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1. Introduction

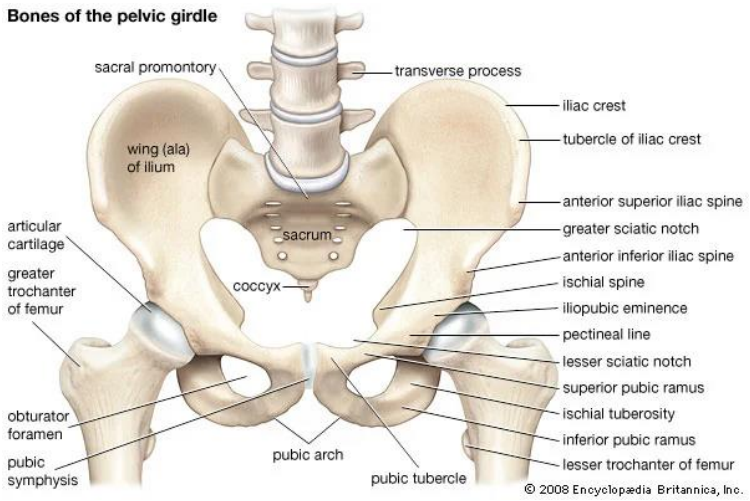
In the file PRACTICA_02_TIPOS_REGRESIONES.ipynb you can see the variants of the Linear Regression algorithm. The variants of Linear Regression are as follows:

- ❖ Simple Linear Regression
- ❖ Multiple Linear Regression
- ❖ Polynomial regression
- ❖ Advanced Linear Regression

For practical reasons, the variants of Linear Regression to the Dataset were carried out with data of biomechanical problems in the human body. The code of the linear regression algorithms applied in the DataSet can be seen in the PRACTICA_02_REGRESION_LINEAL.ipynb file.(TEAM, 2018)

2. Brief description of the Concepts used in the DataSet.

2.1. Pelvis: Also called bony pelvis or pelvic girdle, in human anatomy, a complex of basin-shaped bones that connects the trunk and legs, supports and balances the trunk, and contains and supports the intestines, urinary bladder, and internal sex organs. The pelvis consists of pairs of hip bones, connected in front by the symphysis pubis and behind by the sacrum; Each is made up of three bones:



the blade-shaped ilium, above and on each side, representing the width of the hips; the ischium, behind and below, on which the weight falls when sitting; and the pubis, in front. All three are joined in early adulthood in a triangular suture in the acetabulum, the cup-shaped socket that forms the hip joint with the head of the femur (thigh bone). The ring formed by the pelvis functions as a birth canal in women. The pelvis provides attachment to the muscles that balance and support the trunk and move the legs, hips, and trunk. In the human baby, the pelvis is narrow and unsupportive. As the child begins to walk, the pelvis widens and tilts, the sacrum descends deeper into its joint with the iliacs, and the lumbar curve of the lower back develops. (Abella, et al., 2023)

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2.2. Pelvic Incidence: The pelvic incidence varies during growth to sacroiliac joint mobility. The pelvic incidence angle (PI), described by Duval-Beaupere, is the morphological angle considered by the pelvis. It is formed by a line perpendicular to the platform of the sacrum that begins in the middle of it towards distal and a second line that goes from the center of the femoral heads (CCF) to the middle of the platform of the sacrum.

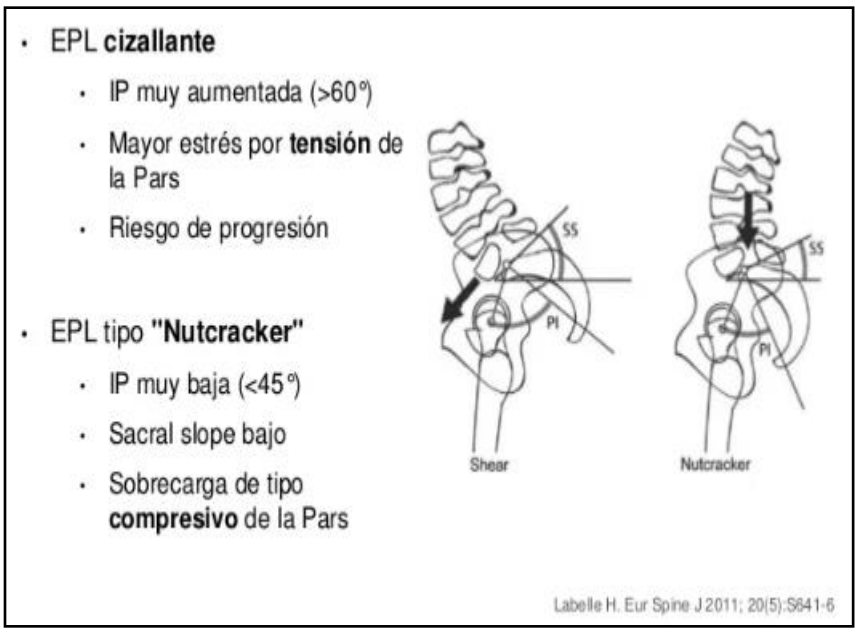

Image of pelvic incidence, image obtained http://image.slidesharecdn.com/espondilolistesis-140507165603-phpapp01/95/espondilolistesis-35-638.jpg?cb=1399481854

The incidence can vary from one individual to another. When it is increasing, it is associated with a pronounced lumbar lordosis, as well as thoracic kyphosis and cervical lordosis higher than normal (dynamic type), which corresponds to curves in the spine with a very pronounced profile. Conversely, a lower than normal angle is associated with slightly pronounced spinal curves (static type). (Contemporánea, Neurocirugía Contemporánea, 2019)

2.3. Pelvic Tilt: In particular, the inclination of the pelvis in the sagittal plane, which is defined as the rotation of the pelvis around the transverse axis that crosses the center of both coxofemoral joints, has shown usefulness when assessing posture. Pelvic tilt is considered positive if the antesuperior iliac spines (ESIAs) go downwards and negative if they go upwards. On a lateral x-ray of the pelvis, the inclination of the pelvis can be easily measured as the angle between a line joining the symphysis of the sacral promontory. A neutral pelvic tilt is defined by a 60° pelvic tilt. (Contemporánea, Neurocirugía Contemporánea, 2019)

Prepared by: Biochemical Engineering Intern Vargas Carreño Leonardo Augusto

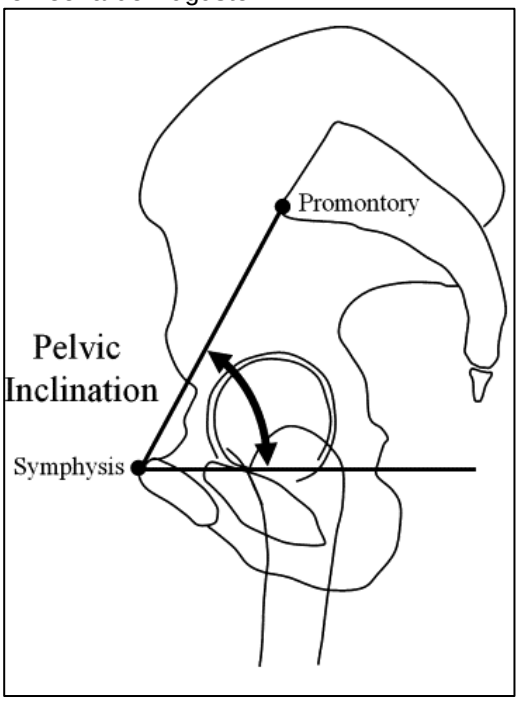

Image Pelvic Tilt, image obtained inclinacion_pelvica [Contemporary Neurosurgery] (neurocirugiacontemporanea.com)

2.4. Lumbar lordosis (Lumbar Lordosis): is a normal inward curvature of the spine in the lumbar region (lower back). This curvature is necessary to maintain the body's balance and absorb impacts when walking, running, and other physical activities.

If the lumbar curvature becomes excessive, lumbar hyperlordosis can occur, which can lead to low back pain and other health problems. There are two types of Lumbar Lordosis, they are the following:

2.4.1. Lumbar hyperlordosis: it is a condition that can occur when the lumbar region (lower back) there are experiences of stress or extra weight that can cause it to arch more than normal, sometimes it is accompanied by pain or muscle spasms.

2.4.2. Lumbar hypolordosis: less common than lumbar hyperlordosis, it occurs when a minor curvature in the lumbar region or a flattening of the lower back is observed. (Wikipedia, Wikipedia, 2023)

2.5. Sacral Slope: is a position parameter dependent on the angle and the parallel line between the sacral end plate and a horizontal line. There are four types of this condition:

2.5.1. Type 1 Lordosis: the sacral slope is less than 35 degrees; the apex of lordosis is centered in the middle of the L5 body; the lower arc of lordosis is minimal and decreases towards zero as the sacral slope approaches the horizontal; the turning point (transition between upper kyphosis and lumbar lordosis) is low and posterior creating a short lordosis with a negative angle of inclination of lordosis; The upper part of the spine has a significant kyphosis of the thoracolumbar junction and thorax

2.5.2. Type 2 Lordosis: the sacral slope is less than 35 degrees; the apex of lordosis is located at the base of the L4 body; The lower arch of the lordosis is relatively flat; the turning point is higher and more anterior decreasing the angle of inclination of the lordosis, but increasing the number of vertebral bodies included in the lordosis; The entire spine is relatively hypolordosic and hypokyphotic.

2.5.3. Type 3 Lordosis: the sacral slope is between 35 to 45 degrees; the apex of the lumbar lordosis is in the center of the body of L4; the lower arch of the lordosis is more prominent; the turning point is at the thoracolumbar junction and the angle of inclination of the lordosis is almost zero; An average of four vertebrae constitute the arch of lordosis. The spine is well balanced.

2.5.4. Type 4 Lordosis: the sacral slope is greater than 45 degrees; the apex of lordosis is at the base of the L3 vertebra or higher; the lower arc of the lordosis is prominent and the angle of inclination of the lordosis is zero or positive; the number of vertebrae in lordotic orientation is greater than 5; There is a state of segmental hyperextension. (Key, 2010)

2.6. Pelvic Radius: is a technique that is based on measurements of Pelvic Incidence and Sacral Slope. The foundation is between the anatomical position and the orientation of the sacrum with respect to the pelvis and the spinal curvatures that these may cause. (I.G., Sergides; F. McCombe, Peter; White, G.; Mokhtar, Sabarul; R. Sears, William;, 2011)

2.7. Degree Spondylolisthesis: is a condition that occurs when one of the vertebrae of the body slips with respect to the adjacent vertebral body causing radicular or biomechanical symptoms or pain. It is classified according to the degree of sliding of a vertebral body over the adjacent vertebral body. Any pathological process that can weaken the supports that keep the vertebral bodies aligned can allow spondylolisthesis to occur. (Tenny & C. Gillis, 2023)

3. Linear Regressions in the Dataset.

According to the previous definitions, you can define which are the dependent variables and the independent variables of the Biomechanical Column Dataset.

Independent Variables (X)	Dependent variables (Y)
• **Pelvic Incidence** • **Pelvic Tilt Numeric** • **Lumbar Lordosis Angle**	❖ Pelvic Radius ❖ Degree Spondylolisthesis ❖ Sacral Slope

We are going to use two Biomechanical column datasets; the 2C termination will be used for linear regression algorithms and the 3C termination to make the predictions of the dependent variable.

```
data= pd.read_csv("archivo_csv/BIOMECHANICAL_column_2C_weka.csv") #Dataset for algorithms

data_prueba= pd.read_csv("archivo_csv/BIOMECHANICAL_column_3C_weka.csv") # Dataset to make predictions
```

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First we will analyze the dataframe with the following codes:

```
Input: data.info()
```

Output:

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 310 entries, 0 to 309
Data columns (total 7 columns):
# column non-null count dtype
---  ------                    --------------  -----
0 pelvic_incidence 310 non-null float64
1 pelvic_tilt numeric 310 non-null float64
2 lumbar_lordosis_angle 310 non-null float64
3 sacral_slope 310 non-null float64
4 pelvic_radius 310 non-null float64
5 degree_spondylolisthesis 310 non-null float64
6 class 310 non-null object
dtypes: float64(6), object(1)
memory usage: 17.1+ KB
```

We have a total of 310 data per column of which six columns contain data of type float and only one column has data of type object. For the algorithms that we are going to use, it is not necessary to use the last column because of the type of data it contains, so the entire column will be removed from the dataframe.

```
data_NON_class= data.drop(["class"], axis=1)
```

We will continue to perform the correlation of data in order to have an idea with which data we can work, the following code will be used:

```
Input: data_NON_class.corr()
```

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Output:

	pelvic_incidence	pelvic_tilt numeric	lumbar_lordosis_angle	sacral_slope	pelvic_radius	degree_spondylolisthesis
pelvic_incidence	1.000000	0.629199	0.717282	0.814960	-0.247467	0.638743
pelvic_tilt numeric	0.629199	1.000000	0.432764	0.062345	0.032668	0.397862
lumbar_lordosis_angle	0.717282	0.432764	1.000000	0.598387	-0.080344	0.533667
sacral_slope	0.814960	0.062345	0.598387	1.000000	-0.342128	0.523557
pelvic_radius	-0.247467	0.032668	-0.080344	-0.342128	1.000000	-0.026065
degree_spondylolisthesis	0.638743	0.397862	0.533667	0.523557	-0.026065	1.000000

Independent Variables

Dependent variables

It is important to define which variables are going to be used as Independent and as Dependents, although according to the correlations we can relate to each other in order to define the variables. According to the literature previously consulted Pelvic_radius, sacral_slope and degree_spondylolisthesis are data that will vary according to the problems either pelvic or lumbar. Based on this we can see that sacral_slope has the best correlation compared to Pelvic Radius and degree_ spondylolisthesis so for this specific practice sacral_slope will be used as a dependent variable; Biomechanical problems will be used to develop linear regression algorithms.

All the codes of the linear regression algorithms can be seen in the PRACTICA_02_REGRESION_LINEAL.ipynb file.

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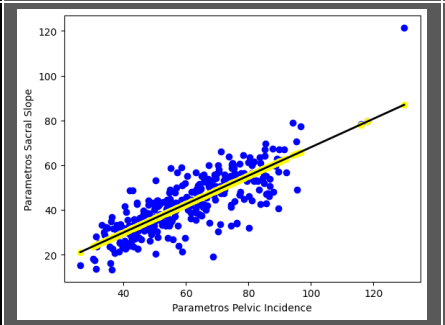
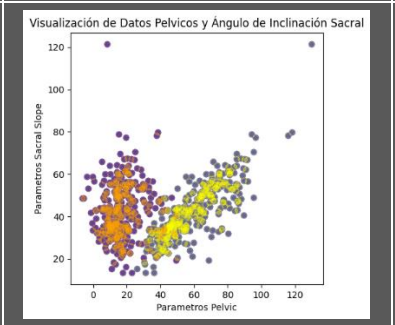
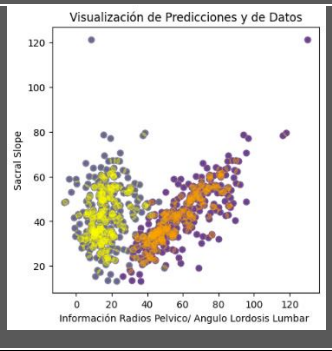
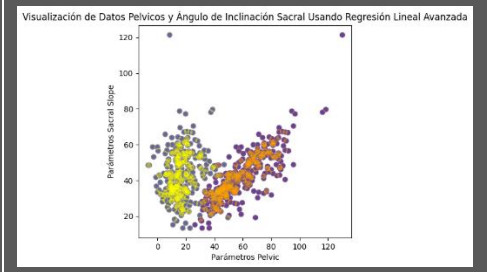
Regression algorithms				
Results	**Simple Linear**	**Linear Multiple**	**Polynomial**	**Advanced Linear**
R2	0.664159783972475	1.0	1.0	1.000
Straight Equation	Y= [0.63465775]X + 4.55916136615285	Y= [1. -1.] X+ -7.766445264678623e-10	Y= X[1. -1.] + -7.766445264678623E-10	
First 4 Predictions Sacral Slope	44.56025417, 29.34695797, 48.24393689, 48.53904455	40.47523153, 28.99595951, 46.61353893, 44.64413016	40.47523153, 28.99595951, 46.61353893, 44.64413016	40.47523153, 28.99595951, 46.61353893, 44.64413016
Linear Regression Plot				

Sacral Slope data of the DataSet that was used for predictions	
First 4 Facts Sacral Slope	40.475232, 28.995960, 46.613539, 44.644130

Calculation of True Errors in Percentage of the first four data			
E RLS	**E RML**	**E RP**	**E RLA**
10.092648	1.421077E-10	1.421077E-10	1.421428E-10
1.210508	1.388667E-09	1.388667E-09	1.388618E-09
3.497692	9.935563E-11	9.935563E-11	9.937087E-11
8.724359	2.209636E-08	2.209636E-08	2.209631E-08

The calculation of errors can provide us with information about the accuracy and sensitivity of the linear regression algorithms for the Biomenanical Column Dataset, as we can see the simple linear regression is not the best option to predict the deviation of the sacrum (sacrum slope). More than two conditions are required to make the predictions, as we can see with the results from linear multiple regression to advanced linear regression where we obtain results of minimal true errors and the results obtained in the predictions are similar to the values of the dataset that is used to make the comparisons. For this dataset this trend can be observed because for Sacral Slope more than one pelvic or lumbar problem is required likewise we would see the same trend if we wanted to make the predictions for pelvic_radius and degree_ spondylolisthesis.

4. Conclusions.

- ✓ Predictions of a Dependency variable were made using different types of Linear Regression Algorithms.
- ✓ The different types of Linear Regression Algorithms were applied using a dataset with 310 data.
- ✓ I am not a doctor or biomedical who can perform more thoroughly the study of these data, try to interpret the data according to the basic concepts in order to define how the algorithms are going to be used. If there is a more precise method you can add another programming file to the folder or send it to me via email.

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