering the high cost of an MCU when compared to the very low cost and portability associated with the Thera-Band tubing. One limitation of the current study was that the testing protocol favoured those training on the MCU. Morrissey et al. [19] stated when different modes of strength training are compared, most improvement is usually observed from the mode that matches the testing routine. Recommendations for future research would be to devise an alternative testing protocol to test baseline and post-training neck strength, such as the use of a neck dynamometer.

This study also found that the neck musculature can demonstrate large increases in strength over a relatively short period of time. This successful adaptation was conditional on an adequate training stimulus and that the mode of training was highly specific to the cervical musculature since general whole-body strengthening programs have not produced comparable gains in cervical strength [7,19]. Recommendations from this study are that pilots that begin flight training engage in cervical neck training 10 weeks prior to the commencement of flying high performance aircraft, to more adequately prepare the neck for the stress of flying high performance aircraft. Additionally a neck-strengthening program should be in place for those returning to service after a break in flying to increase neck strength.

A further limitation of this study when considering application to high performance pilots, was the subjects volunteering for this study were not currently flying high performance aircraft. Neck training may be

impaired by simultaneous +Gz exposure during aerial combat sorties. Thus, application of these programs would require greater care in periodising training so that the development of neck strength does not impede the current flight activities of the pilots.

5. Conclusions

The application of a 10 week, twice-weekly neck muscle resistance-training program resulted in increased cervical muscular strength. It was also suggested that training on the MCU may elicit a greater increase in isometric cervical muscle strength than training with the Thera-Band tubing. Larger subject numbers may have produced a significant difference between the two training groups. Future research is needed to establish if increasing neck strength is an effective way to combat +Gz induced neck injuries in pilots flying high performance aircraft.

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