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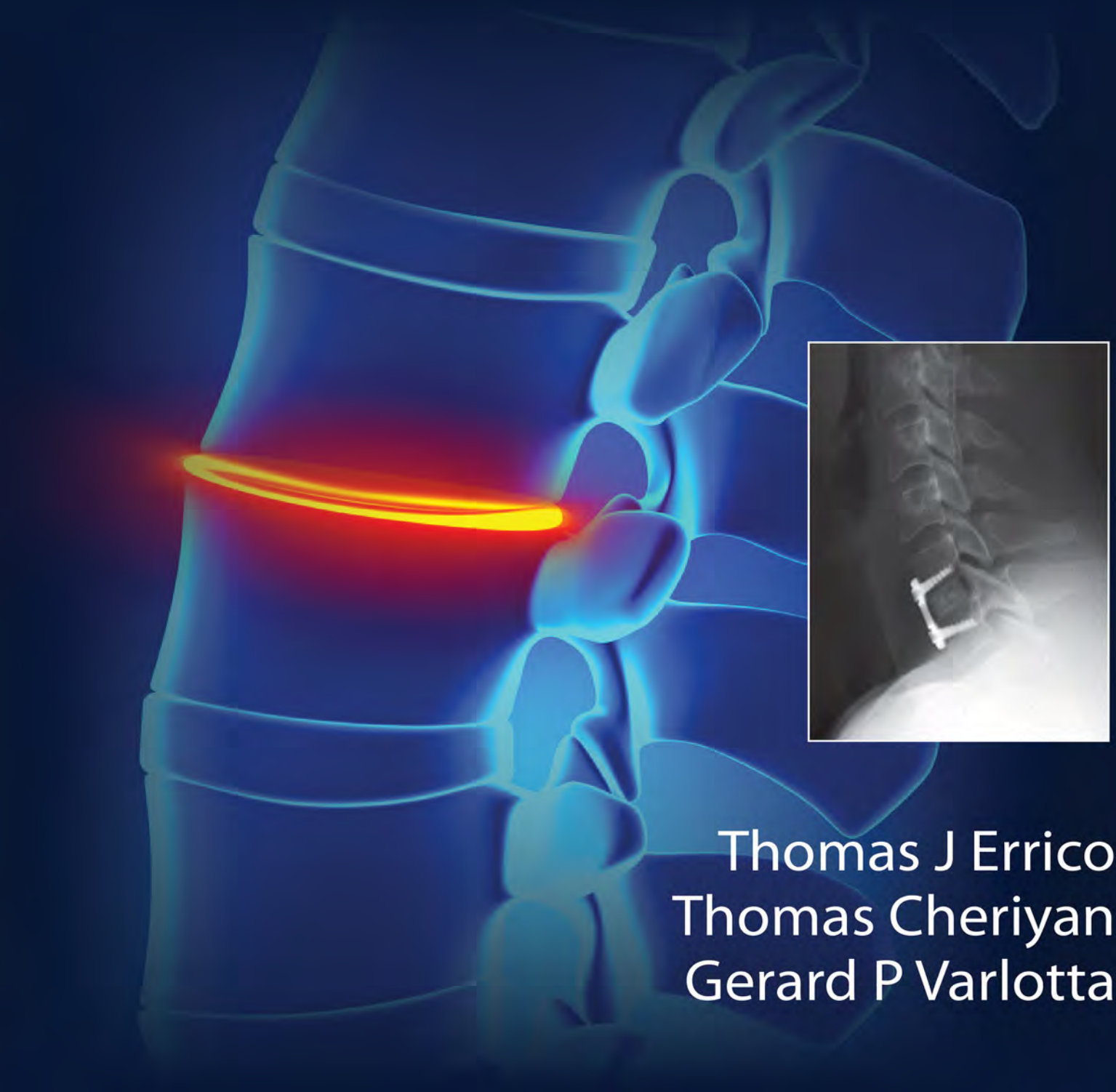
Spinal Disorders & Treatments

The NYU-HJD Comprehensive Textbook



Thomas J Errico
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CHAPTER

3

Balance, Posture and Stability in Spinal Disorders

Virginie Lafage, Barthelemy Liabaud, Frank Schwab, Jean-Pierre Farcy

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INTRODUCTION

A comprehensive understanding of spinal disorders demands an appropriate interpretation of a patient's symptomatology within the landscape of the patient's functional domain. Pain and decreased ability become most symptomatic when a patient loses his or her ability to perform activities of daily living (ADLs). ADLs require the most basic of human functions: standing, balance and stability.

Balance and stability represent a more dynamic understanding of patient's dysfunction. Some patients remain functional despite observed local or regional deformity. While these patients have pathologic entities, they are capable of compensation by altering their alignment in attempts to increase their stability. Other patients have significant deformity that they may have tolerated for decades, but then, rather quickly, lose their compensatory mechanisms.

A better understanding of the vital role of pelvic parameters and the static interrelationship of these parameters in predicting the fate of multiple spinal disorders has been elucidated from research done in the past few decades. When a patient presents with back pain, spine specialists see the end result of a failed mechanism. A good understanding of the complex interplay of muscle, fascia, joint mechanics, vestibular and somatosensory systems will help better predict which spinal deformities will ultimately benefit from surgical intervention.

Subsequent chapters address specific normal parameters of regions of the spine and the examination of deformities. This chapter reviews the concepts of the spinal parameters with the juxtaspinal regions such as the pelvis, and lower extremities for a clear understanding of the interplay of a balanced spine and its role in posture, leading to balance and stability. The complexity of standing and the definitions of balance, stability, and posture as well as novel ways of assessing the spinal influences of maintaining this equilibrium will be discussed.

BALANCE, STABILITY AND POSTURE

The understanding and analysis of human standing is quite complex. Balance, posture, and stability are some of the terms used to describe this state; each representing a distinct aspect. Balance is a state of equilibrium. Stability is the state or quality of maintaining equilibrium and self-restoring as needed. Posture is the relative disposition of the parts of the body (Fig. 3.1).

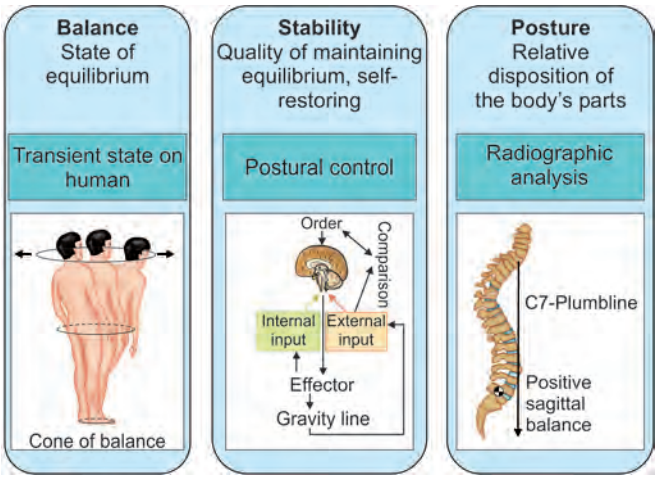

Fig. 3.1: Balance, stability and posture.

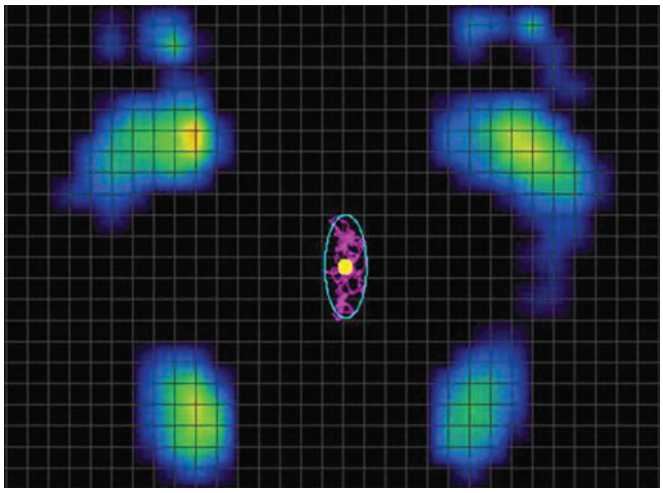

Fig. 3.2: An example of a stabilometry platform localizing the center of pressure. The graph obtained from this stabilometry platform can help the clinician to quantify the subject stability and also may permit the characterization of the postural control system (speed and acceleration of the COP travel, surface covered by the COP).

Balance and Stability

In stance, the body is submitted to the force of gravity and to the ground reaction. These forces are, respectively, applied on the center of mass (COM) and center of pressure (COP). As defined by Brisson[1] in 1803, ''[In a state of equilibrium ...] the body is positioned between two aligned, equal and opposite forces''. In other words, the body is balanced only when the COM and the COP are aligned on the same vertical line. Standing itself may be classified as a simple activity, but maintenance of balance, posture and stability requires a rapid processing of signals from the visual, vestibular, and somatic systems[2] (Fig. 3.1).

Because our body is made of different moving parts all leading to a dynamic COM, this perfect alignment is almost never reached. And as soon as the COM is not aligned with the COP, a moment is created that would cause the body to fall in the absence of a sophisticated control system (nervous system and muscles). In order to stay as close as possible to a state of balance, two stabilization mechanisms, which have been described by Gagey et al.,[3] come into play: the COM maneuver and the COP maneuver depending on whether the COM or COP is mobilized to reach the balance state. In the COM maneuver, the body parts are moved in space in order to localize the COM above the COP. In the COP maneuver, the feet pressures are adjusted in such a way to bring the COP below the COM. Both maneuvers help in maintaining the standing position.

Historically, the first measurement device for human posture was proposed by Vierordt[4] in 1860. A quill was placed on the head of a subject to record the body sways on a piece of paper. Evolution of technology and understanding of balance has lead to current devices, which precisely quantify the standing stability. This group of devices is called stabilometry platforms. These platforms measure, for a given sampling rate, the location of the COP (i.e. the ground reaction, Figure 3.2). In a dynamic condition, the COP does not coincide with the projection on the gravity line (GL). It has been demonstrated[5-7] that the signal measured may be dissociated in two components: a controlled slow sway that represents the motion of the COM and a noncontrolled quick sway around the GL projection that represents the displacement of the COP around the projected GL.

Posture

In the context of an orthopedics evaluation, X-ray images are the most common way to quantify a subject's posture. Although radiographs permit an evaluation of vertebral alignment and pelvic landmarks, current standard techniques using 36-inch cassettes only offer a limited view and do not capture foot position or the global alignment of a person in space.

The authors of the chapter combined the technology of full-length radiographs with force plate acquisition to further improve our understanding of human standing sagittal alignment.[8] This technique presents not only the advantages of a standard radiographic analysis but also offer the ability to investigate the relative location of the body parts in regard to the GL and to the feet location (Fig. 3.3).

Based on the hypothesis that the mean location of the COP is a good estimation of the projected GL on the floor in the neutral (static) standing position,[9] the compensatory mechanisms required to maintain a standing posture in the setting of age-related changes and spinal deformity were investigated and are summarized hereafter.

How Does New Technology Help us in to Better Assess Patients with Spinal Deformity?

Age-related Changes

The aging process and deformity of the spinal column can lead to altered sagittal plane alignment. Despite the expanded use of radiographic parameters, optimal

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spinal alignment remains currently poorly defined. However, a number of radiographic parameters have been developed as guides of sagittal alignment. Values of thoracic kyphosis by Cobb measurements and lumbar lordosis are commonly used to measure regional alignment. Global spinal alignment is commonly assessed by the plumb line method drawn onto full-length radiographs.[10-13] The plumb line represents a common and convenient visual display of apparent sagittal plane alignment but its value as a marker of true postural balance has been questioned.[14] Even though radiographs can capture the alignment of osseous structures, they do not place them in relation to the distribution of forces and do not capture the association to position of the feet in a standing subject.[8] More recently pelvic parameters have been examined in order to improve the evaluation of sagittal plane alignment.[15-17]

While numerous teams have investigated age-related changes in asymptomatic subjects based on radiographic measurements, little is known regarding the overall posture adopted by those aging subjects. Through force plate analysis, foot position and transmission of forces across the feet can be analyzed. The center of these recorded pressures on a force plate, in the still standing position, reflects the projected center of gravity (GL). This GL may enhance our understanding of spinopelvic alignment in patients with spinal deformity. As Dubousset has noted in the "cone of economy" concept, ideal balance, and lowest energy use is noted in a state of minimal displacement of the entire body GL over the feet. Through an analysis of pelvic and spinal column offsets from the projected GL (and foot position), norms of alignment in a healthy population can be established, and pathologic states of spinal deformity can be studied in reference to such a benchmark population.[8] By combining force plate technology and standard radiographic analysis, it has been demonstrated that radiographic changes (with age, the trunk tilts forward) are compensated by a posterior translation of the pelvis. This basic mechanism allows for maintenance of a fixed offset between the GL and the heels, independently of the subject age[8] (Figs. 3.4A to C).

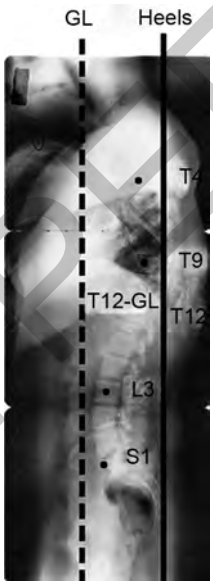

Fig. 3.3: Projection of anatomical landmarks, gravity line (GL, dotted line), and heel line on digital X-rays. The gravity line and heels line are projected on each X-ray to evaluate offsets between these lines and radiological landmarks.

Global head-to-feet analysis brings to light the limitation of standard X-rays and the interest of the EOS system and/or force plate that would allow a better understanding of the role of the lower extremity in the setting of spinopelvic alignment.

Spinal Deformity

Lafage et al.[18] evaluated the impact of sagittal vertebral axis (SVA) offset on GL, pelvic parameters and spinopelvic position relative to the feet in standing subjects. The SVA is the distance from a plumb line drawn from C7 and the posterosuperior corner of S1. An offset > 2.5 cm anteriorly or posteriorly is considered beyond the normal range.[12]

By using varying SVA values, three distinct groups were created (neutral, sagittal backward, and sagittal forward). Significant differences between groups were noted for a number of radiographic and GL parameters. Increasing SVA leads to a posterior pelvic shift in relation to the feet. Increasing pelvic incidence was also noted in the sagittal forward displaced SVA group. However, no significant difference in the GL-heels offset (GHO) was noted across subject groups (Figs. 3.5A to C). It appears that pelvic shift is a key component in maintaining a fixed GHO even in the setting of a variable SVA and trunk inclination. This study highlights the role of the pelvis as a compensatory mechanism (translation and rotation).[18]

Findings related to the higher pelvic incidence in the setting of sagittal deformity raise the question of whether pelvic morphology can predispose a patient to sagittal plane malalignment, whether changes can occur in the sacral endplate or, as suggested by Skalli et al., sagittal malalignment can lead to compensatory motion in the sacroiliac joint.[19] Lafage et al. findings were consistent with

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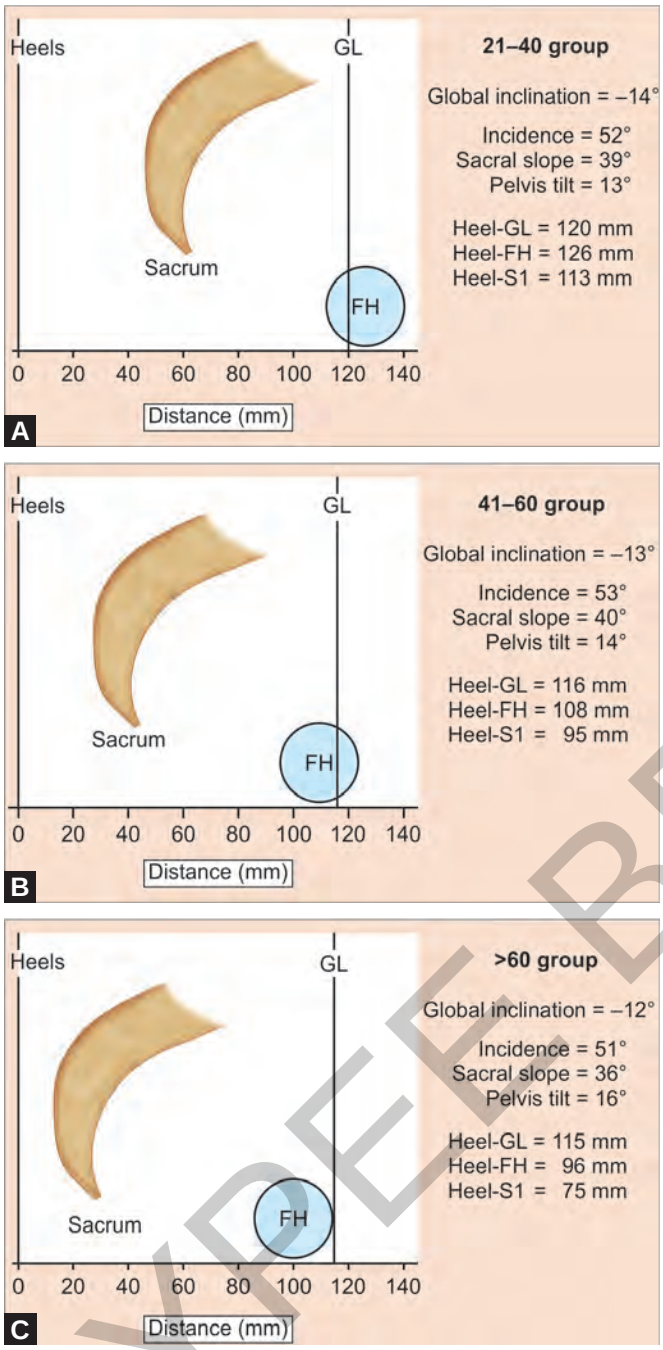
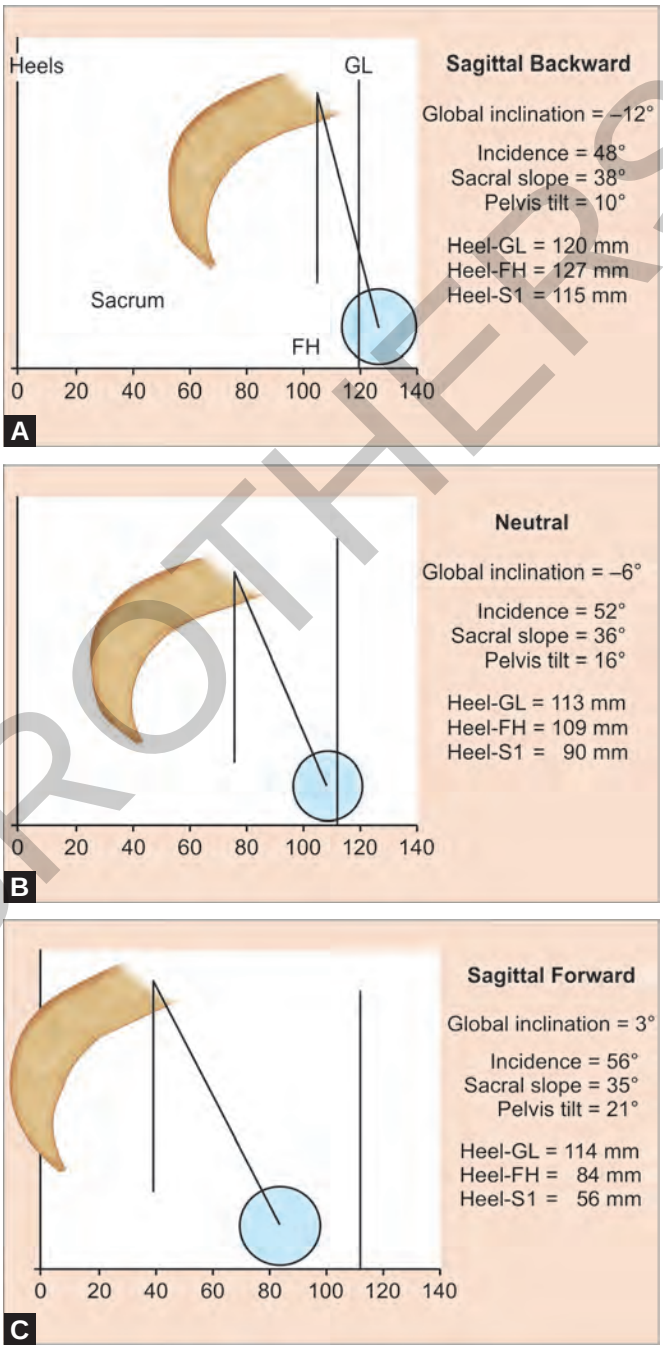


Figs. 3.4A to C: Relative locations of the pelvis [femoral heads (FH) and sacrum] in regard to the gravity line (GL) and heel line. This comparison of age-related changes in asymptomatic subjects illustrates the posterior translation of the pelvis with advance age and the rather fixed offset between gravity lines and heal line.



Figs. 3.5A to C: Relative locations of the pelvis, FH (femoral head), GL (gravity line), and heel line.

those studies focusing on adult asymptomatic population,[8] meaning the same global mechanisms of compensation can take place in both asymptomatic and symptomatic populations.

It appears that even wide variations in SVA can be tolerated so long as compensatory mechanisms come into play to maintain standing alignment. It is evident from the data in Lafage et al.'s study that the role of the lower extremities and pelvis are critical in understanding spino-pelvic posture as well as malalignment observed in pathologic states. As SVA offset increased, a

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posterior shift of the pelvis occurred. This would require a change in the degree of hip flexion or extension given the noted posterior translation of the pelvis in relation to the feet with increasing SVA offset. Furthermore, changes in knee and ankle joint positioning may affect the GL relationship to the feet.

CONCLUSION

The understanding of optimal balance and its application in the treatment of patients suffering from spinal deformity is complex and not yet fully understood. While imaging methods offer structural analyses of the vertebral column, the ability to evaluate spinal balance is limited. Force plate analysis may be used to analyze the distribution of forces across the feet and to estimate the GL, which may enhance our understanding of balance in deformity patients. Norms of balance in a healthy population should be established by assessing pelvic and spinal column offsets from the projected GL. Establishing healthy balance guidelines may improve the identification and treatment of pathogenic spinal deformities. The establishment of the relationship between truncal inclination (quantified by the SVA) and pelvis translation highlight that changes in knee and ankle joint position may affect the GL relationship to the feet, and reinforce the importance of a full-body evaluation when assessing the sagittal deformity of the spine.

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