Maiers *et al. Chiropractic & Manual Therapies* (2025) 33:2
https://doi.org/10.1186/s12998-024-00566-9

Chiropractic & Manual Therapies

RESEARCH **Open Access**

The association between individual radiographic findings and improvement after chiropractic spinal manipulation and home exercise among older adults with back-related disability: a secondary analysis

Michele J. Maiers[1,2*], Andrea K. Albertson[1], Christopher Major[1], Heidi Mendenhall[1] and Christopher P. Petrie[1]

Abstract

Background Some chiropractors use spinal x-rays to inform care, but the relationship between radiographic findings and outcomes is unclear. This study examined the association between radiographic findings and 30% improvement in back-related disability in older adults after receiving 12 weeks of chiropractic spinal manipulation and home exercise instruction.

Methods This IRB-approved secondary analysis used randomized trial data of community-dwelling adults age ≥ 65 with chronic spinal pain and disability. Data were collected during the parent trial between January 2010-December 2014. The primary outcome of the parent study was ≥ 30% improvement in Oswestry Disability Index (ODI) at 12 weeks, a clinically important response to care. In this secondary analysis, two chiropractic radiologists independently assessed digital lumbar radiographs for pre-specified anatomic, degenerative, and alignment factors; differences were adjudicated. The unadjusted association between baseline radiographic factors and 30% ODI improvement was determined using chi-square tests.

Results From the parent trial, 120 adults with baseline lumbar radiographs were included in this study. Mean age was 70.4 years (range 65–81); 59.2% were female. Mean baseline disability (ODI = 25.6) and back pain (5.2, 0–10 scale) were moderate. Disc degeneration (53.3% moderate, 13.3% severe), anterolisthesis (53.3%), retrolisthesis (36.6%) and scoliosis (35.0%) were common among the participant sample. After 12-weeks of treatment, 51 (42.5%) participants achieved 30% improvement in back disability. No alignment, degenerative, or anatomic factors were associated with ODI improvement at 12 weeks (all $p > 0.05$), regardless of severity of radiographic findings.

Conclusion We found no association between a predetermined subset of radiographic findings and improvement in back-related disability among this sample of older adults. As such, this study provides preliminary data suggesting that imaging may be unhelpful for predicting response to chiropractic spinal manipulation and home exercise.

*Correspondence:
Michele J. Maiers
mmaiers@nwhealth.edu

Full list of author information is available at the end of the article

Keywords Spinal manipulation, Home exercise, Radiography, Back pain, Older adults, Disability, Degeneration, Alignment, Responder, Chiropractic

Introduction

Individuals age 65 and older comprise an increasingly large proportion of the population among high-income nations [1]. Low back pain is highly prevalent among older adults, affecting 21–75% annually [2]. Nonsurgical, nonpharmacologic approaches to care are of particular interest for older adults with spine-related pain and disability, given their increased risk of complications from pharmacologic interventions and spine surgery [3–6].

Most spine-related complaints in seniors have no definite pathology, making them potentially amenable to chiropractic treatment and other nonoperative approaches [7, 8]. There is growing evidence that spinal manipulation and exercise, commonly prescribed by Doctors of Chiropractic, reduces pain and pain-related disability in older adults [9–13]. Recent studies estimate that adults ages 65 or older account for 14–16% of adult chiropractic users, and this proportion is increasing over time [14–18].

Spinal radiographs may aid the clinical examination and diagnosis of spine conditions. For providers who perform spinal manipulation, radiographs also identify pathologic conditions that are known or thought to be contraindications to manipulation, such as fractures, malignancies, severe osteoporosis, or abdominal aortic aneurysm [19]. Historically and anecdotally, chiropractors have additionally used spinal radiographs to inform segmental spinal manipulation decisions, care management plans, or to determine who may respond to spinal manipulation [20, 21]. The extent to which this is currently practiced is not well described in the literature [22]. Moreover, there is a paucity of research supporting the use of imaging for these purposes. One observational study of over 2,000 adult chiropractic patients with low back pain found that diagnostic imaging did not result in better clinical outcomes [23]. Given potential risks associated with unnecessary imaging, including radiation, cost, and unnecessary pursuit of incidental findings, it is important to more thoroughly explore imaging practices for older adult patients [24]. The association between baseline radiographic findings and clinical outcomes among older adult chiropractic users is unknown. Specifically, it has not been determined whether baseline radiographic findings help predict early pain and functional response to chiropractic spinal manipulation and home exercise in older adults with back and neck pain.

The goal of this study was to examine the association between anatomic, degenerative, and anatomical radiographic findings commonly noted in chiropractic practice, and 30% improvement in back-related disability in older adults after 12 weeks of chiropractic spinal manipulation and home exercise instruction.

Methods

This retrospective cohort study is a secondary analysis of randomized clinical trial (RCT) data collected on community-dwelling adults ages 65 years or older with chronic spinal pain and disability, and was approved by the Institutional Review Board at Northwestern Health Sciences University [25–27]. Recruitment and data collection for the parent RCT was conducted from January 2010 through December 2014. All participants enrolled in the parent RCT received the same study intervention, consisting of primarily high-velocity, low-amplitude chiropractic spinal manipulation plus home exercise instruction for 12 weeks [26]. In this secondary study, we included adults who had baseline radiographs taken of the lumbar spine to determine eligibility for the parent trial, which excluded individuals with advanced spinal stenosis, fracture, or severe osteoporosis. Routine imaging for spinal pain in older adults was considered a best practice the time of the study. Participants who did not have radiographs taken at baseline had advanced imaging within one year prior to trial enrollment, and were therefore not required to have lumbar radiographs in the absence of new clinical symptoms [25]. Those participants were excluded from this study.

Participant demographic information, as well as pain and functional measures collected in the parent RCT, were also included in this analysis. The primary outcome of the parent study was a clinically significant change in disability, considered to be ≥ 30% improvement in Oswestry Disability Index (ODI) after 12 weeks of study intervention [28]. These results are reported elsewhere [27].

In this study, a team of three chiropractic radiologists and two researchers (also chiropractors with clinical experience) agreed on radiographic findings of the lumbar spine conventionally considered in the chiropractic profession to be of possible clinical importance, including anatomic, degenerative, and alignment factors [29, 30]. Methods for assessing and scoring them were identified based on the literature and common practice among chiropractic radiologists (Appendix 1) [31–42]. These methods were further pilot tested by two chiropractic radiologists, who independently assessed a subsample of digital lumbar radiographs. Their experience was used to refine the methods of standardization used by the radiologists in this study.

Once the methodology to identify radiographic factors was finalized, two rounds of radiographic readings were undertaken by study radiologists (HM, CM) on the images of 10 study participants each. These were independently evaluated, with the radiologists convening after each round to consult with one another to identify agreement, discuss differences, and reach consensus on findings as needed. This process helped ensure assessment protocols were suitable for the remainder of the analysis, which followed. Findings were independently entered into Excel spreadsheets. Once completed, the study coordinator (AA) compared radiologists' findings and checked scoring for consistency. Discrepancies were identified and presented to the radiologists for discussion and consensus. A third radiologist (CP) was available to adjudicate disagreements.

Descriptive baseline statistics are reported for this subsample of the parent RCT. Analysis for this study includes assessing the unadjusted association between individual baseline radiographic factors and 30% ODI improvement with unadjusted logistic regression. Analyses were conducted using SAS 9.4® software.

Table 1 Baseline characteristics of participants

Baseline characteristics	Overall N = 120 n (%)
Demographic	
Mean age (sd)	70.4 (4.7)
Age 70 or older	55 (45.8)
Female	71 (59.2)
White race	114 (95.0)
Lifestyle choices	
BMI, mean (sd)	28.6 (5.9)
Tobacco use (any)	10 (8.3)
Average weekly exercise: *2–3 times/week or more*	73 (60.8)
Amount of physical activity in daily routine: ≥ *moderate*	65 (54.2)
Low back status	
Low back pain duration, years (median, IQR)	15.0 (5–30)
Low back pain severity: mean, past week (0≥10)	5.2 (2.2)
Low back pain severity ≧ 5.0	54 (45.0)
Low back pain + any leg pain (QTF ≥ 2, range 2–4)	48 (40.0)
Leg pain severity past week (0–10) mean (sd)	3.1 (2.2)
Back-related disability (Oswestry Disability Index) mean (sd) (0-100)	25.6 (9.6)
Function	
Short Performance Physical Battery (SPPB), mean (sd)	8.6 (1.8)
SPPB < 10 (at least 1 mobility limitation)	76 (63.3)
Psychosocial	
Geriatric Depression Scale (GDS), mean, (median)	2.0 (2.2)

sd = standard deviation; BMI = Body Mass Index; IQR = interquartile range; QTF = Quebec Task Force

Results

Of 182 participants in the parent trial, 120 (66%) had baseline lumbar radiographs with complete baseline and 12-week data and were therefore included in this study. Mean participant age was 70.4 years (range 65–81) and 59.2% were female (Table 1). Mean baseline back-related disability (ODI = 25.6) and back pain (5.2, 0–10 scale) were moderate, and 40% of adults reported some leg pain at baseline. The most common radiographic findings are reported in Table 2, and included disc degeneration (53.3% moderate, 13.3% severe), anterolisthesis (53.3%), retrolisthesis (36.6%) and scoliosis (35.0%).

Fifty-one adults (42.5%) achieved at least 30% ODI improvement after 12 weeks of treatment. No alignment, degenerative, or anatomic factors identified in lumbar radiographs were associated with this clinically meaningful improvement in disability at 12 weeks (i.e. all $p > 0.05$), regardless of severity of radiographic findings. A subset of results for the most common radiographic findings are reported in Table 3. The association between retrolisthesis and 30% improvement in ODI was borderline but did not reach statistical significance in this sample.

Discussion

Baseline individual lumbar radiographic findings were not associated with recovery from back related disability in this sample of older adults receiving 12 weeks of chiropractic spinal manipulation and home exercise. While 42% of participants did achieve 30% improvement in back-related disability, neither the presence or absence of a pre-defined set of degenerative changes or anatomic features, nor their severity, appear to have influenced this clinical outcome. Even cases with advanced radiographic changes or abnormalities were no more likely to respond to the chiropractic and home exercise treatment delivered in the study. While this research is a retrospective analysis of only a relatively small sample ($n = 120$), it adds to the growing debate over the usefulness of routine lumbar imaging for older adults with nonspecific back pain [43].

The American College of Radiology recommends that radiography, in addition to MRI or CT without contrast, is usually appropriate for "elderly individuals" for back pain [44]. This recommendation is made for older adults with or without radiculopathy and in the absence of evidence of trauma or other variables that give rise to the suspicion of osteoporosis or vertebral fracture. In contrast, Choosing Wisely, an initiative that aims to reduce waste in healthcare and avoid unnecessary tests and procedures, does not identify age as an absolute risk factor for imaging requirements [45]. The American Academy of Family Physicians (AAFP) recommends withholding imaging for low back pain within the first six weeks of symptom onset unless red flags are present [46]. The

Table 2 Radiographic findings in RCT participants with lumbar spine x-rays

Variable	*N* = 120 *n* (%)
Coronal measures	
Scoliosis (> 10 degrees)	42 (35.0)
Mean Cobb angle (sd)	17.3 (6.5)
Scoliosis levels	
L1-L5	11/42 (24.4)
L2-L5	11/42 (24.4)
L1-L4	8/42 (17.8)
T12-L5	3/42 (6.7)
Other	9/42 (21.4)
Trunk shift (≥ 2 cm)	4 (3.3)
Sagittal measures	
Lumbar lordosis (mean, sd)	52.0 (12.1)
Sacral base angle (mean, sd)	35.2 (8.6)
Ferguson's weight bearing line*	
Normal	44 (36.7)
Anterior	56 (46.7)
Posterior	20 (16.7)
A or P weightbearing alteration	76 (63.3)
Anterolisthesis (any)	64 (53.3)
One level	53/64 (82.8)
Two levels	11/64 (17.2)
Maximal anterior translation level:	
L4 on L5	40/64 (62.5)
L5 on S1	14/64 (21.9)
Other	10/64 (15.6)
Millimeters of slip** (mean, sd)	3.3 (0.8)
Meyerding classification*	
Grade I	63/64 (98.4)
Grade II	1/64 (1.6%)
Wiltse-Newman type	
Type 3	55/64 (85.9)
Type 2	9/64 (14.1)
Retrolisthesis (any)	44 (36.6)
Vertebral wedging	17 (14.2)
None	103 (85.8)
1 level	15 (12.5)
2 levels	2 (1.7)
Disc degeneration	
Any level(s), severe	16 (13.3)
Any level(s), moderate	64 (53.3)
Any level(s), mild	107 (89.2)
Any disc degeneration	117 (97.5)
L1-L2	
Mild	75 (62.5)
Moderate	16 (13.3)
L2-L3	
Mild	70 (58.3)
Moderate	29 (24.2)
L3-L4	
Mild	72 (60.0)
Moderate	26 (21.7)
L4-L5	
Mild	70 (58.3)
Moderate	35 (29.2)
L5-S1	
Mild	55 (45.8)
Moderate	44 (36.7)
Severe	9 (7.5)
Anatomic features	
Five lumbar vertebrae	119 (99.2)
Transitional vertebrae (any)	25 (20.8)
Bilateral	20 (16.7)
Facet tropism (L5-S1)	5 (4.2)
Prior surgery (decompression)	1 (0.8)
Blocked vertebrae	0
Hemi-vertebrae	0
Any adjudication	102 (85.0)

L = lumbar; S = sacral; sd = standard deviation; A = anterior; P = posterior

*Ferguson's: from middle of L3 body

**maximal slip level if > 1 vertebrae

Note: there were no surgical fusion cases

AAFP does not identify older age as a singular risk factor, unless associated with a minor fall, lifting injury or evidence of osteoporosis [47]. Similar to AAFP, the American College of Physicians/ American Pain Society recommend against routine imaging in patients with non-specific low back pain. They further clarify that among patients older than 50 years of age without other risk factors, delaying imaging in lieu of a standard course of care is appropriate [48]. Of note, a review of red flag indicators among 16 low back pain guidelines found inconsistencies across most red flags, including age as a frank indicator of additional clinical caution [49]. Further, in the presence of red flags, MRI or CT are recommended modes of imaging over plain film due to higher sensitivity [50].

Other clinical research conducted on this topic has failed to demonstrate a positive relationship between imaging and improved outcomes. A study by Jarvik demonstrated that older adults who had early imaging for an episode of new low back pain did not have better outcomes after one year compared to those with no or delayed imaging [51]. Moreover, those who received early imaging had substantially greater use of interventions and total cost of care compared to the study group that did not have earlier imaging. Ash et al. found that neither the patient nor the provider having knowledge of diagnostic imaging results impacted clinical outcomes for conservative management of acute low back pain, with the exception of general health status which improved more among those who were blinded to their imaging results [52]. Jarvik and team concluded that the value of early imaging based on age alone is uncertain despite

Table 3 Unadjusted association between radiographic features and improvement in disability

Radiographic feature	Overall *n* = 120 *n* (%)	*n* (%) with factor that met 30% ODI reduction *n* (%)	Odds ratio	95% CI	*p*-value*
Coronal					
Scoliosis					
No scoliosis	78 (65.0)	33 (42.3)	ref	ref	ref
Scoliosis (> 10 degrees)	42 (35.0)	18 (42.9)	1.02	0.48, 2.18	0.954
Sagittal					
Ferguson's weight bearing line					
Normal	44 (36.7)	19 (43.2)	ref	ref	ref
Anterior	56 (46.7)	24 (42.9)	1.03	0.50, 2.12	0.941
Posterior	20 (16.7)	8 (40.0)	0.88	0.33, 2.35	0.804
Anterolisthesis					
None	56 (46.7)	24 (42.9)	ref	ref	ref
One level	53 (44.2)	20 (37.7)	0.70	0.34, 1.47	0.348
Two levels	11 (9.2)	7 (63.6)	2.59	0.71, 9.36	0.148
Retrolisthesis					
None	76 (63.3)	37 (48.7)	ref	ref	ref
Any level(s)	44 (36.6)	14 (31.8)	0.49	0.23, 1.07	0.071
Disc degeneration (most advanced)**					
Mild	49 (40.8)	21 (42.9)	ref	ref	ref
Moderate	55 (45.8)	23 (41.8)	0.95	0.46, 1.96	0.890
Severe	16 (13.3)	7 (43.8)	1.06	0.37, 3.07	0.913
Anatomic					
Transitional vertebra					
None	95 (79.2)	37 (39.0)	ref	ref	ref
L5 or S1	25 (20.8)	14 (56.0)	1.995	0.82, 4.86	0.129

Ref = reference value

CI = confidence interval

*Chi square p-value from unadjusted logistic regression

**Only 3 adults did not have any disc degeneration. We used mild disc degeneration as the reference group for logistic regression and added those 3 to the 46 with mild degeneration as one group for analysis

some guidelines recommending the use of early imaging on older adults [51].

The literature demonstrates that common degenerative changes of the spine, likened to "grey hair or wrinkles", do not correlate with symptoms of back pain or disability [45, 53]. Brinjikji et al. recommend that imaging findings must be interpreted in the context of the patient's clinical condition due to high proportion of asymptomatic patients with spinal degeneration on imaging [53]. One such example is the case of lumbar spinal stenosis, a finding estimated to be present in 1 out of 5 adults over 60 years old and increases with age [54]. Notably, more than 80% of these cases are asymptomatic [54]. Recognizing the dissociation between imaging findings and clinical symptoms may be of particular importance here, as stenosis is one of the more common conditions for surgical intervention in older adults [55].

Osteoporosis is also common in old age, and is a safety consideration when treating older adults with manual therapy [56]. A history of osteoporosis increases the likelihood of vertebral compression fracture, underscoring the importance of a thorough account of risk factors for osteoporosis [57]. It is important to note that, if osteoporosis is suspected, radiography is not sensitive for bone loss [58]. Dual-energy x-ray absorptiometry (DXA) is the preferred course of imaging to assess bone loss [59]. As a consideration for individuals with spinal pain and osteoarthritis, a recent meta-analysis found that the frequency of osteoporosis is not greater in individuals with osteoarthritis compared to matched controls [60]. In fact, in this population where osteophyte formation is commonly associated with degenerative changes, bone mineral density can be increased in that region [60].

Some back pain sufferers believe that imaging is a necessary component of care [61]. Worrying and health anxiety, both of which could be either alleviated or potentiated by imaging, has been shown to increase the risk developing of long term back-related disability [62–65].

Risks of unnecessary imaging include psychological distress and fear avoidance behavior resulting from an 'abnormal' imaging report, as well as financial, psychological, and potential medical complications associated with follow-up testing for incidental findings [51, 66]. Imaging influences expectations for prognosis and outcome of spine care [45, 52]. As per protocol in this study, all participants who did not have recent lumbar imaging underwent x-rays to help determine inclusion and exclusion criteria. Enrolled participants received assurance that there were no clinical or radiographic indications suggesting the need for referral or that would exclude them from participating in the study. It is possible that this clinical confirmation created psychological receptivity to respond to care. Participants' previous history of imaging, and in particular how imaging was discussed or used to inform care in the past, may have created the potential for study participants to perceive their condition as either more or less problematic, and possibly perceive themselves as either more or less likely to respond to care.

Limitations

The parent randomized controlled trial from which this sample was taken excluded participants with significant unmanaged comorbidities, multiple lumbar surgeries, or those at high risk of adverse events with spinal manipulative therapy (e.g. severe osteoporosis). It is possible that a more inclusive sample may have resulted in otherwise not detected associations between imaging and improvement. The small sample in this retrospective study allowed only for unadjusted analyses. Given the small sample size, we examined individual radiographic features and compared improvement among those with a specific finding to those without it, rather than counts of features or a composite score based only on radiographs. However, there may be constellations of features that collectively impact outcomes (better or worse). Such an investigation was beyond the scope of this study and sample. No participant in this sample had none of the radiographic findings considered in this analysis. Retrolisthesis was the only factor that independently neared statistical significance in unadjusted testing, and could possibly be found to influence recovery in a larger sample. We are unable to report the impact of two or more levels of retrolisthesis with confidence due to the limited number of adults with this condition. Radiographs were not taken on 34% of participants in the parent RCT, due to recent lumbar imaging acquired from other healthcare facilities. In these instances, imaging reports were used in the parent trial to determine eligibility to participate but not included in this analysis due to variation in format (e.g. MRI vs. radiograph) and comprehensiveness of radiology reports. Finally, while we attempted to minimize misclassification bias by utilizing two chiropractic radiologists who independently assessed the presence or absence of specified radiographic findings, it is possible that their training and standardization led to shared misclassification of individual data points.

Conclusion

The result of this study suggests imaging may not be helpful for predicting who will be a responder to chiropractic spinal manipulation and home exercise, and that spinal manipulation may reasonably proceed without imaging on older adult patients in the absence of red flags or suspected contraindications to care. While exploratory in nature, this secondary analysis may inform future research into the association of anatomical and degenerative changes in older adults and outcomes of care. Finally, these results can inform chiropractic education and provide prevalence estimates of radiographic changes for chiropractors who treat older adults.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12998-024-00566-9.

Supplementary Material 1

Acknowledgements

The authors would like to acknowledge and thank Mary Forte, PhD, DC for data analysis.

Author contributions

Conception/design: MM, AA, CP. Acquisition of data: MM. Analysis/Interpretation of data: MM, AA, CM, HM, CP. Drafting and revising manuscript: MM, AA, CM, HM, CP. Approved the submitted version of manuscript: MM, AA, CM, HM, CP.

Funding

The parent randomized control trial was funded by the U.S. Department of Health and Human Services Health Resources and Services Administration (HRSA), Bureau of Health Professions (BHPr), Division of Medicine and Dentistry (DMD), grant number R18HP15127. The content and conclusions of this manuscript are those of the authors and should not be construed as the official position or policy of, nor should any endorsements be inferred by the U.S. government, HHS, HRSA, BHPr, or the DMD.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board (IRB) of Northwestern Health Sciences University (NWHSU), Project Number: 2023-1. The parent randomized control trial received ethics approval from NWHSU IRB, Project Number: 103-78-10-09.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details
[1]Northwestern Health Sciences University, 2501 W 84th Street, Bloomington, MN 55431, USA
[2]RAND Research Across Complementary and Integrative Health Institutions (REACH) Center, 1776 Main Street, Santa Monica, CA 90401-3208, USA

Received: 1 July 2024 / Accepted: 18 December 2024
Published online: 07 January 2025

References

1. Werner CA, The Older Population. 2010. 2010 Census Briefs, C2010BR-09. US Census Bureau. Available from: https://www.census.gov/library/stories/2023/05/2020-census-united-states-older-population-grew.html Accessed May 17, 2024.
2. de Souza IMB, Sakaguchi TF, Yuan SLK, Matsutani LA, do, Espírito-Santo AS, Pereira CAB, Marques AP, editors. Prevalence of low back pain in the elderly population: a systematic review. Clinics. 2019;74:789. https://doi.org/10.6061/clinics/2019/e789. PMID: 31664424; PMCID: PMC6807687.
3. O'Neil CK, Hanlon JT, Marcum ZA. Adverse effects of analgesics commonly used by older adults with osteoarthritis: focus on non-opioid and opioid analgesics. Am J Geriatr Pharmacother. 2012;10(6):331–42. https://doi.org/10.1016/j.amjopharm.2012.09.004.
4. Foster NE, Anema JR, Cherkin D, et al. Prevention and treatment of low back pain: evidence, challenges, and promising directions. Lancet. 2018;391(10137):2368–83. https://doi.org/10.1016/S0140-6736(18)30489-6.
5. Deyo RA, Mirza SK, Martin BI, Kreuter W, Goodman DC, Jarvik JG. Trends, major medical complications, and charges associated with surgery for lumbar spinal stenosis in older adults. JAMA. 2010;303(13):1259–65. https://doi.org/10.1001/jama.2010.338.
6. Forsth P, Olafsson G, Carlsson T, et al. A Randomized, Controlled Trial of Fusion surgery for lumbar spinal stenosis. N Engl J Med. 2016;374(15):1413–23. https://doi.org/10.1056/NEJMoa1513721.
7. Wong AYL, Karppinen J, Samartzis D. Low back pain in older adults: risk factors, management options and future directions. Scoliosis Spinal Disord. 2017;12:14. https://doi.org/10.1186/s13013-017-0121-3. PMID: 28435906; PMCID: PMC5395891.
8. Enthoven WTM, Geuze J, Scheele J, Bierma-Zeinstra SMA, Bueving HJ, Bohnen AM, et al. Prevalence and red flags regarding specified causes of back pain in older adults presenting in general practice. Phys Ther. 2016;96(3):305–12. https://doi.org/10.2522/ptj.20140525.
9. National Board of Chiropractic Examiners. In: Himelfarb I, editor. Practice analysis of Chiropractic 2020. Greeley, Colorado: National Board of Chiropractic Examiners; 2020.
10. Maiers M, Bronfort G, Evans R, et al. Spinal manipulative therapy and exercise for seniors with chronic neck pain. Spine J. 2014;14(9):1879–89. https://doi.org/10.1016/j.spinee.2013.10.035.
11. Leininger B, McDonough C, Evans R, Tosteson T, Tosteson AN, Bronfort G. Cost-effectiveness of spinal manipulative therapy, supervised exercise, and home exercise for older adults with chronic neck pain. Spine J. 2016;16(11):1292–304. https://doi.org/10.1016/j.spinee.2016.06.014.
12. Learman KE, Showalter C, O'Halloran B, Cook CE. Thrust and nonthrust manipulation for older adults with low back pain: an evaluation of pain and disability. J Manipulative Physiol Ther. 2013;36(5):284–91. https://doi.org/10.1016/j.jmpt.2013.05.007.
13. Cecchi F, Molino-Lova R, Chiti M, et al. Spinal manipulation compared with back school and with individually delivered physiotherapy for the treatment of chronic low back pain: a randomized trial with one-year follow-up. Clin Rehabil. 2010;24(1):26–36. https://doi.org/10.1177/0269215509342328.
14. Hawk C, Ndetan H, Evans MW Jr. Potential role of complementary and alternative health care providers in chronic disease prevention and health promotion: an analysis of National Health Interview Survey data. Prev Med. 2012;54(1):18–22. https://doi.org/10.1016/j.ypmed.2011.07.002.
15. Weigel P, Hockenberry JM, Bentler SE, et al. A longitudinal study of chiropractic use among older adults in the United States. Chiropr Osteopat. 2010;18:34. https://doi.org/10.1186/1746-1340-18-34.
16. Weigel PA, Hockenberry J, Bentler SE, et al. The comparative effect of episodes of chiropractic and medical treatment on the health of older adults. J Manipulative Physiol Ther. 2014;37(3):143–54. https://doi.org/10.1016/j.jmpt.2013.12.009.
17. Wolinsky FD, Liu L, Miller TR, et al. The use of chiropractors by older adults in the United States. Chiropr Osteopat. 2007;15:12. https://doi.org/10.1186/1746-1340-15-12.
18. Forte ML, Maiers M. Functional limitations in adults who utilize Chiropractic or Osteopathic Manipulation in the United States: analysis of the 2012 National Health interview survey. J Manipulative Physiol Ther. 2017;40(9):668–75. https://doi.org/10.1016/j.jmpt.2017.07.015.
19. Bussieres A, Taylor J, Peterson C. Diagnostic imaging practice guidelines for musculoskeletal complaints in adults - an evidenced-based approach - part 3: spinal disorders. J Manipulative Physiol Ther. 2008;31:33–88.
20. Jenkins HJ, Downie AS, Moore CS, French SD. Current evidence for spinal X-ray use in the chiropractic profession: a narrative review. Chiropr Man Th. 2018;26:48. https://doi.org/10.1186/s12998-018-0217-8. PMID: 30479744; PMCID: PMC6247638.
21. Young KJ. Evaluation of publicly available documents to trace chiropractic technique systems that advocate radiography for subluxation analysis: a proposed genealogy. J Chiropr Humanit. 2014;21(1):1–24. https://doi.org/10.1016/j.echu.2014.09.001. PMID: 25431540; PMCID: PMC4245702.
22. Corso M, Cancelliere C, Mior S, Kumar V, Smith A, Côté P. The clinical utility of routine spinal radiographs by chiropractors: a rapid review of the literature. Chiropr Man Th. 2020;28(1):33. https://doi.org/10.1186/s12998-020-00323-8. PMID: 32641135; PMCID: PMC7346665.
23. Jenkins HJ, Kongsted A, French SD, Jensen TS, Doktor K, Hartvigsen J, Hancock M. What are the effects of diagnostic imaging on clinical outcomes in patients with low back pain presenting for chiropractic care: a matched observational study. Chiropr Man Th. 2021;29(1):46. https://doi.org/10.1186/s12998-021-00403-3. PMID: 34814923; PMCID: PMC8611826.
24. Chou R, Fu R, Carrino JA, Deyo RA. Imaging strategies for low-back pain: systematic review and meta-analysis. Lancet. 2009;373(9662):463 – 72. https://doi.org/10.1016/S0140-6736(09)60172-0. PMID: 19200918.
25. Maiers MJ, Hartvigsen J, Schulz C, Schulz K, Evans RL, Bronfort G. Chiropractic and exercise for seniors with low back pain or neck pain: the design of two randomized clinical trials. BMC Musculoskelet Disord. 2007;8:94. https://doi.org/10.1186/1471-2474-8-94.
26. Vihstadt C, Maiers M, Westrom K, et al. Short term treatment versus long term management of neck and back disability in older adults utilizing spinal manipulative therapy and supervised exercise: a parallel-group randomized clinical trial evaluating relative effectiveness and harms. Chiropr Man Th. 2014;22:26. https://doi.org/10.1186/s12998-014-0026-7.
27. Maiers M, Hartvigsen J, Evans R, et al. Short- or long-term treatment of spinal disability in older adults with Manipulation and Exercise. Arthritis Care Res (Hoboken). 2019;71(11):1516–24. https://doi.org/10.1002/acr.23798.
28. Ostelo RW, Deyo RA, Stratford P, Waddell G, Croft P, Von Korff M, Bouter LM, de Vet HC. Interpreting change scores for pain and functional status in low back pain: towards international consensus regarding minimal important change. Spine (Phila Pa 1976). 2008;33(1):90 – 4. https://doi.org/10.1097/BRS.0b013e31815e3a10. PMID: 18165753.
29. Yochum TR, Rowe LJ. Essentials of Skeletal Radiology. Lippincott Williams & Wilkins, Philadelphia, Pa., 3rd edition. 2005.
30. Ammendolia C, Bombardier C, Hogg-Johnson S, Glazier R. Views on radiography use for patients with acute low back pain among chiropractors in an Ontario community. J Manipulative Physiol Ther. 2002;25(8):511 – 20. https://doi.org/10.1067/mmt.2002.127075. PMID: 12381973.
31. Garg K, Aggarwal A. Facet Tropism in Lumbar Spine and Cervical Spine: A Systematic Review and Meta-Analysis. World Neurosurg. 2021;147:47–65. doi: 10.1016/j.wneu.2020.11.171. PMID: 33309642.
32. Wilke H-J, Rohlmann F, Neidlinger-Wilke C, Werner K, Claes L, Kettler A. Validity and interobserver agreement of a new radiographic grading system for intervertebral disc degeneration: Part I. lumbar spine. Eur Spine J. 2005;15(6):720–30. https://doi.org/10.1007/s00586-005-1029-9.
33. Kim H, Kim H, Moon E, et al. Scoliosis Imaging: what radiologists should know. Radiographics. 2010;30(7):1823–42.
34. Hefti F. Pathogenesis and biomechanics of adolescent idiopathic scoliosis (AIS). J Child Orthop. 2013;7(1):17–24. https://doi.org/10.1007/s11832-012-0460-9.
35. Lafage V, Schwab F, Skalli W, Hawkinson N, Gagey PM, Ondra S, Farcy JP. Standing balance and sagittal plane spinal deformity: analysis of spinopelvic and gravity line parameters. Spine. 2008;33(14):1572–8. https://doi.org/10.1097/BRS.0b013e31817886a2.
36. Harrison DE, Harrison DD, Cailliet R, Janik TJ, Holland B. Radiographic analysis of lumbar lordosis - centroid, Cobb, TRALL, and Harrison posterior tangent

methods. Spine. 2001;26(11). https://doi.org/10.1097/00007632-200106010-00003.
37. Savarese LG, Menezes-Reis R, Bonugli GP, Herrero CFPDS, Defino HLA, Nogueira-Barbosa MH. Spinopelvic sagittal balance: what does the radiologist need to know? Radiol Bras. 2020 May-Jun;53(3):175–84. https://doi.org/10.1590/0100-3984.2019.0048. PMID: 32587427; PMCID: PMC7302896.
38. Naqvi SZG, Ali A, Siddiqui A, Ali SD, Qureshi M, Aliuddin IM. Measurement of Lumbosacral Angle in normal radiographs: a cross-sectional study. J Liaquat Uni Med Health Sci. 2020;19(04):238–41. https://doi.org/10.22442/jlumhs.20190697.
39. Malfair D, Flemming AK, Dvorak MF, Munk PL, Vertinsky AT, Heran MK, Graeb DA. Radiographic evaluation of scoliosis: review. Am J Roentgenol. 2010;194(3 Suppl). Available from: https://doi.org/10.2214/ajr.07.7145
40. Koslosky E, Gendelberg D. Classification in brief: the Meyerding classification system of Spondylolisthesis. Clin Orthop Relat Res. 2020;478(5):1125–30. https://doi.org/10.1097/CORR.0000000000001153.
41. Wiltse LL, Classification. Terminology and measurements in Spondylolisthesis. Iowa Orthop J. 1981;1:52–7.
42. Shen M, Razi A, Lurie JD, Hanscom B, Weinstein J. Retrolisthesis and lumbar disc herniation: a preoperative assessment of patient function. Spine J. 2007 Jul-Aug;7(4):406–13. https://doi.org/10.1016/j.spinee.2006.08.011. Epub 2007 Jan 2. PMID: 17630138; PMCID: PMC2278018.
43. Hawk C, Schneider MJ, Haas M, Katz P, Dougherty P, Gleberzon B, et al. Best practices for chiropractic care for older adults: a systematic review and consensus update. J Manipulative Physiol Ther. 2017;40(4):217–29. https://doi.org/10.1016/j.jmpt.2017.02.001. Epub 2017 Mar 14. PMID: 28302309.
44. American College of Radiology. ACR Appropriateness Criteria®: Low Back Pain. Available from: https://acsearch.acr.org/docs/69483/narrative/. Accessed January 10, 2024.
45. Hall AM, Aubrey-Bassler K, Thorne B, Maher CG. Do not routinely offer imaging for uncomplicated low back pain. BMJ. 2021;372. https://doi.org/10.1136/bmj.n291.
46. American Academy of Family Physicians. Clinical recommendations: Back pain [Internet]. [cited 2024 Sep 18]. Available from: https://www.aafp.org/family-physician/patient-care/clinical-recommendations/all-clinical-recommendations/cw-back-pain.html
47. Casazza BA. Diagnosis and treatment of acute low back pain. Am Fam Physician. 2012;85(4):343–50. PMID: 22335313.
48. Chou R, Qaseem A, Snow V, et al. Diagnosis and treatment of low back pain: a joint clinical practice guideline from the American College of Physicians and the American Pain Society. Ann Intern Med. 2007;147:478–91. https://doi.org/10.7326/0003-4819-147-7-200710020-00006. [Epub 2 October 2007].
49. Verhagen AP, Downie A, Popal N, Maher C, Koes BW. Red flags presented in current low back pain guidelines: a review. Eur Spine J. 2016;25(9):2788–802. https://doi.org/10.1007/s00586-016-4684-0.
50. Rao D, Scuderi G, Scuderi C, Grewal R, Sandhu SJ. The Use of Imaging in Management of patients with Low Back Pain. J Clin Imaging Sci. 2018;8:30. https://doi.org/10.4103/jcis.JCIS_16_18.
51. Jarvik JG, Gold LS, Comstock BA, et al. Association of Early Imaging for Back Pain with Clinical outcomes in older adults. JAMA. 2015;313(11):1143–53. https://doi.org/10.1001/jama.2015.1871.
52. Ash LM, Modic MT, Obuchowski NA, Ross JS, Brant-Zawadzki MN, Grooff PN. Effects of diagnostic information, per se, on patient outcomes in acute radiculopathy and low back pain. AJNR Am J Neuroradiol 2008 Jun-Jul;29(6):1098–103. https://doi.org/10.3174/ajnr.A0999
53. Brinjikji W, Luetmer PH, Comstock B, Bresnahan BW, Chen LE, Deyo RA, et al. Systematic literature review of imaging features of spinal degeneration in asymptomatic populations. AJNR Am J Neuroradiol. 2015;36(4):811–6. https://doi.org/10.3174/ajnr.A4173.
54. Katz JN, Zimmerman ZE, Mass H, Makhni MC. Diagnosis and management of lumbar spinal stenosis: a review. JAMA. 2022;327(17):1688–99. https://doi.org/10.1001/jama.2022.5921.
55. Szpalski M, Gunzburg R. Lumbar spinal stenosis in the elderly: an overview. Eur Spine J. 2003;12 Suppl 2(Suppl 2). https://doi.org/10.1007/s00586-003-0612-1
56. Wright NC, Looker AC, Saag KG, Curtis JR, Delzell ES, Randall S, et al. The recent prevalence of osteoporosis and low bone mass in the United States based on bone mineral density at the femoral neck or lumbar spine. J Bone Min Res. 2014;29(11):2520–6. https://doi.org/10.1002/jbmr.2269.
57. Pouresmaeili F, Kamalidehghan B, Kamarehei M, Goh YM. A comprehensive overview on osteoporosis and its risk factors. Ther Clin Risk Manag. 2018;14:2029–49. https://doi.org/10.2147/TCRM.S138000.
58. Genant HK. Current state of bone densitometry for osteoporosis. Radiographics. 1998 Jul-Aug;18(4):913–8. https://doi.org/10.1148/radiographics.18.4.9672976.
59. Lim LS, Hoeksema LJ, Sherin K, ACPM Prevention Practice Committee. Screening for osteoporosis in the adult U.S. population: ACPM position statement on preventive practice. Am J Prev Med. 2009;36(4):366–75. https://doi.org/10.1016/j.amepre.2009.01.013.
60. Kim D, Pirshahid AA, Li Y, Varghese T, Pope JE. Prevalence of osteoporosis in osteoarthritis: a systematic review and meta-analysis. Osteoporos Int. 2022;33(8):1687–93. https://doi.org/10.1007/s00198-022-06376-0.
61. Hall A, Coombs D, Richmond H, Bursey K, Furlong B, Lawrence R, et al. What do the general public believe about the causes, prognosis and best management strategies for low back pain? A cross-sectional study. BMC Public Health. 2021;21(1):682. https://doi.org/10.1186/s12889-021-10664-5.
62. Jensen OK, Nielsen CV, Stengaard-Pedersen K. One-year prognosis in sick-listed low back pain patients with and without radiculopathy. Prognostic factors influencing pain and disability. Spine J. 2010;10(8):659–75. https://doi.org/10.1016/j.spinee.2010.03.026.
63. Alhowimel A, Alotaibi M, Coulson N, Radford K. Psychosocial consequences of diagnosing nonspecific low-back pain radiologically: a qualitative study. Physiother Theory Pract. 2022;38(7):890–6. https://doi.org/10.1080/09593985.2020.1802799.
64. Rajasekaran S, Dilip Chand Raja S, Pushpa BT, Ananda KB, Ajoy Prasad S, Rishi MK. The catastrophization effects of an MRI report on the patient and surgeon and the benefits of 'clinical reporting': results from an RCT and blinded trials. Eur Spine J. 2021;30(7):2069–81. https://doi.org/10.1007/s00586-021-06809-0.
65. Angst F, Lehmann S, Sandor PS, Benz T. Catastrophizing as a prognostic factor for pain and physical function in the multidisciplinary rehabilitation of fibromyalgia and low back pain. Eur J Pain. 2022;26(7):1569–1580. doi: 10.1002/ejp.1983. Epub 2022 Jun 11. PMID: 35634793.
66. Modic MT, Obuchowski NA, Ross JS, Brant-Zawadzki MN, Grooff PN, Mazanec DJ, et al. Acute low back pain and radiculopathy: MR imaging findings and their prognostic role and effect on outcome. Radiology. 2005;237(2):597–604. https://doi.org/10.1148/radiol.2372041509.

Publisher's note