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Thoracolumbar Extension Mobilizations and Patients with Excessive Thoracolumbar Kyphosis: A Quasi-Experimental Study

Background: Loss of sagittal balance can lead to excessive thoracolumbar (TL) kyphosis, which is a postural impairment characterized by an increase in kyphotic curvature in these two regions of the spine. Excessive TL kyphosis has been shown to adversely affects quality of life and activities of daily living (ADL).

Objectives: This study aimed to investigate immediate spinal motion and resultant postural changes after the application of single thoracic extension mobilization. This was compared to the application of two extension mobilizations, one of which was applied to the lumbar region in the second group of patients with excessive TL kyphosis.

Design: Quasi-experimental study.

Methods: A total of 53 participants (71.6 years, 20 male/33 female) were recruited. All participants had greater than 40° of TL kyphosis, as measured with a single gravity-dependent inclinometer positioned over the T1 spinous process. One group received thoracic extension mobilization only, whereas the other group received both thoracic and lumbar extension mobilization.

Results: Both groups demonstrated an improvement (decrease) in the thoracolumbar kyphosis angle. The group that received thoracic mobilization alone demonstrated a 6.46° change ($P<0.0001$), while the group that received both mobilizations demonstrated a change of 11.96° ($P<0.0001$). Combined mobilization applied to both the thoracic and lumbar regions resulted in a significantly greater change (reduction) in TL kyphosis (5.50°, $P<0.0001$).

Conclusion: The results demonstrate that the addition of a second mobilization to the lumbar region results in greater active TL extension and reduced TL kyphosis. Clinicians treating patients with excessive kyphotic curvature should be mindful of the contribution of the lumbar region to loss of sagittal balance. The addition of this simple manual mobilization to the lumbar region appears to yield better short-term improvements in patients with overly kyphotic spinal posture.

Keywords: *Thoracolumbar extension; Mobilization; Thoracolumbar kyphosis*

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INTRODUCTION

Older patients with degenerative spinal changes may present with loss of spinal sagittal balance, resulting in thoracic hyperkyphosis, lumbar kyphosis, or Flatback Syndrome.[1] Individuals with excessive thoracolumbar kyphosis reported limitations in instrumental activities of daily living (IADL) and lower scores in response to topics about health conditions, satisfaction with human relationships and economic conditions, and quality of life when compared to a control group.[2] Various impairments and functional limitations associated with excessive kyphosis have been reported, such as difficulty in bending, walking, climbing, and rising from a chair.[3,4] Reduction of the lumbar lordotic curve is also associated with significant alterations in quality of life, and is associated with a reduction in the Oswestry Disability

Index (ODI) score, basic activities of daily living (BADL), and IADL, such as walking, lifting, climbing, and working in the kitchen.[3,5,6]

Thoracolumbar kyphosis is an anterior spinal concavity typically ranging between 20–40 degrees dependent on age and sex.[7] Although greater ranges have been reported[8] excessive thoracolumbar kyphosis is regarded as a kyphotic angle greater than 40°.[7,9] The ability to reduce one's thoracolumbar kyphosis can be negatively impacted by aging; individuals aged 22–29 years averaged 37.43° of active thoracic extension motion, while individuals aged 70+ years averaged only 11.85° of active thoracic extension.[10] Two potential sources of this loss of thoracic extension have been described: 1) the kyphotic angle in the lower thoracic region is greater in older individuals when compared to a younger cohort, and 2) the amount of available range of motion (ROM) in the middle and lower thoracic regions is less in older individuals.[11] Various congenital spinal pathologies have been shown to increase the kyphotic angle; however, thoracic disc degeneration appears to be the primary cause.[6,11] Utilizing Magnetic Resonance Imaging (MRI), research has determined that there are more degenerative changes in the intervertebral discs (IVD) of the thoracic spine with age.[6] In a study of 1407 subjects, excessive kyphosis was related to degenerative changes in thoracic IVD's.[3]

Lumbar lordosis is a posterior spinal concavity that typically ranges from to 20–45 degrees.[12] Roussouly et al. found that the amount of lordosis ranged from 41–82 degrees when measuring between S1 and the inflection point, which is the point where the spine transitions from kyphosis to lordosis.[13,14] The average ROM into lumbar extension ranges from to 20–30 degrees depending upon age and sex.[5] Aging is associated with a decrease in lumbar lordosis and lumbar range of motion (ROM).[5,15] It has been shown that at L1–L3 there was a 20% reduction in lordosis, and the amount of lumbar extension was reduced by 31% as age increased.[15] Disc degeneration, aging, reduction of the sacral slope (Figure 1), disc space narrowing, and anterior wedging of the lumbar vertebral body all contribute to the development of lumbar kyphotic deformity, and a reduction in lordosis and extension ROM.[16–18]

Multiple surgical and conservative treatment approaches have been used to address sagittal imbalance. Surgical approaches, such as vertebroplasty and kyphoplasty[19] and various anterior and posterior fusion constructs have been used for excessive lumbar kyphosis.[20,21] Exercise intervention has been recommended for the management of kyphotic posture. Individuals who completed a corrective kyphosis exercise program displayed an average reduction in thoracolumbar kyphosis by six degrees and improvements in spinal extensor muscle strength following the conclusion of the study and in a one-year follow-up.[22,23] Similar improvements have been observed in additional studies of thoracic kyphotic posture following therapeutic exercise intervention[24,25] while groups that completed lumbar stabilization exercises demonstrated postural improvements and decreased disability when compared to a control group.[26] Other combinations of interventions such as taping, exercise, and manual interventions such as PA mobilization and Kaltenborn mobilizations have been shown to be beneficial and may reduce the amount of thoracolumbar kyphosis.[27–30] However, it remains unclear how thoracic mobilization only, often the primary focus of many clinicians treating excessive kyphosis, compared to a combination of thoracic and lumbar mobilizations.

The purpose of this study was to compare the outcomes of active spinal extension and thoracolumbar posture in two groups of patients: one group of patients who underwent thoracic extension mobilization performed with patients in hook-lying position compared to a second group who received the same thoracic extension mobilization and a hook-lying lumbar extension mobilization.

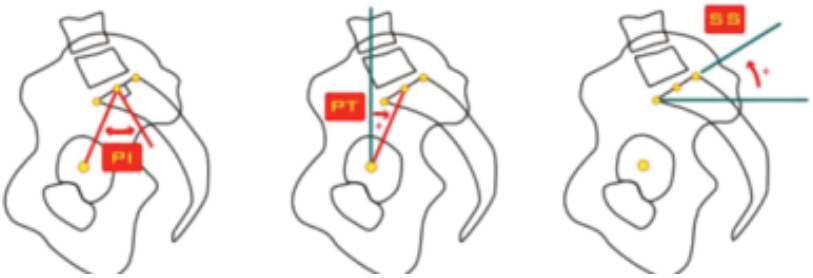

Figure 1. Pelvic Incidence, Pelvic tilt, and sacral slope[14]

SUBJECTS AND METHODS

Study Design

A quasi-experimental design was used to evaluate the immediate effects of one or two spinal extension mobilizations in the two groups of patients with excessive TL kyphosis. Using informational posters placed in waiting areas, older adults with excessive kyphotic posture were recruited from two different outpatient orthopedic physical therapy settings. Prior to the start of the study, all participants received verbal information about the study and provided written informed consent. This study was approved by the Institutional Review Board of Oakland University, Rochester Michigan (Figure 2).

Participants

Eligible participants were adults aged 60 years or older who met the inclusion criteria of greater than 40 degrees of TL kyphosis, as determined by a single inclinometer measurement technique (Figure 3). A total of 53 participants (20 males and 33 females) with an average age of 71 years and a range of 60-86 years were included. A coin toss was used to determine the first participant's group assignment, and then participants were assigned by simple alternate assignments thereafter. A total of 26 participants were randomly placed into the thoracic mobilization only treatment group, and 27 were placed in the thoracic and lumbar mobilization treatment groups (Table 1).

Mobility and posture assessment

To capture the inclusion criteria measurement of greater than 40 degrees of TL kyphosis, and both the pre- and post-mobilization measurements, each participant was seated at the edge of an electric mobilization table. The table was elevated, and its moveable head piece was angled so that each participant could sit with their feet firmly in contact with the ground, and the hips were positioned at 60 degrees of flexion. A standard goniometer was used to ensure hip positioning, as high reliability of goniometric assessment of hip flexion has been reported.[31] A fluid-filled inclinometer was set to the zero-position using an adjacent wall prior to placing it on each participant. The T1 spinous process (SP) was found by palpating the first rib and manually tracing it medial to the tip of the SP.[32]

At this point, each participant was instructed to lift his/her chest up and forward fully and arch his/her lower back. Tactile cueing of the manubrium and T7-T8 spinal level assisted each participant in their most upright postural position. After achieving this position, the inclinometer was placed over the T1 SP

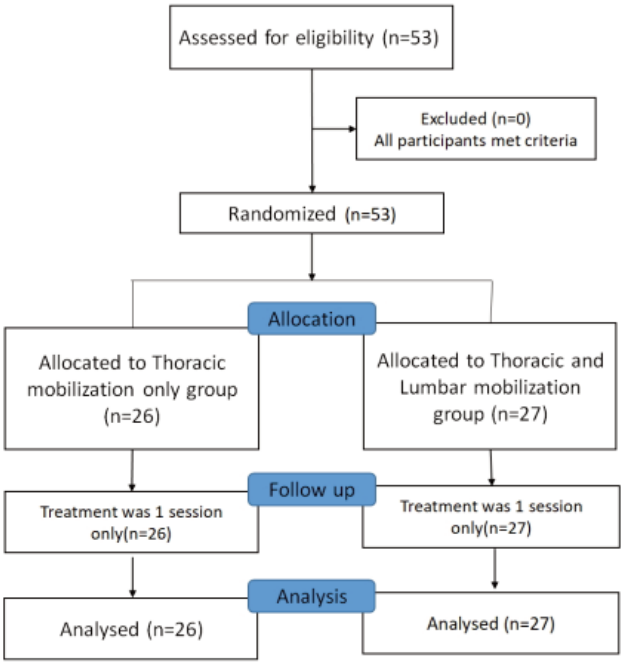

Figure 2. Flow chart

(Figure 3). Equal pressure was exerted on each foot of the inclinometer to ensure accurate and consistent measurement. Prior studies have demonstrated that inclinometers have excellent intrarater reliability.[33,34] This positioning method and inclinometer placement were used for each participant in both groups. All measurements were performed by the primary investigator, a Physical Therapist with 37 years of clinical experience, who held an Orthopedic Manual Physical Therapist certificate. The PI was not blinded to the measurements or participant group assignment.

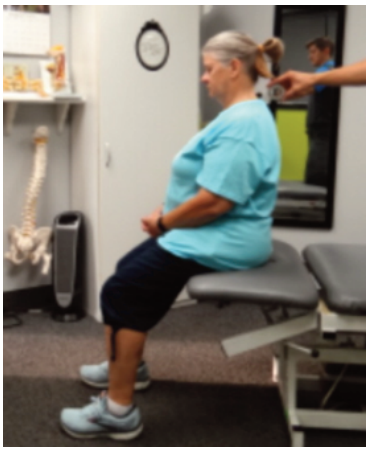

Figure 3. Inclinometer placed over the T1 spinous process for measurement of thoracolumbar kyphosis

Figure 4. Thoracic extension mobilization

Figure 5. Lumbar extension mobilization

Interventions

Thoracic Mobilization Group

Participants assigned to the "thoracic only extension mobilization group" received 30 seconds of manual extension. One 10-second extension mobilization was applied sequentially to the T6, T7, and T8 segments. A pool noodle with a wooden dowel inserted served as the fulcrum point, over which each of the three mid-thoracic segments was extended. A dowel-enhanced pool noodle offers a comfortable means to deliver semi-specific stabilization of the caudal vertebrae of a particular segment and passive angular movement in the direction of extension of the cranial vertebrae of the segment (Figure 4). After this series of three total thoracic mobilizations was applied, each participant returned to the seated measurement position, and inclinometry was repeated at T1. This ended the participation.

Combined Thoracic and Lumbar Mobilization Group

All participants assigned to the "thoracic and lumbar extension mobilization group" first received the same thoracic extension mobilization applied to the T6-T8 segments. Each participant in this group also underwent lumbar extension mobilization (Figure 5). For this mobilization procedure, participants were placed in a hook-lying position, and an extension mobilization force was applied to the thoracolumbar, mid-lumbar, and lower lumbar regions. Extension was held for 10 s in each of the three regions for a total of 30 s. During this lumbar mobilization, passive lumbar extension was achieved as follows: the participant was instructed to first actively perform a bridging maneuver and then lower their lumbar region down onto the investigator's proximal forearm.

As the patient sets their lumbar region onto the clinician's forearm, a semi-specific lumbar extension motion occurs over the forearm. In addition, the investigators' forearm was placed just distal to the participants' ASIS. This distal forearm pressed lightly in the posterior direction, which assisted in passively producing an anterior pelvic tilt. Anterior pelvic tilting provides an additional passive lumbar extension force over the proximal forearm (Figure 5). This mobilization was performed as documented in Evjenth's text.[35] All mobilizations were performed by the primary investigator, a Physical Therapist with 37 years of clinical experience who held an Orthopedic Manual Physical Therapist certificate.

Data Analysis

All data were analyzed in aggregate form using quantitative statistics in SPSS v 26.0 (IBM, Chicago, IL.). Descriptive statistics, including means and standard deviations, were used to characterize the study participants where appropriate. Data were assessed for the required assumptions, including normality, using visual analysis of boxplots, histograms, and Q-Q plots. Groups were assessed using tests of difference; independent samples t-tests were used to assess baseline differences in age and ROM, and baseline differences in sex were assessed using Fisher's Exact Test. Within-group differences in ROM were assessed using paired t-tests, and between-group differences were assessed using independent sample t-tests.

RESULTS

The primary outcome of interest was immediate improvement in the active thoracic extension measurement. The secondary outcome of interest was whether the improvement in active thoracic extension facilitated an improvement in thoracolumbar kyphosis measurement. Mobilization techniques were intended to deliver a comfortable and effective, albeit non-specific, stretch into extension. None of the patients reported any adverse reactions. The participant demographics are presented in Table 1. There were no significant differences between the groups at baseline.

There were significant differences within the groups in the seated active spinal extension immediately following the application of mobilization. The "thoracic extension mobilization group" demonstrated improved ROM of 6.46°±1.63, 95% CI [5.80,7.12], $P<0.0001$. The "thoracic and lumbar extension mobilization group" demonstrated improvements of 11.96°±4.21, 95% CI [10.30,13.63], $P<0.0001$. There were significant between-group differences, with the group receiving mobilization in both spinal regions demonstrating significantly greater gains in active spinal extension, 5.50°±0.88, [3.73,7.27], $P<0.0001$ with a resulting large effect size, d=1.71,95% CI [1.07,2.34] (Table 2).

DISCUSSION

The purpose of this study was to determine whether the addition of a second mobilization procedure

Table 1. Group assignments

Demographic Data	Thoracic and Lumbar Treatment Group	Thoracic Only Treatment Group	*P*-value
Total Participants	27	26	
Average Age (years)	71.89 ± 6.76	71.42 ± 12.87	0.871
Gender	9 Male	11 Male	0.577
	18 Female	15 Female	

Table 2. Improvement in active thoracolumbar extension

Group Assignment	Pre-mobilization thoracolumbar extension	Post-mobilization thoracolumbar extension	Improvement in thoracolumbar extension	Within group differences	Between group differences
Thoracic Mobilization Group	44.85° ± 4.39	38.38° ± 4.27	6.46° ± 1.63 [5.80,7.12]	$P<0.0001$	5.50°±0.88 [3.73,7.27] $P<.0001$
Thoracic and lumbar mobilization Group	44.96° ± 5.35	33.00° ± 5.24	11.96° ± 4.21 [10.30,13.63]	$P<0.0001$	d=1.71 [1.07,2.34]

applied to the lumbar region would assist in improving (increasing) spinal extension and thereby reduce excessive kyphosis in a group of elderly patients compared to the use of thoracic extension mobilization alone. The data indicated that both mobilization procedures increased active spinal extension, which assisted patients in improving (reducing) their postural kyphosis. The addition of the second lumbar extension mobilization resulted in a significantly greater gain.

The 53 participants in this study favorably represent "older" patients who may seek conservative care for spinal pain, stiffness, and postural impairments. The literature supports the anatomical correlation between the increasing incidence of IVD degeneration with increasing age and various postural and spinal ROM impairments.[3,6,11] Prior studies have demonstrated that progressive thoracolumbar kyphosis increases with increasing age.[10,11] Data from the 2020 Census show that the baby boom generation (1946-1964) is estimated to be about 73 million individuals. By the year 2030 all boomers will turn 65.[36] It is estimated that 20–40% of adults aged 60 and above demonstrate an increased thoracolumbar kyphosis.[37] From a societal perspective, it is expected that the proportion of older patients will continue to increase, and there is a need for research into spinal mobilization techniques which may be suitable and beneficial for this segment of the population. While there are multiple studies documenting the positive effects of therapeutic exercise on thoracolumbar kyphosis[38–40] our study suggests that these simple to perform, generally pain-free, mobilization techniques are also of great benefit.

The two manual interventions investigated in this study were performed with patients placed in a hook-lying position, which is a position that is well tolerated by the elderly. Ten-second passive extension mobilizations were applied over three thoracic segments and over three different areas in the lumbar region. Provided in this fashion, these techniques require little equipment and are quite time-efficient for clinicians who work with individuals presenting with kyphotic postural impairments. As an additional benefit to patients with excessive TL kyphosis, both thoracic and lumbar manual interventions can be easily taught to patients as self-mobilization exercise techniques performed in the same hook-lying position incorporating a swimming noodle and dowel. There are several limitations to consider when interpreting this study. First, the interventions only occurred in a single session, and there was no long-term follow-up to assess the carryover of results. During this session, the overall dose (10 s per segment × 3 segments) was lower than the typical clinical application of mobilization. It is not clear whether greater treatment durations would result in different outcomes. Second, the PI performed both pre- and post-measurements, as well as all interventions. While this eliminates the possibility of inter-rater error for both measurements and mobilizations, it could introduce the possibility of measurement bias.

CONCLUSION

The findings of this study support the use of these two-hook-lying passive extension mobilization techniques to improve (reduce) excessive thoracolumbar kyphosis. Hyperkyphotic postures have been shown to have adverse effects on the basic and instrumental activities of daily living. The authors believe that these two manual interventions are safe, comfortable, easy to learn, time-efficient, and effective at improving (increasing) active thoracolumbar extension and reducing kyphotic deformity in the immediate term. The effectiveness of these two manual interventions should be longitudinally evaluated.

1. This study was performed using two groups of older patients who are representative of individuals who, because of the aging process and intervertebral disc degeneration, may develop spinal kyphotic deformities.
2. This study incorporated an additional lumbar extension mobilization technique that is easy to apply and enhances the overall treatment effect in terms of improving spinal extension mobility, thereby further assisting in reducing thoracolumbar kyphosis.
3. Population demographics indicate a need for effective manual conservative care interventions that address excessive kyphosis in the older population.

Conflicts of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data availability statement

The dataset is available from the corresponding author upon reasonable request.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The study protocol and design were approved by the Daegu University Clinical Research Ethics Committee (approval number: 1040621-202201-HR-004).

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REFERENCES

1. Bae JS, Jang JS, Lee SH, Kim JU. Radiological analysis of lumbar degenerative kyphosis in relation to pelvic incidence. *Spine J.* 2012;12(11):1045-1051.
2. 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. *J Gerontol A Biol Sci Med Sci.* 2005;60(5):633-637.
3. Schneider DL, von Muhlen DG, Barrett-Connor E, Sartoris DJ. Kyphosis does not equal vertebral fractures: The Rancho Bernardo Study. *J Rheumatol.* 2004;31(4):747-752.
4. Takahashi T, Ishida K, Hirose D, et al. Trunk deformity is associated with a reduction in outdoor activities of daily living and life satisfaction in community-dwelling older people. *Osteoporos Int.* 2004;16(3):273-279.
5. Dvořák J, Vajda EG, Grob D, Panjabi MM. Normal motion of the lumbar spine as related to age and gender. *Eur Spine J.* 1995;4(1):18-23.
6. Goh S, Tan C, Price RI, et al. Influence of age and gender on thoracic vertebral body shape and disc degeneration: an MR investigation of 169 cases. *J Anat.* 2000;197(4):647-657.
7. Fon G, Pitt M, Thies A. Thoracic kyphosis: range in normal subjects. *Am J Roentgenol.* 1980;134(5):979-983.
8. Boyle JJ, Milne N, Singer KP. Influence of age on cervicothoracic spinal curvature: An ex vivo radiographic survey. *Clin Biomech.* 2002;17(5):361-367.
9. Voutsinas SA, Macewen GD. Sagittal profiles of the spine. *Clin Orthop Relat Res.* 1986;(210):235-242.
10. O'Gorman H, Jull G. Thoracic kyphosis and mobility: the effect of age. *Physiother Pract.* 1987;3(4):154-162.
11. Morita D, Yukawa Y, Nakashima H, et al. Range of motion of thoracic spine in sagittal plane. *Eur Spine J.* 2013;23(3):673-678.
12. Lin RM, Jou IM, Yu CY. Lumbar lordosis: normal adults. *J Formos Med Assoc.* 1992;91(3):329-333.
13. Roussouly P, Gollogly S, Berthonnaud E, Dimnet J. Classification of the normal variation in the sagittal alignment of the human lumbar spine and pelvis in the standing position. *Spine.* 2005;30(3):346-353.
14. Le Huec JC, Faundez A, Dominguez D, et al. Evidence showing the relationship between sagittal balance and clinical outcomes in surgical treatment of degenerative spinal diseases: a literature review. *Int Orthop.* 2015;39:87-95.
15. Dreischarf M, Albiol L, Rohlmann A, et al. Age-related loss of lumbar spinal lordosis and mobility - a study of 323 asymptomatic volunteers. *PLoS One.* 2014;9(12).
16. Hansen BB, Bendix T, Grindsted J, et al. Effect of lumbar disc degeneration and low-back pain on the lumbar lordosis in supine and standing. *Spine.* 2015;40(21):1690-1696.
17. Takeda N, Kobayashi T, Atsuta Y, Matsuno T, Shirado O, Minami A. Changes in the sagittal spinal alignment of the elderly without vertebral fractures: a minimum 10-year longitudinal study. *J Orthop Sci.* 2009;14(6):748-753.
18. Takemitsu Y, Harada Y, Iwahara T, Miyamoto M, Miyatake Y. Lumbar degenerative kyphosis. *Spine.* 1988;13(11):1317-1326.
19. McGirt MJ, Parker SL, Wolinsky JP, Witham TF, Bydon A, Godaslan ZL. Vertebroplasty and kyphoplasty for the treatment of vertebral compression fractures: An evidenced based review of literature. *Spine J.* 2009;9:501-508.
20. Kostuik JP, Maurais GR, Richardson WJ, Okajima Y. Combined single stage anterior and posterior osteotomy for correction of latrogenic lumbar kyphosis. *Spine.* 1988;13(3):257-266.
21. Bridwell KH, Lenke LG, Lewis SJ. Treatment of spinal stenosis and fixed sagittal imbalance. *Clin Orthop Relat Res.* 2001;384:35-44.
22. Katzman WB, Wanek L, Shepherd JA, Sellmeyer DE. Age-related hyperkyphosis: its causes, consequences, and management. *J Orthop Sports Phys Ther.* 2010;40(6):352-360.

23. 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. *Arch Phys Med Rehabil.* 2009;90(2):358-361.
24. Seidi F, Rajabi R, Ebrahimi I, Alizadeh MH, Minoonejad H. The efficiency of corrective exercise interventions on thoracic hyper-kyphosis angle. *J Back Musculoskelet Rehabil.* 2014;27(1):7-16.
25. Vaughn DW, Brown EW. The influence of an in-home based therapeutic exercise program on thoracic kyphosis angles. *J Back Musculoskelet Rehabil.* 2007;20(4):155-165.
26. Cho I, Jeon C, Lee S, Lee D, Hwangbo G. Effects of lumbar stabilization exercise on functional disability and lumbar lordosis angle in patients with chronic low back pain. *J Phys Ther Sci.* 2015;27 (6): 1983-1985.
27. Bautmans I, Arken JV, Mackelenberg MV, Mets T. Rehabilitation using manual mobilization for thoracic kyphosis in elderly postmenopausal patients with osteoporosis. *J Rehabil Med.* 2010; 42(2):129-135.
28. Shum GL, Tsung BY, Lee RY. The immediate effect of posteroanterior mobilization on reducing back pain and the stiffness of the lumbar spine. *Arch Phys Med Rehabil.* 2013;94(4):673-679.
29. Kamali F, Shirazi SA, Ebrahimi S, Mirshamsi M, Ghanbari A. Comparison of manual therapy and exercise therapy for postural hyperkyphosis: A randomized clinical trial. *Physiother Theory Pract.* 2016;32(2):92-97.
30. Park SE, Wang JS. Effect of joint mobilization using KEOMT and PNF on a patient with CLBP and a lumbar transitional vertebra: a case study. *J Phys Ther Sci.* 2015;27(5):1629-1632.
31. Holm I, Bolstad B, Lütken T, Ervik A, Rø kkum M, Steen H. Reliability of goniometric measurements and visual estimates of hip ROM in patients with osteoarthrosis. *Physiother Res Int.* 2000;5: 241-248.
32. Kaltenborn FM, Evjenth O. *Manual mobilization of the joints.* Oslo, Norway: Norli; 2000.
33. Lewis JS, Valentine RE. Clinical measurement of the thoracic kyphosis. A study of the intra-rater reliability in subjects with and without shoulder pain. *BMC Musculoskelet Disord.* 2010;11:1.
34. Barrett E, Mccreesh K, Lewis J. Intrarater and interrater reliability of the flexicurve index, flexicurve angle, and manual inclinometer for the measurement of thoracic kyphosis. *Rehabil Res Pract.* 2013;2013:1-7.
35. Evjenth O, Hamberg J. *Muscle stretching in manual therapy: A clinical manual. The spinal column and TM - joint.* Volume II. Alfta, Sweden: Alfta Rehab Forlag; 1984:131.
36. US Census Bureau. America counts: stories behind the numbers. www.census.gov/library/ stories/2019/12.
37. Duangkaew R, Bettany-Saltikov J, van Schaik P, Kandasamy G, Hogg J. PROTOCOL: Exercise interventions to improve back shape/posture, balance, falls and fear of falling in older adults with hyperkyphosis: A systematic review. *Campbell Syst Rev.* 2020;16(3):e1101.
38. González-Gálvez N, Gea-García GM, Marcos-Pardo PJ. Effects of exercise programs on kyphosis and lordosis angle: A systematic review and meta-analysis. *PLoS One.* 2019;14(4):e0216180.
39. Seidi F, Rajabi R, Ebrahimi I, Alizadeh MH, Minoonejad H. The efficiency of corrective exercise interventions on thoracic hyper-kyphosis angle. *J Back Musculoskelet Rehabil.* 2014;27(1):7-16.
40. Ball JM, Cagle P, Johnson BE, et al. Spinal extension exercises prevent natural progression of kyphosis. *Osteoporos Int.* 2009;20(4):481-489.