Manual Therapy xxx (2012) 1–7

Contents lists available at SciVerse ScienceDirect

Manual Therapy

journal homepage: www.elsevier.com/math

Original article

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

June Quek [a,*], Yong-Hao Pua [a], Ross A. Clark [b], Adam L. Bryant [b]

[a] Department of Physiotherapy, Singapore General Hospital, Outram Road, Singapore 169608, Singapore
[b] School of Physiotherapy, The University of Melbourne, Australia

ARTICLE INFO

Article history:
Received 4 April 2012
Received in revised form
17 July 2012
Accepted 23 July 2012

Keywords:
Thoracic kyphosis
Posture
Cervical spine
Range-of-motion

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 $\rho = -0.48$) whereas greater CVA was significantly associated with greater cervical flexion (Spearman $\rho = 0.30$) and general rotation ROM ($\rho = 0.33$), but not with upper cervical rotation ROM ($\rho = 0.15$). 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

* Corresponding author. Tel.: +65 6321 4132.
E-mail address: guuday@gmail.com (J. Quek).

1356-689X/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.math.2012.07.005

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 injury, diabetic neuropathy, unstable angina, uncontrolled cardio-respiratory 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.

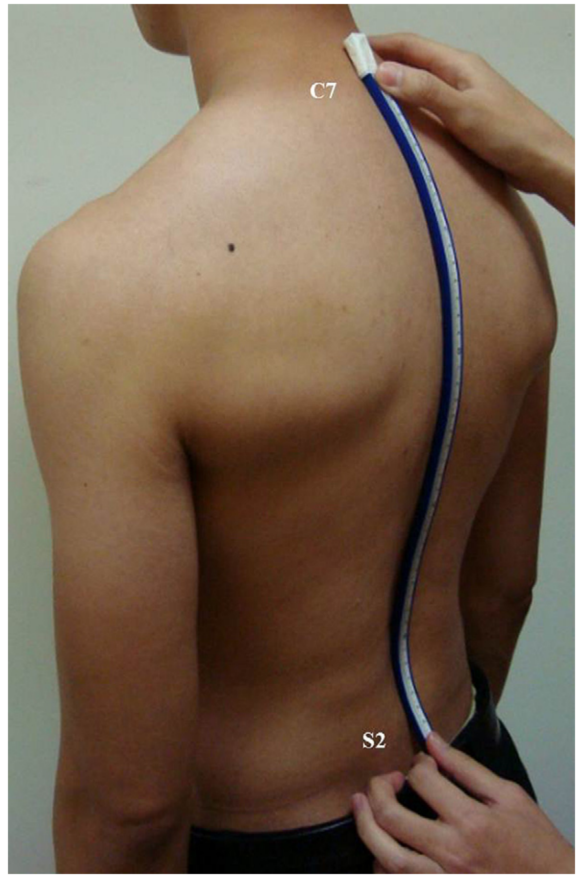

Fig. 1. Measurement of thoracic kyphosis using the flexicurve.

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

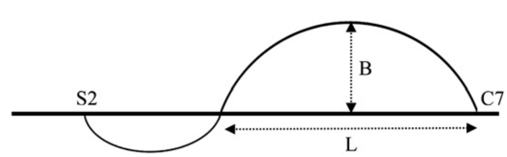

Fig. 2. The kyphosis index is calculated from thoracic width (B) divided by the horizontal length (L) multiplied by 100 ($B/L \times 100$).

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 (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 ranged 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.

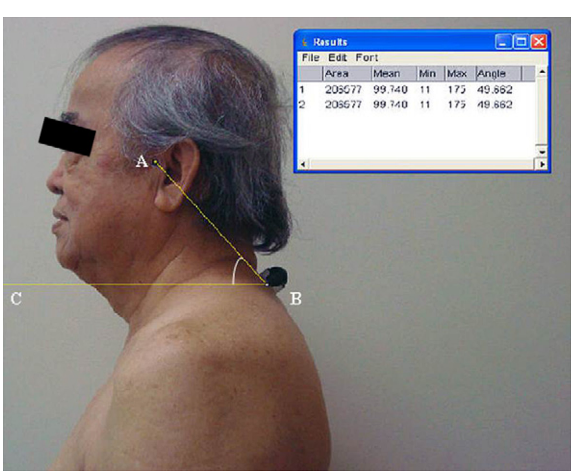

Fig. 3. Measurement of forward head posture as represented by the craniovertebral angle (acute angle subtended by the line AB and BC).

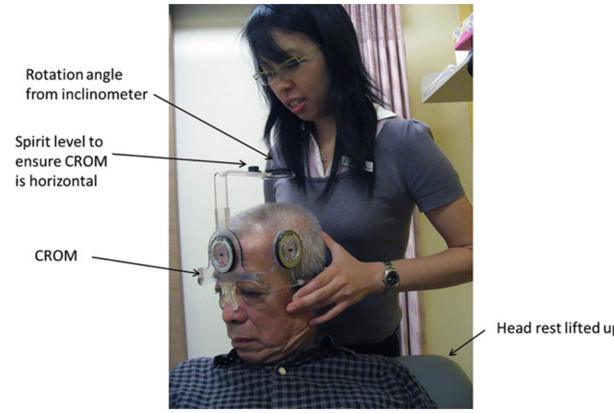

Fig. 4. Measurement of upper cervical rotation range of motion using the Cervical Range of Motion (CROM) device.

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),

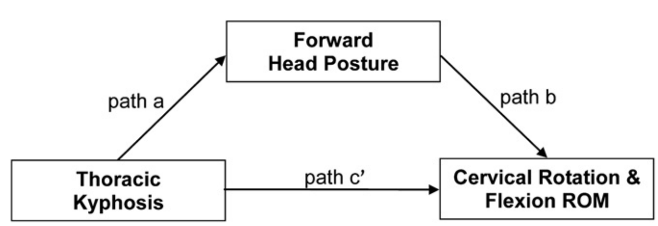

Fig. 5. Mediation model of association between thoracic kyphosis and cervical ROM. For presentation clarity, covariates – namely, age, gender, body weight and neck disability index – are not displayed.

Please cite this article in press as: Quek J, et al., Effects of thoracic kyphosis and forward head posture on cervical range of motion in older adults, Manual Therapy (2012), http://dx.doi.org/10.1016/j.math.2012.07.005

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 interrelations 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).

Table 1
Demographic characteristics of the subjects ($n = 51$).

Characteristics	Mean ± SD (range)
Age (years)	66 ± 4.9 (60–78)
Female/male	29/22
Height (metres)	1.61 ± 0.1 (1.45–1.89)
Mass (kg)	61 ± 14.5 (41–130)
BMI (kg/m^2)	23.4 ± 3.8 (17.1–36.4)
Ethnicity	
Chinese	46
Malay	2
Indian	2
Others	1
Employment status	
Full-time paid	17
Part-time or casual paid	6
Not paid or retired	28
Education	
Primary or less	14
Secondary	23
Tertiary or more	14
Living alone	3
Number of comorbidities	
0	5
1	25
≥2	21
Smoker	
No	47
Yes	1
Former	3
Presently on pain medication (number)	7
Total cervical rotation ROM (degree)	125 ± 19.9 (66–167)
Total upper cervical ROM (degree)	76 ± 16.5 (26–106)
Cervical flexion (degree)	50 ± 9.2 (33–81)
Cervical pain on visual analogue scale (/10)	2.0 ± 1.7 (0–6)
Thoracic kyphosis index[a]	10.6 ± 2.3 (5.1–16.4)
Craniovertebral angle (degree)[b]	45.6 ± 6.7 (31–59)
Neck disability index (/100)	18.0 ± 12.5 (0–44)

ROM = Range of Motion.
[a] Greater values indicate greater kyphosis curve.
[b] FHP is represented by Craniovertebral Angle (CVA), greater CVA values indicates less FHP.

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. Mediational 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 2
Spearman correlation matrix for thoracic kyphosis, craniovertebral angle, total cervical rotation, cervical flexion, upper cervical rotation ROM, gender, age, weight and neck disability index ($n = 51$).

Variables	1	2	3	4	5	6	7	8
Thoracic kyphosis (1)								
Craniovertebral angle[c] (2)	−0.48[b]							
Total cervical rotation (3)	−0.13	0.33[a]						
Cervical flexion (4)	0.04	0.30[a]	0.49[b]					
Upper cervical rotation (5)	−0.41	0.15	0.70[b]	0.31[a]				
Gender – female (6)	−0.30[a]	0.24	0.08	0.10	−0.02			
Age (7)	−0.30[a]	0.14	−0.42[b]	−0.08	−0.51[b]	0.38[b]		
Weight (8)	0.15	−0.15	−0.01	−0.08	0.09	−0.74[b]	−0.46[b]	
Neck disability index (9)	−0.05	0.06	−0.20	−0.23	−0.02	0.38[b]	0.15	−0.31[a]

Gender coded as male = 0, female = 1.
[a] $P < 0.05$ (2-tailed).
[b] $P < 0.01$ (2-tailed).
[c] 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).

Table 3
Regression coefficients and tests of indirect effects for mediational analyses ($n = 51$).[a]

Measurements	Direct effect path c′	Path a	Path b	Indirect effect a × b (95% CI)[b]
Total cervical rotation				
Thoracic kyphosis		−1.32[e]		−1.2 (−2.8, −0.27)[f]
Craniovertebral angle[g]	−0.03		0.91[c]	
Cervical flexion				
Thoracic kyphosis		−1.32[e]		−0.58 (−1.3, −0.12)[f]
Craniovertebral angle[g]	0.61		0.44[d]	
Cervical upper rotation				
Thoracic kyphosis		−1.32[e]		−0.54 (−1.56, 0.2)
Craniovertebral angle[g]	0.41		0.41	

[a] 95% CI = 95% confidence interval.
[b] Bias-corrected and accelerated 95% CI generated from 5000 bootstrapped samples.
[c] $P < 0.05$ (2-tailed).
[d] $P = 0.05$.
[e] $P < 0.005$ (2-tailed).
[f] Statistically significant.
[g] FHP is represented by Craniovertebral Angle (CVA), greater CVA values indicates less FHP.

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 model although the actual biological processes are likely 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.

Grant support

This study was supported by Singapore Physiotherapy Association Research Grant (RF09-004) and Singhealth Foundation Research Grant (SHF/FG551S/2011).

Competing interests

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

Acknowledgements

We wish to express our gratitude to all participants of this study. We also thank Ms Tan Bee Yee, Ms Jennifer Liaw, and Ms Karen Koh for supporting this study.

References

Arnold CM, B B, Harrison EL, Olszynski W. The reliability of five clinical postural alignment measures for women with osteoporosis. Physiotherapy Canada 2000;52(4):286–94.

Ball JM, Cagle P, Johnson BE, Lucasey C, Lukert BP. Spinal extension exercises prevent natural progression of kyphosis. Osteoporosis International 2009; 20(3):481–9.

Balzini L, Vannucchi L, Benvenuti F, Benucci M, Monni M, Cappozzo A, et al. Clinical characteristics of flexed posture in elderly women. Journal of the American Geriatrics Society 2003;51(10):1419–26.

Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology 1986;51(6):1173–82.

Bartynski WS, Heller MT, Grahovac SZ, Rothfus WE, Kurs-Lasky M. Severe thoracic kyphosis in the older patient in the absence of vertebral fracture: association of extreme curve with age. AJNR American Journal of Neuroradiology 2005;26(8): 2077–85.

Benedetti MG, Berti L, Presti C, Frizziero A, Giannini S. Effects of an adapted physical activity program in a group of elderly subjects with flexed posture: clinical and instrumental assessment. Journal of Neuroengineering and Rehabilitation 2008;5:32.

Brunton J, Brunton E, Aoife NM. Reliability of measuring natural head posture using the craniovertebral angle. Irish Ergonomics Review 2003:37–41.

Caine MP, McConnell AK, Taylor D. Assessment of spinal curvature: an evaluation of the flexicurve and associated means of analysis. International Journal of Rehabilitation Research 1996;19(3):271–8.

Capuano-Pucci D, Rheault W, Aukai J, Bracke M, Day R, Pastrick M. Intratester and intertester reliability of the cervical range of motion device. Archives of Physical Medicine and Rehabilitation 1991;72(5):338–40.

Cleland JA, Glynn P, Whitman JM, Eberhart SL, MacDonald C, Childs JD. Short-term effects of thrust versus nonthrust mobilization/manipulation directed at the thoracic spine in patients with neck pain: a randomized clinical trial. Physical Therapy 2007;87(4):431–40.

De-la-Llave-Rincon AI, Fernandez-de-las-Penas C, Palacios-Cena D, Cleland JA. Increased forward head posture and restricted cervical range of motion in patients with carpal tunnel syndrome. Journal of Orthopaedic & Sports Physical Therapy 2009;39(9):658–64.

Di Bari M, Chiarlone M, Matteuzzi D, Zacchei S, Pozzi C, Bellia V, et al. Thoracic kyphosis and ventilatory dysfunction in unselected older persons: an epidemiological study in Dicomano, Italy. Journal of the American Geriatrics Society 2004;52(6):909–15.

Efron B, Tibshirani R. An introduction to the bootstrap. New York: Chapman & Hall; 1993. pxvi, p. 436.

Elvey R, O'Sullivan P. A contemporary approach to manual therapy. In: Boyling, Jull, editors. Modern manual therapy. Amsterdam: Elsevier; 2004.

Fernandez-de-las-Penas C, Alonso-Blanco C, Cuadrado ML, Pareja JA. Forward head posture and neck mobility in chronic tension-type headache: a blinded, controlled study. Cephalalgia: An International Journal of Headache 2006; 26(3):314–9.

Greendale GA, Huang MH, Karlamangla AS, Seeger L, Crawford S. Yoga decreases kyphosis in senior women and men with adult-onset hyperkyphosis: results of a randomized controlled trial. Journal of the American Geriatrics Society 2009; 57(9):1569–79.

Greendale GA, Nili NS, Huang MH, Seeger L, Karlamangla AS. The reliability and validity of three non-radiological measures of thoracic kyphosis and their relations to the standing radiological Cobb angle. Osteoporosis International 2011;22(6):1897–905.

Hall T, Briffa K, Hopper D. Clinical evaluation of cervicogenic headache: a clinical perspective. Journal of Manual & Manipulative Therapy 2008a;16(2):73–80.

Hall T, Chan HT, Christensen L, Odenthal B, Wells C, Robinson K. Efficacy of a C1-C2 self-sustained natural apophyseal glide (SNAG) in the management of cervicogenic headache. Journal of Orthopaedic & Sports Physical Therapy 2007; 37(3):100–7.

Hall T, Robinson K. The flexion-rotation test and active cervical mobility—a comparative measurement study in cervicogenic headache. Manual Therapy 2004;9(4):197–202.

Hall TM, Robinson KW, Fujinawa O, Akasaka K, Pyne EA. Intertester reliability and diagnostic validity of the cervical flexion-rotation test. Journal of Manipulative and Physiological Therapeutics 2008b;31(4):293–300.

Hart DL, Rose SJ. Reliability of a noninvasive method for measuring the lumbar curve*. Journal of Orthopaedic & Sports Physical Therapy 1986;8(4):180–4.

Hermann KM, Reese CS. Relationships among selected measures of impairment, functional limitation, and disability in patients with cervical spine disorders. Physical Therapy 2001;81(3):903–14.

Hinman MR. Comparison of thoracic kyphosis and postural stiffness in younger and older women. Spine Journal 2004;4(4):413–7.

Hole DE, Cook JM, Bolton JE. Reliability and concurrent validity of two instruments for measuring cervical range of motion: effects of age and gender. Manual Therapy 1995;1(1):36–42.

Kado DM, Huang MH, Barrett-Connor E, Greendale GA. Hyperkyphotic posture and poor physical functional ability in older community-dwelling men and women: the Rancho Bernardo study. Journals of Gerontology Series A: Biological Sciences and Medical Sciences 2005;60(5):633–7.

Kado DM, Lui LY, Ensrud KE, Fink HA, Karlamangla AS, Cummings SR. Hyperkyphosis predicts mortality independent of vertebral osteoporosis in older women. Annals of Internal Medicine 2009;150(10):681–7.

Kado DM, Prenovost K, Crandall C. Narrative review: hyperkyphosis in older persons. Annals of Internal Medicine 2007;147(5):330–8.

Katzman WB, Sellmeyer DE, Stewart AL, Wanek L, Hamel KA. Changes in flexed posture, musculoskeletal impairments, and physical performance after group exercise in community-dwelling older women. Archives of Physical Medicine and Rehabilitation 2007;88(2):192–9.

Katzman WB, Vittinghoff E, Kado DM. Age-related hyperkyphosis, independent of spinal osteoporosis, is associated with impaired mobility in older community-dwelling women. Osteoporosis International 2011;22(1):85–90.

Krauss J, Creighton D, Ely JD, Podlewska-Ely J. The immediate effects of upper thoracic translatoric spinal manipulation on cervical pain and range of motion: a randomized clinical trial. Journal of Manual & Manipulative Therapy 2008; 16(2):93–9.

Lau HM, Wing Chiu TT, Lam TH. The effectiveness of thoracic manipulation on patients with chronic mechanical neck pain — a randomized controlled trial. Manual Therapy 2011;16(2):141–7.

Lau KT, Cheung KY, Chan KB, Chan MH, Lo KY, Chiu TT. Relationships between sagittal postures of thoracic and cervical spine, presence of neck pain, neck pain severity and disability. Manual Therapy 2010;15(5):457–62.

Lundon KM, Li AM, Bibershtein S. Interrater and intrarater reliability in the measurement of kyphosis in postmenopausal women with osteoporosis. Spine (Phila Pa 1976) 1998;23(18):1978–85.

MacKinnon DP, Lockwood CM, Hoffman JM, West SG, Sheets V. A comparison of methods to test mediation and other intervening variable effects. Psychological Methods 2002;7(1):83–104.

Mackinnon DP, Lockwood CM, Williams J. Confidence limits for the indirect effect: distribution of the product and resampling methods. Multivariate Behavioral Research 2004;39(1):99.

Malmstrom EM, Karlberg M, Melander A, Magnusson M. Zebris versus Myrin: a comparative study between a three-dimensional ultrasound movement

analysis and an inclinometer/compass method: intradevice reliability, concurrent validity, intertester comparison, intratester reliability, and intraindividual variability. Spine (Phila Pa 1976) 2003;28(21):E433–40.
March LM, Brnabic AJ, Skinner JC, Schwarz JM, Finnegan T, Druce J, et al. Musculoskeletal disability among elderly people in the community. Medical Journal of Australia 1998;168(9):439–42.
Milne JS, Williamson J. A longitudinal study of kyphosis in older people. Age and Ageing 1983;12(3):225–33.
O'Leary T, Sterling, Jull. Whiplash, headache, and neck pain: research-based directions for physical therapies. Edinburgh: Churchill Livingstone; 2008a. p. 200.
O'Leary T, Sterling, Jull. Whiplash, headache, and neck pain: research-based directions for physical therapies. Edinburgh: Churchill Livingstone; 2008b. p. 31.
Ordway NR, Seymour R, Donelson RG, Hojnowski L, Lee E, Edwards WT. Cervical sagittal range-of-motion analysis using three methods. Cervical range-of-motion device, 3space, and radiography. Spine (Phila Pa 1976) 1997;22(5): 501–8.
Pawlowsky SB, Hamel KA, Katzman WB. Stability of kyphosis, strength, and physical performance gains 1 year after a group exercise program in community-dwelling hyperkyphotic older women. Archives of Physical Medicine and Rehabilitation 2009;90(2):358–61.
Pearsall D, Reid J. Line of gravity relative to upright vertebral posture. Clinical Biomechanics 1992;7(2):80–6.
Perriman DM, Scarvell JM, Hughes AR, Lueck CJ, Dear KB, Smith PN. Thoracic hyperkyphosis: a survey of Australian physiotherapists. Physiotherapy Research International 2011.
Pfeifer M, Begerow B, Minne HW. Effects of a new spinal orthosis on posture, trunk strength, and quality of life in women with postmenopausal osteoporosis: a randomized trial. American Journal of Physical Medicine & Rehabilitation 2004;83(3):177–86.
Poole E, Treleaven J, Jull G. The influence of neck pain on balance and gait parameters in community-dwelling elders. Manual Therapy 2008;13(4): 317–24.
Porterfield JA, DeRosa C. Mechanical neck pain: perspectives in functional anatomy. Philadelphia: Saunders; 1995. px, p. 228.
Preacher KJ, Hayes AF. SPSS and SAS procedures for estimating indirect effects in simple mediation models. Behavior Research Methods, Instruments, & Computers 2004;36(4):717–31.
Preacher KJ, Hayes AF. Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behavior Research Methods 2008;40(3):879–91.
Raine S, Twomey LT. Head and shoulder posture variations in 160 asymptomatic women and men. Archives of Physical Medicine and Rehabilitation 1997; 78(11):1215–23.
Rasband WS. Image J. Bethesda, Maryland, USA: U.S. National Institute of Health, http://rsb.info.nih.gov/ij/; 1997.
Rheault W, Albright B, Beyers C, Franta M, Johnson A, Skowronek M, et al. Intertester reliability of the cervical range of motion device. Journal of Orthopaedic & Sports Physical Therapy 1992;15(3):147–50.
Ro H, Gong W, Ma S. Correlations between and absolute rotation angle, anterior weight bearing, range of flexion and extension motion in cervical herniated nucleus pulposus. Journal of Physical Therapy Science 2010;22:447–50.
Ryan SD, Fried LP. The impact of kyphosis on daily functioning. Journal of the American Geriatrics Society 1997;45(12):1479–86.
Shrout PE, Bolger N. Mediation in experimental and nonexperimental studies: new procedures and recommendations. Psychological Methods 2002;7(4):422–45.
Simpson SR. Evaluation of a flexible ruler technique for measuring lumbar lordosis in the clinical assessment of low back pain. Journal of the Society of Occupational Medicine 1989;39(1):25–9.
Sinaki M, Brey RH, Hughes CA, Larson DR, Kaufman KR. Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. Osteoporosis International 2005;16(8):1004–10.
Sobel ME. Asymptotic confidence intervals for indirect effects in structural equation models. In: Leinhardt S, editor. Sociological methodology. San Francisco: Jossey-Bass; 1982. p. 290–312.
Szeto GP, Straker LM, O'Sullivan PB. A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work–1: neck and shoulder muscle recruitment patterns. Manual Therapy 2005;10(4):270–80.
Takahashi T, Ishida K, Hirose D, Nagano Y, Okumiya K, Nishinaga M, et al. Trunk deformity is associated with a reduction in outdoor activities of daily living and life satisfaction in community-dwelling older people. Osteoporosis International 2005;16(3):273–9.
Takasaki H, Hall T, Oshiro S, Kaneko S, Ikemoto Y, Jull G. Normal kinematics of the upper cervical spine during the Flexion-Rotation Test – in vivo measurements using magnetic resonance imaging. Manual Therapy 2011;16(2):167–71.
Tillotson KM, Burton AK. Noninvasive measurement of lumbar sagittal mobility. An assessment of the flexicurve technique. Spine (Phila Pa 1976) 1991;16(1): 29–33.
Tousignant M, de Bellefeuille L, O'Donoughue S, Grahovac S. Criterion validity of the cervical range of motion (CROM) goniometer for cervical flexion and extension. Spine (Phila Pa 1976) 2000;25(3):324–30.
Tousignant M, Duclos E, Lafleche S, Mayer A, Tousignant-Laflamme Y, Brosseau L, et al. Validity study for the cervical range of motion device used for lateral flexion in patients with neck pain. Spine (Phila Pa 1976) 2002;27(8):812–7.
Treleaven J. Sensorimotor disturbances in neck disorders affecting postural stability, head and eye movement control. Manual Therapy 2008;13(1):2–11.
Vaughn DW, Brown EW. The influence of an in-home based therapeutic exercise program on thoracic kyphosis angles. Journal of Back and Musculoskeletal Rehabilitation 2007;20:155–65.
Vernon H, Mior S. The neck disability index: a study of reliability and validity. Journal of Manipulative and Physiological Therapeutics 1991;14(7):409–15.
Wainner RS, Whitman JM, Cleland JA, Flynn TW. Regional interdependence: a musculoskeletal examination model whose time has come. Journal of Orthopaedic & Sports Physical Therapy 2007;37(11):658–60.
Walmsley RP, Kimber P, Culham E. The effect of initial head position on active cervical axial rotation range of motion in two age populations. Spine (Phila Pa 1976) 1996;21(21):2435–42.
Yanagawa TL, M M, Burgess K, Young L, Hanley D. Assessment of thoracic kyphosis using the flexicurve for individuals with osteoporosis. Hong Kong Physiotherapy Journal 2000;18(2):53–7.
Yoo WG, An DH. The relationship between the active cervical range of motion and changes in head and neck posture after continuous VDT work. Industrial Health 2009;47(2):183–8.

Please cite this article in press as: Quek J, et al., Effects of thoracic kyphosis and forward head posture on cervical range of motion in older adults, Manual Therapy (2012), http://dx.doi.org/10.1016/j.math.2012.07.005