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Research Article

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Spinopelvic Anatomic Parameters Prediction Model of NSLBP based on open dataset

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Abstract

Objective: *The purpose of this study is to perform analysis through the low back pain open data set to predict the incidence of non-specific chronic low back pain (NSLBP) to obtain a more accurate and convenient sagittal spinopelvic parameter model.*

Methods: *The logistic regression analysis and multilayer perceptron (MLP) algorithm is used to construct a NSLBP prediction model based on the parameters of the spinopelvic parameters from open data source.*

Results: *Degree of spondylolisthesis (DS), Pelvic radius (PR), Sacral slope (SS), Pelvic tilt (PT) are four predictors screened out by regression analysis that have significant predictive power for the risk of NSLBP. The overall accuracy of the equation prediction model is 85.8%.The MLP network algorithm determines that DS is the most powerful predictor of NSLBP through more precise modeling. The model has good predictive ability of 95.2% of accuracy.*

Conclusions: *MLP models play a more accurate role in the construction of predictive models. Computer science is playing a greater role in helping precision medicine clinical research.*

Keywords: Spinopelvic Alignment; Sagittal Parameters; Radiographic; Non-Specific Chronic Low Back Pain; Multilayer Perceptron

Introduction

Pain, muscle tension or stiffness localized below the costal margin and above the inferior gluteal folds with or without sciatica are considered as the non-specific chronic low back pain (NSCLBP) which cause substantial burden to patients and society and affected by a combination of physical, psychological, environmental, cultural and social factors [1-3]. The possible origin of pain sources of NSLBP include variable combinations of degenerative alterations in one or more discs, facet joints, and/or ligaments, with or without regional and/or global alterations in spinal alignment [4]. A lack of coordination of the muscles that support the spine is one of the proposed mechanisms for the onset and/or persistence of NSLBP [5]. Initial non-pharmacological treatment includes educations of self-management and normal activities or exercises resumption, and psychological programs for those with persistent symptoms [6].Treatment focuses on reducing pain and its consequences became the main treatment for NSLBP because of its unknow pathoanatomical cause. Analgesic medicines, non-pharmacological therapies, first-line treatments, such as rest, opioids, spinal injections and surgery, timely review also are parts of the management [7].

However, determining the multifactorial cause of NSLBP is complicated and anatomical abnormalities are common in the spine and may be clinical asymptoms [8]. Standing radiographs to assess sagittal spinal alignment and MRI scan to determine the mechanism of injury could be beneficial to alternative treatment options to decrease the pain and functional limitations [9]. Although specific exercise training therapies are recommended to treat persistent NSLBP, they were not more cost-effective compared with other interventions for low back pain [10, 11]. As for the aspect of decreasing pain and disability in people with chronic low back pain, multidisciplinary biopsychosocial rehabilitation interventions were more effective than usual care (moderate quality evidence) and physical treatments (low quality evidence) [12].

Spinopelvic mobility concerns about the complex interaction of hip, pelvis, and spine [13]. Acetabular anteversion, pelvic tilt, and lumbar lordosis coordinated biomechanically among spinopelvic motion [14]. Larger lumbar lordosis due to larger pelvic incidence may be a risk factor for the development of standing-induced low back pain [15]. Normal spinopelvic parameters change along with the posture like from standing to sitting [16-18]. Sagittal plane deformities and global spinal alignment have in the generation of pain and disability. Restoration or maintenance of physiological sagittal spinal alignment is imperative to achieve good clinical outcomes.

The purpose of this study is to perform analysis through the low back pain open data set to predict the incidence of NSLBP to obtain a more accurate and convenient sagittal spinopelvic parameter model.

Methods

Data processing

Our data source is from the open dataset of Kaggle. Data contains parameters of 310 observations. There are 13 attributes for analyzation purposes, which 12 are numeric predictors (X_1,X_2,…, X_{12}) and 1 is binary class attribute (0=Abnormal, 1=Normal) with no demographics (*Table 1*).

Table 1 Data discerption

		type	Assignment
Predictors (X)	X1 Pelvic Incidence	numeric, float64	(°)
	X2 Pelvic Tilt	numeric, float64	(°)
	X3 Lumbar Lordosis Angle	numeric, float64	(°)
	X4 Sacral Slope	numeric, float64	(°)
	X5 Pelvic Radius	numeric, float64	(mm)
	X6 Degree Spondylolisthesis	numeric, float64	(°)
	X7 Pelvic Slope	numeric, float64	(°)
	X8 Direct Tilt	numeric, float64	(°)
	X9 Thoracic Slope	numeric, float64	(°)
	X10 Cervical Tilt	numeric, float64	(°)
	X11 Sacrum Angle	numeric, float64	(°)
	X12 Scoliosis Slope	numeric, float64	(°)
Class_att (Y)	Attribute Class	categorical, object	0=Abnormal, 1=Normal

Apply independent sample T test descriptive statistics to find out what significantly contribute to the outcome of NSLBP. Binary logistic regression analysis was used to predict the relationship between the dependent variable (Y) and the independent variable (X). In this study, Y stands for Class_att (Abnormal or Normal). And 12 numeric predictors of X are list in Table1. To build a more accurate prediction model, Multilayer Perceptron (MLP) is applied. The MLPs breaks this restriction and classifies datasets by using a more robust and complex architecture to learn regression and classification models for difficult datasets. The MLP procedure produces a predictive model for NSLBP based on the values of the predictor variables in the regression equation.

Spinopelvic parameters Measurement

Optimal position for radiologic measurement of lordosis is standing with arms supported while shoulders are flexed at a 30° angle [19]. The digitized thoracic points on the lateral radiographs were all vertebral body corners of T1–T12. Subjects held onto a vertical pole with hands at elbow level to keep the upper extremities from projecting over the spine.

First interpret the lumbar X-rays and determine the degree of lumbar lordosis. Then determine the lumbar curve's Cobb angle from an X-ray taken in profile, using the centroid, tangential radiologic assessment of lumbar lordosis method (TRALL), or using the Harrison posterior tangent line-drawing methods (Figure 1) [20-22].

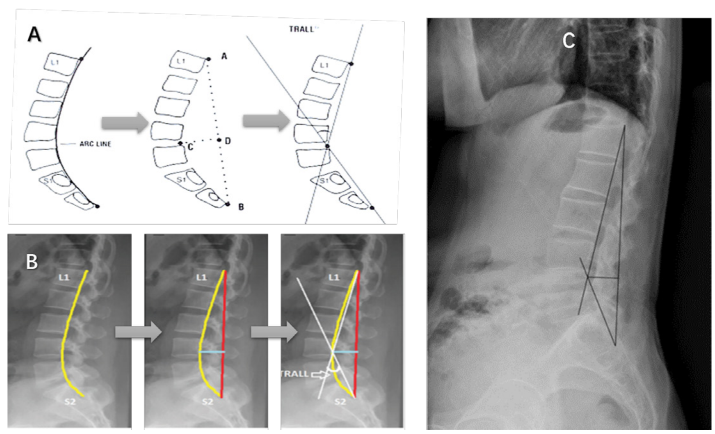

Figure 1: Tangential Radiologic Assessment of Lumbar Lordosis Method (TRALL)
A: sketches of TRALL measurement procedure principle;
B: TRALL measurement actual operation steps in X-ray image;
C: Result graph of TRALL measurement procedure

Centroid method, Cobb method and the posterior tangent method are three different radiographic analysis methods (Figure 2) [23]. 1) The Centroid method use four digitized body corners to construct the intersection (centroid) of vertebral body diagonals. The centroid method requires three adjacent vertebrae to construct segmental angles and either three or four vertebrae to construct global angles (Figure 2-A). 2) Cobb method use the inferior vertebral body corners on each thoracic segment were used to construct segmental Cobb angles (e.g., CobbT1–T2). Segmental and global Cobb angles are constructed with lines drawn on vertebral body endplates. The posterior tangent method uses the superior-posterior and inferior-posterior body corners (Figure 2-B) [21]. 3) The posterior tangent method uses the two posterior vertebral body corners. Lines are drawn tangent to the midposterior vertebral body through these two points. These lines are the slopes in an engineering analysis of columns. Relative rotation angles (segmental angles) are created by intersecting adjacent tangents. Absolute rotation angles (global angles) are constructed by intersecting tangents on the cranial and caudal segments of the curve. Global angles are sums of the intervening segmental angles (Figure 2-C).

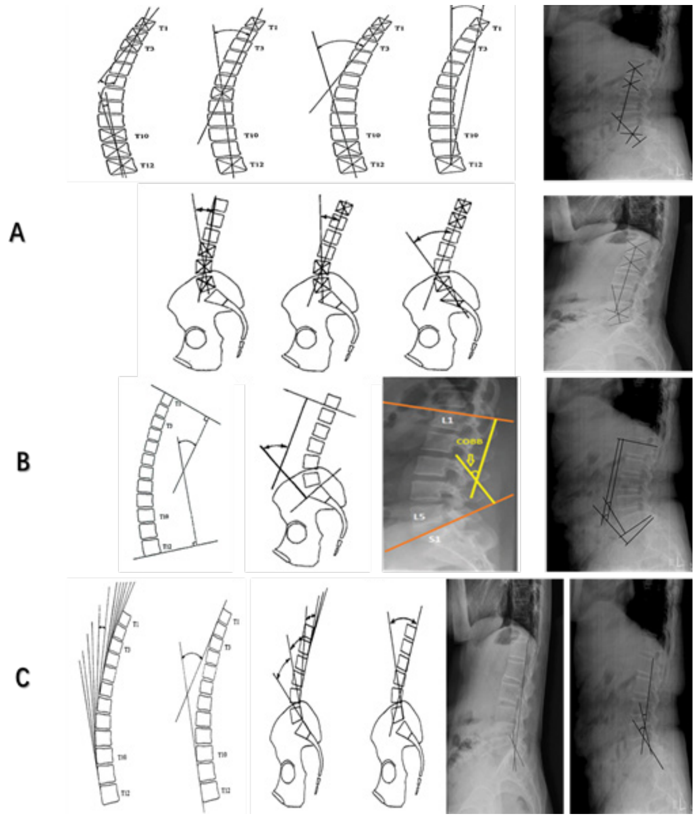

Figure 2: Different radiographic analysis methods
A: centroid method. B: Cobb method. C: The posterior tangent method.

Results

Spinopelvic parameters of normal are significantly different from the abnormal in Pelvic incidence (51.69±12.37 vs. 64.69±17.66,F=17.77,P=0.00), Pelvic tilt (12.82±6.78 vs.19.79±10.52, F=15.85,P=0.00), Lumbar lordosis angle (43.54±12.36 vs.55.93±19.67, F=26.93,P=0.00), Sacral slope (38.86±9.62 vs. 44.90±14.52, F=15.10,P=0.00), Pelvic radius (123.89±9.01 vs.115.08±14.09, F=10.95,P=0.00), Degree spondylolisthesis (2.19±6.31 vs.37.78±40.70, F=50.08,P=0.00).

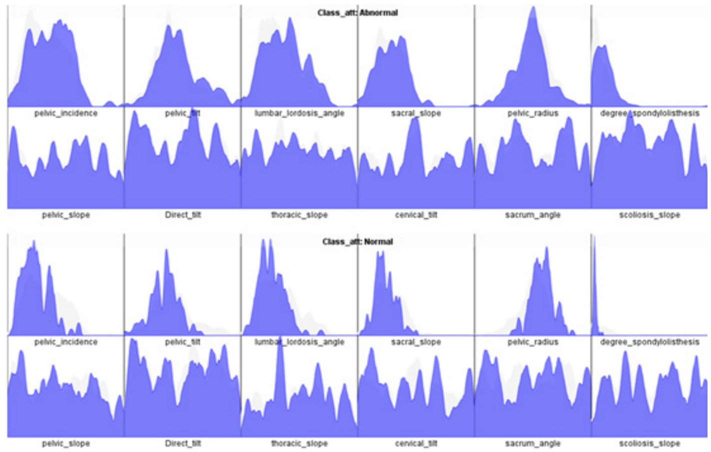

Figure 3 Descriptive of Spinopelvic parameters

Logistic regression model of NSLBP

It can be observed that the model is statistically significant in Omnibus Tests of Model Coefficients (χ^2=210.918, P<0.005). The Hosmer and Lemeshow goodness of fit test is not statistically significant (P=0.144), indicating that the model fits well. The proportion of variation that can be explained by the dependent variable is 69.0% (Nagelkerke R2).

Table 2 Classification tablea

	Observed value		Predictive value		
			class		**Percentage Correct**
			Abnormal	Normal	
Step 4	class	Abnormal	186	24	**88.6**
		Normal	20	80	**80.0**
	Overall Percentage				**85.8**

[a] The cut value is 0.500

The overall accuracy of the equation prediction model is 85.8% as shown in Table 2. This model can correctly classify 85.8% of the research objects. The sensitivity of the model is 88.6% and the specificity is 80.0%. 90.3% of the observations that predicted with NSLBP were correct. And 76.9% of the observations that predicted without NSLBP were correct.

Table 3 logistic Regression Predicting Likelihood of NSLBP based on PT,SS,PR,DS

	B	S.E.	Wald	*df*	Sig.	Exp(B)	95% CI for EXP(B)	
							Lower	Upper
Pelvic tilt	-0.07	0.03	5.16	1	0.02	0.94	0.88	0.99
Sacral slope	0.11	0.02	25.72	1	0.00	1.12	1.07	1.17
Pelvic radius	0.11	0.02	22.85	1	0.00	1.12	1.07	1.17
Degree spondylolisthesis	-0.17	0.02	52.24	1	0.00	0.85	0.81	0.89
Constant	-15.46	3.27	22.30	1	0.00	0.00		

The method of selecting variables in this statistical process is "Forward: LR" method. The variables in the equation table lists the variables and their parameters that are finally screened into the model (Table 3). The "Sig." column represents the P value of the corresponding variable in the model, and "Exp (B) and 95% CI for EXP (B)" represent the OR value of the corresponding variable and its 95% confidence interval. Research subjects with higher values in "Sacral slope" and "Pelvic radius" both had 1.12 times risk of low back pain. And these two parameters both increased risk of low back pain is significant (OR=1.12, 95% CI: 1.07-1.17, P=0.00).

Multilayer Perceptron Model of NSLBP

Select the one dependent variable of Class_att and four predictors in the regression equation. Specify 30% of the sample to prevent overfitting the sample set in the setting before proceed. And randomly allocate 71.3% of the samples to the training set and 28.7% to the test set in this MLP model. The predictive value of overall percentage in training dataset is 88.7%, while is 87.6% in testing dataset. According to the ROC curve, the areas of "Abnormal" and "Normal" in the area model below the curve are both 0.952, indicating that the model has good predictive ability. The importance of influence of the parameters in the model on the occurrence of NSLBP is ranked as follows (Table 4): Degree spondylolisthesis (100%), Pelvic radius (45.9%), Sacral slope (40.1%), Pelvic tilt (21.4%).

Table 4 Variable importance

	Importance	Normalized importance
Pelvic tilt	0.103	21.4%
Pelvic radius	0.221	45.9%
Degree of spondylolisthesis	0.482	100.0%
Sacral slope	0.193	40.1%

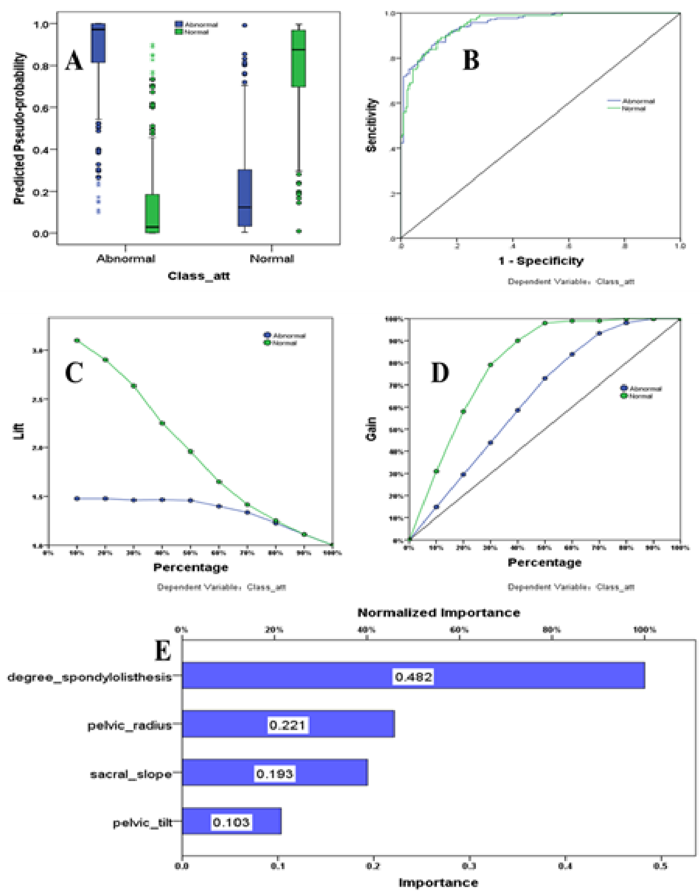

Figure 4: MLP prediction model for NSLBP
A: graph of predicted pseudo-probability; B: ROC curve; C: Gain graph;
D: Lift graph; E: Graph of Independent Variables Importance

Discussion

Predictive model evaluation

In this study, the regression model screened out four predictors that can affect the occurrence of NSLBP, and the model accuracy rate was 85.8%. In the regression model, the four predictors can promote or lower the risk of NSLBP, and the positive and negative effects are different. While in the MLP model, the order of the influence of each predictor affects the accuracy of the prediction model. In the MLP prediction model established by the predictor, spondylolisthesis is the most predictive factor that determines the occurrence of NSLBP, and the model accuracy rate reaches 95.2%, suggesting The MLP model is more accurate in predicting multiple factors.

Spinopelvic parameters and NSLBP

Spondylolisthesis refers to translation of 1 vertebral segment compared with the sub adjacent level, which can be described according to its degree of severity, causing mechanical or radicular symptoms or pain. Meyerding classification is accurate for measuring slip percentage, graded according to degree of slippage; based on the ratio of the overhanging part of the superior vertical body to the anterio-posterior length of the inferior vertebral body [24]. It is found that there is a huge difference between normal and abnormal lumbar spondylolisthesis. It shows that it plays an important and decisive role in predicting the NSLBP model. This fact tells us that most of the causes of NSLBP may come from lumbar spondylolisthesis, and vice versa.

Pelvic radius (PR) the distance from the hip axis (located in the middle between the two femoral bead mid-points) to the posterior-superior corner of the S1 endplate, which the standard values was 137 ± 9 mm [25, 26]. The pelvic radius parameter is also significantly different in the normal (123.89±9.01) and abnormal (115.08±14.09) category models in our study. In the regression model, for every 1mm increase in PR, the incidence of NSLBP increases by 1.12 times. In the MLP prediction model, the weight for predicting the occurrence of NSLBP accounts for 45.9%. PR is related to the stability of the pelvic space structure and also determines the balance of the spine. The sagittal balance of the spinopelvic is defined by the parameters based on notable biomechanical forces involved in the transmission of constraints with the broadening and verticalization of the pelvis and the upright position characteristic of the spinal curves structured, and the supporting muscles modified.

Sacral slope (SS) is an angle subtended by a line parallel to the sacral end plate and a horizontal reference line [27]. The normal range of value for the SS was from -32° to -49° [28]. The angle between the superior plate of S1 and the horizontal reference line with a normal range from 36-42°. Normal (38.86±9.62) vs. abnormal (44.90±14.52) of SS in this study is significantly different according to the analyzing. And the range of normal SS in our study meets the standard of the ideal spinopelvic parameter for eliminating residual pain and disability in adult spinal deformity, which is around 30 degree [29]. The anatomical orientation of the pelvis with a high SS was one of the predisposing factors for degenerative spondylolisthesis which leads to NSLBP [30].

The pelvic tilt (PT) is an angle measured by a vertical reference line from the center of the femoral head and a line from the center of the femoral head to the midpoint of the sacral end plate [27]. The (anterior or posterior) pelvic tilt describes here the angle between the anterior pelvic plane and the coronal plane of the body [31]. Significant differences in pelvic tilt were found in this study between people with and without NSLBP (12.82±6.78 vs.19.79±10.52), which indicates that the evaluation of radiographic spinopelvic parameter is more accurate comparing to the measurement of individual related motion and posture captured by wearable sensors31. In addition, our analyzed outcomes are consistent with those of patients treated with minimally invasive surgical treatment of transforaminal lumbar interbody fusion, that is, a greater decrease in PT is associated with an improvement in back pain [32].

Conclusion

DS, PR, SS, PT are four predictors screened out by regression analysis that have significant predictive power for the risk of NSLBP. The multi-layer perceptron network algorithm determines that DS is the most powerful predictor of NSLBP through precise modeling. Through data analysis and modeling, accurate screening of pelvic spine parameters that affect NSLBP can help prevent and treat patients with NSLBP more quickly.

This method uses the NSLBP open database for analysis, and further application in clinical should be the next step ahead. Although computer science has its strong advantages in data analysis, its application in the field of medical clinical research requires more verification and screening.

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References

1. Pinto RZ, Verwoerd AJH, Koes BW (2017) Which pain medications are effective for sciatica (radicular leg pain)? BMJ 359: j4248.
2. Hartvigsen J, Mark J Hancock, Alice Kongsted, Quinette Louw, Manuela L Ferreira, et al. (2018) What low back pain is and why we need to pay attention. The Lancet 391: 2356-2367.
3. JWS V (2018) Low back pain. Nature reviews Disease primers 4: 53.
4. Barrey CY, Le Huec J (2019) Chronic low back pain: Relevance of a new classification based on the injury pattern. Orthopaedics & Traumatology: Surgery & Research 105: 339-346.
5. New CC, Dannaway J, New H, New CH (2017) Motor control exercise for chronic non-specific low-back pain (PEDro synthesis). BRIT J SPORT MED 51: 1037-1038.
6. Foster NE, Johannes R Anema, Dan Cherkin, Roger Chou, Steven P Cohen, et al. (2018) Prevention and treatment of low back pain: evidence, challenges, and promising directions. The Lancet 391: 2368-2383.
7. Maher C, Underwood M, Buchbinder R (2017) Non-specific low back pain. The Lancet 389: 736-747.
8. Sheehan NJ (2010) Magnetic resonance imaging for low back pain: indications and limitations. ANN RHEUM DIS 69: 7-11.
9. Ames CP, Justin S Smith, Justin K Scheer, Shay Bess, S Samuel Bederman, et al. (2012) Impact of spinopelvic alignment

on decision making in deformity surgery in adults. Journal of Neurosurgery: Spine 16: 547-564.
10. Hayden JA, Maria N Wilson, Samuel Stewart, Jennifer L Cartwright, Andrea O Smith, et al. (2019) Exercise treatment effect modifiers in persistent low back pain: an individual participant data meta-analysis of 3514 participants from 27 randomised controlled trials. Brit J Sport Med 2019: bjsports-2019-101205.
11. Miyamoto GC, Lin CC, Cabral C, van Dongen JM, van Tulder MW (2019) Cost-effectiveness of exercise therapy in the treatment of non-specific neck pain and low back pain: a systematic review with meta-analysis. Br J Sports Med 53: 172-181.
12. Kamper SJ, Andreas T Apeldoorn, Alessandro Chiarotto, Rob J E M Smeets, Raymond W J G Ostelo, et al. (2015) Multidisciplinary biopsychosocial rehabilitation for chronic low back pain: Cochrane systematic review and meta-analysis. BMJ 350: h444.
13. Haffer H, Adl AD, Perka C, Pumberger M (2020) The Impact of Spinopelvic Mobility on Arthroplasty: Implications for Hip and Spine Surgeons. J Clin Med 9.
14. Lum ZC, Coury JG, Cohen JL, Dorr LD (2018) The Current Knowledge on Spinopelvic Mobility. The Journal of Arthroplasty 33: 291-296.
15. Misir A, Turan Bilge Kizkapan, Suleyman Kasim Tas, Kadir Ilker Yildiz, Mustafa Ozcamdalli, et al. (2019) Lumbar spine posture and spinopelvic parameters change in various standing and sitting postures. EUR SPINE J 28: 1072-1081.
16. Shimizu T, Ronald A Lehman, J Alex Sielatycki, Suthipas Pongmanee, Meghan Cerpa, et al. (2020) Reciprocal change of sagittal profile in unfused spinal segments and lower extremities after complex adult spinal deformity surgery including spinopelvic fixation: a full-body X-ray analysis. The Spine Journal 20: 380-390.
17. Chae D, Thong Phi Nguyen, Sung-Jun Park, Kyung-Yil Kang, Chanhee Won, et al. (2020) Decentralized convolutional neural network for evaluating spinal deformity with spinopelvic parameters. Comput Meth Prog Bio 197: 105699.
18. Simonet E, Balz Winteler, Jana Frangi, Magdalena Suter, Michael L Meier, et al. (2020) Walking and running with non-specific chronic low back pain: What about the lumbar lordosis angle? J Biomech 108: 109883.
19. Been E, Kalichman L (2014) Lumbar lordosis. The Spine Journal 14: 87-97.
20. Chernukha KV, Daffner RH, Reigel DH (1998) Lumbar Lordosis Measurement. SPINE 23: 74-79.
21. Hong JY, Seung Woo Suh, Hitesh N Modi, Chang Yong Hur, Hae Ryong Song, et al. (2010) Reliability analysis for radiographic measures of lumbar lordosis in adult scoliosis: a case–control study comparing 6 methods. EUR SPINE J 19: 1551-1557.
22. Lee JS, Goh TS, Park SH, Lee HS, Suh KT (2013) Radiographic measurement reliability of lumbar lordosis in ankylosing spondylitis. EUR SPINE J 22: 813-818.
23. Harrison DE, Cailliet R, Harrison DD, Janik TJ, Holland B (2001) Reliability of Centroid, Cobb, and Harrison Posterior Tangent Methods. SPINE 26: e227-e234.
24. Metzger R, Chaney S (2014) Spondylolysis and spondylolisthesis: what the primary care provider should know. J Am Assoc Nurse Pract 26: 5-12.
25. Zhao Y, Cai-Liang Shen, Ren-Jie Zhang, Da-Wei Cheng, Fu-Long Dong, et al. (2016) Sagittal Pelvic Radius in Low-Grade Isthmic Lumbar Spondylolisthesis of Chinese Population. J Korean Neurosurg S59: 292.
26. Jackson RP, Hales C (2000) Congruent spinopelvic alignment on standing lateral radiographs of adult volunteers. Spine 25: 2808-2815.
27. Ghobrial GM, Al-Saiegh F, Heller J (2018) Procedure 31 - Spinopelvic Balance: Preoperative Planning and Calculation. in Operative Techniques: Spine Surgery (Third Edition) (ed. E.M. Baron & A.R. Vaccaro) 2018: 281-287..
28. Legaye J (2007) The femoro-sacral posterior angle: an anatomical sagittal pelvic parameter usable with dome-shaped sacrum. European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society 16: 219-225.
29. Liow MHL, Graham Seow-Hng Goh, Jia Long Chua, Zhixing Marcus Ling, Reuben Chee Cheong Soh, et al. (2020) Sagittally Balanced Degenerative Spondylolisthesis Patients With Increased Sacral Slope and Greater Lumbar Lordosis Experience Less Back Pain After Short-Segment Lumbar Fusion Surgery. Clin Spine Surg 33: E231.
30. Rajakumar DV, Hari A, Krishna M, Sharma A, Reddy M (2017) Complete anatomic reduction and monosegmental fusion for lumbar spondylolisthesis of Grade II and higher: use of the minimally invasive “rocking” technique. Neurosurg Focus 43: E12.
31. Wernli K, O’Sullivan P, Smith A, Campbell A, Kent P (2020) Movement, posture and low back pain. How do they relate? A replicated single- case design in 12 people with persistent, disabling low back pain. Eur J Pain 24: 1831-1849.
32. Massie LW, Hesham Mostafa Zakaria, Lonni R Schultz, Azam Basheer, Morenikeji Ayodele Buraimoh, et al. (2018) Assessment of radiographic and clinical outcomes of an articulating expandable interbody cage in minimally invasive transforaminal lumbar interbody fusion for spondylolisthesis. Neurosurg Focus 44: E8.