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Review Article

Does stretching of anterior structures alone, or in combination with strengthening of posterior structures, decrease hyperkyphosis and improve posture in adults? A Systematic Review and Meta-analysis

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Abstract

Kyphosis can lead to back pain, poor posture, and increased falls risk. This systematic review aimed to synthesize research on stretching alone, or in combination with strengthening, as a management for hyperkyphosis in the adult population (≥18 years old). An electronic database search was conducted from February to March 2022. The author and an independent reviewer screened titles and abstracts for inclusion criteria - those whose intervention involved stretching alone or with strengthening exercises. The author appraised and extracted data from included articles and performed a meta-analysis where appropriate. The database and citation search yielded 327 articles, 18 of which met inclusion criteria. One study included performed stretching as a standalone intervention; the remainder used a combination of stretching and strengthening. The meta-analysis (n=3, with 5 exercise groups) found a statistically significant difference (MD = -6.97 (95% CI -9.84, -4.10), p<0.00001) in post-intervention measures of hyperkyphosis favouring the exercise group. The narrative review of studies agrees with this finding, demonstrating statistically significant improvement in hyperkyphosis following various exercise programs. This review suggests that stretching and strengthening exercises improve hyperkyphosis in the short and long term. Low-quality evidence supports stretching as a standalone intervention. Further, more robust research is required to recommend procedures and determine if stretching alone is effective for treating hyperkyphosis in adults.

Keywords: Adults, Exercise, Hyperkyphosis, Posture, Stretching

Introduction

The human spine is the backbone of life, it holds the human trunk erect against gravity sustaining the neutral, upright posture essential for human movement and participation in activities of daily living (ADL)[1]. The biomechanical strength of the spine arises from its four natural curves – cervical, thoracic, lumbar, and sacral – allowing the line of gravity (LOG) to remain within the spine[1]. For muscles to work efficiently and maintain an upright posture, the thoracic spine attains approximately 20-29° curvature from childhood to the third decade[2]. Hyperkyphosis is diagnosed once the thoracic curvature exceeds 40°[3]. Hyperkyphosis increases gravity's leverage on the spine, augmenting the mechanical stress on the spinal structures and soft tissues[4,5].

Hyperkyphosis is not limited to older adults as there is a 38% incidence of hyperkyphosis in individuals aged 20-50 years[5,6] but incidence increases with age[3,4]. Prospective studies found that Cobb's angle - the angle of intersection between the fourth and 12th thoracic vertebra - increases by

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1° every year after 65[7]. Evidence suggests that slouching and poor posture, osteoporosis, vertebral compression fractures, wedge deformity, and muscle imbalances are all possible accelerators of hyperkyphosis[5,7,8]. The adverse effects associated with hyperkyphosis may include pain, slower gait, widened base of support, reduced balance and increased body sway, increasing the risk of falls in men and women[4,6].

Kyphoplasty and vertebroplasty are invasive interventions conducted when hyperkyphosis results from severe pathologies[3,4]. Conservative recommendations include pharmaceutical medicines for pain management and bone-building to reduce the risk of vertebral fractures, especially for osteoporotic patients[3,7]. Non-invasive treatments for hyperkyphosis are available, such as spinal orthoses or taping, which are recommended as an adjunct to exercise rehabilitation[3]. Physiotherapists can perform manual therapy and mobilizations to reduce thoracic angle and pain, and improve posture, and exercise programmes working on strengthening the back extensors and anterior stretching exist, but literature shows no consensus on guidelines for the best exercises or the optimal combination of stretching and strengthening to perform[2,4,8]. Although two previous systematic reviews focused on the effect of exercises on populations suffering from age-related hyperkyphosis (≥45 years old), stretching as a standalone intervention has not been the focus of any previous systematic reviews[6,9].This systematic review aims to synthesize the research on stretching alone, or in combination with strengthening as a management for hyperkyphosis in the adult population (≥18 years old). The secondary aim of this review is to consider the overall effectiveness of exercise programs which include stretching on hyperkyphosis.

Materials and Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement structured this review[10].

Eligibility Criteria

Studies were included if they; recruited patients with diagnosed hyperkyphosis, defined as more than 40° curvature in the sagittal plane of the thoracic spine[3]; included adults aged ≥18 years; were retrievable and in English; and dated between 1990 and 2022. Systematic reviews, meta-analysis, study proposals and protocol papers were not included but any other study type (RCT, controlled study etc.) was.

Studies which included participants with scoliosis or other spinal disorders, or participants with specific medical conditions (e.g., cancer, cystic fibrosis, stroke) due to condition-specific treatment plans were not included.

Information sources and Search

The following databases were searched on 18 March 2022: Allied and Complementary Medicine Database (AMED), Cumulative Index of Nursing and Allied Health Literature (CINAHL), Medical Literature Analysis and Retrieval System Online (MEDLINE), Cochrane Library, Physiotherapy Evidence Database (PEDro) and Google Scholar. ProQuest was used to search the final databases, the Nursing & Allied Health, the Health & Medical Collection, and the Sports & Medicine Index.

The Population, Intervention, Comparator and Outcome (PICO) framework supported the identification of keywords from the research questions: does stretching of anterior structures decrease hyperkyphosis and improve posture in adults?[11] However, a comparator was not used to allow the inclusion of multiple study types[11] [kyphosis, kyphotic, hyperkyphosis], [adult, middle age, older adult], [stretching, exercise] and [posture, cobb angle] were combined with Boolean phrases "AND" and "OR"[11].

Following the database searches and removal of duplicates via RefWorks (ProQuest LLC RefWorks [software] 2022), RW and a second reviewer (CRP) screened the titles and abstracts. Full-text articles were retrieved and reviewed independently by RW and CRP against inclusion criteria. Any discrepancies between reviewers were discussed and resolved for final inclusion[10]. Papers included and the reference list of included studies were screened for eligibility to ensure no relevant studies were missed. Data from included studies was extracted by RW and were extracted into Microsoft Excel, version 2016 (Microsoft Corp, Redmond, WA). A random sample (17%) of papers were independently extracted and checked by CRP for quality and accuracy. The data extraction included the primary author, year of publication, the study design, inclusion/exclusion criteria, sample size, exercise intervention procedures and comparator (where applicable), time to follow-up, level of supervision, outcome measure(s) used and each report's main statistical findings.

Quality Assessment

The Effective Public Health Practice Project, Quality Assessment Tool for Quantitative Studies (EPHPP), was used for the quality appraisal, as an expert-recommended tool with established construct validity for systematic reviews appraising randomized and non-randomized studies across health-related topics[12]. The EPHPP has excellent inter-rater reliability (ICC=0.77) and good test re-test reliability[13]. The EPHPP assesses: 1) selection bias, 2) study design, 3) confounders, 4) blinding, 5) data collection methods, 6) withdrawals and dropouts, 7) intervention integrity and 8) analysis. The first six sections are scored as strong, moderate, or weak based on the EPHPP dictionary[13]. All studies were included in this review regardless of their appraisal score.

Table 1. PRISMA diagram of the screening process.

	Identification of studies via databases and registers		Identification of studies via other methods	
Identification	Records identified from: Databases (n = 313) ⇒ *AMED* (n = 4) *CINAHL* (n = 59) *COCHRANE* (n = 72) *GOOGLE SCHOLAR* (n= 19) *MEDLINE* (n = 89) *PEDRO* (n = 39) *PROQUEST* (n = 31) ⇓	Records removed *before screening*: Duplicate records removed (n = 112)	Records identified from: Citation searching (n = 14) ⇓	
Screening	Titles and abstracts screened (n = 201). ⇒ ⇓	Records excluded (n = 159)	Reports sought for retrieval (n = 14) ⇓	
	Reports sought for retrieval (n = 42) ⇓		Reports assessed for eligibility (n = 14) ⇒ ⇓	Reports excluded: No kyphosis in inclusion criteria (n=4) No stretching intervention (n=4) Not peer reviewed article (n=3)
	Reports assessed for eligibility (n = 42) ⇒ ⇓	Reports excluded: No kyphosis in inclusion criteria (n = 6) No stretching intervention (n=11) Not English (n = 4) Not peer reviewed (n = 5) Spinal disorder (n = 1)		
Included	Studies included in review (n = 13) Follow-up reports included in review (n = 2) Studies included from citation search (n = 3)			

Statistical Analysis

Data was extracted and sorted into tables and figures based on characteristics, interventions, and key results. A meta-analysis was conducted using post-intervention mean kyphosis measurements and standard deviation. Studies with multiple intervention groups were input as individual entries compared to the control group in the meta-analysis. A forest plot was generated using Review Manager (RevMan) [Computer program] version5.4[14]. Forest plot results were considered homogenous with an I^2 of less than 50% indicating the results from the multiple studies are sufficiently similar[15]. A narrative review of the studies not qualifying for the meta-analysis is presented in the results section.

Results

Study Selection

The search yielded 313 articles, and once duplicates were removed, 201 article abstracts and titles were independently screened for eligibility by RW and CRP. Title and abstract screening excluded 159 papers, and 42 articles were retrieved for independent full-text screening by RW and CRP. From the search of the databases, 15 articles were included with no disagreement between reviewers. Two papers were follow-up publications of one year[16] and three years[17]. One RCT could not be included in the meta-analysis due to limited study design and reporting data but is included in the narrative review[18]. Fourteen articles from citation searching were screened, with three meeting inclusion criteria. In total, 16 studies and 2 follow-up articles were included (Table 1).

Table 2. Characteristics of included studies.

Authors	Country	Study Design	Main Inclusion	Main Exclusion	N	Mean age (years)	Intervention
Abd-Eltwab & Ameer, 2021[22]	Egypt	CCT	18-30 y/o Female University Students Diagnosed with kyphosis Non physically active	MSK/neuro abnormalities, Spinal surgery, Pregnant	14	E: 22.86 C: 21.43	E: General active exercises C: TheraBand exercises
Almasoodi, Mahdavinejad & Ghasmi, 2020[23]	Iran	RCT	Male 25-42 y/o FHP: ≥ 44, HPK: ≥42, Forward shoulder: ≥49	Other PA, spinal surgery	30	E: 35.13 C: 34.26	E: NASM exercises C: Traditional Exercise
Azizi et al., 2012[18]	Iran	CCT	Not stated	Not stated	30	20.7	E: Land exercise C: Water exercises
Jabbar & Gandomi, 2021[20]	Iran	CCT	18-25 y/o, kyphosis ≥45, FHP: ≥46	Other medical interventions, Fractures, or spine surgery	30	E: 21.66 C: 19.73	E: NASM Exercise C: Sahrmann corrective exercise
Jang et al., 2019[21]	South Korea	Group matched clinical trial	≥65 y/o, kyphosis ≥40, no other health conditions	Not stated	44	E: 74.6 C: 76.8	E: Thoracic correction exercise (supervised) C: Thoracic correction exercise (at home)
Kamali et al., 2016[5]	Iran	RCT	18-30 y/o, kyphosis ≥45	Scoliosis, spinal fracture, cancer, tumour, spinal abnormalities	39	E: 23.1 C: 23.6	E: Stretching and strengthening C: Manual Therapy
Karimian et al., 2019[28]	Iran	Semi-experimental	HKP ≥42, FHP ≥45, Forward shoulder ≥52	History of fracture or joint disease in the spine, osteoporosis	23	E: 45.2 C: 44.1	E: NASM exercise C: Control
Katzman et al., 2017[8]	USA	RCT	≥60 y/o, kyphosis ≥40	Not able to reduce kyphosis by 5°, medical conditions impacting participation	103	70	E: Group multimodal exercise C: Waitlist Control
Katzman et al., 2021[17]	USA	Cohort study/ Follow-up	≥60 y/o, kyphosis ≥40	Not able to reduce kyphosis by 5°, medical conditions impacting participation	43	73.8	E: Group multimodal exercise follow-up Katzman 2017
Katzman et al., 2007[27]	USA	Cohort study	≥65 y/o, ≥50 kyphosis	Vertebral compression fracture, serious medical condition	21	72	E: Group multimodal exercise
Pawlowsky, Hamel & Katzman, 2009[16]	USA	Follow-up cohort	65-80 y/o, kyphosis, ≥50	Vertebral compression fracture, serious medical condition	19	72	E: Group multimodal exercise – Follow-up from Katzman 2007
Katzman et al., 2017[7]	USA	Pretest - post test	≥60 y/o, kyphosis ≥40	Not able to reduce kyphosis by 5°, medical conditions impacting participation	99	E: 72 C: 70.2	E: Group multimodal exercise Control: Health education
Mousavi et al., 2019[24]	Iran	RCT	Male 18-20 y/o Kyphosis ≥42, FHP ≥46, Forward shoulder ≥52	History of fracture, fracture, or surgery on the spine	42	E: 22.38 C1: 22.07 C2: 21.93	E: Strengthening and stretching C1: MFR & CE C2: Control
Park & Choung, 2020[25]	South Korea	Pretest - post-test	Kyphosis ≥40	Spinal surgery, arthritis	30	Not stated	E: Self stretching C1: MET C2: Control

Table 2. *(Cont. from previous page).*

Authors	Country	Study Design	Main Inclusion	Main Exclusion	N	Mean age (years)	Intervention
Park, Kim & Kim, 2020[26]	South Korea	RCT	Kyphosis ≥40, SIS	Shoulder, cervical or thoracic joint surgery	30	E: 50.9 C1: 49.2 C2: 50.2	E: Thoracic extension and trunk strengthening exercises C1: Mobilizations C2: E & C1
Seidi et al., 2014[30]	Iran	CCT	18-25 y/o, kyphosis ≥42, FHP ≥44, Forward shoulder ≥49	History of fracture or surgery, scoliometer >5	56	20.85	E: LCEP C1: CCEP C2: Control
Tarasi et al., 2019[29]	Iran	Quasi-experimental	18-28 y/o, Kyphosis ≥42 Non-athlete university student	History of fractures, surgery or joint disease, regular PA	97	23.82	E: Spine strengthening, mobility and alignment C: Normal daily routine
Yoo, 2013[19]	Republic of Korea	Case study	n/a	n/a	1	36	Session 1: Stretching Session 2: Thoracic extension Session 3: Cervical and scapular

Abbreviations: CCT: Controlled clinical trial RCT: Randomized controlled trial, y/o: years old, MSK: musculoskeletal, Neuro: Neurological, E: Experimental, C: Control/comparison, FHP: Forward head posture, HKP: Hyperkyphosis, NASM: National Academy of Sports Medicine, MFR&CE: Myofascial release and correction exercise, MET: Muscle Energy Technique, PA: Physical Activity, SIS: Subacromial impingement syndrome, LCEP: Local corrective exercise program, CCEP: Comprehensive corrective exercise program.

Characteristics of Included Studies

The 18 studies took place in five different countries. Table 2 lists the characteristics of the studies, including country, study design, inclusion/exclusion criteria, number of participants, average age, and interventions. Overall, 749 participants were included, ranging from one[19] to 101 participants[8]. The average age of participants ranged from 19[20] to 77 years old[21]. One study included only females[22] and two included only male participants[23,24]. Inclusion criteria for kyphosis ranged from 40°[7,8,17,21,25,26] to 50°[16,27]. There was one case study[19], one grouped matched trial[21], one semi-experimental study[28], one cohort[27], two follow-up articles[16,17], two pre-test post-test studies[7,25], one quasi-experimental[29], five RCTs[5,8,23,24,26] and four controlled clinical trials (CCT)[18,20,22,30].

Intervention Procedures

All included studies had stretching with or without strengthening as the main component in at least one intervention (Table 3). Three included studies used the National Academy of Sports Medicine (NASM) exercise protocol. One semi-experimental study compared the NASM to a control group[28] and the other two studies compared NASM to another exercise procedure[20,23]. Five articles used the same group multi-modal exercise plan (GMEP), two comparing it to a control group[7,8], one for a pre-test, post-test study[27] and two follow-up articles[16,17]. One study compared the efficacy of an exercise procedure with or without a TheraBand[22]. Another study compared land versus water-based environments for the same exercise procedures[18].

Three different interventions - an exercise program, mobilizations, and a combination group – were compared in one study[26]. Another study compared a corrective exercise (CE) program and a combination of myofascial release (MFR) and CE (MFR/CE) to a control group[24]. A local corrective exercise program (LCEP) was compared to a comprehensive corrective exercise program in a CCT (CCEP)[30]. Park & Choung (2020) compared exercise to muscle energy technique (MET), while Kamali et al. (2016) compared it to manual therapy[5,25]. Finally, two studies compared their intervention to control[21,29], and one case study used an individualized program[19].

An in-depth review of the intervention procedures highlighted nine exercise programs where stretching preceded strengthening exercises[5,18–23,28,30]. Seven procedures implemented strengthening exercises before stretching[7,8,16,17,24,27,29]. Stretching was a standalone intervention in one study[25] while in another, stretching occurred before and after the strengthening component[26]. Stretching of pectoralis major and minor against a wall or supine on a foam roller was used in every study. Other interventions targeted stretching of the sternocleidomastoid, levator scapulae and upper trapezius muscles[20,23,24,28,29]. Strengthening exercises

Table 3. Intervention Procedures.

Authors	Intervention	Experimental (E) Procedures	Intervention frequency & duration	Supervision	Control/comparator (C) procedures	Follow-up period
Abd-Eltwab & Ameer, 2021[22]	E: General active exercise C: TheraBand exercises	General active exercise: Thoracic stretching, thoracic extension, extension in lying with cervical retraction exercise 15 sec hold, 15 sec rest, 10 sets, 2 min rest between exercises	60 min session 3 days a week 4 weeks	Not stated	TheraBand exercises: neck retraction, scapular retraction, resistive shoulder blade squeeze 15 sec hold, 15 sec rest, 10 sets, 2 min rest between exercises	Immediately following intervention
Almasoodi, Mahdavinejad & Ghasmi, 2020[23]	E: NASM exercises C: Traditional Exercise	NASM exercises: Self-myofascial release (1-3 sets, 30 sec), stretching (1-3 sets, 7-10 isometric contractions, 30 sec hold), isolated strengthening (1-2 sets, 10-15 reps, 2:4 ratio), dynamic movements (1-2 sets, 10-15 reps, 30 sec rest)	3 days a week 8 weeks (Session duration not stated)	Not stated	Traditional: Stretching (30 sec hold add 5 sec. every 2 weeks) stabilization exercises (6 reps, 2 sec. hold -> 10 reps 10 sec. hold) and strengthening (3 reps of 12 at 40% 1ORM increase by 10% every 2 weeks)	Immediately following intervention
Azizi et al., 2012[18]	E: Land exercise C: Water exercises	Land: Stretching (stretch anterior chest, 10-15 sec. hold, 15 sets), strengthening (weakened back muscles 10-15 sec. hold, 5-10 sets)	10 minutes of exercises 8 weeks	Not stated	In water: Same as on land	Immediately following intervention
Jabbar & Gandomi, 2021[20]	E: NASM Exercise C: Sahrmann corrective exercise	NASM exercises: Self-myofascial release (1-3 sets, 30 sec), stretching (1-3 sets, 7-10 isometric contractions, 30 sec hold), isolated strengthening (1-2 sets, 10-15 reps, 2:4 ratio), dynamic movements (1-2 sets, 10-15 reps, 30 sec rest)	60 min sessions 3 days a week 8 weeks	Physiotherapist and 2 exercise specialists	Sahrmann corrective exercise: deep neck flexor strengthening (3 sets, 15 reps), prone trunk lift, side lying thoracic rotation, quad arm/leg lift, side lying hip abduction (60 sec. hold, 10 reps progress to 12 reps)	Immediately following intervention
Jang et al., 2019[21]	E: Thoracic correction exercise (supervised) C: Thoracic correction exercise (at home)	Thoracic correction exercises: facilitate diaphragmatic (3 sets of 7 reps) breathing, thoracic mobility (10 reps, 10 sec hold), thoracic stability (10 reps, 10 sec holds), and awareness of thoracic alignment (3 min holds)	60 min sessions 2 days a week 8 weeks	Physical therapist and senior exercise specialist	Same exercises but at home prescribed via a booklet	Immediately following intervention and 8 weeks post
Kamali et al., 2016[5]	E: Stretching and strengthening exercises C: Manual Therapy	Stretching of pectoralis major, extensor muscles, and latissimus dorsi, (15 sec holds, 10 sets) and strengthening of anterior neck flexors and back extensor muscles (15 sec hold, 10 sets)	20-30 min sessions 15 sessions over 5 weeks	Physiotherapist at home 1 per week, phone 2 per week	Manual therapy (Muscle energy, myofascial release, mobs)	Immediately following intervention
Karimian et al., 2019[28]	E: NASM exercise C: Control	NASM exercises: Self-myofascial release (1-3 sets, 30 sec), stretching (1-3 sets, 7-10 isometric contractions, 30 sec hold), isolated strengthening (1-2 sets, 10-15 reps, 2:4 ratio), dynamic movements (1-2 sets, 10-15 reps, 30 sec rest)	45-60 min sessions 3 days a week 12 weeks	Not stated	Control procedures not stated	Immediately following intervention
Katzman et al., 2017[8]	E: Group multimodal exercise C: Waitlist Control	Group multimodal exercise – Strengthening (3 sets of 8 reps), ROM exercises (30 sec hold, 1-3 reps) and posture training & practice neutral spine 3 times a day	1-hour sessions 2 days a week 12 weeks	Physical therapist and trained assistant	Waitlist control - given the intervention 3 months after the intervention group	Immediately following intervention And 6 months follow-up
Katzman et al., 2021[17]	E: Group multimodal exercise follow-up Katzman et al. (A) 2017	Group multimodal exercise – Strengthening (3 sets of 8 reps), ROM exercises (30 sec hold, 1-3 reps) and posture training & practice neutral spine 3 times a day	1-hour sessions 2 days a week 12 weeks	Physical therapist and trained assistant	N/A	2-3 years post intervention

Table 3. *(Cont. from previous page).*

Authors	Intervention	Experimental (E) Procedures	Intervention frequency & duration	Supervision	Control/comparator (C) procedures	Follow-up period
Katzman et al., 2007[27]	E: Group multimodal exercise	Group multimodal exercise – Strengthening (3 sets of 8 reps), ROM exercises (30 sec hold, 1-3 reps) and posture training & practice neutral spine 3 times a day	2 days a week 12 weeks (Session duration not stated)	Not stated	N/A	Immediately following intervention
Pawlowsky, Hamel & Katzman, 2009[16]	E: Group multimodal exercise – Follow-up from Katzman 2007	Group multimodal exercise – Strengthening (3 sets of 8 reps), ROM exercises (30 sec hold, 1-3 reps) and posture training & practice neutral spine 3 times a day	2 days a week 12 weeks (Session duration not stated)	Not stated	N/A	1 year following intervention
Katzman et al., 2017[7]	E: Group multimodal exercise Control: Health education	Group multimodal exercise – Strengthening (3 sets of 8 reps), ROM exercises (30 sec hold, 1-3 reps) and posture training & practice neutral spine 3 times a day	1-hour sessions 3 days a week 6 months	Physical therapist and trained assistant	Control health education- were given 1:1 instruction after the 6 months on exercise protocol with videos and handouts	Immediately following intervention
Mousavi et al., 2019[24]	E: Strengthening and stretching C1: MFR/CE C2: Control	Corrective exercise - vertebral column strengthening (8-10 reps, 1-2 sets), motility enhancement (10 reps, 1 set) and alignment enhancement (30 sec hold, 1-2 sets)	1 hour session 3 days a week 8 weeks	Not stated	C1: Corrective exercises with myofascial release C2: Control group – normal daily activity	Immediately following intervention & 4 weeks post
Park & Choung, 2020[25]	E: Self stretching C1: MET C2: Control	Self-stretching: standing stretch of pectoralis major – 10 sec. hold 10 reps, 3 sets with 30 sec. rest	12 min session (Frequency and duration not stated)	Not Stated	C1: MET: resisting manual retraction in supine Control: sit for 12 min. with knee and hips flexed to 90	Immediately following intervention
Park, Kim & Kim, 2020[26]	E: Thoracic extn and trunk strengthening exercises C1: Mobilizations C2: E & C1	Exercise: improve thoracic extension, trunk strength & flexibility, foam roll stretch, march on roll, thoracic extension on the wall, standing neck/chest stretch (10 reps, 2 sets)	15 min sessions 3 days a week 4 weeks	Single therapist	C1: Mobilization: grade III on thoracic spine 30 reps 4 sets C2: Combination of mobilization and exercises (2 sets of mob, 1 set exercises)	Immediately following intervention
Seidi et al., 2014[30]	E: LCEP C1: CCEP C2: Control	LCEP: stretch pectoral muscles and strengthen back extensor muscles - stretching, self-mobs, strengthening (reps and sets set to the individual using overload principle)	3 days a week 12 weeks (Session duration not stated)	Examiners	CCEP: correction of abnormalities as a chain reaction, chin tuck and adduct scapulae and erect thoracic spine. Control group: not stated	Immediately following intervention
Tarasi et al., 2019[29]	E: Spine strengthening, mobility and alignment C: Normal routine	Exercise: spine strengthening (8 reps, 2 sets), spinal alignment (10 reps, 1 set) and spinal mobility (1 set 30 sec. hold)	60 min session 3 days a week 12 weeks	Examiner and collaborators (1:5)	Normal daily routine	Immediately following intervention
Yoo, 2013[19]	Session 1: Stretching Session 2: Thoracic extn Session 3: Cervical and scapular	Session 1: thoracic stretching, Session 2: thoracic extn, Session 3: muscle exercise for cervical and scapular posture 5 sets, 30 reps	Once daily Each of the 3 sessions lasted 10 days	Not stated	N/A	Immediately following every session

Abbreviations: E: Exercise, C: Control/Comparator. Extn: Extension, Sec.: Seconds, Reps: Repetitions, Min.: Minutes, RM: Repetitions Maximum, NASM: National Academy of Sports Medicine, ROM: Range of motion, Mobs.: Mobilisations, MFR/CE: Myofascial release and correction exercise, MET: Muscle Energy Technique, LCEP: Local corrective exercise program, CCEP: Comprehensive corrective exercise program.

Table 4. Results of included studies.

Authors	Interventions	Outcome measure	Findings		
			Experimental (E, Index of Kyphosis: IK,)	Control/Comparator (C)	Between-group difference
Abd-Eltwab & Ameer, 2021[22]	E: General active exercise C: TheraBand exercises	Flexicurve index of kyphosis	**Pre-test (IK):** 3.87 +/- 0.26 **Post-test (IK):** 3.51 +/-0.17 **Significance:** *p=0.020 **% Change:** 9.3	**Pre-test (IK):** 3.99 +/-0.46 **Post-test (IK):** 3.06 +/- 0.14 **Significance:** *p=0.002 **% Change:** 23.3	*p=0.000
Almasoodi, Mahdavinejad & Ghasmi, 2020[23]	E: NASM exercises C: Traditional Exercise	Flexicurve	**Pre-test** (°): 47.6 +/- 2.64 **Post-test** (°): 38.4 +/- 2.82 **Significance:** Not stated **% Change:** 19.32	**Pre-test** (°): 48.26 +/- 1.9 **Post-test** (°): 43.73 +/-2.18 **Significance:** Not stated **% Change:** 9.3	*p=0.000
Aziz et al., 2012[18]	E: Land exercise C: Water exercises	Flexicurve	**Pre-test** (°): 56 **Post-test** (°): 48 **Significance:** Not stated **% Change:** 14.3	**Pre-test** (°): 55.5 **Post-test** (°): 48 **Significance:** Not stated **% Change:** 13.5	Not stated
Jabbar & Gandomi, 2021[20]	E: NASM Exercise C: Sahrmann corrective exercise	Spinal Mouse	**Pre-test** (°): 49.26 +/- 11.13 **Post-test** (°): 46.6 +/- 11.32 **Significance:** *p=0.032 **% Change:** 5.4	**Pre-test** (°): 50.4 +/-6.73 **Post-test** (°): 48.06 +/- 8.11 **Significance:** *p=0.043 **% Change:** 4.6	p=0.19
Jang et al., 2019[21]	E: Thoracic correction exercise (supervised) C: Thoracic correction exercise (at home)	Dual Inclinometer	**Pre-test** (°): 57 +/- 2.9 **Post-test** (°): 54.8 +/- 2.8 **Significance:** Not stated **% Change:** 3.8 **Follow-up** (°): 54.9 +/- 2.7	**Pre-test** (°): 55.7 +/- 4.9 **Post-test** (°): 56.5 +/- 5.5 **Significance:** Not stated **% Change:** 1.4 **Follow-up** (°): 55.6 +/- 4.8	*p<0.01
		Flexicurve index of kyphosis (best)	**Pre-test (IK):** 13.7 +/- 1.3 **Post-test (IK):** 13.2 +/- 1.2 **Significance:** Not stated **% Change:** 3.6 **Follow-up (IK):** 13.4 +/- 1.2	**Pre-test (IK):** 13.5 +/- 1.2 **Post-test (IK):** 13.5 +/- 1.2 **Significance:** Not stated **% Change:** 0.0 **Follow-up (IK):** 13.4 +/- 1.2	*p<0.01
Kamali et al., 2016[5]	E: Stretching and strengthening exercises C: Manual Therapy	ProReflex upright	**Pre-test** (°): 32.5 +/- 8.4 **Post-test** (°): 29.9 +/- 8.3 **Significance:** *p<.001 **% Change:** 8.0	**Pre-test** (°): 31.7 +/- 6.3 **Post-test** (°): 28.5 +/- 6.4 **Significance:** *p<.001 **% Change:** 10.1	P=0.855
Karimian et al., 2019[28]	E: NASM exercise C: Control	Photo-grammetric analysis	**Pre-test** (°): 44.76 +/- 1.94 **Post-test** (°): 41.15 +/- 2.23 **Significance:** Not stated **% Change:** 8.1	**Pre-test** (°): 43.71 +/- 2.38 **Post-test** (°): 44.2 +/- 2.71 **Significance:** Not stated **% Change:** 1.1	*p=0.003
Katzman et al., 2017[8]	E: Group multimodal exercise C: Waitlist Control	Cobb angle	**Pre-test** (°): 57.5 +/- 13.6 **Post-test** (°): -1.4 **Significance:** Not stated **% Change:** 2.4	**Pre-test** (°): 54.2 +/- 10.4 **Post-test** (°): 0.3 **Significance:** not stated **% Change:** 0.6	p=0.09
		Debrunner kyphometer	**Pre-test** (°): 51.4 +/- 7.9 **Post-test** (°): -3.8 **Significance:** Not stated **% Change:** 7.4	**Pre-test** (°): 52.7 +/- 7 **Post-test** (°): 1 **Significance:** Not stated **% Change:** 1.9	*p<0.0001
Katzman et al., 2021[17]	E: Group multimodal exercise follow-up Katzman 2017	Debrunner kyphometer	**Pre-test** (°): 53.8 +/- 8.1 **Post-test** (°): 50.2 +/- 9.7 **Follow-up** (°): 48.9 +/- 11.9 **Significance:** p=0.077 **% Change:** 6.7	N/A	N/A
Katzman et al., 2007[27]	E: Group multimodal exercise	Debrunner kyphometer (best)	**Pre-test** (°): 50 +/- 6 **Post-test** (°): -6 +/- 0.3 **Significance:** *p<.001 **% Change:** 10	N/A	N/A
Pawlowsky, Hamel & Katzman, 2009[16]	E: Group multimodal exercise – Follow-up from Katzman 2007	Debrunner kyphometer (best)	**Pre-test** (°): 50 +/- 9 **Post-test** (°): 45 +/- 6 **Follow-up** (°): 42 +/- 6 **Significance:** *p=0.022 **% Change:** 16	N/A	N/A

Table 4. *(Cont. from previous page).*

Authors	Interventions	Outcome measure	Findings			
			Experimental (E, Index of Kyphosis: IK,)	Control/Comparator (C)	Between-group difference	
Katzman et al., 2017[7]	E: Group multimodal exercise Control: Health education	Cobb angle	**Pre-test** (°): 56.8 +/- 12.2 **Post-test** (°): -3.3 **Significance**: Not stated **% Change**: 5.8	**Pre-test** (°): 57.9 +/- 12.9 **Post-test** (°): -0.3 **Significance**: Not stated **% Change**: 0.5	p=0.009	
		Debrunner kyphometer	**Pre-test** (°): 54.1 +/- 8.2 **Post-test** (°): -3.8 **Significance**: Not stated **% Change**: 7.0	**Pre-test** (°): 54.1 +/- 9.1 **Post-test** (°): -0.9 **Significance**: Not stated **% Change**: 1.7	*p=0.03	
Mousavi et al., 2019[24]	E: Strengthening and stretching C1: MFR/CE C2: Control	Flexible Ruler	**Pre-test** (°): 47.73 +/- 2.97 **Post-test** (°): 41.11 +/- 1.77 **Follow-up** (°): 43.04 +/- 1.99 **Significance**: *p=0.001 **% Change**: 13.9	<u>MFR/CE</u> **Pre-test** (°): 48.68 +/- 2.59 **Post-test** (°): 40.42 +/- 1.59 **Follow-up** (°): 42.16 +/- 2.28 **Significance**: *p=0.001 **% Change**: 17.3	<u>Control</u> **Pre-test** (°): 47.97 +/- 2.99 **Post-test** (°): 48.09 +/- 2.71 **Follow-up** (°): 47.98 +/- 2.59. **Significance**: p=0.852 % **Change**: 0.3	**MFR/CE & CE**: p=0.006 (Follow-up: p=0.044) **MFR/CE & Control** *p=0.001 (Follow-up: *p=0.001) **CE & Control:** *p=0.001 (Follow-up: *p=0.001)
Park & Choung, 2020[25]	E: Self stretching C1: MET C2: Control	Bubble inclinometer	**Pre-test** (°): 44.3 +/- 1.97 **Post-test** (°): 34.6 +/- 1.71 **Significance**: *p<0.01 **% Change**: 21.9	<u>MET</u> **Pre-test** (°): 43.9 +/- 1.32 **Post-test** (°): 34.4 +/- 1.19 **Significance**: *p=0.01 **% Change**: 21.6.	<u>Control</u> **Pre-test** (°): 43.5 +/- 0.97 **Post-test** (°): 43.4 +/- 0.95 **Significance**: p=0.78 **% Change**: 0.2	*p<0.01 between interventions and control
Park, Kim & Kim, 2020[26]	E: Thoracic extension & trunk strengthening C1: Mobilizations (mobs) C2: Combo C1 & E	Bubble inclinometer	**Pre-test** (°): 44.1 +/- 1.85 **Post-test** (°): 41.4 +/- 2.72 **Significance**: *p=0.002 **% Change**: 6.1	<u>Mobs</u> **Pre-test** (°): 44.5 +/- 2.07 **Post-test** (°): 41.4 +/- 2.36 **Significance**: *p=0.001 **% Change**: 7.9	<u>Combo</u> **Pre-test** (°): 45.2 +/- 2.2 **Post-test** (°): 40.1 +/- 2.23 **Significance**: *p=0.001 **% Change**: 11.3	*p=0.011
Seidi et al., 2014[30]	E: LCEP C1: CCEP C2: Control	Flexicurve	**Pre-test** (°): 48.07 +/- 2.01 **Post-test** (°): 43.03 +/- 2.08 **Significance**: *p=0.001 **% Change**: 10.5	<u>CCEP</u> **Pre-test** (°): 47.28 +/- 2.11 **Post-test** (°): 35.03 +/- 2.27 **Significance**: *p=0.001 **% Change**: 25.9	<u>Control</u> **Pre-test** (°): 46.56 +/- 2.04 **Post-test** (°): 45.94 +/- 2.01 **Significance**: p=0.137 **% Change**: 1.3	**LCEP & Control** *p=0.001 **CCEP & Control** *p=0.001
Tarasi et al., 2019[29]	E: Spine strengthening, mobility and alignment C: Normal daily routine	Flexible Ruler	**Pre-test** (°): 48 +/- 3.01 **Post-test** (°): 40.76 +/- 2.30 **Significance**: *p=0.001 **% Change**: 15.1	**Pre-test** (°): 47.66 +/- 2.81 **Post-test** (°): 48 +/- 3.04 **Significance**: p=0.08 **% Change**: 0.7	*p=0.001	
Yoo, 2013[19]	Session 1: Stretching Session 2: Thoracic extension Session 3: Cervical and scapular	Dual Inclinometer	**Pre-test** (°): 47 **Post-session 1** (°): 46 **Post session 2** (°): 44 **Post session 3** (°): 40 **% Change**: 14.9	N/A	N/A	

**Significant at alpha level < 0.05, Statistics reported as mean and standard deviation (SD).*
Abbreviations: NASM: National Academy of Sports Medicine, MFR/CE: Myofascial release and correction exercise, MET: Muscle energy technique, LCEP: Local corrective exercise program, CCEP: Comprehensive corrective exercise program.

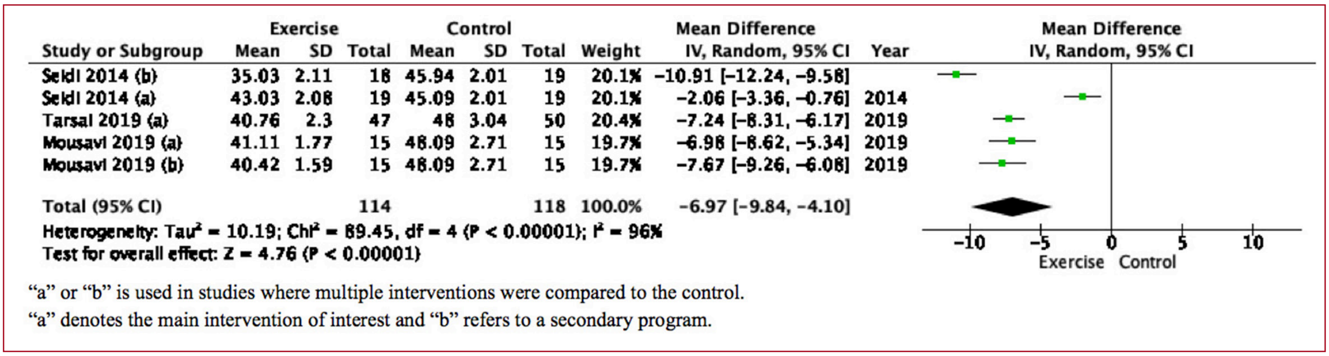

Figure 1. Forest plot: Flexicurve post-intervention measures exercise program versus control.

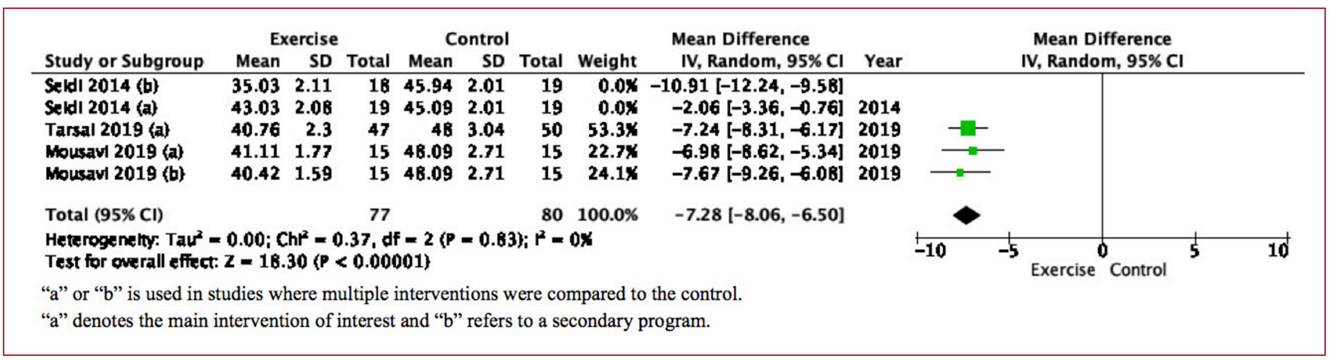

Figure 2. Forest plot: Flexicurve post-intervention measures exercise program versus control without Seidi et al. (2014)[30].

targeted back extensors[5,7,8,16,17,19–24,26–30] and deep neck flexors[19,20,22,23,28,30].

Dosage ranged from 12 sessions over 4 weeks[22,26] to 72 sessions over 24 weeks[7]. Two studies conducted their intervention twice a week for 12 weeks[8,27], following up at one year[16] and three years[17] without further intervention. Three studies conducted interventions three days a week for 12 weeks[28–30]. Two studies were performed three days a week for four weeks[22,26] and 15 sessions over five weeks[5]. Finally, four studies took place three days a week for eight weeks[7,20,23,24] and one more, over eight weeks with unspecified frequency[18].

This review identified several different outcome measures used within the articles (Table 3). Radiographic measurement of Cobb's angle, the current gold standard measure for kyphosis, was used as the primary measure in two studies[7,8]. The most utilized tool was the Flexicurve ruler (or flexible ruler), measuring kyphosis in five studies[18,23,24,29,30] and the measurement of kyphosis index in two studies[21,22]. Five studies used the debrunner kyphometer[7,8,16,17,27]. The dual inclinometer was used in two studies[19,21], and two used the bubble inclinometer[25,26]. Two studies used cameras – one conducting a six-camera motion analysis (ProReflex)[5] and the other using photogrammetric analysis[28]. Finally, one study used the spinal mouse[20].

Results

The key results from the included studies are listed in Table 4. Percent change in kyphosis ranged from 2.4%[8] to 21.9%[25].

Within-group difference

Ten included studies reported significant within-group improvements in kyphotic angle ($p<0.05$) for the intervention[5,20,22,24–27,29,30]; and seven studies did not state within-group significance[7,8,18,19,21,23,28]. Of the two follow-up articles, one showed maintained but non-significant improvements in participants' kyphotic angle two to three years following the intervention[17], and the other showed significant improvements in kyphosis one year following the intervention[16]. Mousavi et al. (2019) reported significant improvements in their CE and MFR/CE groups immediately

Table 5. Quality of included studies.

Authors	Selection Bias	Study Design	Confounders	Blinding	Data collection methods	Withdrawal and drop out	Global rating
Abd-Eltwab & Ameer, 2021[22]	Weak	Strong	Moderate	Moderate	Strong	Weak	Weak
Almasoodi, Mahdavinejad & Ghasmi, 2020[23]	Strong	Strong	Moderate	Moderate	Strong	Strong	Strong
Azizi et al., 2012[18]	Moderate	Strong	Weak	Moderate	Weak	Weak	Weak
Jabbar & Gandomi, 2021[20]	Moderate	Strong	Strong	Moderate	Moderate	Strong	Strong
Jang et al., 2019[21]	Strong	Strong	Moderate	Strong	Strong	Strong	Strong
Kamali et al., 2016[5]	Weak	Strong	Moderate	Moderate	Strong	Weak	Weak
Karimian et al., 2019[28]	Moderate	Strong	Weak	Moderate	Moderate	Weak	Weak
Katzman et al., 2017[8]	Strong	Strong	Strong	Moderate	Moderate	Strong	Strong
Katzman et al., 2021[17]	Weak	Moderate	Strong	Moderate	Strong	Strong	Moderate
Katzman et al., 2007[27]	Moderate	Moderate	Moderate	Weak	Strong	Strong	Moderate
Katzman et al., 2017[7]	Strong	Strong	Strong	Moderate	Moderate	Strong	Strong
Mousavi et al., 2019[24]	Moderate	Moderate	Moderate	Weak	Weak	Weak	Weak
Park & Choung, 2020[25]	Moderate	Strong	Weak	Weak	Weak	Weak	Weak
Park, Kim & Kim, 2020[26]	Moderate	Strong	Moderate	Moderate	Moderate	Weak	Moderate
Pawlowsky, Hamel & Katzman, 2009[16]	Moderate	Moderate	Moderate	Weak	Strong	Weak	Weak
Seidi et al., 2014[30]	Moderate	Strong	Weak	Weak	Strong	Strong	Weak
Tarasi et al., 2019[29]	Moderate	Strong	Moderate	Weak	Weak	Weak	Weak
Yoo, 2013[19]	Strong	Weak	Moderate	Weak	Weak	Weak	Weak

Key: Green = strong rating, yellow = Moderate rating, red = weak rating using the Effective Public Health Practice Project Quality Assessment Tool of Quantitative Studies.

following the intervention and at four weeks of follow-up[24]. Three articles stated moderate to high effect size[24,26,30].

Between-group difference

Nine articles reported significant improvements in the intervention of interest compared to the control/active comparator[7,8,21–23,25,26,28–30]; two studies did not report between-group significance[18], and between-group significance was not possible due to the study design of four papers[16,17,19,27]. Six articles reported low to moderate effect sizes[5,20,21,27–29]. Non-significant differences were reported in two studies, one whose active comparator was another exercise program[20] and the other conducted manual therapy as the active comparator[5]. Mousavi et al. (2019) showed significant differences in kyphotic angle post-intervention and follow-up (four weeks post-intervention) between the control and the CE and MFR/CE, post-intervention and follow-up[24].

Meta-analysis

Only three studies had data that appeared sufficiently homogenous to conduct a meta-analysis, containing 115 participants in the intervention and 84 participants in the control groups[24,29,30]. The Flexicurve outcome measure was used in all three studies. One study compared a single intervention to control[29] while the other two each compared two separate interventions to the control (Figure 2)[24,30]. The meta-analysis demonstrated that the exercise interventions had significantly different kyphotic angles than the control groups immediately following the interventions ($p<0.00001$) (Figure 1). However, the meta-analysis demonstrated a significant degree of heterogeneity (I^2: 96%, $p<0.00001$). Removal of the largest post-intervention measures of kyphosis produced by Seidi et al 2014[30] lowered the heterogeneity of the analysis reporting non-significant homogenous differences (I^2: 0%, $p=0.83$, Figure 2)[15,24,29,31]. Seidi et al. (2014) methods were like the other two studies included in the meta-analysis, however, these other two studies look specifically at spine strengthening and mobility while Seidi et al. (2014) interventions also incorporated muscles of the neck and shoulder girdle.

Quality of included studies

Table 5 presents the score for each study's rating in the first six categories and their global rating. Ten studies were scored as weak (55%)[5,16,18,19,22,24,25,28–30], three as moderate (17%)[17,26,27], and five as strong (28%)[7,8,20,21,23]. The highest incidence of strong ratings across the articles was in the study design category, with thirteen studies attaining this rating[5,7,8,18,20–23,25,26,28–30]. Ten studies had weak withdrawal and dropout ratings[5,16,18,19,22,24–26,28,29]. Eight studies did not report withdrawal and dropouts[16,18,22,24–26,28,29]. Thirteen studies reported no significant difference between participants on few[18], some[5,16,21–27,29] or most[7,8,17,20] comparators at baseline.

Discussion

The meta-analysis and the narrative review of the included studies suggest that a comprehensive exercise program, including strengthening back extensor muscles and lengthening anterior chest muscles, leads to significant improvements in hyperkyphosis. This review however, found only one, low-quality, study which used stretching as a standalone intervention[25], highlighting the limited research in this area, so at present stretching alone as an intervention is not supported.

To our knowledge, this is the first systematic review and meta-analysis that focused on stretching as an intervention for adults suffering from hyperkyphosis. The results of this systematic review are in line with the results of previous studies in terms of the significant effect of exercise on reducing hyperkyphosis[4,6,9,32]. Two previous systematic reviews looked at age-related hyperkyphosis (≥45 years old)[4,32]. This review encompasses more papers by including younger and older adults (≥18 years old); thus, an investigation of trends across the age groups was possible, making the results more generalizable. Two other systematic reviews looked at adults (≥18 years old) suffering from hyperkyphosis, including only RCTs[6,9]. By including only RCTs, these previous reviews had higher quality studies but limited the number of papers that could be included. One review investigated hyperkyphosis and lumbar lordosis[6], and the second investigated all conservative management forms for hyperkyphosis[9]. The focus of this review provides a previously unapproached spotlight on the stretching of anterior structures as part of the management of hyperkyphosis, reinforcing and updating the findings from previous research[6,9].

The age range of this review (19 to 77 years old) allowed for an investigation into the younger and older adults' initial measure of kyphosis and percent change following the intervention. Increased baseline kyphotic angle for older adults' results from age-related degeneration of the thoracic spine resulting in differences between populations[4]. Baseline differences in hyperkyphosis may explain the varied percent change pre- to post-intervention viewed in across the studies.

This review demonstrates weak evidence that stretching of anterior structures has a role in treating kyphosis as a standalone intervention. Evidence suggests that stretching plays a role as part of a global approach to improving posture and statistically significant improvements in hyperkyphosis[30]. The variety of effective interventions and exercises explored in this review demonstrate moderate to strong evidence for a comprehensive approach to the muscles supporting the body's upper quarter. Programs like the GMEP, NASM and CCEP, used in several studies, corroborate that statistically significant improvements in hyperkyphosis can be derived from globally targeting interventions[27,28,30]. However, these are extensive programs conducted under the supervision of professionals, which may not be feasible in clinical practice. Currently, initial physiotherapy appointments with National Health Service (NHS) are 30-minute-long video or telephone sessions[33]. The restricted session with patients would not be enough time to hold patients accountable and provide the supervision and structure to conduct programs such as the GMEP, NASM and CCEP[27,28,30]. The GMEP program shows evidence that group exercise classes can be functional and lead to statistically significant improvements in hyperkyphosis[7,8,16,24,27]. Furthermore, group classes would increase the number of patients able to receive treatment, improve patients' confidence and increase adherence[27].

The GMEP aims to address back extensor strength, range of motion (ROM), and postural alignment, which has been used in multiple studies with older participants, and there is a detailed description of their intervention, increasing reproducibility[27,34]. All articles utilizing these procedures conducted the same dose and demonstrated significant improvements to hyperkyphosis[7,8,27] which were maintained[17] and improved[16] at follow-up. In younger participants, one study has shown statistically significant improvements in hyperkyphosis in an adapted version of the GMEP, conducted over a shorter period (eight weeks), suggesting this program is useful at all ages[24].

The NASM protocol sequentially progresses participants through the inhibit, lengthen, and strengthen stages of exercises for the muscles surrounding the thoracic spine and shoulder girdles[28]. The NASM demonstrated significant improvements in hyperkyphosis over 12 weeks in two studies[23,28] and eight weeks in another[20]. However, only one of the studies indicated how patients would progress their exercise[28]. The three studies investigating the NASM protocols as their primary intervention targeted younger adults making their results less generalizable to the older population.

Across the remainder of the studies, intervention protocols varied on the number, types of exercises and dose of their intervention[5,7,8,16,17,19–21,23,24,27–30].The highest percent change for the intervention of interest came from a study which included only one stretching exercise (standing pectoralis major) as their intervention[25]. However, this study was considered low quality and so further research is required to strengthen their findings[25]. Manual therapy and MFR, the comparators in the two studies, aim to increase tissues' extensibility and ROM[5,24]. Both studies showed statistically significant improvements in hyperkyphosis for the intervention and comparator[5,24]. Kamali et al. (2016) found manual therapy to be as effective as an exercise program[5], and Mousavi et al. (2019) demonstrated weak quality evidence that MFR/CE is superior to CE alone[24]. These articles suggest that exercise and manual therapies effectively reduce hyperkyphosis. But more research is required to determine if combining these treatments with exercises is superior to exercise programs on their own. Jang et al. (2019) compared the prescription of their comprehensive exercise plan supervised in a clinic versus performed at home[21]. Significant differences in the kyphotic angle immediately following the intervention and at eight weeks of follow-up were demonstrated, favouring the supervised group[21].

The meta-analysis demonstrated a significant difference between exercise interventions and controls, but high heterogeneity reduced the confidence in these results[15]. However, one study differed greatly, and heterogeneity lowered significantly once removed[30]. The heterogeneous study by Seidi et al. (2014) compared an LCEP and CCEP to a control group[30]. Seidi et al. (2014) claimed that the CCEP program they developed was more effective than the LCEP because it targets kyphosis as a musculoskeletal disorder in the muscular chain to be treated globally rather than locally[30].

The dosage varied across the studies included, and data suggests that similar statistically significant improvements of kyphosis can occur in interventions at four weeks[22,26] as they do at 26 weeks[7]. Follow-up studies showed that 12-week interventions could result in maintained and improved kyphosis at one[16] and three[17] years of follow-up for older adults. Research is required to determine the longevity of hyperkyphosis targeted interventions for younger adults.

While it was not the focus of this review, a few studies reported a significant reduction in patients' shoulder[23,26] and back[19,22] pain. Pain is a clinically meaningful outcome for patients, and future research is needed to investigate the impact of exercise interventions on hyperkyphotic-related pain.

The EPHPP was used to appraise each article for its methodological and reporting quality, with over half of the papers receiving a weak rating. Due to invasiveness and cost, only two studies used the gold standard outcome measure (Cobb's angle)[7,8], opting for more accessible tools with moderate-high reliability and validity, increasing the risk of measurement error and reducing the confidence of results[34]. Despite the low-quality scores on appraisal, the statistically significant improvements in hyperkyphosis reported by all articles indicate an overall positive effect of stretching and strengthening on hyperkyphosis.

A strength of this review was the systematic approach to searching and collecting papers from multiple databases and two reviewers undertaking independent screening of included articles and a sample appraisal and data extraction. Including a broader age range of adults and multiple study types decreased selection bias and increased this review's sample size and, therefore, generalizability[34]. However, there are also several weaknesses to this review. By including non-RCT articles, the evidence explored in this review was of weak-moderate quality. Additionally, the specific focus on the stretching of anterior structures limited the inclusion of several studies from previous reviews investigating the stretching of other structures[6] and interventions with only strengthening[4,6,9,32]. This limitation did not allow comparisons between interventions with and without stretching. One study's data required extraction from a graph due to poor reporting, resulting in estimations by the author which may not reflect the actual results of this study[18].

Conclusion

This review suggests that supervised interventions with stretching, and strengthening are beneficial short and long-term in managing and treating hyperkyphosis. Higher quality RCT studies are required to determine if stretching is effective as a standalone intervention. The meta-analysis found a statistically significant difference in post-intervention measures of hyperkyphosis favouring strengthening and stretching exercises over controls. The narrative review of the studies not included in the meta-analysis also demonstrated statistically significant improvement in hyperkyphosis following exercise interventions including stretching and strengthening. Further research is required to recommend specific frequency and dosages of interventions and determine what stretches or exercise programs can be effective for all adults.

Disclaimer

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