Can clinical measures of upper quarter postural muscle performance predict neck pain in visual display terminal operators?

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Abstract. *Objective:* The prevalence of neck and shoulder pain in visual display terminal operators is estimated between 40% and 69%. One theory proposed for this is inadequate low load functioning of the postural muscles of the neck and shoulder girdle leading to microtrauma of cervical spine structures. A temporal sequence linking muscle performance to the subsequent development of neck pain has never been established. This pilot study sought to determine whether postural muscle performance factors are associated with neck pain in a population of visual display terminal users.

Methods: Twenty-eight subjects underwent a baseline physical examination. Clinical measurements of low-load deep cervical flexor muscle performance, shoulder girdle muscle endurance, neck column length, head and neck posture and body mass index were made and demographic factors collected. Following the examination, a Neck Pain and Disability Scale questionnaire was administered. Variables were analysed in a regression analysis with the questionnaire scores. Questionnaires were readministered at six months follow up.

Results: Descriptive variables “years of occupational screen based keyboard use” ($p = 0.021$) and “use of reading glasses” ($p = 0.027$) were statistically significantly correlated with Neck Pain and Disability Scale score at baseline, while “hours of home computer use” ($p < 0.001$) was associated with the change in questionnaire score at 6 months follow up. Muscle performance factors did not contribute to either model.

Conclusions: Given the sample size in this pilot study, we cannot rule out an association between muscle parameters and the onset of neck pain and disability. However, the influence of any such association would be weaker than other identified associated variables.

1. Introduction

Musculoskeletal pains are probably the most commonly reported complaint in office workers [19], with VDT operators experiencing an increased rate of primary neck and shoulder pain compared to people performing other office duties [41]. Estimates of the prevalence

of neck pain in VDT operators ranges from 40% [32] to 69% [4] and pain increases with the daily duration of VDT use [1,32].

The aetiology of work related neck pain appears complex, involving physical, psychosocial and individual factors [7,29]. Mechanisms previously suggested for the persistence of neck problems in this population include selective over usage of low-threshold muscle fibres [7,35], nociceptor sensitisation [7] and fear avoidance [24]. Other proposed mechanisms focus on muscular causes and posture including: elevated levels of muscle activity in response to small changes in sagit-

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tal plane head position and impairments in kinaesthetic sense [11], alterations in muscle recruitment strategies with increased activity in upper trapezius and lowered activity in the cervical erector spinae muscles [18,33, 34], and poor and sustained postures and static loading of muscles around the neck and shoulder girdle [4,8, 20,32]. The latter is supported by the increased incidence with increasing time spent at work operating a VDT [41].

Attempts to address the problem of neck pain in VDT operators have included variations in workstation layout, computer screen height, education and use of pause exercises to name only a few, reflecting the multifactorial nature of the condition [1,4,22,23].

According to experimental evidence [31], the osteoligamentous spine contributes around 20% to the minimally needed mechanical stability of the cervical spine, while nearly 80% is provided by the surrounding muscles. Of the surrounding muscles, the deep cervical flexor group is considered to play an important role in stabilising the position of the head on the neck [10,21, 25]. These muscles function to balance and stabilise the head and cervical spine, especially during subconscious postural alignment and static positions [38]. Magnetic resonance imaging used to examine the intensity and patterns of neck muscle use evoked by movements of the head has shown that the deep neck flexor muscles, particularly longus capitis and longus colli, maintain a low but continued level of activity with all movements consistent with a tonic stabilising function [10].

The absence of appropriate support and control by the muscular system has been proposed as one factor that may result in neck pain, headaches and work related upper limb disorders in screen based keyboard operators [20]. The effect of lack of support by key deep and postural muscles, together with the adverse stresses likely to be imposed by overactive axioscapular muscles may have considerable impact on articular tissues [25].

The model of muscular stabilisation, and possible dysfunction in the absence of effective stabilisation is based on the assumption that adequate endurance of the deep cervical flexor and shoulder girdle muscles are a protective factor against the development non-traumatic cervical dysfunction. This would appear to be a logical extension of the work of Panjabi [30] which experimentally demonstrated the role of these muscles in supporting and controlling the cervical lordosis and of the theoretical framework of spinal muscle functional stabilisation provided by Bergmark [3]. However, there remains no prospective study establishing

the temporal sequence between posture and postural muscle performance measures and work related neck pain in VDT operators. The aim of this two-stage pilot study was to determine whether clinical measures of posture and endurance of the postural muscles of the neck and shoulder girdle are associated with neck pain in a population of visual display terminal users, both at baseline and in follow-up, when considered in the presence of other accepted risk factors for occupational neck pain.

2. Methods

Ethical approval for this study was granted by The University of Newcastle's Medicine and Health Sciences Research Ethics Committee. All subjects read and signed the consent form before participation.

The study consisted of two distinct phases, the first being a cross-sectional study and the second a prospective study with a six month follow up period. The cross sectional design was used to estimate the baseline association between key clinical muscle performance factors, as well as other known risk factors for neck pain in keyboard operators, and the presence of neck pain. During the prospective stage, the exposure of primary interest was clinically measured postural muscle endurance at baseline assessment and the outcome factor was worsening of neck pain status as shown by a change in Neck Pain and Disability Scale scores at six months follow up.

2.1. Participants

Subjects were drawn from 2 call centres in the Newcastle area, a regional centre in New South Wales. To be eligible, participants had to be aged between 17 and 60 years. Their occupation had to involve a minimum of 4 hours of VDT use each day, this figure being considered a critical amount for the development of musculoskeletal disorders in previous studies [32]. Subjects were excluded if they had a history of neck trauma or diagnosed recent concussion. All employees were invited to participate in the study. Subjects entering the study were those people who, having met the eligibility criteria, volunteered to attend an assessment on the date of visit at the workplace by the researcher.

2.2. Measures

2.2.1. Muscle performance measures

Deep cervical flexor muscle performance. This was ascertained using the low load cranio-vertebral flexion test as described by Jull et al. [27]. The test reflects the tonic function of this muscle group [25]. The validity and reliability of this test has been reported in previous studies [12,15,25,26] with previous electromyographic studies demonstrating that reduced performance on this test reflects dysfunction of the deep cervical flexor muscles and is strongly associated with neck pain [15]. This relationship has been found to be consistent regardless of the origin of the neck pain [9].

Each subject was positioned supine lying with the head and cervical spine supported in a neutral position. The method for attaining the neutral position used the technique described by Falla et al. [13,14], whereby subjects were positioned such that a line between their forehead and chin was horizontal and an imaginary line parallel to the bed extended from the tragus to bisect the neck longitudinally. The tongue was placed on the roof of the mouth and the teeth held slightly apart to discourage activity of the jaw depressors. A pressure cuff was inserted behind the neck and inflated to 20 mmHg, which is adequate to fill the space between the testing surface and the neck without pushing the neck into a lordosis. The pressure sensor monitors the slight flattening of the cervical lordosis that occurs with the contraction of the deep neck flexors and registers an increase in pressure. Any unwanted head lift and general cervical flexion will result in a decrease in pressure. Surface EMG electrodes were secured to the left and right sternocleidomastoid muscle bellies to assess unwanted motor activity, defined as EMG amplitude in excess of readings taken during forced inspiration. The subject was then formally taught cranio-cervical flexion in a gentle and slow manner and the position held for a five second period. The subject then performed the craniocervical flexion test by controlled performance of the upper cervical flexion action.

The pressure that could be achieved and held in a steady manner for 10 seconds is called the activation score. The tonic capacity of the deep cervical flexors is assessed by monitoring the subjects' ability to sustain the upper cervical flexion position at the activation pressure for 10 repetitions of 10 second holds. Subjects view the dial of the pressure sensor to target the nominated pressure. The holding capacity is presented as a performance index that was calculated by multiplying the target pressure by the number of successful repetitions,

e.g. if a subject achieves a 10mmHg increase in pressure and repeats this performance 10 times then they are awarded a performance index of 100. Loss of pressure of greater than 20% of the target or substitution by superficial muscle activation recorded on EMG was regarded as failure and the number of repetitions to that point was used in the calculation of the holding capacity. A successful completion of a stage involved the ability to target and hold the position steady (pressure recording) for the 10 seconds independent of activity of the superficial neck flexors (EMG).

Shoulder girdle muscle endurance. Holding capacity of the shoulder girdle has been closely linked to head and neck posture and control of the region [25]. The holding capacity was assessed through a modification of Kendall et al's grade 3 classical muscle test for lower trapezius [28]. The patient was positioned in prone lying with the load removed by keeping the arm at the side. The scapula was placed in a neutral position and the subject asked to hold the position for a 10 second period. Any substitution by latissimus dorsi, levator scapulae or upper trapezius was noted. The number of 10 second repetitions without substitution was recorded to a maximum of 10.

2.2.2. Postural measures

Neck column length. Neck column length was measured as described by Grimmer et al. [22] and established as reliable by Blizzard et al. [5]. Each subject was measured in sitting with hips, knees and ankles at 90 degrees and head vertically aligned. The anterior neck column length was measured from the point of the chin to the level of the sternal notch, using a tape measure placed on the skin and conforming to the neck contours. The posterior column length was measured in the same manner from the bony occipital protuberance to the level of the spinous process of C7. The variable "column length difference" was calculated by subtracting the posterior column length from the anterior column length. Greater anterior column length in relation to posterior column length has previously been associated with the presence of headache [22], a frequently reported disorder in VDT users.

Craniovertebral angle. This was assessed by the method described by Watson and Trott [39] and Treleaven et al. [36], a method with previously established reliability and stability [39]. A lateral photograph was taken of the subject seated in a high backed chair with their feet flat on the floor, knees and hips at 90 degrees, buttocks positioned back in the chair, hands resting in their lap and scapulae against the back of the chair. The

craniovertebral angle is formed by a postural reference line connecting the tragus and C7 spinous process transecting the true horizontal. Markers are placed on the subjects' tragus and C7 spinous process, and a plumb line, placed behind the subject is included in the photograph so that the true horizontal could be calculated. The smaller the craniovertebral angle, the more forward the head posture. Photographs in this study were digitized and craniovertebral angles calculated using the "measuring tool" contained in the computer software program Adobe Photoshop 6.0.

2.2.3. Demographic and background factors

Height and weight were measured to allow calculation of each subject's body mass index. Other factors recorded by questionnaire include subjects' age, gender, use of dentures and use of glasses (not at all, reading only, distance vision only and all the time). Total number of hours engaged in VDT use on a daily basis was also examined, stratified as 4 hours, 5 to 6 hours and 7 hours plus. Length of employment in a VDT-based occupation and amount of home computer use were also recorded. The background features have previously been found to be associated with neck pain in this occupational group and may contribute to the variance in the overall model describing neck pain in this group.

2.2.4. Outcome variable

The outcome variable for analysis at baseline was the subject's score on the Neck Pain and Disability Scale (NPDS) [40], a 20 item questionnaire with each item scored on a zero to five point scale. Having well reported validity and reliability [17,40], this provides a continuous measure between 0 and 100.

2.3. Data analysis

Simple linear regression was applied to assess the associations between theorized risk factors and NPDS score at baseline and change in NPDS score at 6-month follow-up. These variables include deep neck flexor muscle activation scores and endurance, shoulder girdle holding capacity, difference between anterior and posterior neck column length, craniovertebral angle, body mass index, length of time employed in an occupation requiring VDT use greater than four hours per day, age, gender, use of glasses and average daily hours engaged in VDT use. Variables whose *p* values obtained from univariate analysis were less than 0.2 were then simultaneously included in a multiple regression model. The

Table 1
Characteristics of the study sample (N = 28)

Demographic variable	Total
Gender (%)	
Male	13 (46.43%)
Female	15 (53.57%)
Age in years – mean (SD)	34.86 (10.55)
Main type of computer use (%)	
Word processing	3 (10.71%)
Data Acquisition	6 (21.43%)
Data entry and acquisition	19 (67.86%)
Years in similar role mean (SD)	5.73 (4.03)
Hours of daily computer use (%)	
4 to 5	2 (7.14%)
5 to 6	10 (35.72%)
7 or more	16 (57.14%)
Hours of daily home computer use median (range)	0.75 (0 to 3)
Use of glasses at work (%)	
never	14 (50.00%)
reading only	4 (14.29%)
always	10 (35.71%)
Use of dentures	
yes	0
no	28

change in R^2 obtained by removing variables one by one from the model was used to select the most parsimonious model. Goodness of fit of the final model was explored by assessing normality of the residuals using the Shapiro-Wilk test. A *p* value of less than 0.05 was considered to be statistically significant. All analyses were performed using STATA version 6.0.

3. Results

Thirty-three people consented to participate in the study, with 28 participants completing all requirements. The characteristics of the participants are given in Table 1.

Of the 5 people who were not included in the study sample, one person was transferred out of the Newcastle area prior to the collection of physical examination data, two subjects were unavailable for physical assessment due to ill health on the dates arranged for onsite data collection and two further subjects failed to return the questionnaires, meaning there was no outcome data for these individuals.

The findings of the baseline physical assessment are detailed in Table 2. The mean NPDS score at baseline was 14.85 (standard deviation = 7.27).

Regression analysis was used to determine the association between NPDS score, and the study variables outlined previously (Table 3). Results of the multivariate analysis revealed that years of occupational screen

Table 2
Physical measures from subject examination

Physical characteristic	
Body mass index mean (SD)	27.71 (5.82)
Neck column length difference (cm) median (interquartile range)	0.50 (−0.25 to 2.5)
Activation score (mmHg) mean(SD)	6.04 (2.05)
Performance index median (interquartile range)	32 (24 to 45)
Shoulder girdle endurance (repetitions) median (interquartile range)	10 (7 to 10)
Cranio-vertebral angle (degrees) mean (SD)	48.83 (7.27)

Table 3
Univariate regression coefficients and multivariate regression coefficients of statistically significant variables at baseline

Variable	Univariate regression for NPDS at baseline			NPDS score entire sample (ADJ R ² = 26.4%)		
	Coefficient	Standard error	P value	Coefficient	Standard error	P value
Age	0.09	0.194	0.643			
Gender	−0.95	4.041	0.817			
Years of occupational screen based keyboard use	−1.14	0.458	0.020	−1.08	0.434	0.021
Hours worked each day	2.83	1.473	0.066			
Hours of home computer use	1.16	2.928	0.696			
Use of glasses						
– Reading	12.47	5.594	0.035	12.03	5.098	0.027
– Always	5.42	4.085	0.196			
Body mass index	0.26	0.349	0.471			
Difference in neck column length	0.52	0.967	0.595			
Craniovertebral angle	−0.41	0.271	0.138			
Activation score	0.31	1.003	0.757			
Repetitions at activation score	0.32	0.800	0.696			
Performance index	0.05	0.116	0.646			
Shoulder girdle muscle endurance	−0.45	0.952	0.641			

Table 4
Univariate regression coefficients and multivariate regression coefficients of statistically significant variables of change score

Variable	Univariate regression for change in NPDS			Change in NPDS score at 6 months (ADJ R ² = 28.41%)		
	Coefficient	Standard error	P value	Coefficient	Standard error	P value
Age	−0.31	0.191	0.118			
Gender	−0.38	4.132	0.928			
Years of occupational screen based keyboard use	−0.36	0.499	0.479			
Hours worked each day	−0.72	1.844	0.700			
Hours of home computer use	7.07	2.446	0.009	6.53	2.421	0.014
Use of glasses						
– Reading	−6.70	5.647	0.249			
– Always	1.47	4.494	0.328			
Body mass index	0.07	0.371	0.848			
Difference in neck column length	−0.86	0.986	0.394			
Craniovertebral angle	−0.16	0.265	0.549			
Activation score	−0.75	0.971	0.447			
Repetitions at activation score	0.73	0.783	0.364			
Performance Index	0.06	0.111	0.610			
Shoulder girdle muscle endurance	−0.80	0.835	0.350			

based keyboard use ($p = 0.021$) and the use of reading glasses ($p = 0.027$) were statistically significantly correlated with NPDS score. This described 26.43% of the overall variation in the NPDS score. None of the muscle performance or postural factors measured contributed to the regression model in this sample.

Twenty-three people completed the six-month fol-

low up with four people lost due to resignation from the workplace and one questionnaire not returned. A change score for the NPDS was calculated and ranged from −20.6 to 19. The results of the multivariate analysis for change in NPDS score are given in Table 4. Hours of home computer use ($p = 0.014$) was significantly correlated with the NPDS change. This de-

scribed only 28.41% of the variance in change of NPDS score at six months follow-up. Once again, no muscle performance or postural factor contributed to the model describing change in Neck Pain and Disability Scale score on follow-up.

4. Discussion

4.1. Associations between baseline variables

A clear protective association exists between the number of years employed in a similar task and baseline Neck Pain and Disability Scale scores, with each year employed being associated with a 1.077 point reduction in score measured. This could likely be due to a survival effect within the participant group whereby those people who have experienced occupational neck pain have left the industry. This highlights one of the methodological challenges to this pilot study, being the inability to assemble a true inception cohort of people entering the call centre industry. Given the nature of the workforce and limitations of access to industry, this is a difficult problem to resolve.

The use of reading glasses is also a strong predictor of pain and disability at baseline. Compared to a person who did not use glasses at work, use of reading glasses was associated with a 12-point increase in Neck Pain and Disability Scale score. This was also elevated when compared to people who used glasses continually. What remains clear from this result is that there is a significant difference in neck pain and related disability between those people who use glasses as an intermittent facial orthotic and those who either do not use, or use them continually. This could be related to postural adaptations as individuals accommodate to focussing at different distances, with and without the assistance of glasses.

4.2. Associations at 6 month follow-up

Hours of home computer use proved to be strongly associated with change in Neck Pain and Disability Scale score at six months, with each additional hour of home use associated with a 6.53 point increase in score difference.

This may represent a confounding influence in assessments of VDT related neck pain in the workforce. Home computers have become almost ubiquitous and their everyday use is a common part of life for many people. In spite of the attention given in industry to

work station design and recommendations regarding frequency of breaks and other work practices, most home computer work stations do not receive the same attention in their design. Nor are the recommendations related to positioning and usage necessarily thought about or practiced in the home setting. The magnitude of the effect of each additional hour is large given the reported range of between zero and three hours, but may possibly reflect either additional postural stress as time spent at a VDT unit or could be an expression of the difference between an ergonomically designed work station and the arrangement of a home computer. Depending on the extent of home use, this has the potential to impact detrimentally on the musculoskeletal health of these individuals.

The mean questionnaire scores of the cohort at follow up show little change from the baseline measurements with mean NPDS scores being 14.85 at baseline and 13.85 at six months follow up. Given the findings of Gerr et al. [16] that 58 cases of neck and shoulder pain in 100 person years of observation could be demonstrated within the first 12 months of employment in workers performing extensive occupational computer use, a trend toward increased neck pain and disability questionnaire scores would have been expected. One possible reason for this may be that all the currently used neck pain questionnaires, including the Neck Pain and Disability Scale, have been validated using clinical populations. It is possible that these questionnaires may not be sensitive enough or responsive enough for the sample used in this study since the participants were generally describing neck pain at a subclinical level.

4.3. Associations with muscle and postural performance measures

The lack of a significant association between any muscle performance factors and Neck Pain and Disability Scale score at baseline or six months follow up was unexpected given the postural role of these muscles. This may be due to the small sample size ($n = 28$) and lack of statistical power, although the study was still sufficiently large to show an effect of other variables, i.e. years of occupational screen based keyboard use, hours of home computer use and the categorical variable of use of reading glasses. This can be interpreted as indicating that the effect of the postural muscle parameters on neck pain is much less than the other parameters just mentioned. Formal power calculations assuming 80% power and $p = 0.05$, indicate that the current sample size should have detected the following effects:

1.95 for activation score (SD = 2.05)
 0.22 for performance index (SD = 17.66)
 1.86 for shoulder girdle endurance (SD = 2.15)

From this it seems likely that even if these muscle parameters can be shown in a larger sample to have an association with neck pain or its change over time, then this effect would be far weaker than the influence of the other factors whose relative magnitude has allowed them to be identified as significantly associated in the current study.

The absence of appropriate support and control by the muscular system has been proposed as one factor that may result in neck pain, headaches and work related upper limb disorders in screen based keyboard operators [20]. The effect of lack of support by key deep and postural muscles, together with the adverse stresses likely to be imposed by overactive axiосcapular muscles have been suggested to have considerable impact on articular tissues [25].

There is clinical evidence that the deep cervical flexors lose their endurance significantly in patients with neck pain and cervicogenic headaches [2,27,39]. There is also evidence that these symptoms respond to a treatment regime that includes deep cervical flexor muscle retraining [2,20]. Fibre transformation has been demonstrated in the ventral neck muscles of people with symptomatic neck problems, with increased proportions of glycolytic IIb and transitional IIc muscle fibres present [37]. This represents a transformation in the direction away from the type I slow oxidative fibres and type IIa fibres that would be expected to predominate muscles whose role largely involves tonic action. Furthermore, these changes would not be expected to be associated with a normal aging process as the fibre type proportions do not alter with increasing age in either longus colli or multifidus in the cervical region [6].

However, there is no indication from the results of this pilot study, that these muscle function measures can be used to predict those individuals prone to the development of neck pain in the workplace as none of these factors met the criteria for inclusion into the multivariate analysis. Furthermore, there are other easily identified factors that have been shown to be more strongly associated with neck pain in this occupational setting.

5. Conclusions

Whilst measures of postural muscle performance have been shown to be useful in assessing and manag-

ing patients in the rehabilitation setting, the current pilot study does not support the role of a relationship that can be used as a tool for predicting individuals who are likely to develop neck related pain and disability as a result of occupational VDT use. Should a relationship exist, then it appears to be much weaker than other previously implicated factors. Nor do these results suggest that any trial of targeted exercise for these structures might be a useful prophylactic strategy against the development of neck disorders in this occupational group. These negative results however should be verified in a larger study to rule out type II error (false negative).

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