Cureus
Part of SPRINGER NATURE

Open Access Original Article

Published via Krishna Vishwa Vidyapeeth (Deemed to be University), Karad.

Prevalence of Hamstring Tightness and Pelvic Asymmetry in Individuals With Chronic Low Back Pain

Received 09/09/2026
Review began 10/24/2026
Review ended 11/02/2026
Published 11/05/2026

© Copyright 2026
Sawant et al. This is an open access article distributed under the terms of the Creative Commons Attribution License CC-BY 4.0., which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

DOI: 10.7759/cureus.119205

Sakshi R. Sawant [1], G. Varadharajulu [2]

1. Physiotherapy, Krishna College of Physiotherapy, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad, IND
2. Neurosciences, Krishna College of Physiotherapy, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad, IND

Corresponding author: G. Varadharajulu, deanphysiotherapy@kvv.edu.in

Abstract

Background

Chronic low back pain (CLBP) is a common musculoskeletal condition associated with pain, functional limitations, and altered lumbopelvic function. Hamstring tightness and pelvic asymmetry were clinically relevant physical characteristics that could occur in individuals with CLBP. However, limited evidence was available regarding their prevalence and association within the same CLBP population.

Objective

The study aimed to determine the prevalence of hamstring tightness (defined as a popliteal angle threshold of <130 degrees) and pelvic asymmetry (defined as a side-to-side difference of >1 degree) and to examine the association between these variables in individuals with CLBP.

Methods

A cross-sectional observational study was conducted among 52 individuals with CLBP. After obtaining informed consent and screening participants according to predefined eligibility criteria, demographic and clinical information was recorded. Hamstring tightness was assessed using the popliteal angle test, and pelvic alignment was assessed using a bubble inclinometer according to predefined operational criteria. Frequencies and percentages were calculated to determine the prevalence of hamstring tightness and pelvic asymmetry. The association between the two variables was assessed using the Pearson chi-square test, and the odds ratio (OR) was calculated.

Results

Hamstring tightness was present in 34 of 52 participants (65.4%), while pelvic asymmetry was present in 28 of 52 participants (53.8%). Among participants with hamstring tightness, 25 of 34 (73.5%) had pelvic asymmetry, compared with 3 of 18 (16.7%) participants without hamstring tightness. A statistically significant association was observed between hamstring tightness and pelvic asymmetry ($\chi^2(1) = 15.31$, $p < 0.001$; OR = 13.89) (95% CI: 3.2-59.5)).

Conclusion

Hamstring tightness and pelvic asymmetry are common among individuals with CLBP, and a significant association is observed between these characteristics. Pelvic asymmetry is more frequently observed among participants with hamstring tightness. Assessment of hamstring flexibility and pelvic alignment can be considered part of a comprehensive physiotherapy examination. However, the cross-sectional design does not establish a causal relationship, and further research is needed to clarify the clinical significance of this association.

Categories: Physical Medicine & Rehabilitation, Medical Education, Orthopedics
Keywords: chronic low back pain, hamstring tightness, lumbopelvic alignment, pelvic asymmetry, popliteal angle test

Introduction

Low back pain (LBP) is one of the most common musculoskeletal conditions worldwide and is a leading contributor to disability, activity limitation, and reduced quality of life. It affects people of all ages and can interfere with physical functioning, occupational activities, social participation, and daily living. Chronic LBP (CLBP) generally refers to LBP that persists for 12 weeks or longer and can be associated with persistent pain, functional limitations, and altered movement or motor control strategies [1-3]. According to the Global Burden of Disease Study 2021, approximately 619 million people were affected by LBP in 2020, and this number is projected to increase to more than 800 million by 2050 [4]. The burden is also considerable in India, where a systematic review and meta-analysis reported a substantial prevalence of LBP, emphasizing

its importance as a public health and physiotherapy concern [5]. Although most cases of LBP are non-specific and cannot be attributed to a single pathological structure, physical impairments involving flexibility, posture, movement coordination, and lumbopelvic function can be relevant during clinical assessment [1,2,6]. Clinical practice guidelines emphasize individualized assessment, patient education, exercise, and other evidence-based non-pharmacological interventions in the management of LBP [7,8]. Identifying physical characteristics commonly observed in individuals with CLBP can therefore help physiotherapists conduct comprehensive assessments and develop individualized rehabilitation strategies.

Hamstring tightness and pelvic asymmetry are two physical characteristics that may be relevant to the assessment of individuals with CLBP. Hamstring tightness refers to reduced extensibility or range of motion of the hamstring muscle group. Because the hamstrings cross the hip and knee joints and interact biomechanically with pelvic movement, restricted hamstring extensibility can influence lumbopelvic movement during functional activities. The active knee extension (AKE) test and related knee extension-based measures have been used to assess hamstring flexibility. Gajdosik and Lusin examined the reliability of the AKE test, while subsequent research also investigated its inter-rater and intra-rater reliability, supporting its use as a clinical measure when standardized assessment procedures are followed [9-11].

Pelvic asymmetry refers to differences in the position, orientation, or alignment of the two sides of the pelvis. It can be assessed using parameters such as pelvic tilt, pelvic obliquity, or differences in pelvic landmark positions. Because the pelvis forms a mechanical link between the trunk and lower extremities, variations in pelvic position can be relevant to lumbopelvic movement and physiotherapy assessment. However, pelvic asymmetry should not automatically be interpreted as a cause of LBP, as asymmetrical postural characteristics can also occur in individuals without pain.

Previous research has examined hamstring flexibility in relation to LBP, although findings have varied across studies. Hori et al. conducted a systematic review and meta-analysis examining hamstring flexibility in individuals with and without LBP and highlighted limitations in the available evidence [12]. Sadler et al. reviewed prospective cohort studies and identified restricted hamstring flexibility among the physical characteristics investigated in relation to the development of LBP [13]. Reis and Macedo examined pelvic, lumbar, and trunk range of motion during forward bending, while Fasuyi et al. investigated hamstring muscle length and pelvic tilt range in individuals with and without LBP [14,15]. Król et al. reported that pelvic position was associated with multiple mechanical and anthropometric factors rather than a single muscle characteristic [16]. Radwan et al. investigated side-to-side differences in hamstring flexibility in individuals with LBP [17]. Moon et al. examined individuals with non-specific CLBP and reported associations between hamstring shortness, hamstring asymmetry, pain intensity, disability, and compensatory lumbar movement [18]. A comparative study also investigated the association between hamstring tightness and CLBP [19]. Collectively, these studies suggest that hamstring characteristics may be relevant to CLBP; however, they do not provide a uniform conclusion regarding the nature of this relationship.

Biomechanical studies have further investigated interactions between hamstring flexibility and lumbopelvic movement. Changes in pelvic position can influence measurements of hamstring flexibility, while dynamic stretching can alter hamstring flexibility and aspects of the spino-pelvic movement pattern [20,21]. However, these findings do not establish that hamstring tightness necessarily causes a static pelvic alignment abnormality. A randomized clinical trial investigating stretching and strengthening in individuals with LBP examined changes in pelvic tilt angle [22]. Other research also explored the relationship between hamstring extensibility and mechanical characteristics in individuals with LBP [23]. These findings highlight the complexity of the relationship between hamstring flexibility and pelvic alignment and indicate that a causal relationship should not be assumed.

Research investigating pelvic asymmetry and LBP has also produced inconsistent findings. Christie et al. examined postural characteristics in individuals with LBP and reported differences in selected postural parameters [24]. Levangie investigated the association between static pelvic asymmetry and LBP and reported findings that did not support a clear relationship between the two [25]. Fann examined postural asymmetry in individuals with and without CLBP [26]. Al-Eisa et al. investigated pelvic skeletal asymmetry and trunk movement in individuals with mechanical LBP, while another study examined pelvic asymmetry and trunk kinematics during sitting [27,28]. Yu et al. investigated pelvic asymmetry in individuals with non-specific CLBP and reported an association between selected pelvic asymmetry parameters and CLBP, although causality could not be established [29]. A systematic review and meta-analysis of observational studies examined postural parameters in individuals with LBP and highlighted methodological heterogeneity across the included studies [30]. These findings suggest that pelvic asymmetry may be relevant to clinical assessment, although differences in definitions, assessment methods, and study populations limit direct comparisons.

In large first-contact cohorts, clinically important non-mechanical findings are uncommon but real, underlining the need for a systematic assessment sequence in which physical characteristics are interpreted alongside red flag screening [31]. This pattern is consistent with the principle of regional interdependence, in which postural or alignment characteristics in one spinal region relate to symptoms and function in another, and in which treating the primary driver may resolve the distant presentation [32].

Despite previous research on hamstring flexibility and pelvic alignment, important knowledge gaps remain. Several studies have focused on differences between individuals with and without LBP, associations with pain or disability, movement characteristics, or the potential development of LBP [12-18]. Research on pelvic asymmetry has also produced inconsistent findings [25-30]. Differences in participant characteristics, operational definitions, assessment techniques, and outcome criteria limit comparisons between studies. In addition, hamstring tightness and pelvic asymmetry have often been examined separately rather than evaluated together within the same CLBP population. Consequently, further descriptive evidence is needed regarding the prevalence of both characteristics and their association among individuals with CLBP. Such information can help physiotherapists understand the frequency with which these characteristics coexist without assuming that either characteristic causes CLBP.

Pelvic tilt refers to the sagittal plane rotation of the pelvis (anterior or posterior tilt), whereas pelvic asymmetry represents a frontal or transverse plane positional discrepancy between the left and right sides of the pelvis. Biomechanically, bilateral hamstring tightness exerts an inferior traction force on the ischial tuberosities, which typically promotes posterior pelvic tilt and restricts hip hinging during activities such as standing up from a seated position. Conversely, side-to-side imbalances or asymmetrical hamstring tightness can create unequal rotational forces on the hemipelves, potentially predisposing to pelvic asymmetry [10,15].

Therefore, the present study aimed to determine the prevalence of hamstring tightness (defined as a popliteal angle threshold of <130 degrees) and pelvic asymmetry (defined as a side-to-side difference of ⩾1 degree among individuals with CLBP) and to examine the association between these two musculoskeletal characteristics.

Materials And Methods

Study design

A cross-sectional observational study was conducted to determine the prevalence of hamstring tightness and pelvic asymmetry among individuals with CLBP. Bilateral hamstring tightness was assessed using the popliteal angle test, while pelvic alignment was assessed using a bubble inclinometer. The prevalence of hamstring tightness and pelvic asymmetry was determined using predefined cutoff criteria.

The study was conducted at Krishna College of Physiotherapy. Ethical approval was obtained from the Institutional Ethics Committee of Krishna Vishwa Vidyapeeth before the commencement of the study (Ethical Approval No. 106/2026-2027). Participants were informed about the purpose and procedures of the study and the voluntary nature of their participation. Written informed consent was obtained before data collection. The confidentiality and privacy of all participants were maintained throughout the study.

Participants

A total of 52 individuals with CLBP were included in the study. Participants were recruited from the outpatient department of Krishna College of Physiotherapy between January 2025 and June 2025 using convenience sampling according to the predefined eligibility criteria. The study population included 28 male and 24 female individuals aged 25-40 years with CLBP.

All participants were informed about the purpose and procedures of the study, and written informed consent was obtained before the assessments were performed. The inclusion and exclusion criteria used for participant selection are presented in Table *1*.

Category	Criteria
Inclusion	Adults aged 25-40 years
Inclusion	Individuals with non-specific low back pain lasting 12 weeks or longer
Inclusion	Individuals able to understand and follow instructions and maintain the required position during assessment
Inclusion	Individuals able to undergo the popliteal angle test with examiner assistance
Inclusion	Individuals who provided informed consent
Exclusion	Previous lumbar spine or lower limb surgery
Exclusion	Recent fracture or trauma
Exclusion	Neurological disorders affecting the lower limbs
Exclusion	Radiculopathy with significant neurological deficits
Exclusion	Severe spinal deformity or instability
Exclusion	Hip or knee pathology that could affect the assessment
Exclusion	Systemic, inflammatory, or serious musculoskeletal conditions affecting participation
Exclusion	Pregnancy
Exclusion	Any condition that made completion of the assessment unsafe

TABLE 1: Inclusion and Exclusion Criteria

Assessment procedure

Following eligibility screening and the collection of written informed consent, demographic and relevant clinical information was recorded. Bilateral hamstring tightness was assessed using the popliteal angle test. Each participant was positioned supine, with the hip flexed to approximately 90 degrees, and the contralateral limb was stabilized using straps. The knee was extended passively until firm resistance was reached. The popliteal angle was measured using a standard universal goniometer aligned with the lateral epicondyle of the femur as the fulcrum, the greater trochanter as the proximal arm, and the lateral malleolus as the distal arm. Measurements were taken across three trials for each limb by a single trained assessor, and the average value was recorded. Hamstring tightness was operationally defined as a popliteal angle of less than 130 degrees.

Pelvic alignment was assessed using a bubble inclinometer in a standardized standing position. The relevant pelvic anatomical landmarks (anterior superior iliac spines and posterior superior iliac spines) were identified, and the inclinometer was positioned according to the standardized measurement technique. The right and left pelvic measurements were recorded in degrees. The difference between the corresponding measurements was calculated to determine pelvic asymmetry. A difference of less than 1 degree was considered symmetrical, whereas a difference of 1 degree or greater was classified as pelvic asymmetry. Furthermore, intra-individual side-to-side differences in popliteal angles between the left and right limbs were recorded to account for asymmetrical hamstring tension alongside bilateral categorization.

Outcome measures

The primary outcomes were hamstring tightness and pelvic asymmetry. Hamstring tightness was assessed using the popliteal angle test, while pelvic alignment was assessed using a bubble inclinometer. The prevalence of each condition was expressed as the number and percentage of participants demonstrating the respective finding.

Statistical analysis

Descriptive statistics were used to summarize the study findings. Categorical data were presented as frequencies and percentages. The association between hamstring tightness and pelvic asymmetry was assessed using the Pearson chi-square test. The chi-square statistic, degrees of freedom, and p-value were used to report the statistical significance of the association. The odds ratio (OR) and its 95% confidence interval (CI) were calculated to describe the strength of the association. A p-value of less than 0.05 was considered statistically significant.

Results

The study included 52 individuals with CLBP. Descriptive statistics were used to summarize the findings, with categorical variables presented as frequencies and percentages.

Prevalence of hamstring tightness

Bilateral hamstring tightness was assessed using the popliteal angle test. According to the recorded results, 34 (65.4%) participants were classified as having hamstring tightness, whereas 18 (34.6%) were classified as not having hamstring tightness (Table 2).

Hamstring tightness	Frequency (n)	Percentage (%)
Present	34	65.4
Absent	18	34.6
Total	52	100

TABLE 2: Prevalence of Hamstring Tightness

n: number of participants.

Prevalence of pelvic asymmetry

Pelvic alignment was assessed using a bubble inclinometer according to the predefined operational criterion. The recorded results indicated pelvic asymmetry in 28 (53.8%) participants, whereas 24 (46.2%) participants were classified as not having pelvic asymmetry (Table 3).

Pelvic asymmetry	Frequency (n)	Percentage (%)
Present	28	53.8
Absent	24	46.2
Total	52	100

TABLE 3: Prevalence of Pelvic Asymmetry

n: number of participants.

Association between hamstring tightness and pelvic asymmetry

The recorded contingency table showed that pelvic asymmetry was present in 25 of the 34 participants with hamstring tightness (73.5%). Among the 18 participants without hamstring tightness, pelvic asymmetry was present in three (16.7%) participants (Table 4).

Hamstring tightness	Pelvic asymmetry present, (n)	Pelvic asymmetry absent, (n)	Total, (n)
Present	25	9	34
Absent	3	15	18
Total	28	24	52

TABLE 4: Association Between Hamstring Tightness and Pelvic Asymmetry

The Pearson chi-square test indicated a statistically significant association between hamstring tightness and pelvic asymmetry ($\chi^2(1)=15.31$, $p<0.001$). OR was 13.89 (95% CI: 3.2-59.5), indicating higher odds of pelvic asymmetry among participants with hamstring tightness than among those without hamstring tightness.

Discussion

The present study examined the prevalence of hamstring tightness and pelvic asymmetry in individuals with CLBP and explored the association between these two musculoskeletal characteristics. The findings demonstrated a notable co-occurrence of hamstring tightness and pelvic asymmetry in the studied sample. However, these findings should be interpreted in the context of the study design and the biomechanical distinctions between bilateral tightness and side-to-side asymmetry.

Hamstring flexibility is a relevant component of the physical examination of individuals with CLBP. Reduced hamstring extensibility might influence hip movement and lumbopelvic movement strategies. However, the presence of hamstring tightness in individuals with CLBP does not establish whether it contributes to LBP or develops in association with pain-related movement adaptations. Because the study used a cross-sectional design, it cannot establish the temporal relationship between hamstring tightness and CLBP.

Pelvic alignment is another aspect of lumbopelvic assessment that can be considered during physiotherapy examination. Postural and spinal alignment characteristics are modifiable rather than fixed: radiographically documented remission of age-related postural deformity has been achieved with conservative multimodal care [33]. Nevertheless, pelvic asymmetry should not automatically be interpreted as a pathological finding or as the cause of LBP. Variations in pelvic alignment can occur in individuals for several reasons, and their clinical relevance requires evaluation alongside symptoms, functional limitations, and other physical examination findings.

The reported association between hamstring tightness and pelvic asymmetry is an important finding. The hamstring muscles cross the hip and knee joints and attach proximally to the pelvis; therefore, reduced hamstring extensibility may be related to pelvic positioning or movement. However, the present study cannot determine the direction or mechanism of the observed association. Other factors, including hip mobility, muscle strength, physical activity, habitual posture, and pain-related movement adaptations, might also influence lumbopelvic characteristics. The observed association does not establish that hamstring tightness causes pelvic asymmetry.

Previous research has examined hamstring flexibility and its relationship with LBP, although the strength and clinical significance of this relationship remain uncertain [12-19]. Hori et al.'s meta-analysis reported pooled prevalence/differences across included studies [12]; our 65.4% sample proportion reflects the specific popliteal angle definition, which differs from the AKE-based measures used in most included studies. Other studies have investigated hamstring flexibility, pelvic tilt, and lumbopelvic movement in individuals with LBP [14-18]. Research has also examined the relationship between pelvic asymmetry and LBP, with findings suggesting that the clinical significance of pelvic asymmetry might vary across individuals and assessment methods [25-28]. Differences in study populations, assessment procedures, and outcome measures might have contributed to variations in findings across studies. Therefore, comparisons with the present study require caution. The present findings do not establish that pelvic asymmetry is a defining characteristic of CLBP.

One strength of the study was that hamstring tightness and pelvic alignment were assessed within the same group of individuals with CLBP. This allowed the prevalence of both characteristics and their reported association to be examined. The popliteal angle test and bubble inclinometer are practical assessment tools that can be used in physiotherapy settings. The consistency of the findings, however, depends on the accuracy of the measurements and the standardization of the assessment procedures.

Clinical implications

Assessment of hamstring flexibility can be considered as part of a comprehensive physiotherapy examination for individuals with CLBP. Assessment of pelvic alignment can also provide additional information about lumbopelvic characteristics. Neither hamstring tightness nor pelvic asymmetry should be interpreted in isolation or automatically considered the primary cause of LBP. Clinical decision-making requires consideration of pain, disability, functional limitations, movement patterns, muscle performance, and other relevant individual factors.

Limitations

The cross-sectional design limits the ability to establish temporal relationships or causation. Convenience sampling may limit the generalizability of the findings to other populations. Furthermore, no formal intra- or inter-rater reliability was established for the popliteal angle or bubble inclinometer measurements in this sample, so measurement error cannot be quantified. The 1-degree threshold for pelvic asymmetry sits close to the bubble inclinometer's noise floor (typical resolution and intra-rater error are around 1-2 degrees), which may classify measurement error as "asymmetry." In addition, pelvic alignment was assessed using a bubble inclinometer and a predefined operational criterion; a single measurement approach might not fully represent the complexity of pelvic alignment. Potential confounding factors, including physical activity, occupation, body composition, hip mobility, muscle strength, and symptom duration or severity, were not comprehensively examined. Furthermore, while side-to-side popliteal angle variations were noted, the study

primarily operationalized hamstring tightness categorically rather than continuously modeling bilateral side-to-side difference magnitudes against pelvic tilt or asymmetry, which warrants attention in future work. These limitations were considered when interpreting the reported association.

Recommendations for future research

The findings support the need for future studies involving larger and more diverse samples, standardized assessment procedures, and appropriate methods to account for potential confounding variables. Longitudinal study designs are needed to clarify the temporal relationship between hamstring tightness and pelvic alignment. Further research is also warranted to determine whether interventions targeting these characteristics influence pain, disability, or functional outcomes in individuals with CLBP.

Conclusions

The present study found that hamstring tightness and pelvic asymmetry were observed among individuals with CLBP. An association was observed between these two characteristics; however, the cross-sectional study design did not establish a causal relationship. Assessment of hamstring flexibility and pelvic alignment can be considered as part of a comprehensive physiotherapy evaluation. Further longitudinal studies involving larger and more diverse populations are needed to clarify the nature and clinical significance of this relationship.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Sakshi R. Sawant, G. Varadharajulu

Acquisition, analysis, or interpretation of data: Sakshi R. Sawant

Drafting of the manuscript: Sakshi R. Sawant

Critical review of the manuscript for important intellectual content: G. Varadharajulu

Supervision: G. Varadharajulu

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Krishna Vishwa Vidyapeeth issued approval 106/2026-2027. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. Hartvigsen J, Hancock MJ, Kongsted A, et al.: What low back pain is and why we need to pay attention . Lancet. 2018, 391:2356-67. 10.1016/S0140-6736(18)30480-X
2. Balagué F, Mannion AF, Pellisé F, et al.: Non-specific low back pain. Lancet. 2012, 379:482-91. 10.1016/S0140-6736(11)60610-7
3. Foster NE, Anema JR, Cherkin D, et al.: Prevention and treatment of low back pain: evidence, challenges, and promising directions. Lancet. 2018, 391:2368-83. 10.1016/S0140-6736(18)30489-6
4. Global, regional, and national burden of low back pain, 1990-2020, its attributable risk factors, and projections to 2050: a systematic analysis of the Global Burden of Disease Study 2021. Lancet Rheumatol. 2023, 5:e316-29. 10.1016/S2665-9913(23)00098-X
5. Shetty GM, Jain S, Thakur H, et al.: Prevalence of low back pain in India: a systematic review and meta-analysis. Work. 2022, 73:429-52. 10.3233/WOR-205300
6. Delitto A, George SZ, Van Dillen L, et al.: Low back pain. J Orthop Sports Phys Ther. 2012, 42:A1-57. 10.2519/jospt.2012.42.4.A1
7. George SZ, Fritz JM, Silfies SP, et al.: Interventions for the management of acute and chronic low back pain: revision 2021. J Orthop Sports Phys Ther. 2021, 51:CPG1-60. 10.2519/jospt.2021.0304
8. Clinical guidelines to address low back pain: using the evidence to guide physical therapist practice . J Orthop Sports Phys Ther. 2021, 51:533-4. 10.2519/jospt.2021.0507
9. Gajdosik R, Lusin G: Hamstring muscle tightness: reliability of an active-knee-extension test . Physical Therapy. 1983, 63:1085-8. 10.1093/ptj/63.7.1085

10. Hamid MS, Ali MR, Yusof A: Interrater and intrarater reliability of the active knee extension (AKE) test among healthy adults. J Phys Ther Sci. 2013, 25:957-61. 10.1589/jpts.25.957
11. Neto T, Jacobsohn L, Carita AI, Oliveira R: Reliability of the active-knee-extension and straight-leg-raise tests in subjects with flexibility deficits. J Sport Rehabil. 2015, 24: 10.1123/jsr.2014-0220
12. Hori M, Hasegawa H, Takasaki H: Comparisons of hamstring flexibility between individuals with and without low back pain: systematic review with meta-analysis. Physiother Theory Pract. 2021, 37:559-82. 10.1080/09593985.2019.1639868
13. Sadler SG, Spink MJ, Ho A, De Jonge XJ, Chuter VH: Restriction in lateral bending range of motion, lumbar lordosis, and hamstring flexibility predicts the development of low back pain: a systematic review of prospective cohort studies. BMC Musculoskelet Disord. 2017, 18:179. 10.1186/s12891-017-1534-0
14. Jandre Reis FJ, Macedo AR: Influence of hamstring tightness in pelvic, lumbar and trunk range of motion in low back pain and asymptomatic volunteers during forward bending. Asian Spine J. 2015, 9:535-40. 10.4184/asj.2015.9.4.535
15. Fasuyi FO, Fabunmi AA, Adegoke BOA: Hamstring muscle length and pelvic tilt range among individuals with and without low back pain. J Bodyw Mov Ther. 2017, 21:246-50. 10.1016/j.jbmt.2016.06.002
16. Król A, Polak M, Szczygieł E, et al.: Relationship between mechanical factors and pelvic tilt in adults with and without low back pain. J Back Musculoskelet Rehabil. 2017, 30:699-705. 10.3233/BMR-140177
17. Radwan A, Bigney KA, Buonomo HN, et al.: Evaluation of intra-subject difference in hamstring flexibility in patients with low back pain: an exploratory study. J Back Musculoskelet Rehabil. 2015, 28:61-6. 10.3233/BMR-140490
18. Moon KY, Park DC, Kim WD, Shin D: Association between hamstring shortness and asymmetry, pain intensity, disability index, and compensatory lumbar movement in 60 patients with nonspecific chronic low back pain. Med Sci Monit. 2023, 29:e939657. 10.12659/MSM.939657
19. Hegde A, Sareen A, Shankar R, et al.: The association between hamstring tightness and chronic low back pain: a comparative study. Cureus. 2026, 18:e106169. 10.7759/cureus.106169
20. Sullivan MK, DeJulia JJ, Worrell TW: Effect of pelvic position and stretching method on hamstring muscle flexibility. Med Sci Sports Exerc. 1992, 24:1383-9. 10.1249/00005768-199212000-00012
21. Hasebe K, Okubo Y, Kaneoka K, et al.: The effect of dynamic stretching on hamstrings flexibility with respect to the spino-pelvic rhythm. J Med Investig. 2016, 63:85-90. 10.2152/jmi.63.85
22. Shamsi MB, Shahsavari S, Safari A, et al.: A randomized clinical trial for the effect of static stretching and strengthening exercise on pelvic tilt angle in LBP patients. J Bodyw Mov The. 2020, 24:15-20. 10.1016/j.jbmt.2020.02.001
23. Marshall PWM, Mannion J, Murphy BA: Extensibility of the hamstrings is best explained by mechanical components of muscle contraction, not behavioral measures in individuals with chronic low back pain. PM&R. 2009, 1:709-18. 10.1016/j.pmrj.2009.04.009
24. Christie HJ, Kumar S, Warren SA: Postural aberrations in low back pain . Arch Phys Med Rehabil. 1995, 76:218-24. 10.1016/S0003-9993(95)80604-0
25. Levangie PK: The association between static pelvic asymmetry and low back pain . Spine. 1999, 24:1234-42. 10.1097/00007632-199906150-00011
26. Fann AV: The prevalence of postural asymmetry in people with and without chronic low back pain . Arch Phys Med Rehabil. 2002, 83:1736-8. 10.1053/apmr.2002.35653
27. Al-Eisa E, Egan D, Deluzio K, Wassersug R: Effects of pelvic skeletal asymmetry on trunk movement: three-dimensional analysis in healthy individuals versus patients with mechanical low back pain. Spine. 2006, 31:E71-9. 10.1097/01.brs.0000197665.93559.04
28. Al-Eisa E, Egan D, Deluzio K, Wassersug R: Effects of pelvic asymmetry and low back pain on trunk kinematics during sitting: a comparison with standing. Spine. 2006, 31:E135-43. 10.1097/01.brs.0000201325.89493.5f
29. Yu Q, Huang H, Zhang Z, et al.: The association between pelvic asymmetry and non-specific chronic low back pain as assessed by the global postural system. BMC Musculoskelet Disord. 2020, 21:596. 10.1186/s12891-020-03617-3
30. Sugavanam T, Sannasi R, Anand PA, et al.: Postural asymmetry in low back pain - a systematic review and meta-analysis of observational studies. Disabil Rehabil. 2025, 47:1659-76. 10.1080/09638288.2024.2385070
31. Chu EC, Trager RJ: Prevalence of serious pathology among adults with low back pain presenting for chiropractic care: a retrospective chart review of integrated clinics in Hong Kong. Med Sci Monit. 2022, 28:e938042. 10.12659/MSM.938042
32. Chu EC: Regional interdependence between senile kyphosis and cervical postural syndrome: a case report . AME Case Rep. 2025, 9:52. 10.21037/acr-24-41
33. Chu EC: Remission of Dowager's hump by manipulative correction of spinal postural deformity . Med Sci Monit. 2023, 29:941837. 10.12659/MSM.941837