Original article

Effects of thoracic kyphosis and forward head posture on cervical range of motion in older adults

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ABSTRACT

It is unclear how age-related postural changes such as thoracic spine kyphosis influence cervical range-of-motion (ROM) in patients with cervical spine dysfunction. The purpose of this study was to explore the mediating effects of forward head posture (FHP) on the relationship between thoracic kyphosis and cervical mobility in older adults with cervical spine dysfunction. Fifty-one older adults (30 females, mean [SD] age = 66 [4.9] years) with cervical spine dysfunction — that is, cervical pain with or without referred pain, numbness or paraesthesia — participated. Pain-related disability was measured using the neck disability index (NDI). Thoracic kyphosis was measured using a flexicurve. FHP was assessed via the craniovertebral angle (CVA) measured from a digitized, lateral-view photograph of each subject. Cervical ROM — namely, upper and general cervical rotation and cervical flexion — was measured by the Cervical Range-of-Motion (CROM) device. Greater thoracic kyphosis was significantly associated with lesser CVA (Spearman ρ = -0.48) whereas greater CVA was significantly associated with greater cervical flexion (Spearman ρ = 0.30) and general rotation ROM (ρ = 0.33), but not with upper cervical rotation ROM (ρ = 0.15). Bootstrap mediational analyses, adjusted for age, gender, weight and NDI, revealed significant indirect effects of thoracic kyphosis on cervical flexion and general rotation ROM through a FHP. Our results show that FHP mediated the relationship between thoracic kyphosis and cervical ROM, specifically general cervical rotation and flexion. These results not only support the justifiable attention given to addressing FHP to improve cervical impairments, but they also suggest that addressing thoracic kyphosis impairments may constitute an “upstream” approach.

1. Introduction

Increased thoracic kyphosis, a common age-related postural change, is evident in older adults and may pose a significant health risk. On one extreme, excessive kyphosis (hyperkyphosis) has been associated with increased mortality (Kado et al., 2009), diminished physical performance (Ryan and Fried, 1997; Kado et al., 2005), impaired respiratory function (Di Bari et al., 2004), poor postural control (Sinaki et al., 2005) and a low quality of life (Ryan and Fried, 1997; Balzini et al., 2003; Takahashi et al., 2005). Even in the absence of hyperkyphosis, increasing kyphosis angle has been associated with increasing mobility limitations in older adults (Katzman et al., 2011).

In rehabilitation science, attention has been drawn to understanding how thoracic kyphosis is associated with cervical dysfunctions. This interest was spurred on in part by the considerable empirical support for the positive clinical outcomes following manipulation and mobilization of the thoracic spine in patients with cervical dysfunctions (Cleland et al., 2007; Krauss et al., 2008; Lau et al., 2011). Indeed, it has been suggested that the mobility of the thoracic spine plays a major role in patients with neck impairments and this notion was supported by a recent cross-sectional study (Lau et al., 2010) which indicated that (i) patients with cervical dysfunction had significantly greater thoracic kyphosis compared to healthy controls, and (ii) thoracic kyphosis was significantly associated with neck pain-related disability.

Although evidence is growing to suggest that improving thoracic spine mobility may be associated with improved clinical outcomes in patients with neck dysfunctions, little is known about the mediating mechanisms linking thoracic kyphosis to neck dysfunctions. And yet, understanding these mechanisms is important for refining and developing more targeted and efficient interventions for patients with neck dysfunctions. So, what could be the likely mediator(s)? Based on our reading of the literature, a possible mediator could be a FHP. Indeed, clinical textbooks have often described a close biomechanical link between cervical and thoracic...
spine (Porterfield and DeRosa, 1995; O’Leary et al., 2008b) although direct empirical support, to our knowledge, is lacking. Furthermore, a recent randomized controlled study by Lau et al. (2011) showed that thoracic manipulation improved FHP and cervical flexion ROM, which implicated FHP as a putative mediator. Unfortunately, the authors did not measure thoracic kyphosis; hence, it is difficult to conclude that FHP may indeed be the mediator between thoracic kyphosis and neck mobility.

Against the aforementioned background, the aim of this cross-sectional study was to examine, in a sample of older adults with neck dysfunction, whether FHP mediated the association with thoracic kyphosis and cervical ROM impairments. We hypothesized that an increase in thoracic kyphosis was associated with an increased FHP which in turn, may be associated with decreased mobility of the cervical spine.

2. Methods

2.1. Participants

Fifty-one older adults (30 females, mean [SD] age = 66 [4.9] years) with cervical spine dysfunction — that is, cervical pain with or without referred pain, numbness or paraesthesia — participated. Subjects above the age of 60 years were recruited from the outpatient physiotherapy clinic of Singapore General Hospital. Subjects were excluded if they had a history of spinal or lower limb fractures, neuromuscular disorder, moderate and severe scoliosis, visual impairment not corrected by prescriptive lenses, whiplash injuries, diabetic neuropathy, unstable angina, uncontrolled cardiorespiratory problems, vestibular disease, dizziness, foot deformities, history of falls over the past one year, or significant impaired function due to their lower back or lower limbs that would overshadow their neck pain and affect their standing posture. All participants provided informed consent as outlined by the institution’s ethics committee.

2.2. Covariates

We determined 4 variables — namely, age, gender, body mass, and pain-related neck disability — as study covariates given their potential or documented association with cervical ROM impairments (Hole et al., 1995; Hermann and Reese, 2001). Neck disability was measured using the Neck Disability Index (NDI), a valid and reliable tool consisting of 10 questions related to a person’s activities of daily living and recreational activities (Vernon and Mior, 1991).

2.3. Thoracic kyphosis

Thoracic kyphosis was measured using the flexicurve method — a well-established technique previously used in a large epidemiological prospective study (Kado et al., 2009). Moreover, the validity and reliability of the measurements from the flexicurve method have been established in previous studies (Milne and Williamson, 1983; Hart and Rose, 1986; Simpson, 1989; Tillotson and Burton, 1991; Greendale et al., 2011), with acceptable intra- and inter-rater reliability coefficients of 0.88 and higher (Caine et al., 1996; Lundon et al., 1998; Arnold et al., 2000; Yanagawa et al., 2000). Specifically, one previous study demonstrated the concurrent validity of the flexicurve-derived kyphosis measurements with the radiographs-derived kyphosis measurements (Pearson’s r = 0.69, Greendale et al., 2011). Subjects were instructed to stand in their usual posture whilst the assessor placed the flexicurve over the spinous processes of the thoracic and lumbar spine (Fig. 1). The ends of the flexicurve were aligned according to C7 and S2 spinous processes and the shape of the flexicurve was conformed to the curvature of the spine. Next, the flexicurve was carefully placed on the table and a photograph of the flexicurve imprint was captured using a 7.2 megapixels digital camera (Sony DSC-W110). To minimize visual distortion of the imprint, a circular spirit level was placed on the camera to ensure that the camera was angled parallel to the table surface (on which the flexicurve was placed). The kyphosis index was then calculated using ImageJ (National Institutes of Health), as described in Fig. 2. The principal advantage of using ImageJ is that the image may be enlarged several times and hence, measurement precision is conceivably greater than that associated with tracing the curve on paper as employed in previous studies (for example Hinman (2004), and Vaughn and Brown (2007)). Also, errors arising from tracing by hand are minimized.

In our study, two measurements were obtained and the average was used in the data analysis.

2.4. Forward head posture

FHP was assessed using a digitized, lateral-view photograph of the subject in his/her usual standing posture. Again, to minimize
image distortion, we placed a circular spirit level at the base of the camera to ensure that the camera was perpendicular to the horizontal. Next, the tragus of the subject’s ear was marked, and a plastic pointer was attached to the skin overlying the C7 vertebra. Once the photograph was obtained, we used ImageJ (Rasband, 1997–2007) to measure FHP, quantified by the craniovertebral angle angle (CVA) (ie, the angle between the horizontal line passing through C7 and a line extending from the tragus of the ear to C7; Fig. 3). Notably, lesser CVA indicates greater FHP. FHP measurements showed good test–retest reliability in previous studies (intraclass correlation coefficients ranging from 0.88 to 0.98) (Raine and Twomey, 1997; Brunton et al., 2003).

2.5. Cervical ROM

Range-of-motion of the cervical spine was measured using the cervical range-of-motion (CROM) device, and CROM measurements had established validity (Ordway et al., 1997; Tousignant et al., 2000, 2002; Malmstrom et al., 2003) and reliability (Capuano-Pucci et al., 1991; Rheault et al., 1992; Hall and Robinson, 2004; Hall et al., 2008b; Takasaki et al., 2011). The following measurements were obtained: (i) total active cervical flexion range in upright sitting, (ii) total active cervical rotation ROM in upright sitting, and (iii) passive upper cervical rotation in available full flexion in supine. During seated ROM testing, the thoracic spine was securely strapped to the chair using a stabilization belt to prevent any thoracic spine movement. The patient was instructed to perform each test actively, with manual guidance provided by the examiner to ensure proper alignment if necessary. Specifically, the examiner determined the end of ROM when a firm resistance was felt or when pain was provoked. All subjects were assessed by the same examiner who has postgraduate qualifications and 10 years of clinical experience in musculoskeletal physiotherapy. Noteworthy, because the CROM device comprises spirit inclinometers, CROM readings are only valid when the inclinometers are positioned parallel to the ground plane. Because older adults have varying levels of cervical flexion limitations (Hall and Robinson, 2004), this may adversely affect the construct validity of the upper cervical ROM measurements. To overcome this problem, we attached a circular spirit device to the CROM device (Fig. 4) and we adjusted the inclination of the plinth such that the CROM inclinometer is parallel to the ground plane (Fig. 4). Two measurements were taken for each movement and the average of the two was used for data analysis.

3. Statistical analyses

We used descriptive statistics to characterize the study sample: we used means with SDs for continuous variables and frequencies for categorical variables. Spearman and rank-biserial correlations were used to quantify the interrelations between all variables. We used Spearman’s correlation because this analysis is less sensitive to the influence of outliers.

A mediation model was used to determine whether FHP (the proposed mediator) carried the influence of thoracic kyphosis (the independent variable) on cervical ROM (the dependent variables). In this model (Fig. 5), the total indirect (mediated) effect is quantified by the product of the regression coefficient of thoracic kyphosis on cervical measures (path a) and the regression coefficient of FHP on the cervical measures (path b). We formally assessed mediation using the INDIRECT macro (Preacher and Hayes, 2008), which estimated for FHP its indirect (mediated) effect and the corresponding bootstrapped (5000 samples), bias-corrected and accelerated 95% confidence interval (95% CI). At this point, it should be noted that typically, a causal steps test, as outlined by Baron and Kenny (1986), is used to assess the plausibility of mediation, but this test often lacks statistical power to detect true mediation effects (MacKinnon et al., 2002). More important, the causal step approach does not directly assess the indirect effects and therefore essentially ignores the central question of whether the specific indirect effect is different from zero (Preacher and Hayes, 2008). On the other hand, the Sobel test (Sobel, 1982), while providing inferential testing of the specific indirect effects, requires relatively large sample sizes in order to reasonably satisfy the multivariate normality assumption (Preacher and Hayes, 2004). In contrast, bootstrapping, a nonparametric approach to effect size estimation (Efron and Tibshirani, 1993),
makes no assumption regarding normality and, therefore, is considered more statistically robust than the Sobel test (Shrout and Bolger, 2002; Mackinnon et al., 2004; Preacher and Hayes, 2008).

We conducted separate mediation analyses for each cervical ROM and included in each analysis, age, gender, body mass and NDI as covariates. To improve the robustness of the results, we also included cervical flexion as a covariate in the model predicting upper cervical rotation ROM. All statistical analyses were done with PASW software, version 18. Statistical significance was determined at the 2-sided 0.05 level.

4. Results

The descriptive characteristics of the subjects and their postural and cervical measures are summarized in Table 1. Women reported higher level of pain-related disability (mean NDI, 22% versus 12%; rank-biserial correlation = 0.38, P < 0.01). Table 2 shows the inter-relations among the study variables. As expected, increased age was associated with reduced cervical ROM (Spearman \( \rho = -0.41 \) and \( \rho = -0.51 \) for general and upper cervical rotation, respectively).

The relationships between cervical ROM measures and CVA (lesser CVA indicates greater FHP) were in the expected direction and revealed positive associations between CVA and general cervical rotation (\( \rho = 0.33, P = 0.02 \)), cervical flexion (\( \rho = 0.30, P = 0.03 \)) and upper cervical rotation (\( \rho = 0.15, P = 0.31 \)). The relationships between thoracic kyphosis and CVA revealed significantly negative association (\( \rho = -0.48, P < 0.001 \)).

Table 3 shows the results of the multiple mediator analysis. Thoracic kyphosis was associated with FHP (path a). With the exception of upper cervical rotation ROM, the specific indirect (mediated) effects (path a × b) through FHP were statistically significant for both general cervical rotation and flexion — that is, the 95% CIs of the a × b estimates did not include zero (Preacher and Hayes, 2004).

5. Discussion

To our knowledge, no previous studies have analysed the inter-associations between thoracic kyphosis, FHP and cervical impairments specifically in older adults with neck impairments. This is surprising, considering that neck problems are common in older adults (March et al., 1998) and that the prevalence of hyperkyphosis is high — approximately 1 in 2 men and 65 in 100 women (Bartynski et al., 2005). Accordingly, this study is the first to empirically show that in a group of older adults, thoracic kyphosis had an indirect effect on cervical ROM through a FHP. Mediation analyses indicate that increased kyphosis was associated with a greater FHP (path a), and a greater FHP, in turn, was associated with decreased cervical flexion and general cervical rotation (path b) but not with upper cervical rotation.

5.1. Path a (increased thoracic kyphosis → increased FHP)

In our study, the positive association between thoracic kyphosis and FHP is consistent with the findings by Lau et al. (2010), which also showed that thoracic kyphosis was associated with FHP in patients with neck pain (\( \rho = -0.62, P < 0.01 \)). Of interest, Lau et al. (2010) measured only the upper thoracic spine kyphosis whilst we took into consideration the entire thoracic spine in our measurements. Furthermore, Lau et al. (2010) studied a younger group of patients. Consequently, our findings strengthen and extend Lau et al.’s (2010) findings to an older group of patients. In contrast, Raine and Twomey (1997) found that kyphosis and FHP were not related. However, our results are not directly comparable to theirs mainly because they studied a group of healthy subjects with a diverse age range (17–83 yrs).

5.2. Path b (increased FHP → decreased cervical ROM)

Greater FHP was associated with greater deficits in cervical rotation (\( \rho = 0.33, P = 0.02 \)) and flexion (\( \rho = 0.30, P = 0.03 \)) ROM and these findings agree with those of 5 other studies (Walmsley et al., 1996; Fernandez-de-las-Penas et al., 2006; De-la-Llave-Rincon et al., 2009; Yoo and An, 2009; Ro et al., 2010). In contrast, upper cervical rotation ROM was weakly and non-significantly associated with FHP (\( \rho = 0.15, P = 0.31 \)). Although we acknowledge that the differences in testing positions (seated versus supine) and modes of testing (active versus passive) could have influenced our results, we emphasize that our method of ROM measurements is well validated and widely used (Ordway et al., 1997; Tousignant et al., 2000; Malmstrom et al., 2003; Hall et al., 2007; Hall et al., 2008a; Takasaki et al., 2011). Furthermore, there are plausible explanations for our results. In one previous study, Walmsley et al. (1996) observed that healthy older adults demonstrated reduced cervical ROM (in flexion, extension and general rotation) compared to the younger group, except for upper cervical rotation ROM. These authors suggested that the upper cervical spine potentially allows older adults to compensate for the lack of ROM in the lower segments of the cervical spine. More research is warranted to examine if the upper cervical spine has any other specific roles, especially its contribution to the somatosensory

<table>
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<tr>
<th>Characteristics</th>
<th>Mean ± SD (range)</th>
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<tr>
<td>Age (years)</td>
<td>66 ± 4.9 (60–78)</td>
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<td>Female/male</td>
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<td>1.61 ± 0.1 (1.45–1.89)</td>
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<td>Mass (kg)</td>
<td>61 ± 14.3 (41–130)</td>
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<td>BMI (kg/m²)</td>
<td>23.4 ± 3.8 (17.1–36.4)</td>
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<tr>
<td>Presently on pain medication (number)</td>
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<tr>
<td>Total cervical rotation ROM (degree)</td>
<td>125 ± 19.9 (66–167)</td>
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<tr>
<td>Total upper cervical ROM (degree)</td>
<td>76 ± 16.5 (26–106)</td>
</tr>
<tr>
<td>Cervical flexion (degree)</td>
<td>50 ± 9.2 (33–81)</td>
</tr>
<tr>
<td>Cervical pain on visual analogue scale (/10)</td>
<td>2.0 ± 1.7 (0–6)</td>
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<td>Thoracic kyphosis index*</td>
<td>10.6 ± 2.3 (5.1–16.4)</td>
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<tr>
<td>Craniovertebral angle (degree)b</td>
<td>45.6 ± 6.7 (31–59)</td>
</tr>
<tr>
<td>Neck disability index (100)</td>
<td>18.0 ± 12.5 (0–44)</td>
</tr>
</tbody>
</table>

ROM = Range of Motion.

* Greater values indicate greater kyphosis curve.

b FHP is represented by Craniovertebral Angle (CVA), greater CVA values indicates less FHP.
system, considering its close anatomical relationship with the other sensory systems such as the vestibular and visual systems (Poole et al., 2008; Treleaven, 2008).

5.3. Path ab (how does thoracic kyphosis relate to cervical ROM?)

As mentioned, our principal finding was the mediation effects of FHP on the association between increased thoracic kyphosis and cervical ROM deficits. Although we could not compare our findings with those of others, our findings have biological plausibility. Specifically, a plausible chain of events may link an increasing thoracic spine kyphosis to an inevitable anterior shift in trunk mass through an altered physiological loading of the thoracic spine (Pearsall and Reid, 1992). Consequently, this results in a FHP which ostensibly increases compressive loading in the cervical spine (Szeto et al., 2005) and results in a reduction of cervical ROM. The results of our study support the notion that the loading mechanism of the cervical spine is dictated by the thoracic spine (O’Leary et al., 2008b), and may give evidence to the contributing role of thoracic spine in the development of cervical spine disorders.

6. Implications

Our findings have implications. First, they support the regional interdependence theory by Wainner et al. (2007) in that “seemingly unrelated impairments in a remote anatomical region may contribute to, or be associated with, the patient’s primary complaint”. Given that our mediational results persisted in models adjusted for age and pain-related disability, they not only support the justifiable attention given to addressing FHP to improve cervical impairments (O’Leary et al., 2008a), but they also suggest that addressing thoracic kyphosis impairments may constitute an “upstream” approach. Relatedly, this finding has implications of considerable importance to physiotherapists, given that several studies have shown that thoracic kyphosis is amenable to rehabilitation (Pfeifer et al., 2004; Katzman et al., 2007; Benedetti et al., 2008; Ball et al., 2009; Greendale et al., 2009; Pawlowsky et al., 2009). Despite these arguments, the importance of addressing thoracic kyphosis impairments appears to be neglected by medical practitioners (Kado et al., 2007). Furthermore, in a recent survey conducted among 468 physiotherapists in Australia, 40% of physiotherapists working in hospitals or private practice reported that they encountered hyperkyphosis on a daily basis, and yet they reported having limited knowledge with its management (Perriman et al., 2011). Moreover, all the physiotherapists surveyed reported using visual estimation to measure the kyphosis curve—a method which has been criticised as being crude and unreliable (Perriman et al., 2011). Considering the high prevalence of increased kyphosis encountered by physiotherapists and given the results of the current study, a possible implication is that therapists should consider obtaining more objective kyphosis measurements using the flexicurve—an inexpensive, yet readily accessible and reliable tool (Caine et al., 1996; Lundon et al., 1998; Arnold et al., 2000; Yanagawa et al., 2000).

7. Limitations

Our study has limitations. First, our cross-sectional results may be affected by reverse causation—that is, cervical spine-related impairments could adversely affect posture such that patients may show an adaptive, protective altered motor control behaviour in response to pain (Elvey and O’Sullivan, 2004). Accordingly, intervention studies are needed to establish the presence and direction of causation. Second, although our ROM and posture measurements were well validated and widely used (Ordway et al., 1997; Tousignant et al., 2000; Malmstrom et al., 2003; Hall et al., 2007, 2008a; Greendale et al., 2011; Takasaki et al., 2011), we acknowledged that they were measured in different positions. In our study, it was not feasible to measure upper cervical ROM in the seated position using the CROM device, and future studies should apply greater technological sophistication such as 3D-motion analysis to standardize the testing positions for all measurements. Third, as an exploratory study, we have used a single-mediator

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model although the actual biological processes are likely to be more complex than initially envisaged. For example, future studies may consider a sequential-mediator model wherein thoracic mobility exerts an indirect effect on cervical mobility through the two sequential mediators of thoracic kyphosis and FHP. Fourth, although our measurement method of thoracic kyphosis represents an improvement over previous studies (Raine and Twomey, 1997; Lau et al., 2010), these measurements did not allow us to infer how changes in thoracic angles influence loading distribution throughout the spine.

8. Conclusion

In a sample of older adults with neck dysfunctions, we showed that the negative influence of kyphosis on reduced cervical mobility is exerted through an increase in FHP. We hope that our data would stimulate further study, first to verify our mediational findings using longitudinal or interventional data, and second, to determine whether improving thoracic kyphosis will result in an improvement in FHP and cervical ROM impairments in patients with neck dysfunction.

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Competing interests

The authors have no professional or financial affiliations that may be perceived to have biased the presentation.

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