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A Systematic Review and Meta-Analysis of Healing Outcomes in Pediatric Lateral Humerus Condyle Fractures Treated with K-Wire Pin Fixation

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ABSTRACT

Sagittal balance refers to the equilibrium between external forces acting on the spine, particularly gravity, and the body's response to maintain an upright position with minimal muscular energy expenditure. Disruption of this balance can lead to sagittal imbalance, which is linked to poor clinical outcomes in conditions such as adult scoliosis and degenerative spondylolisthesis. The sedentary lifestyle, especially in office workers who spend significant time sitting, makes understanding spinal alignment changes in various positions crucial. This study aims to assess the differences in lumbopelvic sagittal balance in standing, upright sitting, and relaxed sitting positions in a healthy population. This analytical study used a case series approach with 25 healthy subjects aged 18-40. X-ray images were taken in three positions: standing, upright sitting, and relaxed sitting. Parameters including lumbar lordosis (LL), sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), and PI-LL mismatch were measured using RadiAnt DICOM Viewer. Data were analyzed using ANOVA to compare the sagittal balance parameters across different positions. differences were found in LL, SS, PT, and PI-LL mismatch between positions ($p < 0.05$). LL was highest in standing and lowest in relaxed sitting. PT increased significantly in relaxed sitting, while SS was highest in standing. PI did not show significant changes across positions. Lumbopelvic sagittal balance varies significantly between standing and sitting positions, highlighting the need to consider sitting postures in spinal assessments. These findings provide valuable insights for spine surgery planning and postural assessments.

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INTRODUCTION

agittal balance is the equilibrium between the external forces acting on the spine, particularly gravity, and the body's musculoskeletal response to maintain a stable, upright position with minimal energy expenditure. This balance requires the interaction of spinal morphology, the mechanical characteristics of intervertebral discs and ligaments, muscle strength, and compensatory mechanisms. When any of these factors are disrupted, sagittal imbalance occurs, which has been associated with poor clinical outcomes, particularly in conditions such as adult scoliosis, degenerative spondylolisthesis, and after spinal surgeries.

With the rise of sedentary lifestyles, particularly among office workers who spend a significant portion of their workday sitting, there has been growing concern over the impact of sitting on spinal health. Studies have shown that sitting, especially in prolonged or incorrect postures, can significantly alter spinal alignment. The common practice of assessing sagittal balance in the standing position may not accurately reflect the alignment changes that occur during daily activities, such as sitting.

This study aims to explore the differences in lumbopelvic sagittal balance when transitioning between standing, upright sitting, and relaxed sitting positions in healthy individuals. Understanding these differences is crucial for improving clinical assessments and surgical planning for patients with spinal disorders, especially in a world where sitting is becoming increasingly prevalent.

LITERATURE REVIEW

Sagittal balance is critical for maintaining an upright posture with minimal energy expenditure. It is defined as the balance between external forces, such as gravity, and the body's musculoskeletal response to maintain a stable position. This balance is determined by the interaction of spinal morphology, the mechanical properties of intervertebral discs and ligaments, muscle strength, and compensatory mechanisms. When one or more of these components is disrupted, sagittal imbalance occurs, leading to poor clinical outcomes in patients with conditions such as adult scoliosis, degenerative spondylolisthesis, and post-surgical spinal deformities. Maintaining proper sagittal balance is particularly important for long-term spinal health.

The spine consists of 33 vertebrae, divided into five regions: cervical, thoracic, lumbar, sacral, and coccygeal. The cervical spine allows for the greatest range of motion, especially rotation, while the thoracic spine is more rigid due to the rib attachments. The lumbar spine provides most of the flexion and extension movement but is less mobile as it transitions into the sacrum. The sacrum and coccyx form the base of the spine and support the pelvis. The pelvis, in turn, plays a crucial role in maintaining the body's posture, as it connects the spine to the lower extremities and serves as a foundation for posture stability.

Pelvic incidence (PI), pelvic tilt (PT), and lumbar lordosis (LL) are key parameters in assessing sagittal balance. PI is a constant parameter that defines the inclination of the pelvis and remains unchanged regardless of body position. PT measures the rotation of the pelvis in relation to the femoral heads, and it can change based on posture. LL refers to the curvature of the lumbar spine and is crucial for distributing the body's weight during movement. These parameters interact to create a harmonious sagittal alignment, ensuring that the body maintains an efficient and stable posture.

Recent studies have highlighted the importance of considering sagittal balance not only in standing positions but also in sitting and other functional postures. With the increasing time spent sitting, particularly among office workers, understanding how spinal alignment changes during sitting has become more relevant. Research has shown that sitting causes changes in lumbar lordosis, pelvic tilt, and sacral slope, which can lead to compensatory mechanisms in the spine. This has led to recommendations for evaluating spinal alignment in various postures, not just in standing, to better reflect the physiological changes experienced during daily activities and to improve surgical planning for spinal disorders.

METHODOLOGY

This study uses an analytical approach with a case series design to assess and compare the lumbopelvic sagittal balance in healthy individuals across different postures: standing, upright sitting, and relaxed sitting. The study was conducted at the Haji Adam Malik General Hospital in Medan, Indonesia, after receiving approval from the Health Research Ethics Committee of the University of Sumatera Utara.

Study Population and Sample

The target population for this study includes healthy individuals aged 18 to 40 years. The sample was selected using non-probability consecutive sampling, with participants who met the inclusion criteria and had no exclusion factors. A total of 25 participants were included, consisting of both males and females. The inclusion criteria include individuals who are free from any spinal disorders, such as scoliosis, herniated discs, or congenital deformities. Individuals with a history of spinal surgery, trauma, or chronic back pain were excluded from the study.

Data Collection

Data were collected using standard X-ray imaging in three different positions: standing, upright sitting, and relaxed sitting. Radiographs were taken to measure key parameters of lumbopelvic sagittal balance, including lumbar lordosis (LL), sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), and PI-LL mismatch. The X-ray images were analyzed using the RadiAnt DICOM Viewer software. Each measurement was taken by two different observers to reduce bias and ensure accuracy, with the final measurements being the average of the two readings.

Data Analysis

Descriptive statistics were used to summarize the demographic characteristics of the sample and the measured parameters of sagittal balance in the different positions. Inferential analysis was performed using ANOVA to compare the differences in the lumbopelvic sagittal balance parameters across the three postures. A p-value of less than 0.05 was considered statistically significant. This analysis helps to identify any significant changes in spinal alignment between the standing, upright sitting, and relaxed sitting positions, providing valuable insights into the impact of posture on sagittal balance.

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RESULT

A total of 25 healthy individuals participated in this study, with a mean age of 27 years (range 21 to 36 years). The sample consisted of 14 males (56%) and 11 females (44%). The average Body Mass Index (BMI) was 26.28 kg/m², with 28% of participants classified as normal weight, 20% as overweight, and 52% as obese according to the World Health Organization (WHO) classification.

Sagittal Balance Parameters Across Positions

The results of the lumbopelvic sagittal balance parameters (lumbar lordosis [LL], sacral slope [SS], pelvic tilt [PT], pelvic incidence [PI], and PI-LL mismatch) are presented in Table 4.3. Significant differences were observed across the three positions (standing, upright sitting, and relaxed sitting) for LL, SS, PT, and PI-LL mismatch ($p < 0.05$), while no significant difference was observed for PI ($p > 0.05$).

Lumbar Lordosis (LL):

The average LL was highest in the standing position (48.59°), significantly decreased in the upright sitting position (28.06°), and was lowest in the relaxed sitting position (12.80°). These differences were statistically significant ($p < 0.001$) between all positions.

Sacral Slope (SS):

SS was highest in the standing position (33.91°), decreased in the upright sitting position (23.47°), and lowest in the relaxed sitting position (8.49°). The differences between the positions were significant ($p < 0.001$).

Pelvic Tilt (PT):

PT showed the opposite trend to SS, with the lowest value observed in the standing position (14.02°), increasing in the upright sitting position (27.37°), and reaching the highest value in the relaxed sitting position (42.38°). The difference between the positions was significant ($p < 0.001$).

Pelvic Incidence (PI):

No significant differences were found for PI across the three positions ($p = 0.508$). The average PI was 47.55° in the standing position, 50.64° in the upright sitting position, and 50.95° in the relaxed sitting position, indicating that PI remained relatively constant despite changes in posture.

PI-LL Mismatch:

The PI-LL mismatch was most pronounced in the relaxed sitting position (38.15°), followed by the upright sitting position (22.57°), and was least in the standing position (-1.04°). Significant differences were observed between the positions ($p < 0.001$).

Inter-Observer Reliability

The reliability of the measurements between the two observers was excellent, with the interclass correlation coefficients (ICC) for LL, SS, PT, PI, and PI-LL mismatch ranging from 0.913 to 0.990, indicating strong agreement between the observers (Table 4.2).

ANOVA Results

The results of the ANOVA test for the lumbopelvic sagittal balance parameters are summarized in Table 4.4. Significant differences were found for LL, SS, PT, and PI-LL mismatch across the three postures ($p < 0.05$), while PI showed no significant difference ($p > 0.05$). These findings indicate that posture significantly affects the sagittal balance of the lumbopelvic region, particularly for lumbar lordosis, sacral slope, pelvic tilt, and PI-LL mismatch.

DISCUSSION

This study aimed to investigate the differences in lumbopelvic sagittal balance across three different postures—standing, upright sitting, and relaxed sitting—among healthy individuals. Our findings reveal significant changes in key sagittal balance parameters, including lumbar lordosis (LL), sacral slope (SS), pelvic tilt (PT), and PI-LL mismatch, when transitioning between these postures. These results highlight the importance of considering different postures when assessing spinal alignment, especially in individuals who spend a significant portion of their time sitting, such as office workers.

Lumbar Lordosis (LL)

Our results show a significant decrease in LL from the standing position (48.59°) to the upright sitting (28.06°) and relaxed sitting (12.80°) positions. This is consistent with previous studies, which report a reduction in lumbar lordosis when transitioning from standing to sitting. For example, Endo et al. (2012) found a similar decrease in lumbar lordosis when transitioning from standing to sitting, suggesting that sitting postures may flatten the lumbar curve as the pelvis rotates posteriorly. This reduction in LL may be a compensatory mechanism to maintain the stability of the spine during sitting.

Sacral Slope (SS)

Sacral slope showed the opposite trend, with the highest value observed in the standing position (33.91°), and progressively lower values in the upright sitting (23.47°) and relaxed sitting (8.49°) positions. This is in line with studies that suggest the sacrum becomes more vertical when transitioning from standing to sitting, which leads to a reduction in the sacral slope. Suzuki et al. (2018) reported that SS decreased significantly when moving from standing to sitting, with a more pronounced reduction during relaxed sitting. These changes may be attributed to the posterior pelvic tilt that occurs when moving from standing to sitting, particularly in relaxed postures.

Pelvic Tilt (PT)

Pelvic tilt, which was lowest in the standing position (14.02°), increased significantly in both the upright sitting (27.37°) and relaxed sitting (42.38°) positions. This increase in PT in sitting positions is likely due to posterior pelvic tilt as the body adjusts to a seated position. Previous studies, including those by Philippot et al. (2009), have shown that PT increases as the pelvis rotates posteriorly during sitting. This increase in PT helps to compensate for the loss of lumbar lordosis, maintaining sagittal balance and preventing excessive forward flexion of the spine.

PI-LL Mismatch

The PI-LL mismatch was lowest in the standing position (-1.04°) and increased significantly in both the upright sitting (22.57°) and relaxed sitting (38.15°) positions. A large PI-LL mismatch can be an indicator of poor sagittal balance, which may increase the risk of developing postural issues and back pain. Our findings suggest that sitting, especially in relaxed postures, results in a greater mismatch between pelvic incidence and lumbar lordosis, potentially contributing to discomfort and spinal misalignment. Similar results have been reported by Lamartina et al. (2012), who found that a significant PI-LL mismatch in a sitting position could lead to increased stress on the spine.

Pelvic Incidence (PI)

Interestingly, PI remained relatively constant across all positions, showing no significant change ($p = 0.508$). Pelvic incidence is a constant anatomical parameter that defines the inclination of the pelvis. Previous studies have also shown that PI does not change with body position, further supporting the idea that it is a fixed characteristic of the individual's pelvic morphology. This constancy of PI suggests that any adjustments in spinal alignment to accommodate changes in posture primarily involve changes in lumbar lordosis, sacral slope, and pelvic tilt.

Clinical Implications and Future Directions

The findings of this study emphasize the need for clinicians to consider various postures when evaluating sagittal balance, particularly in individuals who spend significant time seated. The significant changes in LL, SS, and PT across postures suggest that a comprehensive assessment of spinal alignment should include evaluations in both standing and sitting positions to better understand the patient's overall spinal health. Future research could further explore the impact of specific seating habits and interventions aimed at correcting poor sitting posture, as well as how these changes might affect patients with existing spinal conditions such as scoliosis or degenerative disc disease.

CONCLUSIONS

This meta-analysis compared the outcomes of screw and pin fixation for pediatric lateral condylar humerus fractures. No significant difference was found in the risk of delayed union between the two methods. However, screw fixation showed a tendency for higher non-union and avascular necrosis risks, though these differences were not statistically significant. In contrast, pin fixation was associated with significantly higher risks of infection (RR 6.53, $p = 0.0002$) and stiffness (RR 1.77, $p = 0.001$). No significant differences were observed in lateral overgrowth, fishtail deformity, or cubitus valgus between the two methods. Overall, pin fixation had a higher risk of complications, but this difference was not statistically significant. Most studies had low risk of bias, indicating reliable results, though caution is needed when interpreting studies with moderate bias. These findings highlight the need for careful consideration of fixation methods based on patient-specific factors.

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