ISSN 0008-3194 (p)/ISSN 1715-6181 (e)/2017/153–161/$2.00/©JCCA 2017

Innovative application of Cox Flexion Distraction Decompression to the knee: a retrospective case series

Luigi Albano, BSc, DC[1]

Objective: *The purpose of this study is to introduce the application of Cox flexion distraction decompression as an innovative approach to treating knee pain and osteoarthritis.*

Methods: *Six months of clinical files from one chiropractic practice were retrospectively screened for patients who had been treated for knee pain. Twenty-five patients met the criteria for inclusion. The treatment provided was Cox flexion distraction decompression. Pre-treatment and post-treatment visual analog pain scales (VAS) were used to measure the results. In total, eight patients presented with acute knee pain (less than three months' duration) and 18 patients presented with chronic knee pain (greater than three months) including two patients with continued knee pain after prosthetic replacement surgery.*

Results: *For all 25 patients, a change was observed in the mean VAS scores from 7.7 to 1.8. The mean number of treatments was 5.3 over an average of 3.0 weeks. Acute patient mean VAS scores dropped from*

Objectif : *Le but de cette étude est de présenter l'application de la décompression par flexion-distraction de Cox en tant qu'approche novatrice de traitement de la douleur au genou et de l'arthrose.*

Méthodologie : *On a inspecté six mois de dossiers cliniques d'un cabinet de chiropratique rétrospectivement pour trouver des patients traités pour une douleur au genou. Vingt-cinq patients respectaient les critères d'inclusion. Le traitement fourni était la décompression par flexion-distraction de Cox. On a utilisé des échelles visuelles analogues (EVA) avant et après le traitement pour mesurer les résultats. Au total, 8 patients présentaient une douleur aiguë au genou (depuis moins de 3 mois) et 18 patients présentaient une douleur chronique au genou (depuis plus de 3 mois), dont 2 patients avec une douleur toujours présente après la chirurgie de remplacement de prothèse.*

Résultats : *Pour les 25 patients, on a observé un changement des résultats moyens de l'EVA de 7,7 à 1,8. Le nombre moyen de traitements était de 5,3 sur une moyenne de 3,0 semaines. Les résultats moyens de l'EVA des patients atteints de douleur aiguë ont chuté de 8,1 à 1,1 après 4,8 traitements sur 2,4 semaines. Les résultats*

[1] Private practice, Windsor, ON

Corresponding author:
Luigi Albano
Walkerville Chiropractic, 1275 Walker Road, Windsor, ON N8Y 4X9
Tel: 519-258-7979
E-mail: dr.luigialbano@gmail.com

8.1 to 1.1 within 4.8 treatments over 2.4 weeks. Chronic patient mean VAS scores dropped from 7.5 to 2.2 within 5.4 treatments over 3.3 weeks. No adverse events were reported.

Conclusion: *This study showed clinical improvement in patients with knee pain who were managed with Cox flexion distraction decompression applied to the knee.*

(JCCA. 2017;61(2):153-161)

KEY WORDS: knee osteoarthritis, Cox Flexion Distraction Decompression, knee pain, manual therapy, manipulation, chiropractic

moyens de l'EVA des patients atteints de douleur chronique ont chuté de 7,5 à 2,2 après 5,4 traitements sur 3,3 semaines. Aucun incident indésirable n'a été déclaré.

Conclusion : *Cette étude démontre une amélioration clinique chez les patients atteints de douleur au genou qui ont été traités avec la décompression par flexion-distraction de Cox appliquée au genou.*

(JCCA. 2017;61(2):153-161)

MOTS CLÉS : arthrose du genou, décompression par flexion-distraction de Cox, douleur au genou, thérapie manuelle, manipulation, chiropratique

Introduction

The prevalence of knee pain has increased substantially over a 20 year period, independent of age and body mass index (BMI).[1] It affects approximately 30-40% of adults by age 65.[2] Total knee replacement utilization in the United States more than doubled from 1999 to 2008.[3] Studies have shown that increasing physical activity in people with osteoarthritis (OA) reduces pain and depression.[4] If a patient has symptoms of OA, such as knee pain with associated walking disability, he or she may be at increased risk of premature death from cardiovascular disease.[5] Chiropractic treatment for knee OA is typically multimodal, involving manipulation, mobilization, soft tissue techniques, physical therapy modalities, nutritional counseling, exercise, and orthoses for the knee or foot.[6]

Cox flexion distraction decompression (FDD) of the spine is an evidence-based, non-surgical spinal care treatment modality, a form of spinal manipulation in which the human spine is placed in distraction (a type of measured, controlled traction of the spine) delivered on a specialized spinal manipulation instrument (the Cox table).[7] The main difference between Cox FDD and traction is that the treatment is manually applied, according to patient tolerance, with oscillation of the applied forces, all the while maintaining the joint under decompression (i.e. tensile loading plus mechanical stress). This can be performed with or without passive stretch to the specific joint through various ranges of motion (ROM). Its effects on the spine are well researched and documented. Cox FDD has demonstrated a reduction of intradiscal pressure of up to –192mmHg in the lumbar spine and –502mmHg in the cervical spine.[8,9] It is a non-invasive joint therapy for patients that allows for continued, reasonable daily activity or minimal convalescence. Recent research has demonstrated that articular cartilage has the intrinsic ability to repair itself when the joint is exposed to distraction with mechanical stimulation.[10,11]

The application of flexion distraction specifically to the knee with and/or without passive knee flexion has not been well documented. The purpose of this study is to introduce the application of Cox FDD as an innovative approach to the treatment of knee pain and OA. This study was designed in retrospect to treatment. Chart review of 25 patients is presented.

Methods

A retrospective search of patient files over six months was performed from one chiropractic facility. Ethics approval was obtained by the Research Ethics Board of the Canadian Memorial Chiropractic College. Charts that were included in this study were patients with only knee pain and having received Cox FDD applied to the knee with and/or without passive knee flexion. VAS scores were used to assess treatment effectiveness. Thirty-two charts were selected. Three were excluded on the basis of having less than three treatments, and four charts were excluded for not having final VAS scores, resulting in 25 patient records. There were no exclusions based on diagnosis.

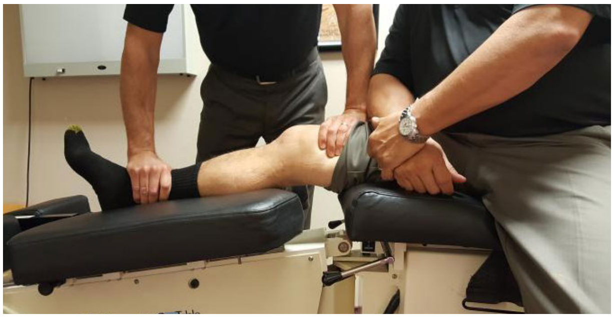

Figure 1.
Initial setup.

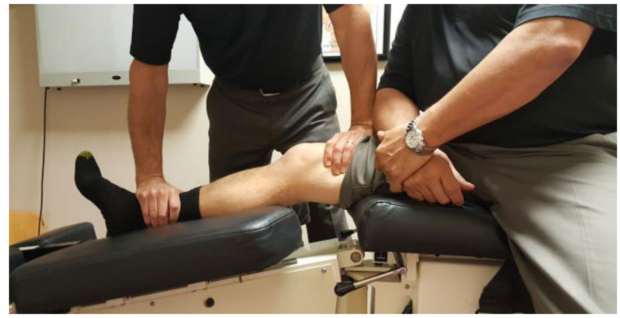

Figure 2.
Flexion Distraction.

The application of treatment followed similar guidelines as used in the Cox Technic spinal protocols.[8] The treatment involved the patient seated at the Cox Table with the affected tibiofemoral joint comfortably resting between the lumbar and dorsal sections of the table (Figure 1). The dorsal section of the table was placed at an angle between 0-15° below horizontal for comfort and to decrease hamstring tension. The caudal section was disengaged to allow for flexion. To create knee joint distraction, the chiropractor applied downward forces above the knee and at the superior aspect of the distal tibiofibular joint (Figure 2). The table was distracted to the "taut point" which is reached when the patient's knee is distracted to the point of the barrier of elasticity. This is the starting point of Cox FDD. The chiropractor controlled the amount of distraction of the device using a foot switch, applied according to patient tolerance. The knee was then distracted and brought to flexion and extension as tolerated by the patient in an oscillatory manner that was smooth and rhythmical for a minimum of 10-15 repetitions (Figures 2, 3, and 4). Each repetition lasted 2-4 seconds. Total treatment time with Cox FDD was approximately 1 minute. Most patients received adjunctive (laser treatment) applied to the knee joint after each Cox FDD session was completed. No adverse events were reported.

Results

The age range of the study participants was between 20 and 80 years, with an average age of 57.5. Seventeen of the eligible charts were considered as chronic with having pain greater than three months and eight were considered acute. Of those, 11 were female and 6 were male. Fourteen patients (56.0%) had previous knee surgery, all of which were in the chronic knee pain group: five meniscectomies, two total knee arthroplasties and seven of unknown surgical type. The acute group was comprised

Figure 3.
Returning to neutral with distraction.

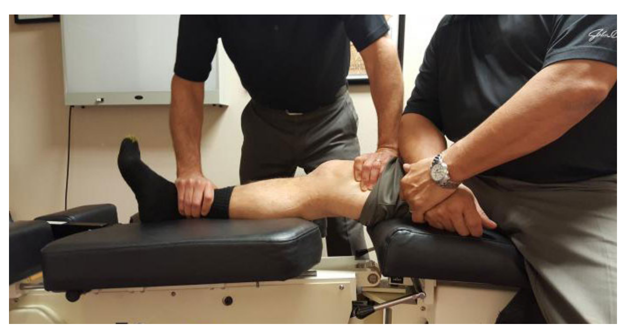

Figure 4.
Back to neutral.

Table 1.
Change in VAS scores for chronic and acute patients.

Group	Average Age (years)	Initial VAS	Post VAS	Average VAS Change	Average No. Treatment	Average Time Span (weeks)
Chronic (n=17)	58.1	7.5	2.2	–5.3	5.4	3.3
Acute (n=8)	49.1	8.1	1.1	–7.0	4.8	2.4
Overall (n=25)	57.5	7.7	1.8	–5.9	5.3	3.0

of two females and six males. None of the acute patients had previous knee surgery.

The reduction in VAS scores for both groups are shown in Table 1. The total average VAS scores for both groups dropped from 7.7 to 1.8 (a reduction of 5.9) in an average of 5.3 treatments over 3.0 weeks. Within the chronic group, the average reduction in VAS scores was from an initial VAS of 7.5 to 2.2 (a decrease of 5.3 points) in 5.4 treatments over 3.3 weeks. The average reduction in VAS within the acute group was from an initial VAS of 8.1 to 1.1 (a reduction of 7.0 points) in 4.8 treatments over 2.4 weeks. There were no patients that reported an increase in pain. One patient did not report any change. None of the acute cases required any treatment three months post-treatment. Most of the chronic cases required ongoing maintenance treatments at a frequency of one treatment per month. In the chronic group, eight out of 17 (47.1%) patients had undergone previous knee surgery ranging from arthroscopic meniscectomy (n = 6) to total knee arthroplasty (n = 2).

The Cox 8 Table allows for real-time force measurements during treatment (Figure 5). Hand pressure, distraction force, table angle and distraction distances are displayed and recorded in real-time as a visual aid. The force applied along the y-axis during treatment was within 20-40 lbs and table distraction distance was within 16-55mm. The treatment flexion angle ranged between 0°–9.1°.

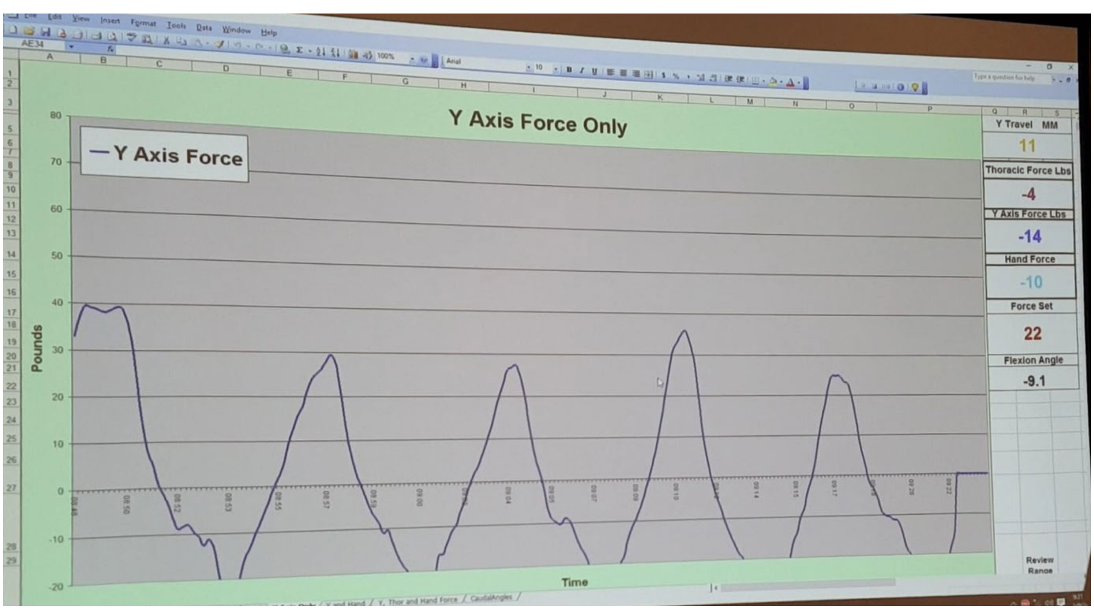

Figure 5.
Cox 8 table forces graph applied to the knee.

The primary clinical diagnoses of the patients in both groups were OA, collateral and cruciate ligament sprains, meniscus tears and sprains, and post-surgical continued knee pain for partial and total knee arthroplasty. In many of the cases there was a combination of these diagnoses.

Discussion

Retrospective Case Series Findings

Both the acute and chronic knee pain groups in this case series responded well to treatment. Almost all of the patients reported a decrease in pain as measured on the VAS with Cox FDD. Notably, most patients reported immediate relief after their first treatment, that lasted from several hours up to two days. At last follow-up, almost all patients reported better mobility, knee joint strength and stability. The last follow-up was performed at 1 to 3 months after treatment. No adverse reactions were reported by any of the patients.

The reduction in VAS scores, number of treatments and duration of care was similar for both groups. Follow-up treatment was evaluated for both groups. Thirteen of the chronic cases returned for follow-up treatments within four weeks and continued with maintenance treatment every three to four weeks and/or as needed. In reviewing the acute group, no patients returned for further treatment after three months.

Previous Studies of Manual Therapy for OA of the Knee

The current study demonstrates a reduction in pain level and treatment duration that are similar with other studies involving manual therapy, exercise and/or surgery. Van den Dolder and Roberts demonstrated a reduction between –8 to –10 mm versus the control group on 100mm VAS.[12] Treatment consisted of transverse friction to the lateral retinaculum, patellofemoral stretches, and the application of sustained medial glide during repeated flexion and extension of the knee. Maher *et al*.[13] showed a statistically significant improvement in ROM but no long-term changes in pain levels using passive knee flexion. Treatment involved the patient laying prone with the knee flexed and the distal femur secured to the table with a stabilization belt and the therapist applied a traction force to the knee. Pollard *et al*.[8] demonstrated a reduction in mean VAS scores from 3.3 to 1.9 in their treatment group. The intervention group received myofascial mobilization and an impulse thrust procedure. Deyle *et al*.[14,15] demonstrated in two randomised controlled trials, improvement in self-reported pain and function when combining manual therapy with exercise versus exercise alone. The treatment applied was soft tissue mobilization and stretching. Khademi-Kalantari *et al*.[16] demonstrated significant relief of knee pain with sustained knee joint traction. Finally, Dwyer *et al*.[17] demonstrated improvement but no statistical improvement between groups when comparing manual and manipulative therapy (joint mobilization, manipulation, and soft tissue treatment) with and without rehabilitation (monitored and/or home program).

Six weeks of continuous knee joint distraction has also been shown to postpone the need for total knee joint arthroplasty in patients younger than age 65.[18] Furthermore, Van der Woude *et al*.[18] have shown that knee articular cartilage has the potential to regenerate, in some cases doubling in thickness with continuous knee joint distraction. Interestingly, these outcomes were maintained even at 5 year follow-up.[18] This could help to partially explain the clinical results observed in the current study.

Knee Physiology

Similarities exist in the physical properties of the knee and spinal joints. The knee meniscus and intervertebral discs are responsible for load transmission, force distribution, shock absorption, and articular cartilage protection.[19] Both structures rely on collagen fibrils to resist tensile forces. Articular cartilage and the extracellular matrix (ECM) are maintained and produced by chondrocytes, specialized cells derived from mesenchymal stem-cells. Chondrocytes produce the cartilage matrix and its components such as proteoglycans (PGs) and glycosaminoglycans (GAGs), that provide the tissue with hydration and its high capacity to withstand compressive loads.[20] The most abundant PG in articular cartilage and the ECM is aggrecan which is composed of a core protein, hyaluronan (HA), and several side chains of GAGs. The most abundant GAG side chains are made up of multiple repeating units of chondroitin-sulphates, keratin-sulphates and dermatan-sulphates. The knee meniscus is predominantly a fibrocartilaginous structure reinforced by highly ordered collagen fibers in a complex orientation. Compressive forces in the intervertebral discs are predominately handled by the nucleus pulposus which is also made up of PGs within a loose framework of collagen fibers. Changes to the viscosity of HA causes densification of tissue and can modify the function of fascia, nerve receptors, muscle layers (epimysium and perimysium gliding) and hydrodynamic properties of connective tissue.[21] It is suggested by the authour that the use of Cox FDD to the knee may cause conformational changes to the synovial capsule and fluid, meniscus, articular cartilage, tendons and entheses, due to the decreased pressure induced by treatment similar to that which occurs in the intervertebral discs.

Increased levels of catabolic enzymes that degrade the ECM occur in patients with OA and rheumatoid arthritis (RA).[22] Arachidonic acid metabolites (PGs, leukotrienes, etc.) and cytokine levels are also increased after inflammatory insult from injury, infection, or in degenerative diseases such as OA and RA. These metabolites signal the biosynthesis of specialized pro-resolving mediators (SPMs) from omega-3 essential fatty acids including eicosapentanoic acid and docosahexanoic acid.[23] SPMs resolve inflammation (catabasis) as opposed to non-steroidal anti-inflammatory medications which block certain steps of inflammation. SPMs initiate healing, contain or limit inflammation, prevent and/or reduce the severity of inflammation, and reduce tissue destruction.[24,25] SPMs include lipoxins, resolvins, protectins and maresins and are known to act as potent regulators of neutrophil infiltration, cytokine and chemokine production, and clearance of apoptotic neutrophils by macrophages which promote the return of tissue homeostasis.[25] Stretching of connective tissue reduces the migration of neutrophils and increases SPM resolvin concentrations.[24]

Passive neurodynamic mobilization has been shown to promote nerve function by limiting or altering intraneural fluid accumulation, preventing the adverse effects of intraneural edema.[26] The use of mobilization techniques, such as those used in the current study, may promote healing of the soft tissues by stimulating the functions of the nervous system to improve adaptability and decrease tissue sensitivity, thereby helping to alleviate symptoms.[27,28]

Mechanotransduction is the process by which biomechanical signals (physical forces) regulate or affect cellular activity and behaviour.[29,30] Paluch *et al*.[29] describes it as how cells sense physical forces and translate them into biochemical and biological responses. Biomechanical signals include compression, stretch (decompression or tension), and shear forces. These forces are converted into chemical signals at the cell surface, acting on cell surface adhesion-receptors and calcium ion channels. They are converted into chemical energy at the cell membrane. Integrins and cadherins are transmembrane proteoglycans that channel mechanotransductive forces and stimuli along the cytoskeletal filaments to distant sites within the cytoplasm and nucleus.[22,23] Genetic transcription of chondrocytes increase the production of aggrecan when influenced by mechanotransduction.[22,23,30] Mechanotransduction stimulates mesenchymal stem cells, found throughout joint tissues, to differentiate into chondrocytes. Chondrocytes are also mechanosensitive and under joint distraction they produce increased levels of PGs, GAGs, and increase ECM.[29-31] It has been shown that mechanical stimulation of chondrocytes antagonizes interleukin-1β and tumor necrosis factor-α.[22] Mechanotransduction has also been shown to reduce the levels of ECM degrading enzymes in OA and RA. Cox FDD, as used in the current study, applies tensile and compressive loads to the ligaments, tendons, menisci, articular cartilage and entheses of the knee all while under reduced joint pressure from distraction.

Cox Flexion Distraction Decompression

Cox FDD was developed by Dr. James M. Cox, DC, DACBR over 40 years ago[32]. Cox Technic is an evidence based non-surgical, chiropractic spinal manipulation that is applied using the Cox Table, by a certified practitioner. Several National Institute of Health funded studies have demonstrated the effectiveness of the technique in its application to the spine.[9,32] This is the first study to document the treatment on the knee. Cox and Bakkum demonstrated the treatment applied to the hip joint in treating gemelli-obturator internus complex (GOIC).[33] Federally funded research has shown that Cox Technic applied to the spine:

1. Decreases intradiscal pressure in the lumbar spine up to –192mmHg.[34]
2. Decreases intradiscal pressure in the cervical spine up to –502mmHg.[35]
3. Increases intervertebral disc height.[34]
4. Increases intervertebral foraminal area up to 28%.[34]

Cramer *et al*.[36] demonstrated that spinal joint fixation leads to degenerative changes of the facet joints. Distraction of the intervertebral disc increases intervertebral disc height, increases perfusion of nutrients, regenerates the extracellular matrix and reverses degeneration.[37-39] Distraction of the knee can regenerate the articular cartilage and increase the tibiofemoral joint space.[11,12,18] The application of flexion distraction specifically to the knee with and/or without passive knee flexion has not been documented and may yield similar effects as that observed in the spine. The results of this study suggest that Cox FDD may be useful in treating patients with knee pain and OA. This study had also helped to devise a potential protocol for clinical treatment.

In the most recent published guidelines for non-surgical management of the knee, manual therapy was not included. The reason provided was that there was insufficient evidence for inclusion.[40] A similar conclusion was made in a systematic review by French *et al*.[41] The Cox 8 table is capable of recording the forces used, flexion angles and distraction distance for each patient. This information allows for quantifiable, standardized treatment with reproduction of these parameters as well as tracking of any changes, information that may be useful in future investigations

Study Limitations

The results of this retrospective study must be gauged with scrutiny, based on the limitations of this study. The decision to apply Cox FDD to the knee was based on necessity and not investigative study. Bias in this study is a major caveat since it was performed in one location by the same practitioner, and patients underwent Cox FDD without a control group. As such, it is unknown if the treatment results in the current study were as a result of the treatment provided or the natural course of the knee pain disorders. Moreover, the only distinguishing characteristics between the different types of knee pain in this study were based on the classification of acute versus chronic knee pain. Specific diagnoses of the source of the knee pain were not part of the inclusion criteria. The groups were not further categorized or compared based on individual clinical diagnosis. The only measure of any changes in pain level was by the use of VAS which is completely subjective. Objective tests and standardized questionnaires such as ROM, WOMAC (Western Ontario McMaster Universities Arthritis Index) and Stair Climb Test (x-step SCT) would have provided more reliable measurable data. In addition, follow-up review for the chronic group in this study was based on patients returning for care for their knee pain or other conditions. All of the acute cases were contacted by telephone or were interviewed during treatment for other conditions unrelated to the knee by the same clinician. Telephone follow-up does not provide for actual physical observation. As well, it skews the pain level by not utilizing the VAS references for the patient.

All of the patients in this study were also given advice regarding bracing, exercise and nutrition (an anti-inflammatory/gluten free diet) . Unfortunately record-keeping of compliance with these recommendations was not maintained as the patients were not provided or sold any products by the treating practitioner.

Currently, a 20-patient randomized controlled study is underway in collaboration with the University of Windsor Faculty of Human Kinetics which uses ROM, WOMAC and the Step Test, and patients will be evaluated before and after treatment. The author also applies Cox FDD treatment to the hip, shoulder and ankle in his clinical practice. Investigation of the effects on these joints has not been performed but similar clinical results to the knee have been observed. Future studies are also planned in order to investigate the effects of Cox FDD therapy on knee joint space, specifically the meniscus and articular cartilage, measured via weight-bearing x-ray and MRI.

Conclusion

The results of this study suggest that Cox FDD of the knee joint may offer benefit for patients with knee pain and/or OA. The use of the Cox 8 table may allow for more standardized and reproducible treatments. The outcomes of this study nevertheless necessitate further research in the form of larger, prospective observational and/or controlled studies to confirm similar results.

Acknowledgments

I thank Dr. James M. Cox, DC, DACBR and Julie Cox-Cid for their encouragement and recommendation to investigate and publish the findings of this study.

Funding sources and potential conflict of interest

No funding sources were offered or provided for this study. Dr Luigi Albano is a chiropractor in private practice and is a certified Cox Technic provider.

References

1. Nguyen US, Zhang Y, Zhu Y, Niu J, Zhang B, Felson DT. Increasing prevalence of knee pain and symptomatic knee osteoarthritis. Ann Intern Med. 2011; 155(11): 725–732.
2. van den Dolder PA, Roberts DL. Six sessions of manual therapy increase knee flexion and improve activity in people with anterior knee pain: a randomized controlled trial. Aust J Physiother. 2006; 52: 261-264.
3. Losina E, Thornhill TS, Rome BN, Wright J, Katz JN. The dramatic increase in total knee replacement utilization rates in the United States cannot be fully explained by growth in population size and the obesity epidemic. J Bone Joint Surg Am. 2012; 94(3): 201-207.
4. Penninx BWJH, Rejeski WJ, Pandya J, Miller ME, Di Bari M, Applegate WB, Pahor M. Exercise and depressive symptoms: a comparison of aerobic and resistance exercise effects on emotional and physical function in older persons with high and low depressive symptomatology. J Gerontol B Psychol Sci Soc Sci. 2002; 57(2): P124-P132.
5. Nüesch E, Dieppe P, Reichenbach S,Williams S, Iff S, Jüni P. All cause and disease specific mortality in patients with knee or hip osteoarthritis: population based cohort study. BMJ. 2011;342:d1165
6. Law A. Diversified chiropractic management in the treatment of osteoarthritis of the knee: a case report. J Can Chiropr Assoc. 2001; 45(4): 232-240.
7. Gudavalli MR, Cox JM, Baker JA, Cramer GD, Patwardhan AG. Intervertebral disc pressure changes during the Flexion-Distraction procedure for low back pain. Abstract from the Proceedings of the International Society for the Study of the Lumbar Spine, Singapore 1998.
8. Pollard H, Ward G, Hoskins W, Hardy K. The effect of a manual therapy protocol on osteoarthritic knee pain: a randomised controlled trial. J Can Chiropr Assoc. 2008; 52(4): 229-242.
9. Cox JM. Low back pain: mechanism, diagnosis and treatment. Seventh Edition. Lippincott, Williams and Wilkins, 2011: 20-29, 362-383.
10. Lafeber F, Intema F, van Roermund P, Marijnissen A. Unloading joints to treat osteoarthritis, including joint distraction. Curr Opin Rheumatol. 2006 18:519-525.
11. Wiegant K, van Roermund P, Intema F, Cotofana S, Eckstein F, Mastbergen S, *et al*. Sustained clinical and structural benefit after joint distraction in the treatment of severe knee osteoarthritis. Osteoarthritis Cartilage. 2013 21:1660-1667.
12. Van den Dolder PA, Roberts DL. Six sessions of manual therapy increase knee flexion and improve activity in people with anterior knee pain: a randomised controlled trial. Aust J Physiother. 2006;52: 261-264.
13. Maher S, Creighton D, Kondratek M, Krauss J, Qu X. The effect of tibio-femoral traction mobilization on passive knee flexion motion impairment and pain: a case series. J Manipulative Physiol Ther. 2010; 18(1):29-36.
14. Deyle GD, Henderson NE, Matekel RL, Ryder MG, Garber MB, Allison SC. Effectiveness of manual physical therapy and exercise in osteoarthritis of the knee. Ann Intern Med. 2000;132:173-180.
15. Deyle GD, Allison SC, Matekel RL, Ryder MG, Stang JM, Gohdes DD, *et al*. Physical therapy treatment effectiveness for osteoarthritis of the knee: a randomized comparison of supervised clinical exercise and manual therapy procedures versus a home exercise program. Phys Ther. 2005; 85: 1301–1317.
16. Khademi-Kalantari K, Aghdam SM, Baghban AA, Rezayi M, Rahimi A, Naimee S. Effects of non-surgical joint distraction in the treatment of severe knee osteoarthritis. J Bodywork Movement Ther. 2014; 18(4): 533-539.
17. Dwyer L, Parkin-Smith GF, Brantingham JW, Korporaal C, Cassa TK, Globe G, Bonnefin D, Tong V. Manual and manipulative therapy in addition to rehabilitation for osteoarthritis of the knee: assessor-blind randomized pilot trial. J Manipulative Physiol Ther. 2015;38(1): 1-21.
18. Van der Woude JT, van Heerwaarden RJ, Wiegant K, van Roermund PM, Saris DB, Mastbergen SC, Lafeber FP. Six weeks of knee joint distraction: sufficient for cartilage tissue repair. Ann Rheum Dis. 2015;74:371.
19. Beaufils P, Verdonk R. The Meniscus. Heidelberg, Dordrecht. Springer 2010.
20. Fox AJS, Bedi A, Rodeo SA. The basic science of human knee menisci. Sports Health. 2012; 4(4): 340-351.
21. Stecco A, Gesi M, Stecco C, Stern R. Fascial components of the myofascial pain syndrome. Curr Pain Headache Rep. 2013;17:352.
22. Leong DJ, Hardin JA, Cobelli NJ, Sun HB. Mechanotransduction and cartilage integrity. Ann N Y Acad Sci. 2011; 1240:32-37.
23. Berrueta L, Muskaj I, Olenich S, Butler T, Badger GJ, Colas RA, Spite M, Serhan CN, Langevin HM. Stretching impacts inflammation resolution in connective tissue. J Cell Physiol. 2016; 231(7): 1621-1627.
24. Serhan C. Novel pro-resolving lipid mediators in inflammation are leads for resolution physiology. Nature. 2014 Jun 5; 510(7503): 92-101.
25. Duvall MG, Levy BD. DHA- and EPA-derived resolvins, protectins, and maresins in airway inflammation. Eur J Pharmacol. 2016; 785: 144-155.
26. Kroeber M, Unglaub F, Guehring T, Nerlich A, Hadi T, Lotz J, Carstens C. Effects of controlled dynamic disc distraction on degenerated intervertebral discs: an in vivo study on the rabbit lumbar spine model. Spine. 2005; 30(2): 181-187.
27. Gilbert KK, Smith MP, Sobczak S, James CR, Sizer PS, Brismée JM. Effects of lower limb neurodynamic

mobilization on intraneural fluid dispersion of the fourth lumbar nerve root: an unembalmed cadaveric investigation. J Man Manip Ther. 2015; 23(5): 239-245.
28. Jeong UC, Kim CY, Park YH, Hwang-Bo G, Nam CW. The effects of self-mobilization techniques for the sciatic nerves on physical function and health of low back pain patients with lower limb radiating pain. J Phys Ther Sci. 2016; 28(1): 46-50.
29. Paluch EK, Nelson CM, Biais N, Fabry B, Moeller J, Pruitt BL, Wollnik C, Kudryasheva G, Rehfeldt F, Federle W. Mechanotransduction: use the forces. BMC Biology. 2015; 13:47.
30. Wang N, Tytell JD, Ingber DE. Mechanotransduction at a distance: mechanically coupling the extracellular matrix with the nucleus. Nature Reviews Molecular Cell Biology. 2009; 10(1): 75-82.
31. Tiku ML, Sabaawy HE. Cartilage regeneration for treatment of osteoarthritis: a paradigm for nonsurgical intervention. Ther Adv Musculoskel Dis. 2015; 7(3): 76-87.
32. Cox JM. Blog #6 – What Is Cox® Flexion Distraction Decompression Spinal Manipulation? http://www.coxtechnic.com/blog/ March 9, 2016.
33. Cox JM, Bakkum BW. Possible generators of retrotrochanteric gluteal and thigh pain: the gemelli-obturator internus complex. J Manipulative Physio Ther. 2005; 28(7): 534-538.
34. Gudavalli MR, Cox JM, Baker JA, Cramer GD, Patwardhan AG. Intervertebral disc pressure changes during the flexion-distraction procedure for low back pain. Abstract from the Proceedings of the International Society for the Study of the Lumbar Spine, Singapore 1998.
35. Gudavalli MR, Potluri T, Carandang G, Havey RM, Voronov LI, Cox JM, Rowell RM, Kruse RA, Joachim GC, Patwardhan AG, Henderson CNR, Goertz C. Intradiscal pressure changes during manual cervical distraction: a cadaveric study. Evid Based Compl Alt Med. 2013: 2013: 954134.
36. Cramer GD, Fournier JT, Henderson CNR, Wolcott CC. Degenerative changes following spinal fixation in a small animal model. J Manipulative Physiol Ther. 2004; 27(3): 141-154.
37. Hee HT, Chuah YJ, Tan BHM, Setiobudi T, Wong HK. Vascularization and morphological changes of the endplate after axial compression and distraction of the intervertebral disc. Spine. 2011; 36(7): 505-511.
38. Hee, HT; Zhang, JT; Wong, HK. Effects of cyclic dynamic tensile strain on previously compressed inner annulus fibrosus and nucleus pulposus cells of human intervertebral disc-an in-vitro study. Jour Orth Research 28 (4) Apr 2010. p.503-9.
39. Guehring T, Omlor GW, Lorenz H, Engelleiter K, Richter W, Carstens C, Kroeber M. Disc distraction shows evidence of regenerative potential in degenerated intervertebral discs as evaluated by protein expression, magnetic resonance imaging, and messenger ribonucleic acid expression analysis. Spine. 2006; 31(15): 1658-1665.
40. McAlindon TE, Bannuru RR, Sullivan MC, *et al*. OARSI guidelines for the non-surgical management of knee osteoarthritis. Osteoarthritis Cartilage. 2014; 22(3): 363-388.
41. French HP, Brennan A, White B, Cusack T. Manual therapy for osteoarthritis of the hip or knee: a systematic review. Man Ther. 2011; 16(2): 109-117.