The apical vertebrae in mild scoliotic spines are subject to extremum weight moments

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Introduction

Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional deformity of the spine. The aetiopathogenesis for AIS is multifactorial and undetermined [1]. The weight of the upperbody segments on the spine can generate lateral bending moments which can potentially exacerbate the deformity during growth [2]. Keenan et al. (2015) showed that the lateral bending moment is maximum at the apical vertebra of Lenke1 scoliosis patients which was expected [2].

Methods

We utilized a recently developed and validated thoracolumbar musculoskeletal model in AnyBody modelling system [3,4] to simulate 13 patient-specific mild AIS cases [5] (average cobb angle = 16), which included 6 lumbar, 5 thoracic, and 2 thoracolumbar major curves. The AIS spines comprise 13 major and 8 minor curve apexes. The apex of a scoliotic spine is the vertebra with the farthest deviation from the midline of the vertebral column.

The weight moment (M_w) applied on each intervertebral joint was calculated in its horizontal cross-section (Figure 1. Left). The vertebral level with regional minimum and maximum of absolute values of M_w in the spine were selected and compared to the apical levels for each case.

Results and Discussion

Including all the major and minor curves, the weight moment on apexes was extremum in 95% of the cases.The regional maximum of M_w occurred at the apexes with the prevalence of 67%. The regional minimum happened in 28% of the cases in which the C7 vertebra had moved towards the major curve apex of a double curve spine. In scoliotic deformities, the center of mass deviates from the midline, and in order to maintain stability, C7 strays to either side of the midline. The translation of the C7 vertebra relative to the sacrum along the horizontal axis describes the coronal spinal balance. We speculated that C7 had laterally moved towards the major curve apex, which by definition is the most deviated vertebra, to reduce the high moment arm and consequently decrease the high values of M_w on the major curve apexes. C7 deviated towards the major curve apex in 85% of the cases. Speculating further, after the primary deformation is developed, the spine tends to reduce the unusual lateral bending moments by deviating C7 towards the primary curve apex. This potentially creates another convex and as the C7 gets closer to the major apex and further from the new minor apex, the weight moment increases on the minor apex, causing a vicious cycle.

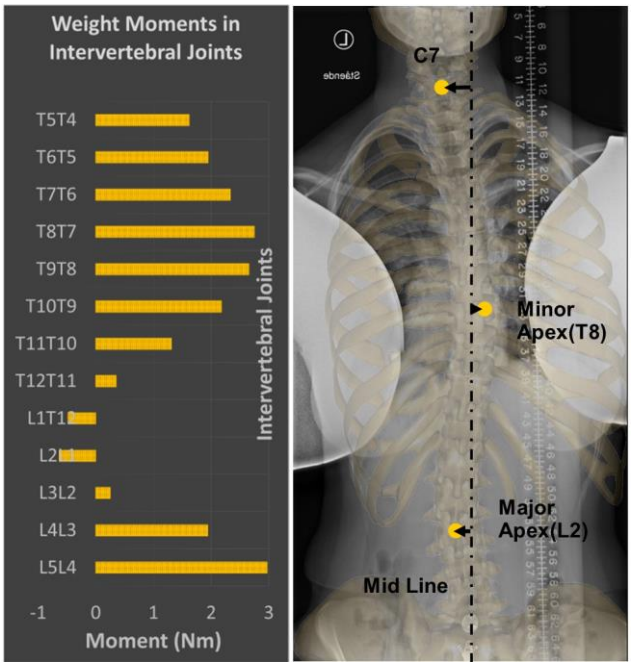

Figure 1: *Left:* The weight moment on intervertebral joints along the spine (N.m) for a patient. The moment is maximum at T8 (minor curve apex) and minimum at L2 (major curve apex). *Right:* Model projection on the radiograph of a patient. The C7 is laterally deviated towards the major curve apex and away from the minor curve apex.

Conclusion

Unexpectedly, we found that the weight moment on the apex of the AIS deformity was minimum in some of the cases, which happened due to the C7 lateral deviation towards the major curve apex. This finding indicates that the C7 moves in the same direction as the major curve apex in a compensatory reaction, and this can end up as a vicious cycle. Increasing the modeled cases and acquiring knowledge about their deformity progression allows further investigation of these speculations.

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