The association between cervical excursion angles and cervical short flexor muscle endurance

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This study employed a randomly selected sample of 427 never-injured subjects to examine the relationship between poor posture and deep cervical short flexor muscle endurance. Poor posture was described as extreme angular excursion of both the upper and lower aspects of the cervical spine. For both men and women, poor deep cervical short flexor muscle endurance was associated only with extremely large excursion angles traced by the upper cervical spine, that is, head posture associated with excessive cervical lordosis rather than a forward translated head position. Further research is needed to clearly define poor cervical posture, and to investigate the specific relationship of deep short cervical flexor endurance with head on neck posture, in order that postural correction is specific to the underlying biomechanics.

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The deep cervical short flexor muscle group is considered to be an important stabiliser of head-on-neck posture (Janda 1988). This muscle group comprises rectus capitus anterior and lateralis, longus capitus and longus colli (Basmajian 1979) which act over the anterior aspect of the upper and middle sections of the cervical spine (Gurumoorthy 1991). Poor performance of this muscle group has been associated with poor cervical resting posture (Arena et al 1991, Janda 1988, Jull 1988, Richardson 1989, Trott 1988), with the most convincing evidence of association coming from a study by Watson and Trott (1993), which found that women with a forward head posture (described by small craniovertebral angles) and self reported frequent cervicogenic headache had significantly poorer deep short cervical flexor endurance than headache-free women. The term "forward head posture" is currently used by clinicians to describe individuals whose head posture is perceived to be poor. However, there is no accepted description of poor resting head posture, nor of the cervical lordosis associated with it (Ayub et al 1984, Braun 1991, Hanten et al 1991, Raine and Twomey 1994, Refshauge et al 1994). The craniovertebral angle is a commonly used research measure for expressing head-on-neck posture and describes the angle found at the intersection of a line drawn from the tragus of the ear through the spinous process of C7 and a horizontal line through C7. However, recent research appears to suggest that this angle is not an adequate descriptor of the shape of the underlying cervical lordosis (Pirunsan et al 1997).

Definition and description of poor posture, and investigation of the association between cervical resting posture and deep short cervical flexor endurance, has been hindered by measurement issues, specifically the lack of an accurate clinical measure of cervical posture, and the difficulty of measuring the activity of the deep cervical short flexor group in living subjects.

A method of measuring cervical resting posture and defining poor posture has been reported by Grimmer (1993, 1996 and 1997). She devised a new instrument, the linear excursion measuring device (LEMD), to quantify the relative horizontal and vertical excursion of the superiormost tip of the helix of the ear and the spinous process of C7, as the head moved from a standardised vertical starting position to its habitual resting position. These anatomical points were chosen to represent the upper and lower aspects of the cervical spine. The movement at each point was expressed as an angle of excursion, computed from the linear measurements using the formula:

$$\text{degrees} = \tan^{-1}\left[\frac{\text{vertical distance}}{\text{horizontal distance}}\right]$$

As previously described (Grimmer 1996 and 1997, Grimmer and Trott 1996) and illustrated in Figure 1, four groups of subjects with extreme angular excursion of both anatomical points were proposed as having poor cervical resting posture. These subjects had various postural presentations, representing either flattened or exaggerated cervical lordoses. Subjects with poor posture had:

- extremely small excursion angles at both superiormost tip of the helix of the ear, and the spinous process of C7 (less than 2 and 3 degrees respectively); or
- extremely large excursion angles at both the superiormost tip of the helix of the ear, and the spinous process of C7 (greater than 8 and 11.5 degrees respectively); or
- one extremely small, and one extremely large angle at these anatomical points (Figure 1).

It is plausible that all poor resting posture, whether or not associated with flattened or exaggerated cervical lordoses, biomechanically disadvantages the performance of the deep cervical short flexor muscle group (Basmajian 1979, Janda 1988, Richardson 1989). This paper employed the concept of poor posture, as described by combinations of extremely small and/or extremely large excursion angles at the superiormost tip of the helix of the ear and the spinous process of C7, to investigate the association with deep cervical short flexor muscle endurance. The hypothesis under investigation was that all subjects with poor cervical resting posture have poorer endurance of the deep cervical short flexor muscle group than subjects whose posture falls within the average population range.

Table1. Combinations of quintile divisions of C7, and helix of the ear excursion angles.

	helix				
C7	1	2	3	4	5
1	poor+poor 1,1	poor+av 1,2	poor+av 1,3	poor+av 1,4	poor+poor 1,5
2	av+poor 2,1	average 2,2	average 2,3	average 2,4	av+poor 2,5
3	av+poor 3,1	average 3,2	average 3,3	average 3,4	av+poor 3,5
4	av+poor 4,1	average 4,2	average 4,3	average 4,4	av + poor 4,5
5	poor+poor 5,1	poor+av 5,2	poor+av 5,3	poor+av 5,4	poor+poor 5,5

Key: av = abbreviation for average

Note: The C7 quintile is always reported first in the combinations of C7 and helix quintiles, for example, 1,1 refers to the those subjects whose posture falls into the first quintile of both C7 and the helix of the ear excursion angle data, and 1,2 refers to those subjects whose posture falls into the first quintile of C7 and the second quintile of the helix of the ear excursion angle data.

Method

Measurement of cervical excursion angles

Cervical resting posture was measured using the linear excursion measurement device described by Grimmer (1993, 1996 and 1997). Subjects sat in a standardised position with their hips, knees and ankles at 90 degrees and their buttocks and thoracic spine against the vertical backboard of the LEMD. Subjects were asked to maximally retract their chin and to sit as upright as possible against a vertical backboard, as illustrated in Figure 2a. Whilst keeping their mid thorax in contact with the backboard, subjects then relaxed into their habitual cervical resting posture (Figure 2b). Linear measurements were taken from the vertical backboard of the horizontal and vertical excursion of the superiormost tip of the helix of the ear, and of the spinous process of C7, and from these an excursion angle was calculated for each anatomical point. The angles for each anatomical point were considered separately in analysis. Preliminary testing indicated a poor association between them ($r^2 = 0.098$ for men ($F_{215} = 23.24, p < 0.05$) and $r^2 = 0.0028$ for women ($F_{210} = 0.59$, $p > 0.05$)), not only suggesting independence of upper and lower cervical excursion but also indicating that a single expression of posture could not be developed by combining them.

Deep cervical short flexor muscle endurance

A method of quantifying the endurance of the deep cervical short flexor muscles was also developed for this study, and described by Grimmer (1994) in an attempt to address the lack of an objective measure of cervical short flexor muscle endurance in a clinical setting. This measure was based on an exercise position described by Trott (1988) to improve the isometric inner range performance of the deep cervical short flexors. Subjects lay supine on a plinth with no pillow and retracted their chin by head-on-neck flexion. While holding this position, they flexed their neck to raise their head approximately two centimetres from the plinth. This movement was controlled using a vertical ruler placed against the

Figure 1. Illustrations of four postures associated with extreme excursion angles. Extremely large excursion angles represent large horizontal movement relative to small vertical movement at the anatomical point.
Extremely small excursion angle represent large vertical movement relative to small horizontal movement at the anatomical point.

subject's temple. Chin thrust is reported to be associated with failure of the deep short cervical flexor muscles (Janda 1988, Richardson 1989). The high load anti-gravity endurance capacity of the deep cervical short flexors was measured as the time (in seconds) between assuming the test position until the chin began to thrust.

Subjects and their selection

The source of subjects for this study was the electoral rolls of two adjacent municipalities in Tasmania, Australia: the Huon and the Esperance Municipalities. The manner in which subjects were selected has been reported previously (Grimmer 1997).

Of the 450 individuals who were approached to participate in the study, there were nine refusals and 14 exclusions: five for previous neck or back injury, three for pregnancy or breast feeding, four for regularly taking non steroidal anti-inflammatory drugs and/or analgesics and two for taking regular medication for migraine headaches. The exclusion criteria were applied with the aim of identifying subjects without previous spinal injury and who had potentially similar influences on their cervical resting posture. Measurements of cervical excursion and cervical short flexor muscle endurance were subsequently taken from 427 subjects.

Reproducibility of measurements

The first 100 subjects to participate in the study were invited to provide a second set of measurements of cervical excursion and cervical short flexor endurance one calendar month later. Ninety-three of the invited subjects did so. The same measurer took all measurements, being blind to those recorded for the previous month.

Analysis

Reproducibility of measurements

The previously untried measures of excursion and deep cervical short flexor muscle endurance, and the lack of better measures, required that their stability be confirmed before further testing was undertaken (Nunnally 1972). Men and women were tested separately to identify gender-related differences. Stability of the measure was tested using linear regression models that compared the results of tests one and two. The findings were reported as r^2 statistics, that is, the amount of variability in the first test that was explained by the second test. Paired t-test statistics described the extent of mean differences in test scores and identified systematic influences on the second test. This approach took account of the combined effect of correlated subject and measurer errors, but did not correct for chance agreement.

A pragmatic view of systematic variation in subjects' behaviour over the two tests was provided by plotting the difference between tests against the first test scores, as suggested by Altman and Bland (1983). Analysis of variance procedures were also conducted under general linear models which took account of random subject effects, to quantify subject and test effects. The output of this procedure was expressed as intraclass correlation coefficients ($ICC_{1,3}$) (Armstrong et al 1992), where a lower 95 per cent confidence limit (CL) of the ICC statistic of at least 0.80, was sought as evidence of moderate agreement between tests (Richman et al 1980).

Testing the association between variables

The association between deep cervical short flexor endurance and the cervical excursion angles was tested in a number of ways. Analyses were conducted on the whole sample, and were then repeated for men and women separately to identify gender effects. This step was undertaken because men are believed to have generally better muscle performance than women, thus potentially influencing habitual cervical resting posture. The strength of the association between deep cervical short flexor endurance and the cervical excursion angles was expressed as r^2 statistics. As previously reported (Grimmer 1996 and 1997), the excursion angles traced by the upper and lower aspects of the cervical spine were divided into quintiles, and these divisions were cross-tabulated to make 25 distinct combinations of upper and lower cervical spine excursion. For each excursion angle, quintiles 1 and 5 were considered to represent the extremes, and the remaining quintiles (2, 3, 4) represented the average.

The mean endurance of the deep cervical short flexor muscle group, and 95 per cent confidence limits around the mean, were calculated for each of the 25 quintile combinations. Mean differences were tested using a one-way analysis of variance procedure. The 25 quintile combinations represented all possible presentations of cervical resting posture in the data set. There were four combinations where both angles were extreme, nine combinations where both angles were within the average range, and 12 combinations where one of the angles was extreme and the other was within the average range (Table 1).

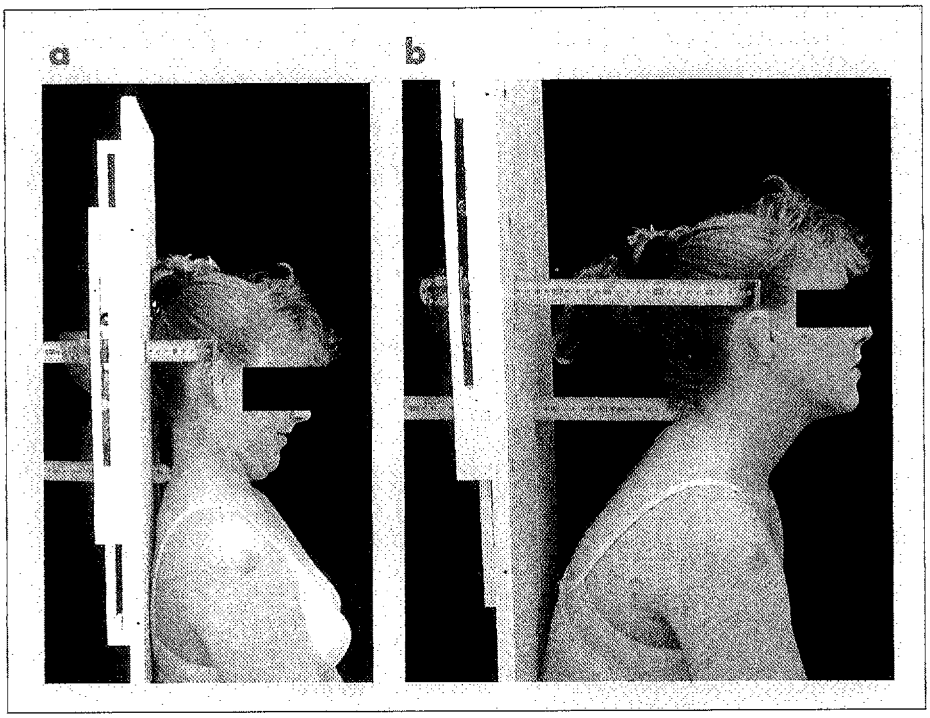

Figure 2a and b. The method of measuring cervical resting posture with the Linear Excursion Measurement Device.

Results

Reproducibility of excursion angles

The angular excursion measurements, taken one month apart, of both the superiormost tip of the helix of the ear and the spinous process of C7 were stable and reproducible (Grimmer 1996 and 1997).

Reproducibility of deep cervical short flexor muscle endurance

As reported previously (Grimmer 1994), there was high correlation (r^2 = 0.88 for men, 0.86 for women) between the two tests, a finding that supported the stability of the measure over a month interval. The between- and within- subject variation within the two sets of scores was small, as indicated by high ICC for both men and women ($ICC_{1,3}$ 0.94 (lower 95 per cent CL 0.90)), and 0.92 (lower 95 per cent CL 0.89) respectively. Examination using the Altman/Bland plot demonstrated an unexpected pattern of variation for both men and women, where measurements taken from subjects with middle to upper range deep cervical short flexor muscle endurance were consistently better on the second test, while there was no change between the two tests in those subjects with poor endurance. Approximately 25 per cent of subjects overall (50 per cent of women and 9 per cent of men) had a mean improvement of two seconds or greater (this value being greater than the 95 per cent confidence interval about the overall mean difference).

Inability to accept the first set of measurements as being truly representative of never-injured subjects' endurance performance dictated that preliminary hypothesis testing should be undertaken on the two sets of available measurements: those taken from the entire sample of 427 subjects, and those taken on the second test from the sample of 93 subjects.

Association between cervical excursion and deep cervical short flexor endurance

In both the main and the retest data set, and for both men and women, there were weak linear associations between the excursion angles of the upper cervical spine (measured by the superiormost tip of the helix of the ear) and deep cervical short flexor

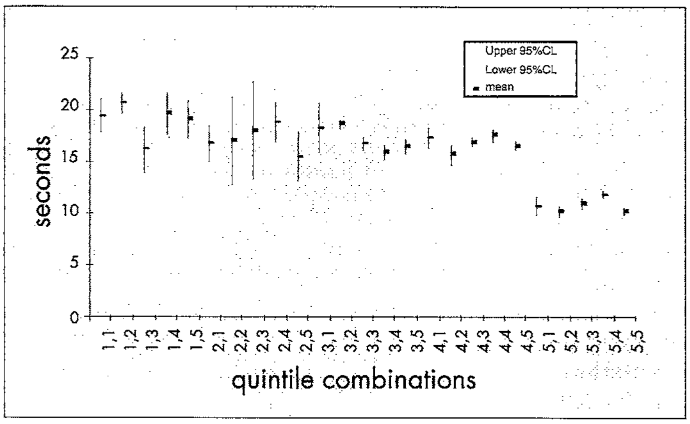

Figure 3. Mean endurance values and 95% confidence limits about the mean, for each of the combinations of quintiles in the excursion angle data.
x axis = combinations of excursion angle quintiles
y axis = endurance capacity of deep cervical short flexor muscles

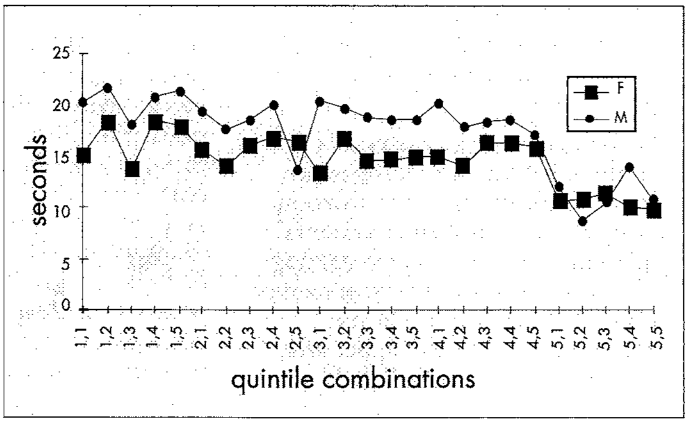

Figure 4. A comparison of mean deep cervical short flexor muscle performance for men and women over the 25 combinations of quintiles in the excursion angle data.
x axis = combinations of excursion angle quintiles
y axis = endurance capacity of deep cervical short flexor muscles

endurance for (main study: r^2 for men = 0.24, and for women, 0.15; retest study: r^2 for men = 0.23, and for women, 0.10). Much weaker associations were observed for lower cervical spine excursion (measured at the spinous process of C7) (main study: r^2 for men = 0.05, and for women, 0.001; retest study: r^2 for men = 0.09, and for women, 0.03). Similarities in the strength of association between cervical excursion angles and deep cervical short flexor muscle endurance in both the main and retest studies suggested that for both men and women, the main data set alone was appropriate for further investigations.

The deep cervical short flexor endurance data were then examined in relation to the quintile divisions of the excursion angles. The number of subjects in each of the 25 combinations of excursion angles ranged from six to 35. There was no pattern to the distribution of the data into the 25 quintile combinations.

Overall, there was a significant difference in mean deep cervical short flexor endurance over the 25 quintile combinations of the excursion angle data ($F_{(24)} = 7.9, p < 0.001$) and there were five groups of subjects whose mean endurance capacity was significantly poorer than the remaining 20 groups. These five groups all involved subjects with extremely large excursion angles of the superiormost tip of the helix of the ear (that is, those subjects with large amounts of vertical excursion in relation to horizontal excursion). The association between deep cervical short flexor endurance and large angles of excursion of the upper cervical spine is illustrated in Figure 3, where it can be seen that the upper 95 per cent confidence limits associated with the mean deep cervical short flexor endurance capacity in each of the five groupings that contain the fifth quintile of the helix excursion angles are lower than the lower 95 per cent confidence limits about the means of the other 20 groups. Figure 3 also illustrates that the excursion of C7 was not significantly associated with deep cervical short flexor endurance.

Despite a significant gender difference in mean deep cervical short flexor muscle endurance (women = 14.4s (SD 5.0): men = 17.8s (SD 4.9): $t_t = -7.1, p < 0.001$), patterns of endurance capacity across the 25 quintile combinations of excursion angles were similar for men and women, where the fifth quintile of excursion of the helix of the ear was significantly associated with lower mean endurance (Figure 4).

Discussion

The hypothesis that poor deep cervical short flexor endurance is associated with all poor cervical posture was not supported by this study. The hypothesis was based on a premise that poor posture was described by extreme excursion at both upper and lower cervical spine, which would mechanically disadvantage deep cervical short flexor performance. Poor cervical short flexor muscle endurance was found to be associated only with those head-on-neck postures described by extremely large excursion angles at the upper cervical spine, that is, head posture associated with exaggerated cervical lordosis. This finding is plausible in that this study measured head-on-neck flexion endurance, and thus focused mainly on the upper cervical spine. With an exaggerated cervical lordosis, the deep short cervical flexors would be placed in a relatively lengthened position and at a mechanical disadvantage to perform the test position of inner range contraction used in this study. Function of deep cervical flexors, with attachments extending from the occiput along the cervical spine to approximately C6 (Gurumoorthy 1991) may also be related to the excursion of C7. However, in the test position used for this study, the lower cervical spine would have been held relatively fixed by the retracted-chin starting position.

This paper reports a method of describing habitual cervical posture using an angle of sagittal translation derived from vertical and horizontal displacement from a vertical starting position. Measurement by this method was the first to suggest that the positions adopted by the upper and lower cervical spine in habitual postural positioning may be independent. This finding questioned the use of single measures of cervical posture, such as the craniovertebral angle, to describe cervical resting posture (Wickens and Kipputh 1937). The authors plan to verify by more exact means, ie x-ray, the nature of the independence of movement of the upper and lower cervical spine, and the cervical lordoses described by small and large excursion angles.

Poor deep cervical short flexor muscle performance will conceivably reduce the stability of the upper and mid cervical spine. Moreover, habitually poor cervical posture and cervicogenic pain are considered to inhibit neural transmissions to the cervical muscles (Gurumoorthy 1991, Janda 1988, Richardson 1989), and the authors suggest that inherently poor cervical muscle performance may fail to provide the spine with sufficient support when placed under any load additional to that required to balance the head against gravity. Despite the finding that men have significantly better endurance capacity of the deep neck flexors than women, the lack of a gender difference in the relationship between deep cervical short flexor endurance and excursion angles suggests that the mechanisms underlying assumption of resting posture are similar for men and women. Further investigations are therefore needed to describe the role of cervical short flexor muscle endurance in head on neck posture.

The findings of this study have implications for physiotherapeutic management of poor posture. Firstly, the authors are hopeful that their findings will encourage physiotherapists to describe posture more clearly with respect to the translation of the upper and lower cervical spine during assumption of habitual posture. Moreover, the authors suggest that intervention to improve deep short cervical flexor endurance capacity is required for patients with large habitual excursion angles of the upper cervical spine, that is, with exaggerated cervical lordosis rather than exaggerated forward translation of the head.

The cross-sectional nature of this study precludes investigation of the direction of association between the performance of the deep cervical short flexor group and cervical posture. The lack of information on the causal links between cervical posture and the muscles of the cervical spine supports the need for longitudinal studies to investigate causal mechanisms underlying the assumption of habitual resting head position.

Conclusion

Poor endurance of the deep cervical short flexor muscles was associated with extremely large excursion angles traced by the upper cervical spine, in which position the head posture was associated with exaggerated cervical lordosis rather than a forward translated position. This study indicates the need to identify the specific elements of poor posture, and to develop appropriate re-education strategies for patients who present with extremely large excursion of the upper cervical spine and poor deep cervical short flexor endurance.

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