MUSCLE ACTIVATION STRATEGIES AND SPINAL LOADING IN THE LUMBAR SPINE WITH SCOLIOSIS

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INTRODUCTION:

It is commonly assumed that a spine with scoliosis experiences greater loading on the concave side and that this asymmetrical loading causes asymmetrical growth and progression of the deformity in skeletally immature patients. However, neither the magnitude of the asymmetrical loading imposed on the spine as a function of the scoliosis curve, nor the resulting mechanically altered vertebral growth and disc remodeling have been quantified; this study addresses loading asymmetry. Direct measurement of the loading asymmetry in the spine during functional activities has not been attempted, because of the lack of instrumentation capable of providing this information in live humans with scoliosis. Therefore, mathematical modeling was used in this study to estimate lumbar spinal loading.

The goals of this study were: (1) to find the plausible magnitude of the spinal loading asymmetry in the spine with scoliosis, (2) to find whether there are muscle strategies that can produce coronal-plane symmetrical loading of the spine, (3) to investigate the physiological costs of these different strategies in terms of muscle forces and the spinal loading.

METHODS:

Spinal loading in scoliosis was estimated by analytical modeling of the lumbar spine and its musculature with increasing degrees of spinal curvature, from 0° Cobb to 51° Cobb (Figure 1). It was assumed that muscle's force generating capacity was not altered by its altered length.

External loading was each of 3 +ve and -ve pure moments and each of 3 +ve and -ve pure forces acting at T-12, and the magnitude was either 50% or 75% of previously calculated maximum efforts found for the 51° Cobb geometry [1]. For each external loading, the muscle activation patterns (muscle force distributions) were determined by employing each of three cost functions in turn (representing three different muscle activation strategies) in an optimization model. The objectives were:

Strategy 1: minimize the sum of cubed muscle stresses only [2];
Strategy 2: minimize spinal asymmetrical load, i.e. no lateral offset of the resultant intervertebral force, similar to 'Follower load' [3];
Strategy 3: reverse the spinal load asymmetry at the curve apex (increased compression on convex side).

In all simulations, upper and lower bounds were placed on muscle stresses and intervertebral displacements according to physiologically plausible limiting values.

RESULTS:

All the maximum efforts were reduced for the spine with 51° Cobb scoliosis. The greatest reduction in effort was for the right axial rotation effort (effort reduced from 85 to 22 Nm), other reductions were 63% or less. Subsequent analyses were made for efforts that were 50% and 75% of the maximum efforts for the 51° Cobb configuration.

DISCUSSION:

We speculate that individuals with scoliosis can adopt different muscle activation strategies, and that these strategies may determine whether or not the spinal loading leads to progression of the scoliosis during growth. Muscle activation patterns generating spinal loading that do not promote curve progression during growth have a greater physiological ‘costs’.

REFERENCES:


Acknowledgement: Supported by NIH R01 AR 46543 and NIH R01 AR 44119.