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Reproducibility of Digital Photography for Assessing Anterior Pelvic Tilt Using MicroDicom Among Patients with Non-Specific Low Back Pain: A Test–Retest Reliability Study

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ABSTRACT

Background: Non-specific low back pain (NSLBP) is frequently associated with anterior pelvic tilt (APT), a postural deviation linked to altered spinal mechanics and musculoskeletal dysfunction. Reliable and accessible tools for quantifying APT are essential for effective rehabilitation practice, particularly in settings where radiographic imaging is impractical. Objective: To evaluate the test–retest reliability of digital photography for measuring APT in individuals with NSLBP using MicroDicom software. Methods: A test–retest reliability study was conducted at the Department of Rehabilitation, National Orthopedic Hospital, Bahawalpur, Pakistan. Forty participants aged 20–40 years with NSLBP were recruited. Standardized lateral-view digital photographs were obtained using a tripod-mounted smartphone camera. The anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS) were palpated and marked, and APT angles were measured in MicroDicom software across three testing sessions. Reliability was evaluated using the intraclass correlation coefficient (ICC[2,1], two-way random effects, absolute agreement), standard error of measurement (SEM), coefficient of variation (CV), and Bland–Altman analysis. Results: The mean APT angles were 16.57° ± 1.51, 15.99° ± 1.54, and 15.97° ± 1.45 across the three sessions. Test–retest reliability was good (ICC[2,1] = 0.872, 95% CI: 0.705–0.939, $p < 0.001$). The SEM was 0.54°, CV was 9.3%, and percentage SEM was 3.3%. Bland–Altman analysis showed a negligible mean bias (0.03°) and narrow 95% limits of agreement (–1.30° to +1.36°), indicating minimal systematic error. Conclusion: Standardized digital photography analyzed with MicroDicom software provides a reliable, non-invasive, and cost-effective method for monitoring APT in adults with NSLBP. While not a substitute for radiographic imaging, it offers a clinically practical tool for postural evaluation in rehabilitation settings.

Keywords
Anterior pelvic tilt; non-specific low back pain; reliability; digital photography; MicroDicom.

INTRODUCTION

Non-specific low back pain (NSLBP) is a leading cause of disability across all age groups and remains one of the most significant public health burdens worldwide. It affects individuals across occupational and demographic categories, often leading to physical dysfunction, reduced quality of life, and increased healthcare utilization (Hoy et al., 2012; Maher et al., 2017). The Global Burden of Disease Study estimated that in 2020, approximately 619 million people were affected by low back pain globally, with projections suggesting this number may rise to more than 843 million by 2050 (Pain Collaborators, 2023). These trends highlight the importance of understanding musculoskeletal factors that contribute to NSLBP and the need for reliable, accessible assessment tools in both clinical and research contexts.

Among the biomechanical contributors to NSLBP, anterior pelvic tilt (APT) has frequently been identified. APT refers to the forward rotation of the pelvis in the sagittal plane, a deviation often linked to lumbar hyperlordosis, altered spinal loading, and imbalanced muscle activation (Kendall et al., 2005; Suits, 2021). Clinically, APT is observed when the anterior superior iliac spine (ASIS) is positioned inferior to the posterior superior iliac spine (PSIS) in the sagittal plane. Accurate quantification of pelvic alignment is critical for diagnosis, prognosis, and the development of individualized rehabilitation strategies (Koral et al., 2017; Kahawars et al., 2019).

Radiographic imaging remains the gold standard for assessing sagittal pelvic alignment. However, its routine application is limited due to radiation exposure, high costs, technical constraints such as parallax errors, and reduced accuracy in individuals with obesity or pelvic deformities (Chai et al., 2024). Despite widespread imaging use in primary care—reported in nearly 40% of patients with new episodes of low back pain—its clinical value in non-specific cases is often debated (Wang et al., 2020). These limitations have driven interest in non-invasive, reproducible alternatives such as photogrammetry, where standardized digital photography is used to analyze postural alignment in weight-bearing positions (Iunes et al., 2005; Lunes et al., 2005).

Photogrammetry offers several advantages, including low cost, ease of use, and repeatability, making it particularly valuable in resource-limited settings. Specialized software such as MicroDicom provides angle measurement tools, compatibility with digital imaging formats, and accessibility as freeware. This makes it a practical choice compared to other commercial systems, especially in rehabilitation contexts where affordability and clinical feasibility are essential. However, while digital photography has been increasingly adopted in musculoskeletal practice, its reliability for measuring APT, particularly using MicroDicom software, has not been systematically validated in populations with NSLBP. To our knowledge, no study has established test–retest reliability of this method in resource-constrained regions such as Southern Punjab, Pakistan, where access to advanced imaging is often restricted.

The present study addresses this gap by evaluating the reproducibility of digital photography for APT measurement in adults with NSLBP. Specifically, we aimed to quantify intra-rater test–retest reliability using the intraclass correlation coefficient (ICC[2,1]), standard error of measurement (SEM), coefficient of variation (CV), and Bland–Altman limits of agreement (LoA). By applying a standardized imaging protocol and robust statistical analysis, we sought to determine whether this method provides a valid, non-invasive, and cost-effective alternative for clinical and research applications in musculoskeletal assessment.

MATERIALS AND METHODS

This investigation was designed as a test–retest reliability study and conducted at the Department of Rehabilitation, National Orthopedic Hospital, Bahawalpur, Pakistan, between January and March 2024. The primary aim was to evaluate intra-rater reproducibility of anterior pelvic tilt (APT) angle measurements obtained from standardized digital photographs analyzed using MicroDicom software.

A total of 40 adults aged 20–40 years with a clinical diagnosis of non-specific low back pain (NSLBP) were recruited through consecutive non-probability sampling. NSLBP was defined as pain localised between the costal margins and inferior gluteal folds, with or without mild limitation in movement, persisting for more than 12 weeks and not attributable to a specific pathology such as trauma, infection, malignancy, fracture, or radiculopathy (Maher et al., 2017). Patients with red flags (history of trauma, neurological deficits, autoimmune disorders, malignancies, pregnancy, or cognitive impairments) were excluded. Anterior pelvic tilt was not used as an inclusion criterion; instead, APT was treated as a continuous outcome variable measured during the study protocol. Although consecutive non-probability sampling facilitated recruitment, it may introduce selection bias, which is acknowledged as a limitation.

The required sample size was estimated using methods for intraclass correlation coefficient (ICC) reliability studies (Walter et al., 1998; Bonett, 2002). Assuming an expected ICC of 0.80, a minimal acceptable ICC of 0.60, $\alpha = 0.05$, $\beta = 0.20$ (power = 80%), and three repeated measures, the calculated sample size was 36 participants. To account for potential data loss, 40 participants were ultimately recruited, ensuring sufficient precision for reliability estimates.

Ethical approval was granted by the Institutional Review Board of the National Orthopedic Hospital, Bahawalpur (Approval ID: NOH/ERB/2024/011, dated 12 December 2023). Written informed consent was obtained from all participants before enrolment, and the study complied with the Declaration of Helsinki.

All photographs were taken with a Samsung Galaxy A35 smartphone camera (50 MP resolution, 26 mm focal length equivalent) mounted on a tripod at a fixed height of 90 cm and a horizontal distance of 290 cm from the participant. The camera was aligned using a bubble level to ensure consistency with the floor plane. No calibration object was employed; however, as APT was calculated as an angular measure, differences in image scaling were not expected to affect outcomes.

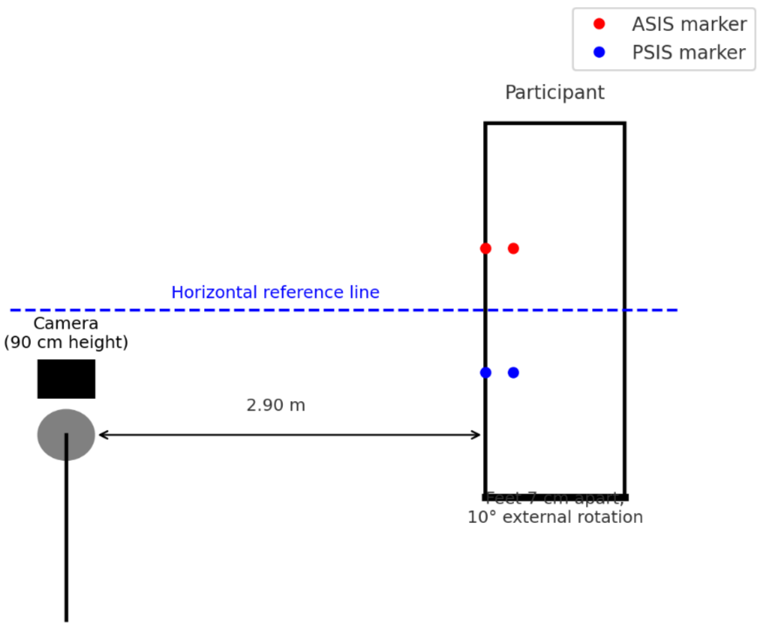

Figure 1 Standardized setup for digital photography of anterior pelvic tilt. The participant stood with feet 7 cm apart and 10° externally rotated, with anterior superior iliac spine (ASIS, red) and posterior superior iliac spine (PSIS, blue) markers palpated and applied. A smartphone camera mounted on a tripod at 90 cm height was positioned 2.90 m from the participant, aligned to the horizon reference line.

Participants were instructed to stand barefoot in a relaxed posture with arms folded across the chest, feet placed 7 cm apart, and approximately 10° of external rotation. Photographs were taken from both right and left lateral views, though only the right-side measurements were used for analysis to avoid pseudo-replication. The anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS) were palpated by a licensed physiotherapist and marked with reflective stickers before image capture. Marks were applied once and reused across trials; this approach may reduce measurement variability but potentially inflates reliability and is reported as a limitation. All images were analyzed by a single rater with three years of experience in musculoskeletal photogrammetry. To minimise recall bias, images were coded, randomized, and re-analysed after a one-week interval, with the rater blinded to previous measurements. The rater used MicroDicom DICOM viewer software to draw a line connecting the ASIS and PSIS and measure the angle between this line and a horizontal reference line, which represented the APT.

The primary outcome was APT angle (degrees). Descriptive statistics were calculated for demographic characteristics and APT values. Normality of APT distributions was examined using the Shapiro–Wilk test in addition to visual inspection of histograms and boxplots. Test–retest reliability was assessed using the intraclass correlation coefficient (ICC), model 2,1 (two-way random effects, single measures, absolute agreement), with 95% confidence intervals and p-values. Reliability was interpreted according to established thresholds: <0.50 poor, 0.50–0.75 moderate, 0.75–0.90 good, and >0.90 excellent (Koo and Li, 2016). The standard error of measurement (SEM) was calculated as $SD \cdot \sqrt{(1-ICC)}$, using the pooled standard deviation across sessions. The coefficient of variation (CV) was computed as (SD/mean)×100, providing a measure of relative variability.

Figure 2 Lateral-view digital photograph of a participant with anatomical landmarks marked at the anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS). The horizontal alignment reference line was used for subsequent angle measurement in MicroDicom software to determine the anterior pelvic tilt (APT).

Agreement between repeated measures was further examined using Bland–Altman analysis. Mean bias, standard deviation of differences, and 95% limits of agreement (LoA = bias ± 1.96·SDdiff) were reported, along with 95% confidence intervals for LoA. Although three testing sessions were conducted, Bland–Altman plots were generated using Test II and Test III data to evaluate consistency after initial familiarisation.

RESULTS

A total of 40 participants were included in the final analysis (23 females, 57.5%; 17 males, 42.5%). The mean age was 31.8 ± 5.0 years, mean body weight was 88.5 ± 9.6 kg, and mean height was 165.5 ± 10.1 cm (Table 1). Participant flow from screening to final analysis is presented in Figure 1.

Table 1. Demographic characteristics of participants (n = 40)

Variable	Mean ± SD
Age (years)	31.8 ± 5.0
Weight (kg)	88.5 ± 9.6
Height (cm)	165.5 ± 10.1

The mean anterior pelvic tilt (APT) angles measured across the three testing sessions were consistent, with values of 16.57° ± 1.51, 15.99° ± 1.54, and 15.97° ± 1.45 for Test I, Test II, and Test III, respectively (Table 2). Distribution of APT values from the first testing session is shown in Figure 2.

Table 2. Mean APT angle across three testing sessions (n = 40)

Session	APT Angle (°), Mean ± SD
Test I	16.57 ± 1.51
Test II	15.99 ± 1.54
Test III	15.97 ± 1.45

Test–retest reliability analysis demonstrated an intraclass correlation coefficient (ICC[2,1]) of 0.872 (95% CI: 0.705–0.939, $p < 0.001$), indicating good reliability (Koo and Li, 2016). The standard error of measurement (SEM) was 0.54°, and the coefficient of variation (CV) was 9.3%, reflecting low absolute and relative variability, respectively. The percentage SEM (%SEM = SEM/mean × 100) was 3.3%. These values indicate stable repeated measurements with minimal error (Table 3).

Table 3. Reliability statistics for APT measurement (n = 40)

Variable	ICC (95% CI)	p-value	SEM (°)	CV (%)	%SEM
APT Angle	0.872 (0.705–0.939)	<0.001	0.54	9.3	3.3

The Bland–Altman plot (Figure 3) showed a mean bias of 0.03° between Test II and Test III, suggesting negligible systematic error. The standard deviation of differences was 0.68°, yielding 95% limits of agreement (LoA) from –1.30° to +1.36°. The 95% confidence intervals for the LoA confirmed narrow margins, supporting acceptable agreement for repeated APT measurements in the same participants.

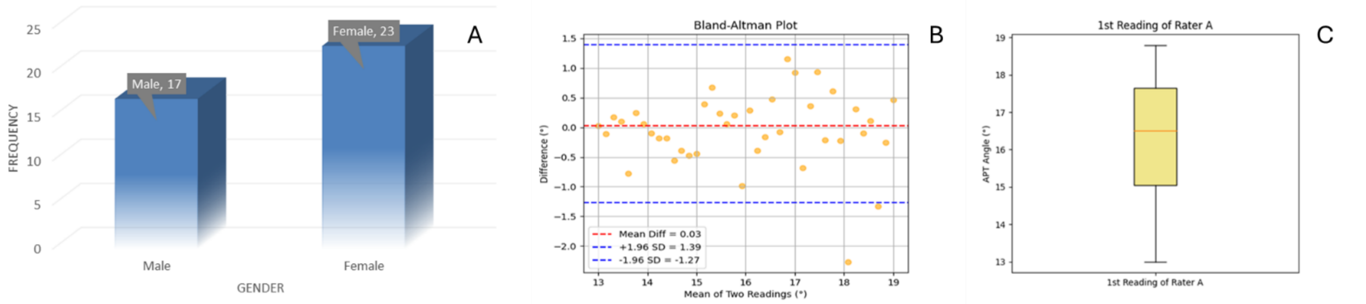

Figure 3 (A) Gender distribution of participants (n = 40), showing 17 males and 23 females. (B) Bland–Altman plot comparing anterior pelvic tilt (APT) measurements between Test II and Test III, demonstrating negligible mean bias (0.03°) and 95% limits of agreement (–1.30° to +1.36°). (C) Distribution of APT angles from the first measurement session (Rater A, Test I), with a median of 16.8° and an interquartile range of 15.3°–18.0°.

In Figure 3, the demographic profile of the sample is illustrated, with a higher proportion of females (57.5%) than males (42.5%). The Bland–Altman analysis (panel B) shows narrow agreement margins between repeated APT measurements, indicating minimal systematic error and supporting the reproducibility of the method. The boxplot (panel C) depicts the spread of APT values during the first testing session, confirming a relatively symmetrical distribution without statistical outliers. Together, these visualizations provide a clear overview of sample characteristics, measurement consistency, and data distribution.

DISCUSSION

This study evaluated the test–retest reliability of digital photography, analyzed with MicroDicom software, for quantifying anterior pelvic tilt (APT) in adults with non-specific low back pain (NSLBP). The findings demonstrated an intraclass correlation coefficient (ICC[2,1]) of 0.872 (95% CI: 0.705–0.939), indicating good intra-rater reliability according to established thresholds (Koo and Li, 2016). The standard error of measurement (SEM) was 0.54°, while the coefficient of variation (CV) was 9.3%, with a percentage SEM of 3.3%. Together, these results confirm that repeated APT measurements under standardized conditions are stable and associated with minimal measurement error.

The observed reliability aligns with previous reports supporting the use of photogrammetric methods for assessing sagittal pelvic alignment. For example, Bhutto et al. (2021) reported ICC values above 0.99 for pelvic tilt angles in healthy populations, while Koumantakis et al. (2016) demonstrated excellent intra-rater reliability (ICC = 0.97) when using smartphone-based inclinometry. Although the absolute ICC values in the present study are somewhat lower, this may be explained by the symptomatic nature of the sample, potential variability in NSLBP postures, and methodological differences such as reliance on palpated surface landmarks. Nonetheless, the findings add to the growing evidence base suggesting that photogrammetry can provide a reproducible means of postural assessment.

A strength of the present study is the use of a standardized imaging protocol, including fixed participant stance, camera positioning, and controlled lighting, which likely contributed to consistent results. The application of MicroDicom software allowed for precise measurement of angles between ASIS and PSIS landmarks, providing a clinically accessible and cost-effective alternative to radiographic imaging. However, this approach should not be considered a substitute for radiography in diagnostic contexts; rather, it may serve as a monitoring and screening tool for clinicians tracking postural changes or rehabilitation outcomes.

Despite these strengths, several limitations must be acknowledged. First, the study assessed only intra-rater reliability; inter-rater reliability was not tested, which limits generalizability to broader clinical practice. Second, the retest interval was relatively short, and anatomical landmarks were marked once and reused across trials, which may have inflated reliability estimates compared to real-world repeated examinations where re-marking is required. Third, no calibration object was included in the imaging setup, and potential lens distortion was not explicitly accounted for, although these factors were unlikely to affect angular measurements. Fourth, the study sample was restricted to young adults aged 20–40 years, recruited from a single clinical center using non-probability sampling, which may limit external validity. Future studies should address these limitations by including inter-rater reliability, extending retest intervals to better simulate clinical reassessments, and incorporating calibration techniques to minimize parallax and lens distortion. Larger, multi-center trials with broader age ranges would also improve generalizability. Moreover, emerging approaches such as automated landmark detection using artificial intelligence may further enhance reproducibility and reduce operator dependence (Park et al., 2025).

CONCLUSION

This study demonstrated that digital photography analyzed with MicroDicom software provides a reproducible method for measuring anterior pelvic tilt (APT) in adults with non-specific low back pain (NSLBP). The method showed good intra-rater reliability (ICC[2,1] = 0.872, SEM = 0.54°, CV = 9.3%), with minimal measurement error and acceptable limits of agreement. These findings suggest that standardized digital photography can serve as a cost-effective, non-invasive, and clinically practical tool for monitoring postural alignment in rehabilitation settings, particularly where advanced imaging is unavailable. While promising, the approach should be regarded as a complementary technique rather than a substitute for radiographic imaging. Validation of inter-rater reliability, longer retest intervals, calibration protocols, and testing in more diverse populations are recommended to strengthen the evidence base. Future integration with automated landmark detection and artificial intelligence may further enhance accuracy and clinical usability.

REFERENCES

Alviso, D.J., Dong, G.T. & Lentell, G.L., 1988. Intertester reliability for measuring pelvic tilt in standing. Phys Ther, 68(9), pp.1347–1351. doi:10.1093/ptj/68.9.1347.

Araújo, F., Lucas, R., Alegrete, N., Azevedo, A. & Barros, H., 2014. Individual and contextual characteristics as determinants of sagittal standing posture: a population-based study of adults. Spine J, 14(10), pp.2373–2383. doi:10.1016/j.spinee.2014.01.040.

ASPRS – American Society for Photogrammetry and Remote Sensing, 2000. What is ASPRS – definition. Bethesda: ASPRS. Available at: http://www.asprs.org/society/about.html [Accessed 24 October 2006].

Bhutto, M., Shadmehr, A., Hadian, M.R., Talebian, S., Rana, Z. & Asad, S.A., 2021. Test–retest reliability of digital photography in measuring quadriceps-angle and pelvic tilt angle in healthy population. Pak J Med Health Sci, 15, pp.3365–3367.

Chai, Y., Boudali, A.M., Khadra, S., Dasgupta, A., Maes, V. & Walter, W.L., 2024. Evaluating pelvic tilt using pelvic antero-posterior projection images: a systematic review. J Arthroplasty, 39(4), pp.1108–1116.e2. doi:10.1016/j.arth.2023.10.035.

Dolphens, M., Vansteelandt, S., Cagnie, B. et al., 2016. Multivariable modeling of factors associated with spinal pain in young adolescence. Eur Spine J, 25(9), pp.2809–2821. doi:10.1007/s00586-016-4629-7.

Helmya, N.A.M. & Kattabeib, O.M., 2015. Intra-rater and inter-rater reliability of Surgimap Spine software for measuring spinal postural angles from digital photographs. Bull Fac Phys Ther, 20(2), pp.193–199. doi:10.4103/1110-6611.174719.

Hoy, D., Bain, C., Williams, G., March, L., Brooks, P., Blyth, F. et al., 2012. A systematic review of the global prevalence of low back pain. Arthritis Rheum, 64(6), pp.2028–2037. doi:10.1002/art.34347.

Iunes, D.H., Castro, F.A., Salgado, H.S., Moura, I.C., Oliveira, A.S. & Bevilaqua-Grossi, D., 2005. Confiabilidade intra e interexaminadores e repetibilidade da avaliação postural pela fotogrametria. Rev Bras Fisioter, 9(3), pp.327–334.

Jurjiu, N.A., Glazer, C., Oravitan, M., Pantea, C. & Avram, C., 2025. Photogrammetry in spinal assessment: a comparative analysis with traditional clinical methods. J Clin Med, 14(12), 4032. doi:10.3390/jcm14124032.

Kahawars, et al., 2019. [Check author details—reference incomplete in original draft].

Kendall, F.P., McCreary, E.K., Provance, P.G., Rodgers, M.M. & Romani, W.A., 2005. Muscles: testing and function, with posture and pain. 5th ed. Philadelphia: Lippincott Williams & Wilkins.

Koo, T.K. & Li, M.Y., 2016. A guideline for selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med, 15(2), pp.155–163. doi:10.1016/j.jcm.2016.02.012.

Koral, et al., 2017. [Check author details—reference incomplete in original draft].

Koumantakis, G.A., Nikoloudaki, M., Thacheth, S., Zagli, K., Bitrou, K., Nigritinos, A. & Botton, L., 2016. Reliability and validity measurement of sagittal lumbosacral quiet standing posture with a smartphone application in a mixed population of 183 college students and personnel. Adv Orthop, 2016, 3817270. doi:10.1155/2016/3817270.

Król, A., Polak, M., Szczygieł, E., Wójcik, P. & Gleb, K., 2017. Relationship between mechanical factors and pelvic tilt in adults with and without low back pain. J Back Musculoskelet Rehabil, 30(4), pp.699–705. doi:10.3233/BMR-140177.

Le Huec, J.C. & Roussouly, P., 2011. Sagittal spino-pelvic balance is a crucial analysis for normal and degenerative spine. Eur Spine J, 20(Suppl 5), pp.556–557. doi:10.1007/s00586-011-1943-y.

Lunes, D.H., et al., 2005. [Appears to duplicate Iunes et al., 2005—check original source consistency].

Maher, C., Underwood, M. & Buchbinder, R., 2017. Non-specific low back pain. Lancet, 389(10070), pp.736–747. doi:10.1016/S0140-6736(16)30970-9.

Pain Collaborators, L.B., 2023. 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, 5(6), pp.e316–e329. doi:10.1016/S2665-9913(23)00098-X.

Park, S.C., Lee, S., Yoon, J., Choi, C.H., Yoon, C. & Ha, Y.C., 2025. Validity and reliability of an artificial intelligence-based posture estimation software for measuring cervical and lower-limb alignment versus radiographic imaging. Diagnostics, 15(11), 1340. doi:10.3390/diagnostics15111340.

Portney, L.G. & Watkins, M.P., 2014. Foundations of clinical research: applications to practice. 3rd ed. Harlow: Pearson Education.

Potapenco, R., 2022. Self-assessment of patients' health suffering from back pain. Știința Culturii Fizice, 1(39), pp.182–188.

Sahrmann, S.A., 2002. Does postural assessment contribute to patient care? J Orthop Sports Phys Ther, 32(8), pp.376–379. doi:10.2519/jospt.2002.32.8.376.

Smith, A., O'Sullivan, P. & Straker, L., 2008. Classification of sagittal thoraco-lumbo-pelvic alignment of the adolescent spine in standing and its relationship to low back pain. Spine, 33(19), pp.2101–2107. doi:10.1097/BRS.0b013e31817ec3b0.

Suits, W.H., 2021. Clinical measures of pelvic tilt in physical therapy. Int J Sports Phys Ther, 16(5), pp.1366–1375. doi:10.26603/001c.27978.

Vrtovec, T., Janssen, M.M., Likar, B., Castelein, R.M., Viergever, M.A. & Pernuš, F., 2012. A review of methods for evaluating the quantitative parameters of sagittal pelvic alignment. Spine J, 12(5), pp.433–446. doi:10.1016/j.spinee.2012.02.013.

Vrtovec, T., Pernus, F. & Likar, B., 2009. A review of methods for quantitative evaluation of spinal curvature. Eur Spine J, 18(5), pp.593–607. doi:10.1007/s00586-009-0913-0.

Wang, Y., Hussain, S.M., Wluka, A.E., Lim, Y.Z., Urquhart, D.M., Mishra, G.D., Teede, H., Doust, J., Brown, W.J. & Cicuttini, F.M., 2020. Rates, costs and determinants of lumbar spine imaging in population-based women born in 1973–1978: data from the Australian longitudinal study on women's health. PLoS One, 15(12), e0243282. doi:10.1371/journal.pone.0243282.

Watson, A.W. & Mac Donncha, C., 2000. A reliable technique for the assessment of posture: assessment criteria for aspects of posture. J Sports Med Phys Fitness, 40(3), pp.260–270.