Title registration for a systematic review: Exercise interventions to improve back shape/posture, balance, falls and fear of falling in older adults with hyperkyphosis: a systematic review

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Title of the review

Exercise interventions to improve back shape/posture, balance, falls and fear of falling in older adults with hyperkyphosis in community: a systematic review

Background

Hyperkyphosis known as the “dowager’s hump” is the most common spinal deformity in older adults. It is characterized by an increase of the anterior curvature thoracic spine when a kyphosis angle is greater than 40° using the Cobb method (Fon, Pitt, & Thies Jr, 1980; Roghani, Zavieh, Manshadi, King, & Katzman, 2017; Voutsinas & Macewen, 1986), whereas the normal range of kyphosis in young adults ranges from 20° - 40° of thoracic curvature (Fon et al., 1980). In terms of biomechanical dysfunction, an increased thoracic kyphosis alters the vertebral column alignment in the sagittal curve of the spine, which leads to an increase in mechanical loading, flexion moments, compression, and shear force on the spine (Balzini et al., 2003; Mika, Unnithan, & Mika, 2005; Pearsaii & Reid, 1992). In addition, changes in spine shape also limit the movement and mobility of the rib cage, which may affect the health and quality of life of older adults (Horie et al., 2009).

The aetiology or causation of hyperkyphosis in older adults remains unclear. (Kado, Prenovost, & Crandall, 2007; Katzman, Wanek, Shepherd, & Sellmeyer, 2010; Roghani et al., 2017). Many theories on the causes of hyperkyphosis have been proposed, such as multiple musculoskeletal, neuromuscular, and sensory impairment (Katzman et al., 2010). The possibility of causes associated with hyperkyphosis includes vertebral fractures and low bone mineral density, degenerative disc disease, back extensor muscle weakness, calcification and ossification of intervertebral ligaments and decreased mobility of spine, proprioceptive and sensory deficits as well as genetics. Bouxsein et al., (2006) demonstrated that the stress loading on the vertebral spine during activities of daily living can gradually affect vertebral wedging and increases compression fractures. In addition, the severity of vertebral wedging increases as bone mineral density decreases (Goh, Price, Leedman, & Singer, 1999; Milne & Lauder, 1976).

Degenerative disc disease is another challenge that affects hyperkyphosis. Schneider et al. (2004) reported that degenerative disc disease is a common radiograph finding associated with hyperkyphosis in older adults. Moreover, Manns, et al. (1996) found a significant correlation between anterior disc height and kyphosis angle; as the anterior disc height decreased, the angle of kyphosis increased. Several studies also suggest that there is an inverse correlation between the kyphosis angle and back extensor muscle weakness in adolescence and older adults (Dastmanesh, Eskandari, & Shafiee, 2013; Granito, Aveiro, Renno, Oishi, & Driusso, 2012; Hirano et al., 2014; Mika et al., 2005). There are two theories that have been proposed for describing back extensor muscle weakness. Firstly, reducing the capability of back muscles to generate an extension moment and control shear force can

result in an increased thoracic kyphosis (Greig, Bennell, Briggs, & Hodges, 2008). Secondly, an increase in the anterior angle of the thoracic spine leads to an increase in both a compression force as well as shear force on the thoracic spine (Pearsaii & Reid, 1992). Further, decreased spinal mobility together with degenerative of the intervertebral ligaments occurs with aging and disturbs the ability of the spine to control normal postural alignment (Kado, Prenovost, et al., 2007; Katzman et al., 2010; Roghani et al., 2017).

The estimated prevalence of hyperkyphosis has been reported to be 20% - 40% of the older adult population aged over 60 years (Kado, Huang, Karlamangla, Barrett-Connor, & Greendale, 2004; Katzman, Sellmeyer, Stewart, Wanek, & Hamel, 2007; Ryan & Fried, 1997; Takahashi et al., 2005). This deformity affects both sexes, particularly women aged over 55 years (Huang, Barrett-Connor, Greendale, & Kado, 2006; Katzman et al., 2010), regardless of vertebral fractures, with the incidence increasing 6 -11% for every 10 year increase in age (Huang et al., 2006). For instance, a longitudinal study on 100 healthy males and females aged 50 years or older, the authors reported a mean thoracic angle increase of 3°per decade (Kobayashi, Atsuta, Matsuno, & Takeda, 2004), whilst another study on men and women reported a mean thoracic kyphosis angle of 26° in persons in their 20s, 53° in those 60 – 74 years of age and 66° in those older than 75 years of age (Kado et al., 2007).

Hyperkyphosis has been associated with impaired pulmonary function, function limitation, falls, fractures, a decreased quality of life, and increased mortality. The ageing process combined with thoracic kyphosis in older adults may restrict the thoracic inspiration capacity and lead to impaired pulmonary function (Kado et al., 2009). Kado et al. (2009) demonstrated that women with hyperkyphosis and vertebral fractures had a greater mortality rate than women affected by either hyperkyphosis or vertebral fractures alone (Kado et al., 2009). Additionally, Takahashi et al., (2005) investigated the association between spinal deformities in the sagittal plane and functional impairment of daily living in community-dwelling subjects. The authors have reported that older adults with hyperkyphosis reported having limitations during daily activities and less satisfaction with life in general. Accentuated thoracic kyphosis is also known to cause displacement of the centre of gravity that can lead to impaired balance and increased risk of falling (Lynn, Sinaki, & Westerlind, 1997). Several studies have reported that hyperkyphosis is associated with an increased premature death (Kado et al., 2009; Milne & Williamson, 1983) and is also an indicator of the negative impact of health outcomes.

The management of age-related hyperkyphosis includes exercises, spinal orthosis, and surgery (Bansal, Katzman, & Giangregorio, 2014). Exercise training is a common approach, which aims to increase spinal muscle strength and stretching exercises for the alignment of posture may reduce hyperkyphosis (Bettany-Saltikov, Turnbull, Ng, & Webb, 2017). Exercise-based interventions may include spinal muscle strengthening, core stabilization exercises as well as stretching exercises. Spinal muscle strengthening refers to weight bearing and resistance exercises on the spine; an increase in spinal muscle strength, which helps to maintain the spine in the upright position (Ball, Cagle, Johnson, Lucasey, & Lukert, 2009). Whereas core stabilization exercises can be described as the ability of the neuromuscular system to control the position and motion of the trunk over the pelvis and legs to allow

optimum production, transfer and control of force and motion to provide stabilization by controlling spinal movement (Kibler, Press, & Sciascia, 2006). Stretching exercise is a therapeutic exercise designed to increase the extensibility of soft tissues, thereby improving flexibility by elongating (lengthening) structures that have adaptively shortened and become hypomobile over time (Kisner & Colby, 2007). The purpose of exercise is two-fold. Firstly to improve the thoracic hyperkyphisis and secondly to delay its progression as well as to alleviate the accompanying complications due to hyperkyphosis in older people (Ailon et al., 2015).

The ageing process is associated with numerous alterations in posture including hip flexion and external rotation, a wide base of support, a forward head posture, and increased thoracic kyphosis (Woodhull-McNeal, 1992). Hyperkyphosis or excessive curvature in the thoracic spine leads to shifts in the centre of gravity and brings the body closer to the edge of the base of support, resulting in a decreased ability to balance and thereby resulting in an increase in the number of falls (Danis, Krebs, Gill-Body, & Sahrmann, 1998). To date, postural training, spinal extensor muscle strength as well as spinal flexibility exercises have been a significant focus of exercise therapy in the management of patients with hyperkyphosis (Bansal et al., 2014).

The goals of corrective exercise include the following; decreased spinal pain, reduced hyperkyphotic posture, increased mobility as well as an improved quality of life. Exercise protocols are generally aimed at corrective posture, increasing the back extensor muscles strength, as well as the increasing core stability of the trunk (Bansal et al., 2014; Hsu et al., 2014; Kado, 2009).

Corrective postural exercises are based on Kendall's theory that suggests back extensor exercises are able to reduce the angle of kyphosis with the strong back muscles counteracting the anteriorly directed gravitational pull on the thoracic spine (Kendall, McCREARY, Provance, Rodgers, & Romani, 2005 and Ball et al., 2009). The theory consist of stretching exercises in the anterior trunk and strengthening exercises in the posterior trunk (Seidi, Rajabi, Ebrahimi, Alizadeh, & Minoonejad, 2014). Core stability exercises, such as yoga, Pilates, and Tai Chi, are considered to consist of a "muscular box" with the abdominals in the front, paraspinals and gluteals in the back, the diaphragm as the roof and the pelvic floor and the hip girdle musculature as the bottom (Akuthota, Ferreiro, Moore, & Fredericson, 2008; Akuthota & Nadler, 2004). This "muscular box" works as a stabiliser for the spine and pelvis which consequently form a kinetic chain during functional movement. These support the upright position and assist balance while walking. Consequently, these function to reduce the risk of falls and improves the quality of life (Sinaki et al., 2002). However, most currently available exercises apply only sagittal plane.

According to Negrini et al. (2005), specific exercises were suggested as the first step in the treatment for adolescent patients with scoliosis and kyphosis. Numerous specific exercises approaches to the management of spinal deformities such as scoliosis and hyperkyphosis are available. These specific exercises consist of the SEAS approach (Scientific Exercise Approach to Scoliosis); the Schroth method i.e. original Schroth, Schroth Best Practice®, the Barcelona Scoliosis Physical Therapy School; the Dobomed method; FITS (Functional Individual Therapy of Scoliosis); the Lyon method as well as Min Mehta's 'Side-shift' exercises (Bettany-

Saltikov et al., 2014). The principles of the Schroth method include improving the patient's awareness of their deformity to promote self-correction; repeated 3D asymmetrical spinal correction exercises, which involves trunk elongation, pelvic alignment, side-shift of thorax, shoulder corrections, and derotation with breathing in lying, sitting and standing positions, scoliosis-specific mobilization; active 3D stabilization; corrective breathing; repetition to correct body schema as well as the integration of postural corrections within activities of daily living (Bettany-Saltikov, Parent, Romano, Villagrasa, & Negrini, 2014).

Berdishevsky (2016) conducted a case study to investigate the effects of an intensive physiotherapy program (the Barcelona Scoliosis Physical Therapy School which is a derivative of the Schroth approach) together with the SpinoMed brace (symmetrical brace) on the kyphosis Cobb angle, pain, quality of life and spinal muscles strength in older adult woman with Scheuermann's kyphosis aged 76 years old. The researcher found that intensive physiotherapy program based on the Barcelona Scoliosis Physical Therapy School and SpinoMed brace were effective for the treatment of older adult with with Scheuermann's kyphosis. However, the generalization of the result of the study was limited due to the involvement only a single participant.

A scoping search identified four narrative reviews that have reported on exercise-based interventions as part of the treatment or management of age-related hyperkyphosis. Ailon et al. (2015) who reviewed the progression of spinal kyphosis in the aging population suggested that exercise intervention can improve thoracic hyperkyphosis, physical functioning, and back extensor muscle strength. On the other hand, several studies have not found any difference in spinal muscle strength, or the kyphosis angle following exercises. Thus, the efficacy of exercise programs for hyperkyphosis demonstrates conflicting results.

Furthermore, Kado et al. (2007) and Kado et al. (2009) reviewed the rehabilitation of having a hyperkyphotic posture in the elderly. The researchers demonstrated that there are numerous exercise interventions such as back strengthening exercises, aerobic exercises, spinal flexion exercises, yoga, pilates as well as postural alignment training for improving hyperkyphosis. All these types of exercises focus on back strength as well as kyphosis outcomes. In addition, Katzman et al. (2010) examined the indications and contradictions of performing exercises for hyperkyphosis. The investigators revealed that flexion exercises tended to increase the risk for vertebral fractures in participants with underlying osteoporosis and vertebral fractures. Hence, flexion exercises or flexion stresses on the spine during exercise or activities daily living need to be avoided and trunk extension exercises are recommended instead.

Further, a recent systematic review by Bansal et al. (2014) examined whether exercise was able to reduce the angle of thoracic kyphosis in older adults aged ≥ 45. The authors found that the existing evidence concerning the effects of exercise on hyperkyphosis in elderly persons were scarce and mostly of low quality. In summary, previous narrative reviews and systematic reviews (Ailon et al., 2015; Bansal et al., 2014; Kado, 2009; Kado, Prenovost, et al., 2007; Katzman et al., 2010) did not focus specially on balance, falls, and fear of falling issues. Therefore, this review is urgently needed to improve the management of older people

with hyperkyphosis. In an attempt at preventing or decreasing the current significant falls rate in this elderly population.

Policy relevance

The ageing process is characterised by degenerative changes in spinal alignment include a forward head posture, rounded shoulders, hip and knee flexion, and increased thoracic kyphosis that is associated with a loss of lumbar lordosis (Hojjati & Sheikhpour, 2013; Milne & Lauder, 1974). Hsu, Chen, Tsauo, & Yang (2014) further demonstrated that an increased thoracic kyphosis had a significant effect on upright posture. That is attributed to a change in the centre of gravity of the body at levels close to the limits of stability and consequently this may lead to an increase in the risk of falls.

In 2013 the National Institute for Health and Care Excellence (NICE) published clinical guidelines regarding the assessment of risk as well as the prevention of falls in older people for health care and other professionals. According to the guideline recommendations, the multifactorial intervention program for older adults with recurrent falls or assessed as being at increased risk of falling includes muscles strengthening and balance training, home hazards assessment and intervention, vision assessment and referral as well as medication review with modification/withdrawal. However, the multifactorial intervention program is not currently concern exercises program for preventing falls in older adults with hyperkyphosis.

This review aims to gather existing research evidence on exercise interventions for older adults with hyperkyphosis. Therefore, this will enable clinicians and researchers as well as policy makers concern hyperkyphosis in older adults that is could potentially be included within this guideline/or policy for prevention of falls.

Objectives

What is the effect of exercises intervention aiming at improve back shape/posture, balance, and reduce falling, as well as fear of falling in older adults with hyperkyphosis?

Existing reviews

A scoping search identified four narrative reviews that have reported on exercise-based interventions as part of the treatment or management of age-related hyperkyphosis. Ailon et al. (2015) who reviewed the progression of spinal kyphosis in the aging population suggested that exercise intervention can improve thoracic hyperkyphosis, physical functioning, and back extensor muscle strength. On the other hand, several studies have not found any difference in spinal muscle strength, or the kyphosis angle following exercises. Thus, the efficacy of exercise programs for hyperkyphosis demonstrates conflicting results.

Furthermore, Kado et al. (2007) and Kado et al. (2009) reviewed the rehabilitation of having a hyperkyphotic posture in the elderly. The researchers demonstrated that there are numerous exercise interventions such as back strengthening exercises, aerobic exercises, spinal flexion exercises, yoga, pilates as well as postural alignment training for improving hyperkyphosis. All these types of exercises focus on a back strength as well as kyphosis outcomes.

In addition, Katzman et al. (2010) examined the indications and contradictions of performing exercises for hyperkyphosis. The investigators revealed that flexion exercises tended to increase the risk for vertebral fractures in participants with underlying osteoporosis and vertebral fractures. Hence, flexion exercises or flexion stresses on the spine during exercise or activities daily living need to be avoided and trunk extension exercises are recommended instead.

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In summary, previous narrative reviews and systematic reviews (Ailon et al., 2015; Bansal et al., 2014; Kado, 2009; Kado, Prenovost, et al., 2007; Katzman et al., 2010) did not focus specially on balance, falls, and fear of falling issues. Therefore, this review is urgently needed to improve the management of older people with hyperkyphosis. In an attempt at preventing or decreasing the current a significant number of falls in the elderly population.

Intervention

Studies which involve exercise intervention, therapeutic exercise, and rehabilitation were included. Studies were excluded if not examine exercise intervention such as spinal orthoses, postural taping, and surgery.

Population

Studies will be included if participants are male or female older adults with identified hyperkyphosis and aged 50 years or older.

Hyperkyphosis in older adults or age-related hyperkyphosis. Hyperkyphosis, also known as dowager's hump, is defined as an excessive anterior curvature of the thoracic spine, and a kyphosis angle greater than 40° when measured using the Cobb method (Fon, Pitt, & Thies, 1980; Voutsinas & MacEwen, 1986).

Outcomes

The outcomes of interest for this review are:

1. **Back shape/posture**: degree of thoracic kyphosis will be measured using the Cobb method, between T2-T12. Lumbar lordosis will be measured.

2. **Balance** included Postural sway and the limits of stability, the risk of falls (i.e. the fear of falling or a history of falls or falls), and back shape/posture (i.e the degree of thoracic kyphosis and lumbar lordosis).

   Postural sway is defined as a movement of centre of mass in quiet stand, and can be measured as anteroposterior and mediolateral displacement.
   The limits of stability is characterised by the maximum range in which the centre of gravity can move safely without moving the feet and without falling.

3. **Risk of falls** (i.e. fear of falling or history of falls or falls) is defined the loss of confidence in older people to participate in activities of daily living, whilst falls, and a history of falls, are defined as at least one fall in the past year.

Study designs

Eligible study designs for this review include:

Randomised controlled trials (RCT), quasi-experimental designs and pre-post intervention studies as well as case report will be included.

Any other studies such as cross-sectional studies, cohort studies and qualitative studies will be excluded.

References

Ailon, T., Shaffrey, C. I., Lenke, L. G., Harrop, J. S., & Smith, J. S. (2015). Progressive spinal kyphosis in the aging population. *Neurosurgery*, 77(suppl_1), S164-S172. doi: 10.1227/NEU.0000000000000944.

Akuthota, V., Ferreiro, A., Moore, T., & Fredericson, M. (2008). Core stability exercise principles. Current sports medicine reports, 7(1), 39-44.

Akuthota, V., & Nadler, S. F. (2004). Core strengthening1. Arch Phys Med Rehabil, 85, 86-92.

Ball, J. M., Cagle, P., Johnson, B. E., Lucasey, C., & Lukert, B. P. (2009). Spinal extension exercises prevent natural progression of kyphosis. Osteoporosis International, 20(3), 481.

Balzini, L., Vannucchi, L., Benvenuti, F., Benucci, M., Monni, M., Cappozzo, A., & Stanhope, S. J. (2003). Clinical characteristics of flexed posture in elderly women. *Journal of the American Geriatrics Society*, 51(10), 1419-1426. doi:10.1046/j.1532-5415.2003.51460.x

Bansal, S., Katzman, W. B., & Giangregorio, L. M. (2014). Exercise for improving age-related hyperkyphotic posture: a systematic review. Archives of physical medicine and rehabilitation, 95(1), 129-140.

Berdishevsky, H. (2016). Outcome of intensive outpatient rehabilitation and bracing in an adult patient with Scheuermann's disease evaluated by radiologic imaging—a case report. Scoliosis and spinal disorders, 11(2), 40.

Bettany-Saltikov, J., Turnbull, D., Ng, S. Y., & Webb, R. (2017). Suppl-9, M6: Management of Spinal Deformities and Evidence of Treatment Effectiveness. The open orthopaedics journal, 11, 1521.

Bettany-Saltikov, J., Parent, E., Romano, M., Villagrasa, M., & Negrini, S. (2014). Physiotherapeutic scoliosis-specific exercises for adolescents with idiopathic scoliosis. *Eur J Phys Rehabil Med*, *50*(1), 111-21.

Bouxsein, M. L., Melton, L. J., Riggs, B. L., Muller, J., Atkinson, E. J., Oberg, A. L., . . . Khosla, S. (2006). Age- and Sex-Specific differences in the factor of risk for vertebral fracture: A Population-Based study using QCT. *Journal of Bone and Mineral Research*, 21(9), 1475-1482. doi:10.1359/jbmr.060606

Danis, C. G., Krebs, D. E., Gill-Body, K. M., & Sahrmann, S. (1998). Relationship between standing posture and stability. Physical Therapy, 78(5), 502-517.

Dastmanesh, S., Eskandari, E., & Shafiee, G. H. (2013). Relationship between physical fitness abilities, trunk range of motion and kyphosis in junior high school students. *Middle-East Journal of Scientific Research*, 13(1), 79-84. doi: 10.5829/idosi.mejsr.2013.13.1.6482

Fon, G., Pitt, M., & Thies, A., Jr. (1980). Thoracic kyphosis: Range in normal subjects. *American Journal of Roentgenology*, 134(5), 979-983. doi:10.2214/ajr.134.5.979

Goh, S., Price, R. I., Leedman, P. J., & Singer, K. P. (1999). The relative influence of vertebral body and intervertebral disc shape on thoracic kyphosis. *Clinical Biomechanics*, 14(7), 439-448. doi:10.1016/S0268-0033(98)00105-3

Granito, R. N., Aveiro, M. C., Renno, A. C. M., Oishi, J., & Driusso, P. (2011). Comparison of thoracic kyphosis degree, trunk muscle strength and joint position sense among healthy and

osteoporotic elderly women: A cross-sectional preliminary study. *Archives of Gerontology and Geriatrics*, 54(2), e199-e202. doi:10.1016/j.archger.2011.05.012

Greig, A. M., Bennell, K. L., Briggs, A. M., & Hodges, P. W. (2008). Postural taping decreases thoracic kyphosis but does not influence trunk muscle electromyographic activity or balance in women with osteoporosis. *Manual Therapy*, 13(3), 249-257. doi:10.1016/j.math.2007.01.011

Hirano, K., Imagama, S., Hasegawa, Y., Wakao, N., Muramoto, A., & Ishiguro, N. (2014). Impact of back muscle strength and aging on locomotive syndrome in community living japanese women. *Nagoya Journal of Medical Science*, 76(1-2), 47-55. https://doi.org/10.1007/s00776-012-0266-0

Horie, J., Murata, S., Inoue, Y., Nakamura, S., Maeda, Y., Matsumoto, Y., . . . Horikawa, E. (2009). A study of the influence of the pulmonary function on the angles of thoracic kyphosis and lumbar lordosis in community-dwelling elderly women. *Journal of Physical Therapy Science*, 21(2), 169-172. doi:10.1589/jpts.21.169

Huang, M., Barrett-Connor, E., Greendale, G. A., & Kado, D. M. (2006). Hyperkyphotic posture and risk of future osteoporotic fractures: The rancho bernardo study. *Journal of Bone and Mineral Research*, 21(3), 419-423. doi:10.1359/JBMR.051201

Hojjati, Z., & Sheikhpour, L. (2013). Seated Exercise Therapy Improves Posture and Balance in Hyperkyphotic Elderly Females, a Randomized Control Trail. World Applied Sciences Journal, 24(3), 331-335.

Hsu, W. L., Chen, C. Y., Tsauo, J. Y., & Yang, R. S. (2014). Balance control in elderly people with osteoporosis. *Journal of the Formosan Medical Association*, *113*(6), 334-339.

Falls in older people: assessing risk and prevention. Retrieved March 12, 2019, from National Institute for Health and Care Excellence website, https://www.nice.org.uk/guidance/cg161/chapter/recommendations#preventing-falls-in-older-people-2

Kado, D. M., Huang, M.-H., Nguyen, C. B., Barrett-Connor, E., & Greendale, G. A. (2007). Hyperkyphotic posture and risk of injurious falls in older persons: the Rancho Bernardo Study. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 62(6), 652-657. https://doi.org/10.1093/gerona/62.6.652

Kado, D. M., Huang, M., Karlamangla, A. S., Barrett-Connor, E., & Greendale, G. A. (2004). Hyperkyphotic posture predicts mortality in older Community-Dwelling men and women: A prospective study. *Journal of the American Geriatrics Society*, 52(10), 1662-1667. doi:10.1111/j.1532-5415.2004.52458.x

Kado, D. M., Lui, L.-Y., Ensrud, K. E., Fink, H. A., Karlamangla, A. S., Cummings, S. R., & the Study of Osteoporotic Fractures. (2009). Hyperkyphosis predicts mortality independent of vertebral osteoporosis in older women. *Annals of Internal Medicine*, 150(10), 681–687. doi: 10.7326/0003-4819-150-10-200905190-00005

Kado, D. M., Prenovost, K., & Crandall, C. (2007). Narrative review: hyperkyphosis in older persons. *Annals of internal medicine*, 147(5), 330-338. doi: 10.7326/0003-4819-147-5-200709040-00008

Katzman, W. B., Sellmeyer, D. E., Stewart, A. L., Wanek, L., & Hamel, K. A. (2007). Changes in Flexed Posture, Musculoskeletal Impairments, and Physical Performance After Group Exercise in Community-Dwelling Older Women. *Archives of Physical Medicine and Rehabilitation*, 88(2), 192-199. doi: 10.1016/j.apmr.2006.10.033

Katzman, W. B., Wanek, L., Shepherd, J. A., & Sellmeyer, D. E. (2010). Age-related hyperkyphosis: Its causes, consequences, and management. *Journal of Orthopaedic and Sports Physical Therapy*, 40(6), 352-360. doi:10.2519/jospt.2010.3099

Kendall, F. P., McCREARY, E. K., Provance, P. G., Rodgers, M. M., & Romani, W. A. (2005). Posture. Muscles: testing and function with posture and pain. 5th ed. Baltimore: Lippincott Williams & Wilkins, 49-117.

Kibler, W. B., Press, J., & Sciascia, A. (2006). The role of core stability in athletic function. Sports medicine, 36(3), 189-198.

Kisner, C., & Colby, L. A. Therapeutic exercise: foundations and techniques. 2007. Philadelphia: FA Davis & Co.

Kobayashi, T., Atsuta, Y., Matsuno, T., & Takeda, N. (2004). A longitudinal study of congruent sagittal spinal alignment in an adult cohort. *Spine*, 29(6), 671-676. doi:10.1097/01.BRS.0000115127.51758.A2

Lynn, S. G., Sinaki, M., & Westerlind, K. C. (1997). Balance characteristics of persons with osteoporosis. *Archives of physical medicine and rehabilitation*, 78(3), 273-277.

Manns, R. A., Haddaway, M. J., McCall, I. W., Cassar Pullicino, V., & Davie, M. W. J. (1996). The relative contribution of disc and vertebral morphometry to the angle of kyphosis in asymptomatic subjects. *Clinical Radiology*, 51(4), 258-262. doi:10.1016/S0009-9260(96)80342-4

Mika, A., Unnithan, V. B., & Mika, P. (2005). Differences in thoracic kyphosis and in back muscle strength in women with bone loss due to osteoporosis. *Spine*, 30(2), 241-246. doi:10.1097/01.brs.0000150521.10071.df

Milne, J. S., & Lauder, I. J. (1974). Age effects in kyphosis and lordosis in adults. *Annals of human biology*, 1(3), 327-337. https://doi.org/10.1080/03014467400000351

Milne, J. S., & Lauder, I. J. (1976). The relationship of kyphosis to the shape of vertebral bodies. *Annals of human biology*, 3(2), 173-179. https://doi.org/10.1080/03014467600001281

Milne, J. S., & Williamson, J. (1983). A longitudinal study of kyphosis in older people. *Age and ageing*, 12(3), 225-233. doi: 10.1093/ageing/12.3.225

Negrini, S., Aulisa, L., Ferraro, C., Fraschini, P., Masiero, S., Simonazzi, P., ... & Venturin, A. (2005). Italian guidelines on rehabilitation treatment of adolescents with scoliosis or other spinal deformities. Europa Medicophysica, 41(2), 183.

Pearsaii, D. J., & Reid, J. G. (1992). Line of gravity relative to upright vertebral posture. *Clinical Biomechanics*, 7(2), 80-86. doi: 10.1016/0268-0033(92)90019-Z

Roghani, T., Zavieh, M. K., Manshadi, F. D., King, N., & Katzman, W. (2017). Age-related hyperkyphosis: update of its potential causes and clinical impacts—narrative review. *Aging clinical and experimental research*, 29(4), 567-577. https://doi.org/10.1007/s40520-016-0617-3

Ryan, S. D., & Fried, L. P. (1997). The impact of kyphosis on daily functioning. *Journal of the American Geriatrics Society*, 45(12), 1479-1486. https://doi.org/10.1111/j.1532-5415.1997.tb03199.x

Schneider, D. L., von Mühlen, D., Barrett-Connor, E., & Sartoris, D. J. (2004). Kyphosis does not equal vertebral fractures: the Rancho Bernardo study. *The Journal of rheumatology*, 31(4), 747-752.

Seidi, F., Rajabi, R., Ebrahimi, I., Alizadeh, M. H., & Minoonejad, H. (2014). The efficiency of corrective exercise interventions on thoracic hyper-kyphosis angle. Journal of Back and Musculoskeletal Rehabilitation, 27(1), 7-16.

Sinaki, M., Itoi, E., Wahner, H., Wollan, P., Gelzcer, R., Mullan, B. P., . . . Hodgson, S. (2002). Stronger back muscles reduce the incidence of vertebral fractures: a prospective 10 year follow-up of postmenopausal women. Bone, 30(6), 836-841.

Takahashi, T., Ishida, K., Hirose, D., Nagano, Y., Okumiya, K., Nishinaga, M., . . . Yamamoto, H. (2005). Trunk deformity is associated with a reduction in outdoor activities of daily living and life satisfaction in community-dwelling older people. *Osteoporosis International*, 16(3), 273-279. doi:10.1007/s00198-004-1669-3

Voutsinas, S. A., & Macewen, G. D. (1986). Sagittal profiles of the spine. *Clinical Orthopaedics and related research* (210), 235-242. doi: 10.1097/00003086-198609000-00034

Woodhull-McNeal, A. P. (1992). Changes in posture and balance with age. Aging Clinical and Experimental Research, 4(3), 219-225.

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Roles and responsibilities

Content and systematic review methodology: Mrs Roongtip Duangkaew, PhD student at Teesside University will be carrying out the research with the support of the rest of the team. She qualified as a physiotherapist and has been working as a lecturer of physiotherapy at the Department of Physical Therapy, Faculty of Allied Health Sciences, Thammasat University, Thailand for over seven years. She has also taught research methods and clinical physiotherapy work as well as student supervision.

Systematic review methods and content knowledge: Dr Josette Bettany-Saltikov will bring significant expertise of Systematic review methods and content to this systematic review, both in terms of knowledge about back shape/ posture, balance, falling and fear of falling in older adults. She has taught systematic review methods to university students at all levels for over 15 years. She has also published a book on how to conduct a systematic review and has been involved in four Cochrane reviews one of which she led. She has authored a number of systematic reviews on diverse topics published in other journals and has significant experience of developing educational programmes from her teaching experience for 23 years as a university Senior lecturer. She also has further content expertise related to the management of back conditions. Josette originally qualified as a

physiotherapist and has been interested in the area of back shape/ posture and balance maintaining back health in and adolescents for over 25 years.

Statistical analysis: Prof. Paul van Schaik will contribute expertise in behavioral science in the context of education. He has extensive experience in advanced statistical data analysis in behavioral research and in behavioral measurement, including the analysis of psychometric questionnaires. His academic work has been recognized for international and national excellence. Paul will direct the analysis of literature with regard to instructional design of educational interventions. He has also been awarded the highly prestigious National Teaching Fellow award in the UK.

Content: Mr Gok Kandasamy will be bring both methodological as well as content expertise relating to back shape in clinical setting. He has over 15 years of experience in higher education, and has held a number of responsibilities which include: Clinical Consultancy, developing an international partnership, teaching and leading at BSc and MSc Physiotherapy and Sports Therapy Programmes. His area of expertise is around development and evaluation of low-cost 3D imaging, mobile, surface topography APP for measuring 3D back shape in a clinical settings.
Information retrieval: Mrs Julie Hogg brings Information retrieval expertise to the team. Julie is an Academic Librarian at Teesside University and will give advice in the search strategy.

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Potential conflicts of interest

None of the team members has any conflicts of interest in the review, nor have any team members been involved in any other systematic review focused on this topic.

Preliminary timeframe

- Date you plan to submit a draft protocol: June 2019
- Date you plan to submit a draft review: January 2020