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Relationship between Spinal Disorders and Physical Attributes

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Keywords: COP; Plantar pressure; Spinal disorders; LBP; CLBP; BMI.

Abbreviations: AL: Anterior Left of Foot; AP: Antero-Posterio; AR: Anterior Right of Foot; BMI: Body Mass Index; BOS: Base of Support; COM: Center of Mass; COP: Center of Pressure; CLBP: Chronic Lower Back Pain; FRD: Functional Research Test; LBP: Lower Back Pain; LOS: Loss of Stability; ML: Medio Lateral; PL: Posterior Left of Foot; PR: Posterior Right of Foot; SCI: Spinal Cord Injury.

Abstract

Spinal disorders are a typical phenomenon in the human masses. The specific cause of these issues is unknown, and there are few studies on the causes of spinal abnormalities induced by a person's physical characteristics. The goal of this study is to discover a link between various spine parameters and the physical attributes of people. This study looked at total 10 spine parameters and several physical attributes of fifty-five individuals obtained with Statico 3D, and footprints were obtained through pedobarography. The footprints were divided into 4 segments: Anterior left and right, posterior left and right. It has been found that many spine parameters are interconnected. The Center of Pressure (COP) of a person has a strong bearing on the spinal disorders like lumbar lordosis and thoracic kyphosis.

Introduction

Nowadays, abnormalities in the spinal region have become a major issue as a result of the modern lifestyle. A decrease in walking ability and spine mobility has been observed in people with spinal disorders [1]. The Spinal deformity not only affects the spatial orientation of body segments and their interdependencies but also gait and walking patterns. The body oscillates when standing, causing the COP to move in both AP and ML directions [2]. The intensity of the issue is determined by the degree of spinal curvature. Individuals suffering from Chronic Low Back Pain (CLBP), have movement patterns that are different from those of a healthy person. The stability of the spine is based on two fundamental mechanisms viz. compressive stresses in the spine and muscle and the trunk stiffness. Muscle stiffness appears to rise in direct proportion to muscle force. Furthermore, it is widely known that increased trunk muscular activation leads to increased compressive pressures acting on the spine [3]. It was observed that foot support decreased COP excursion in the lateral and backward directions during the sitting Functional Reach Test (FRT) but increased it in the forward movement [4]. In LBP subjects, high compressive force on the lumbar region is the leading cause of pain. The foot pronation of LBP subjects resulted in a higher vertical ground force reaction [5,6]. The success of LBP treatment depends on reducing the pain as well as improving the motor control of a patient [7].

Activation of Chronic Lower Back Pain (CLBP) issues can occur for a variety of reasons. Patients tend to experience pain in the lower lumbar region, which can be linked to pelvis tilt and pelvic torsion. They may be further linked to the shoes people wear, the degree of foot flatness, BMI, foot rotation, the centre of pressure, and other factors. Foot placements have an impact on patients with Spinal Cord Injuries (SCI). According to studies, COP should be maintained within the base support of an individual. It has been observed that the ML direction of COP in SCI patients and able-bodied subjects differs [8]. As the patient moves, his or her COP varies at different platform levels, affecting the postural stability of the person [9]. Balance on the ML side is crucial for ambulation and requires accurate foot placement. The location of the COP must be within a few millimeters to sustain ML stability [10]. In fact, neuromuscular control has been found to alter the loss of stability (LOS) in chronic low back pain. It has been established that not only physical but also internal factors influence CLBP or LBP in an individual [5]. Higher subtalar inversion is created when a person walks barefoot. This affects the lower biomechanics of an individual [11]. In fact, the consequences of the magnitude of lower extremity kinetic parameters and the position of the COP in the sagittal plane have a significant correlation [12].

High impact forces during walking and poor foot biomechanics have been considered as a significant cause of LBP, with the latter being linked to lumbopelvic muscular dysfunction and back disorders [13]. Shoe insoles and foot orthotics have been shown to reduce LBP significantly. Even the heels of shoes have been shown to alter the stability of a person, particularly in women. This is due to a diminishing Base of Support (BOS), and the difficulties of maintaining COP and COM relationships with BOS. The COP and COM of a person are affected by their heel height. When the heel height inclination increases, there is a divergence between COM and COP. These factors are too responsible for an unstable COP [14,15]. The position of the foot and lower limbs at foot-ground contact is linked to trunk angle while running and has been linked to lower extremity injuries. According to the observed interaction, greater trunk flexion will alter the relationship between the COM and the foot COP [16]. There is axial torsion of the spine and trunk due to the linear displacement of COP [2]. Since COP is a crucial indicator of load distribution, the footwear industry is very interested in COP of foot striking. As a result, some aspects like COP and COM are taken into account while designing and manufacturing footwear [17]. However, asymmetric gait patterns in the LBP group are naturally unstable and standing upright necessitates adaptive dynamic balance regulation. Lower limb coordination problems during step time may be frequent in people with LBP [18]. In order to further understand the attributes of lower back pain a systematic study has been carried out.

Methodology

The purpose of this study is to look into the relationship between various physical characteristics and spinal disorders using DIERS Statico 3D and pedobarography.

A total of fifty-five candidates, ranging in age from eighteen to twenty-five, volunteered to take part in this study. Their BMI ranged from 17 to 32. Before the study, all of the volunteers were evaluated to ensure that they are not suffering from any other illnesses that would affect the outcome of the study. The research was divided into two stages: the first was to determine various spinal parameters, and the second was to evaluate various foot parameters. DIERS Statico 3D was used in both stages. For stage-1, scans of fifty-five participants were taken using Statico 3D software. Measurement protocols for the standing posture of the subject and the gap from the machine set-up were followed. The subjects followed instructions by staying a few steps away from the camera set-up.

Table 1: Deviation of different spine parameters.

Parameter	Average	SD	Range
Coronal imbalance, mm	21.21	14.49	0.3 - 46.1
Pelvis obliquity, mm	8.48	3.83	0 - 12.0
Pelvic torsion, degree	4.47	2.43	0.6 - 8.2
Sagittal imbalance, degree	4.19	1.87	1.4 – 7.2
Lumbar lordosis Angle , degree	53.20	12.25	25.3 – 65.3
Thoracic kyphosis Angle, degree	49.63	6.01	33.4 – 53.6
Vertebral rotation Right, degree	4.498	1.3	4.1 -12.6
Vertebral rotation Left, degree	7.38	2.7	0 – 3.5
Apical deviation Right, mm	26.91	14.6	1.4 – 7.2
Apical deviation Left, mm	7.57	4.9	0 – 14.5

In stage 2, data was collected from fifty-five volunteers once more, but this time the data was focused only on foot. Each BMI, height, and weight of each participant were measured and recorded. Each participant was instructed to start walking approximately a 2m distance before stepping onto the floor mat at a self-selected speed. Each participant was asked to look straight ahead as they were walking. Various foot parameters were obtained in stage 2 which were used to establish a relation between BMI and spine parameters.

Results & discussion

Three sets of dynamic pedobarograms were obtained for each foot. The data was cropped to a rectangle based on the length and width of the foot. Then the footprint was divided into four parts for observation, as shown in **Figure 1**. These four segments were Anterior Left (AL), Posterior Left (PL), Anterior Right (AR) and Posterior Right (PR). This was done for both left and right foot.

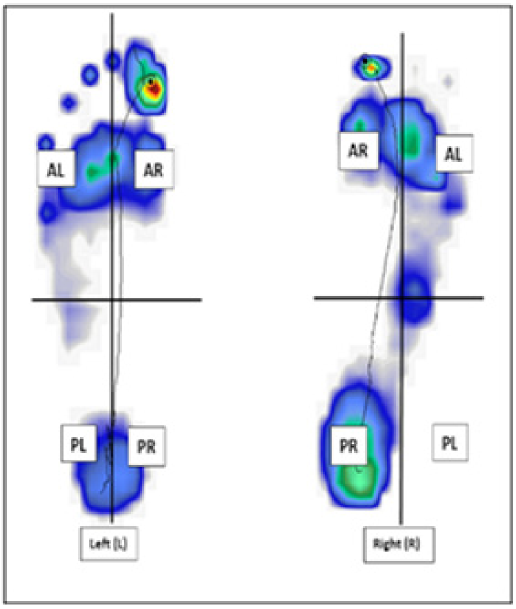

Figure 1: Different sections of foot model.

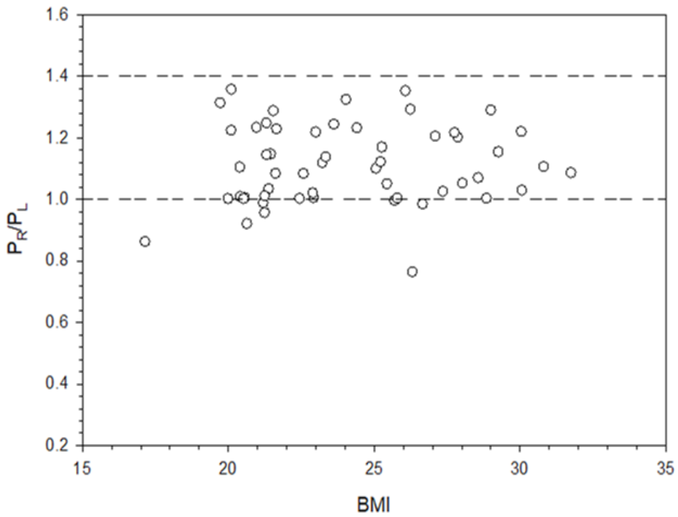

Figure 2: Variation of Right and left leg pressure ratio with BMI.

Figure 2 depicts a relation between ration of left and right foot pressure with BMI of a person. The pressure on left and right foot are within average 1.12 and lies between bandwidth of 1.0 to 1.4 for BMI ranging from 20 kg/m2 to 35 kg/m2. Since the pressure ratio lies between a particular bandwidth for the increase in BMI, it shows that the pressure applied by a person while walking or standing is not affected by the BMI of that person. Further pressure applied on the right foot is often higher than that applied on the left foot. The pressure on right foot can be up to 40% more than left foot. From the graph it can be understood that for 8% increase of BMI from 20 to 30 Kg/m2 the pressure varies between 1.0 to 1.4, this means for most of the cases including a healthy adult having BMI ranging from 18.5 to 20 Kg/m2 BMI to an overweight adult having 30kg/m2 the pressure applied by their foot doesn't show much variation with increase in their BMI.

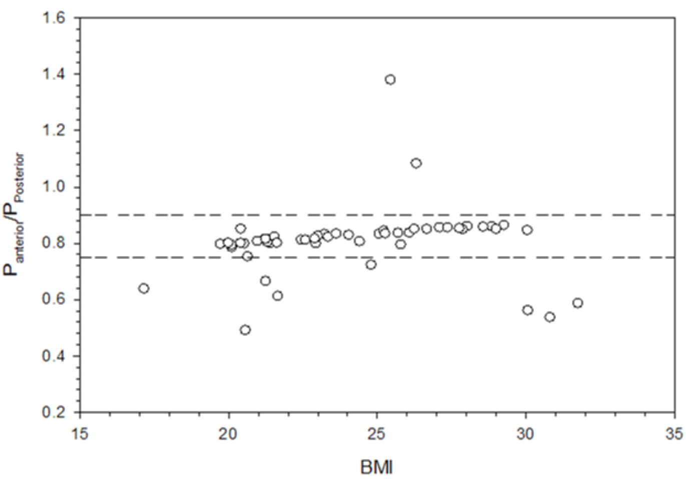

Figure 3: Variation of Anterior and Posterior pressure ratio with BMI.

Figure 3 has been drawn to depict the relation between ratio of posterior and anterior foot part with BMI of a person. The ratio lies between bandwidth of 0.725 to 0.90 for BMI ranging from 20 kg/m2 to 35 kg/m2. Since the pressure ratio lies between a particular bandwidth for the entire range BMI, it shows that the pressure applied by a person while walking or standing is not affected by the BMI of that person. The pressure on the anterior is in a range of 10-25% less than at the posterior of the foot. This means for most of cases including a healthy adult having BMI ranging from 18.5 to 20 Kg/m2 BMI to an overweight adult the pressure applied by their anterior and posterior part of the foot doesn't show much variation with increase in their BMI.

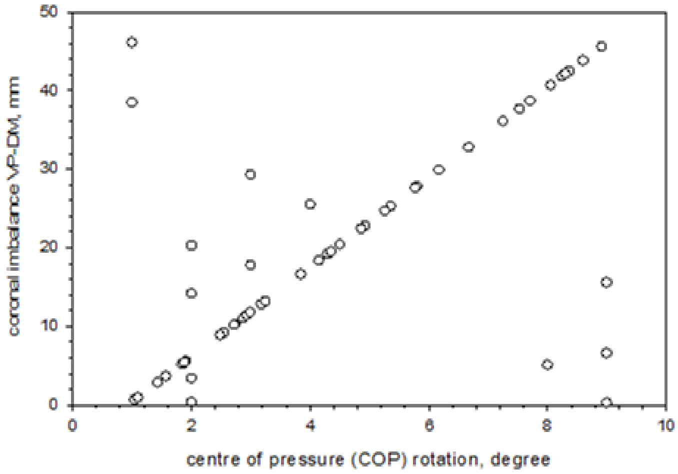

Figure 4: Variation of coronal imbalance with center of pressure.

Figure 4 shows a relation between coronal imbalance with COP in degrees. The graph shows how the degree of rotation of COP affects the coronal imbalance. There was a linear growth of coronal imbalance with an increase in degrees of COP of the foot, mean that with every 0.4 degrees of increased rotation of COP there was an increase of 2 mm coronal imbalance making a strong linear relationship between this two parameter of a person. It can be seen that for every 4% increase in degrees of COP from1.3 to 8.9 there was 2% increase in coronal imbalance. A total of 80% data shows linear relation.

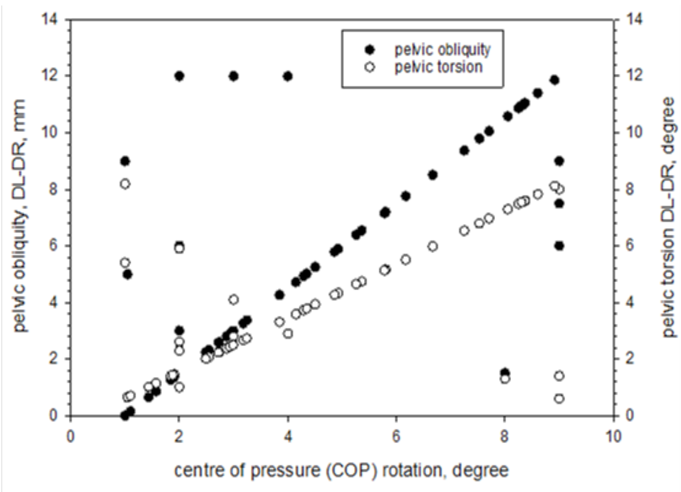

Figure 5: Variation of pelvic torsion and pelvic obliquity with center of pressure.

A relation between pelvic obliquity and pelvic torsion with COP in degrees has been depicted in Figure 5. The figure shows that how the degree of rotation of COP affects pelvic obliquity and pelvic torsion. There was a linear growth of pelvic obliquity and pelvic torsion with the increase in degrees of COP of the foot, means that with every 0.4 degrees of increased rotation of COP there was an increase of 1.0 mm pelvic obliquity and 1.4 degrees of pelvic torsion making a strong linear relationship between these two parameter of a person. This means torsion in pelvic region and the obliquity of the pelvis is directly affected by the placement of COP of the foot. The higher the degree of COP higher will be the chances of pelvic movement leading to torsion of the pelvic region. The rate of rise in pelvic obliquity is higher than the rate of rise in pelvic torsion with the rise in center of pressure. Up to COP of 2.5 the pelvic torsion and pelvic obliquity has same magnitude. However, at COP of 8.9 the pelvic obliquity is approx. 40% higher than pelvic torsion.

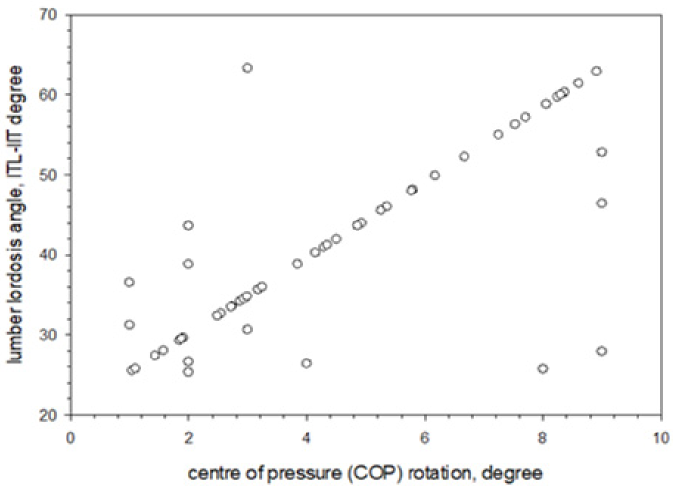

Figure 6: Variation of lumbar lordosis with center of pressure.

Figure 6 shows a relation between lumbar lordosis angle with COP in degrees. The graph shows how the degree of rotation of COP affects the lumbar lordosis angle. There was a linear growth of lumbar lordosis angle with the increase in degrees of COP of foot, that means with every degree of increased rotation of COP there was an increase of 4.7 degrees of lumbar lordosis angle making a strong linear relationship between these two parameters of a person. This means lumbar lordosis is directly affected by the placement of COP on foot. When the COP changes from 1 to 9 degree the rise in lumbar lordosis angle is 2.25 folds. The angle of curvature made by lumbar region of the spine is related by the foot placement of a person. With increase in the degree of COP higher will be the chances of having more curvature in the lumbar region of spine.

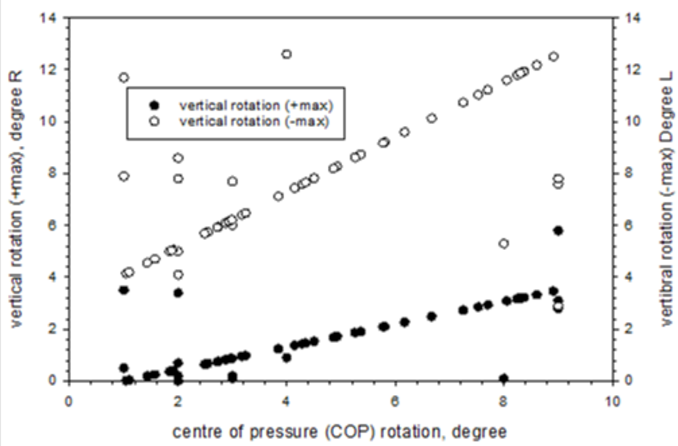

Figure 7: Variation of vertebral ratio with center of pressure.

Figure 7 shows a relation between left and right rotation of vertebrae in degrees with COP in degrees. The graph shows how degree of rotation of COP affects the rotation of vertebrae. There was a linear growth of Left and right rotation of vertebrae with an increase in degrees of COP of the foot, that means with every degree of increased rotation of COP there was an increase of 1.1 degrees of vertebral rotation on left and 0.44 degree of rotation on right side making a strong linear relationship between these two parameter of a person. Vertebral rotation for the left side is already more than the right side starting 4 degrees of rotation. This implies that the rotation of vertebrae in left side is more affected by COP than the right side of vertebral rotation. The diverging characteristics lines indicates that with the rise in COP angle the gap between the right and left vertebral rotation increases up to 2.2 folds.

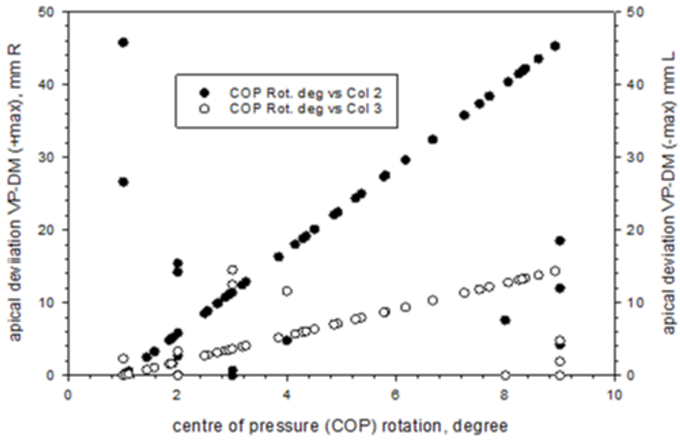

Figure 8: Variation of apical deviation with center of pressure.

Figure 8 shows a relation between left and right apical deviation in mm with COP in degrees. The graph shows how the degree of rotation of COP affects the apical deviation. There was a linear growth of left and right apical deviation with increase in degrees of COP of foot, that means with every degree of increased rotation of COP there was an increase of 5.6 mm of right apical deviation and 1.8 mm of left apical deviation making a strong linear relationship between these two parameter of a person. Apical deviation of the right side increased more than the left side with an increase in COP. For increase in center of pressure from 1 to 9 degrees the apical deviation is approximately 300 times more for the left side than the right side. This means that the deviation of spine from midline VP-DM was more in right side as compared to left side.

Figure 9 shows a relation between a sagittal imbalance in degrees with COP in degrees. The graph shows how the degree of rotation of COP affects the sagittal imbalance. There was a linear growth of sagittal imbalance with an increase in degrees of COP of the foot, which means with every degree of increased rotation of COP there was an increase of 0.7 degrees of sagittal imbalance making a strong linear relationship between these two parameters of a person.

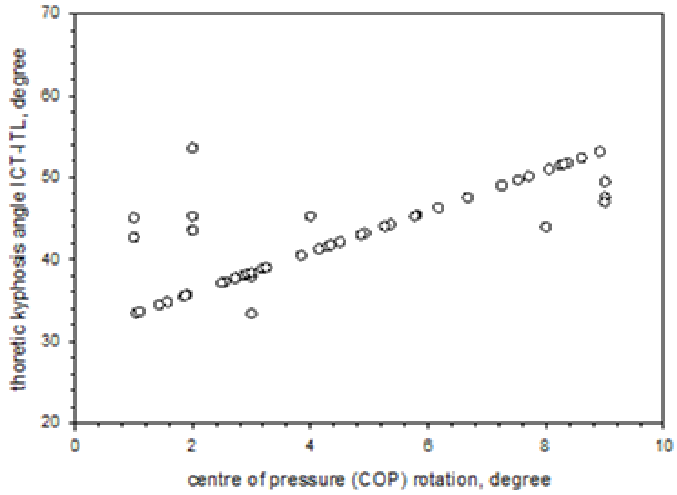

Figure 9: Variation of sagittal imbalance with center of pressure.

Apical deviation of right side increased more than the left side with an increase in COP. This means that the deviation of the spine from midline VP-DM was more in the right side as compared to the left side. From the graph it can be seen that the spine moves in the positive direction from the mean line VP-DP thus affecting the posture of the spine. The movement of the spine away in the positive direction from mid line affects the spine, which leads to various spine disorders.

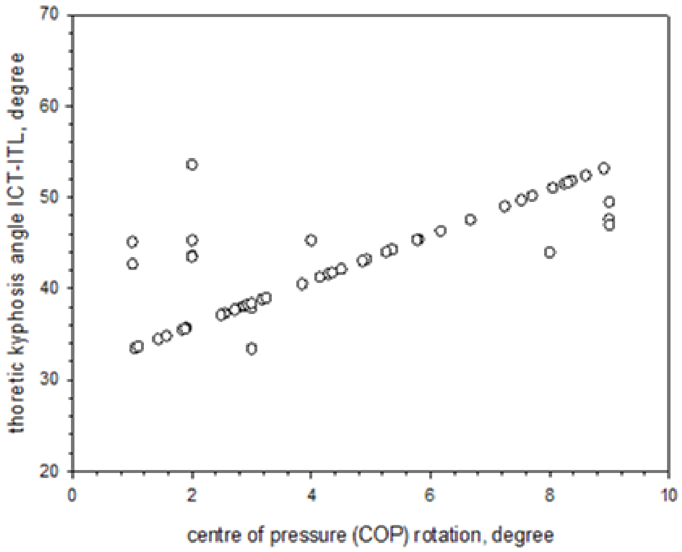

Figure 10: Variation of sagittal imbalance with center of pressure.

Figure 10 shows a relation between thoracic kyphosis angle in degrees with COP in degrees. The graph shows how the degree of rotation of COP affects the angle made by the thoracic region, i.e. angle between T1 and T12. There was a linear growth of thoracic kyphosis angle with the increase in degrees of COP of foot, that means with every degree of increased rotation of COP there was an increase of 2.5 degrees of thoracic kyphosis angle making a strong linear relation between these two parameters of a person. The angle between T1-12 kept on increasing leading to unwanted spine posture which affects the posture of a person. As the angle made by the thoracic region increases the curvature of thoracic area also increase.

Conclusion

The objective of this research was to see if there was a link between certain spine parameters and physical characteristics of subjects. A high relationship existed between COP and every spinal measurement and between COP and plantar pressure was establish.

- It was observed that many spine parameters were interconnected, which means even a small deviation in any parameter can cause problem in spinal region.
- It can be concluded that COP of a person plays an important role in determining the spinal disorders, because due to high COP the spine starts deviating from the mid line VP-DM thus leading to issues like unnecessary rotation of spine in left and right direction, torsion of pelvic region was also observed due to the increased degree of COP.
- The pressure applied by foot did not show any relation with BMI of a person, thus proving that person lying in range from healthy or overweight category doesn't show much variation in foot pressure pattern.
- Most of the spine parameters were linearly related to COP of a person, indicating that the angle at which COP is applied affects the placement of spine parameters causing various spine disorders.
- The COP placement in foot also affects the angle made by spine in thoracic region from T1-T12 and lumbar region from L1-L5, which lead to issues like lumbar lordosis and thoracic kyphosis.

Declaration of competing interest

The authors state that they have no known personal ties or conflicting financial interests that could have influenced the results of this study.

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Limitations

This study was only limited to a sample size Indian origin fifty-five subjects, between the ages of 18 and 25. There was lack of knee rotation, subtalar inversion and eversion, talocrural rotation and leg length discrepancy analysis report.

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