Machine learning for aiding the diagnostic of pathology on the vertebral column

Objective

- The purpose of study is applying machine learning to characterize pathologies of the vertebral column by using six biomechanical attributes derived from the shape and orientation of the pelvis and lumbar spine: pelvic incidence, pelvic tilt, lumbar lordosis angle, sacral slope, pelvic radius and grade of spondylolisthesis.
- Understanding the relationships of these biomechanical characteristics are significantly importance for the discernment of vertebral column disorder in normal and pathologic (abnormal) conditions of the spine and pelvis.

Introduction

- Treatment of vertebral column disorders remains a challenge for orthopaedic surgeons, neurosurgeons and paediatrics.
- Because of the great variety of existing anatomical and clinical forms.

Pathologies of the Vertebral Column

- The vertebral column is a system composed by a group of vertebras, invertebrate discs, nerves, muscles, medulla and joints. The main functions of the vertebral column are as follow: (i) human body support axle; (ii) osseous protector of the spine medulla and nervous roots; and (iii) body's movement axles, making movement possible in three levels: frontal, sagittal and transversal (Neto et al., 2011).
- This complex system can suffer dysfunctions that cause backaches with very different intensities. Disc hernia and spondylolisthesis are examples of pathologies of the vertebral column that cause intense pain. They result of small or several traumas in the column that gradually injures the structure of the intervertebral disc (Neto et al., 2011).

What Causes of Spondylolisthesis?

- Trauma, degenerative, tumour, and birth defects.
- Spondylolisthesis is a forward or backward slippage of one vertebra on an adjacent vertebra.

What are the Symptoms of Spondylolisthesis?

- Lower back or leg pain.
- hamstring tightness.
- numbness and tingling in the legs.

Diagnosis of spondylolisthesis

- Based on imaging, like X-rays, CAT scans or MRI scans.

Treatment

- Most people with spondylolisthesis can be treated conservatively, without the need for surgery.
- Patients who fail to improve with conservative treatment may be a candidate for surgery.

Literature Review

01

Patients with high (PI) and sacral slope (SS) show an increase in the shear forces incident at the lumbosacral junction (Tabet, 2014).

02

The value of PI is higher in spondylolisthesis, increasing linearly, according to the severity of slippage (Tabet, 2014).

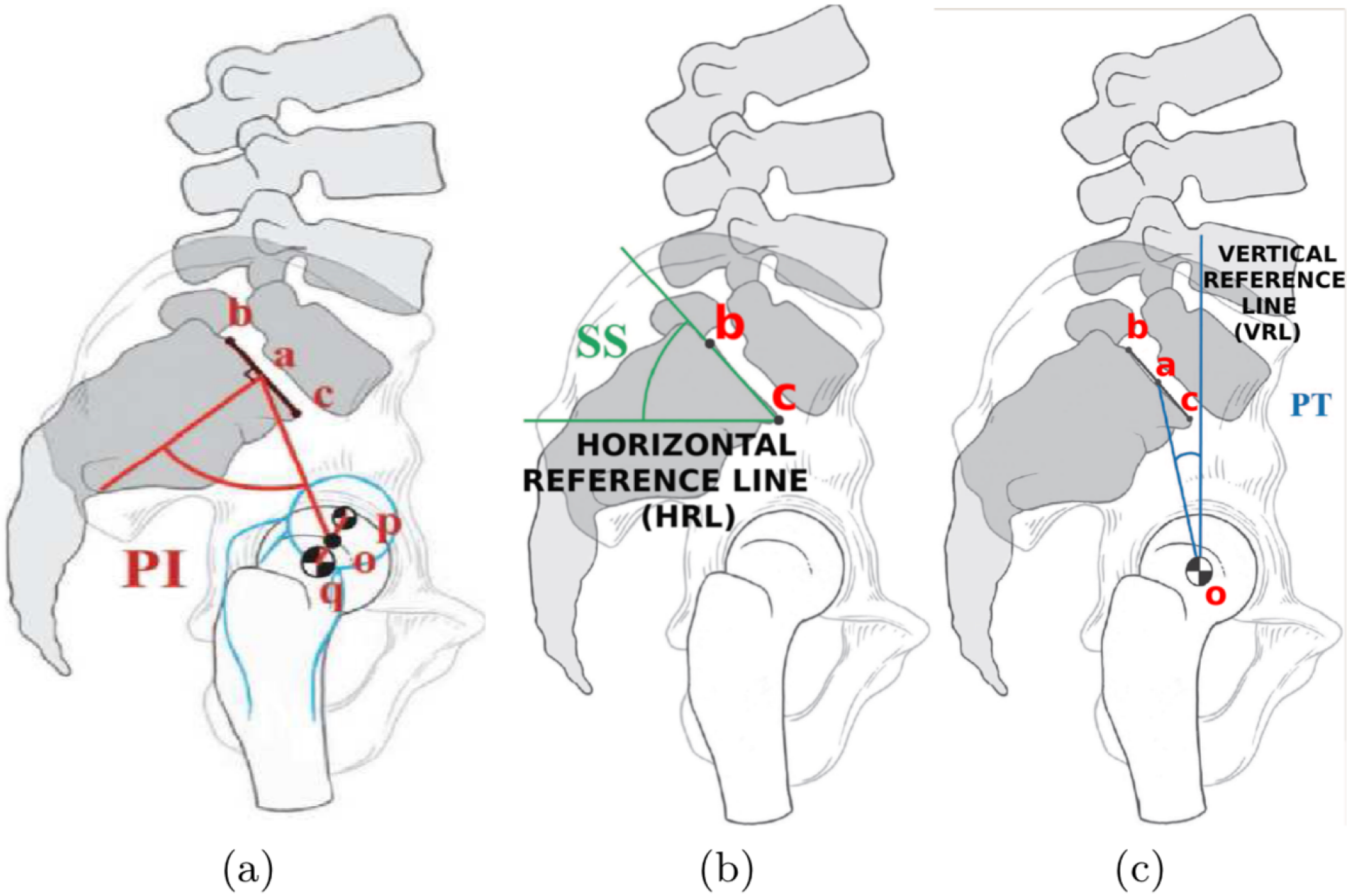
03

The pelvic tilt (PT) and the sacral slope (SS) measure the sacro-pelvic orientation in the sagittal plane (Tabet, 2014).

04

PI is the sum of SS and PT, then, PI is a strong determinant of the spatial orientation of the pelvis in the osthostatism, i.e. the higher the PI, the greater will be the PT or SS, or both (Tabet 2014).

Spino-pelvic System

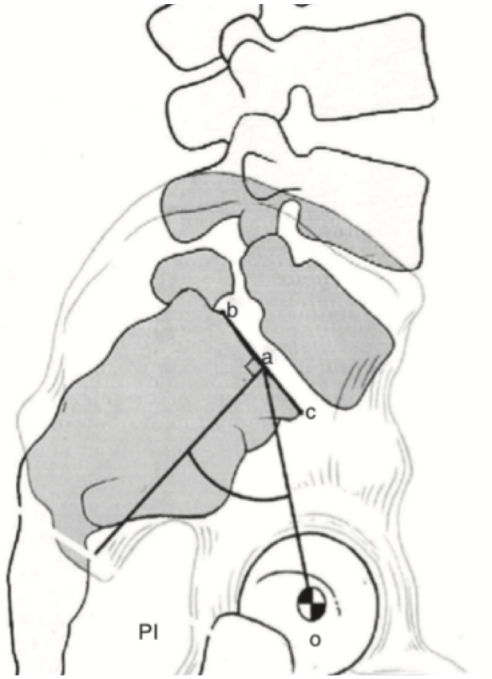


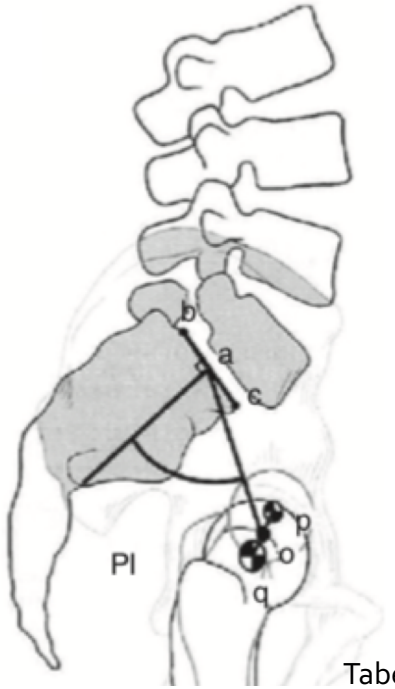
Neto et al., (2011)

Pelvic Incidence (PI)

Pelvic Incidence (PI) is defined as the angle formed by the intersection of a line drawn from the centre of the femoral head towards the midpoint of the sacral endplate (o–a) and a line perpendicular to the centre of the sacral endplate (a). The sacral endplate is defined by a segment (b–c) formed between the posterior horn of the sacrum and the anterior top of the S1 sacral promontory (Tabet ,2014).

When the femoral heads are not perfectly overlapped, the centre of each one of them is marked and a line drawn between two points (q–p) will connect the centre of the two heads. The line (o–a) will be drawn from the centre of the line (q–p), i.e., point (o), to the centre of the sacral endplate (Tabet,2014).



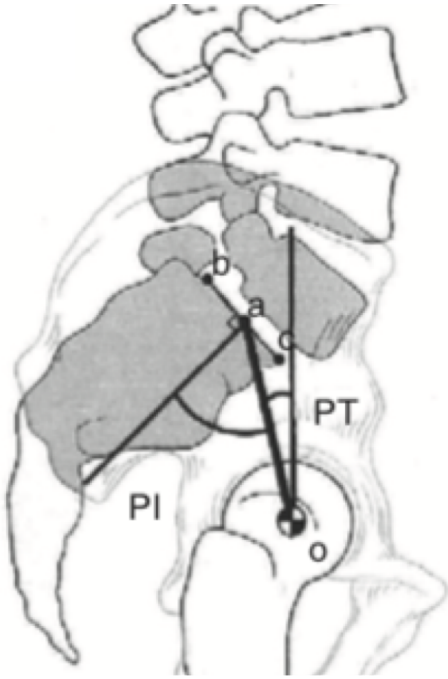


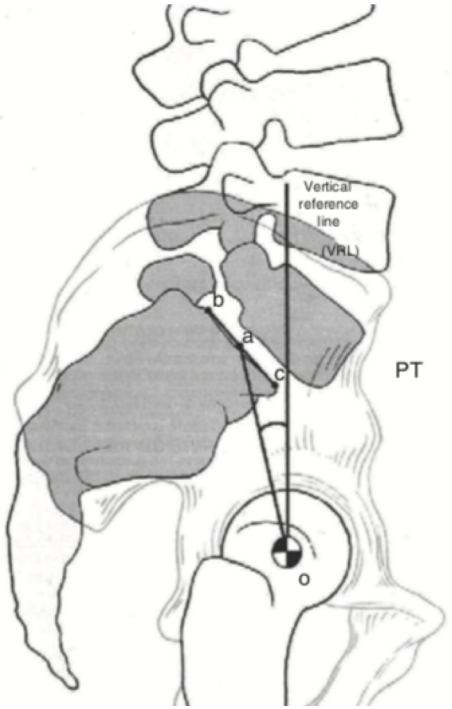
Tabet (2014)

Pelvic Tilt (PT)

Pelvic tilt (PT) is defined by the intersection of a vertical reference line, which originates from the femoral head centre (o) and the midpoint of the sacral endplate (a) (Tabet,2014).

PT can be influenced by PI, since they share the line (o–a) and the terminal sacral plate is a common reference line for both (Tabet,2014).



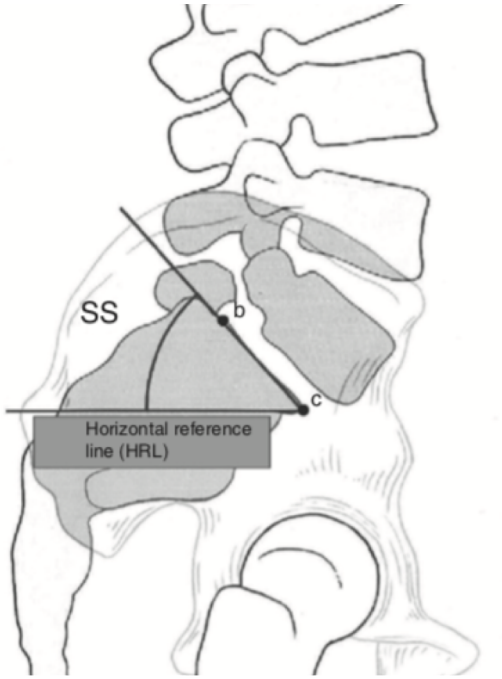


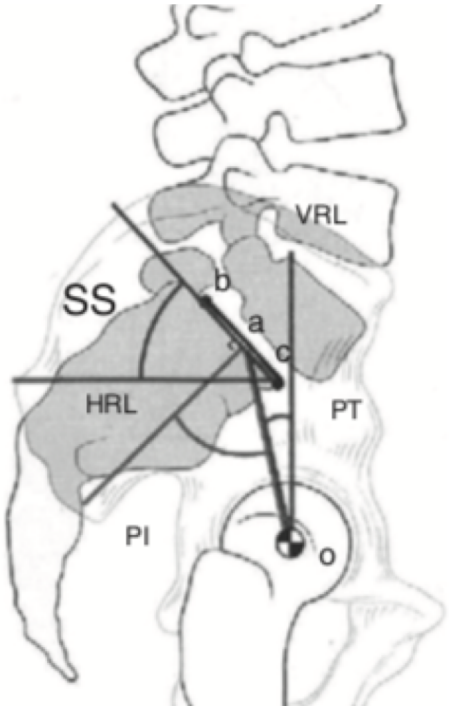
Tabet (2014)

Sacral Slope (SS)

Sacral tilt (SS) is defined as the intersection of the horizontal reference line (HRL) and the sacral endplate (b–c) (Tabet,2014).

The sacral slope (SS) is related to PI and PT because it shares a reference line (b–c) in common along the sacral endplate (Tabet,2014).





Tabet (2014)

Dataset

- The database applied in this study was provided by Dr. Henrique da Mota, who collected it during a medical residence in spine surgery at the Centre M´edico-Chirurgical de R´eadaptation des Massues, placed in Lyon, France. This database contains data about 310 patients obtained from sagittal panoramic radiographies of the spine.
- It is composed of 210 abnormal patients who have pathology in their spines & 100 normal.

Six Biomechanical Attributes

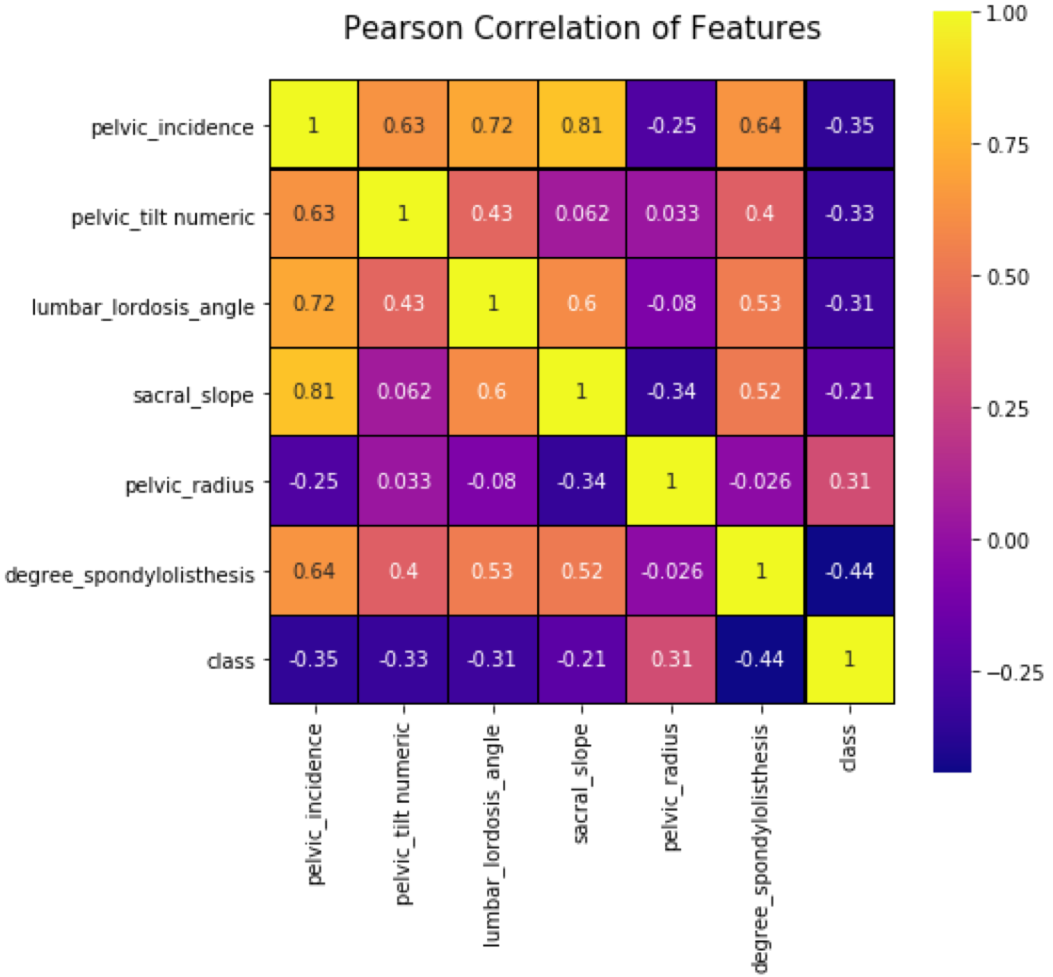
- Each patient in this database is represented with six biomechanical attributes, which correspond to the following parameters of the spino-pelvic system: angle of pelvic incidence, angle of pelvic tilt, lordosis angle, sacral slope, pelvic radius and grade of slipping.
- Pelvic Incidence (PI)
- Pelvic Tilt (PT)
- Lumbar lordosis angle
- Sacral Slope (SS)
- Pelvic radius
- Grade of spondylolisthesis.

Experimental Study

The training dataset was composed in different experiments with 70%, 80% of the data.

Results #1- Pearson Correlation of Features

It is used as a measure for quantifying linear dependence between two continuous variables X and Y. Its value varies from -1 to +1.



The highest correlation of Pelvic Incidence are sacral_slope (0.81), followed by lumbar_lordosis_angle (0.72), degree_spondylolisthesis (0.64) and pelvic_tilt_numermic (0.63)

Results #2- Confusion matrix with random forest

N=93 (30% for test)	Predicted Abnormal	Predicted Normal	
Actual Abnormal	TP=58	FP=8	66
Actual Normal	FN=7	TN=20	27
	65	28	

TP: True Positive
TN: True Negative

(When it predicts Abnormal, how often is it correct)

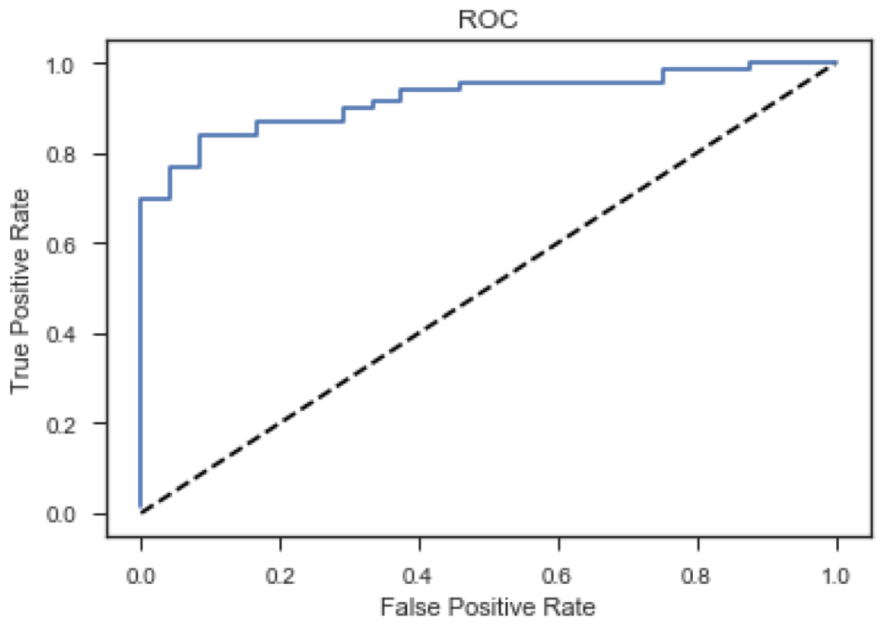
Precision of Abnormal = $\frac{TP}{predicted\ Abnormal} = \frac{58}{65} = 0.89$

Precision of Normal = $\frac{TN}{predicted\ normal} = \frac{20}{28} = 0.71$

- There are two possible predicted class: "Abnormal" and "N ormal".
- The classifier made a total of 93 predictions.
- Out of those 93 cases, the classifier predicted "Abnormal"6 5 times and "Normal" 28 times.
- In reality, 66 patients in the sample have abnormal and 27 p atients are normal

Results #3- ROC Curve with logistic regression

Logistic Regression is a classification algorithm. It is used to predict a binary outcome (1 / 0, Yes / No, True / False) given a set of independent variables.



Receiver Operating Characteristic(ROC) summarizes the model's performance by evaluating the trade offs between true positive rate (sensitivity) and false positive rate(1-specificity).

The area under curve (AUC), referred to as index of accuracy(A) or concordance index, is a perfect performance metric for ROC curve. Higher the area under curve, better the prediction power of the model.

Conclusions

- Strong correlation between pelvic incidence (PI), pelvic tilt (PT) and the sacral slope (SS) and spondylolisthesis.
- Our findings show a good agreement with literatures.
- In this work, incorporate machine learning techniques can significantly help orthopaedist to diagnosis of pathologies on the Vertebral Column.

References

- Neto, A. R., Sousa, R., Barreto, G. D., & Cardoso, J. S. (2011). Diagnostic of Pathology on the Vertebral Column with Embedded Reject Option. Pattern Recognition and Image Analysis Lecture Notes in Computer Science, 588-595. doi:10.1007/978-3-642-21257-4_73
- Tebet, M. A. (2014). Current concepts on the sagittal balance and classification of spondylolysis and spondylolisthesis. Revista Brasileira De Ortopedia (English Edition), 49(1), 3-12. doi:10.1016/j.rboe.2014.02.003