Vertebral rotation estimation during gait in women with scoliosis using a 3D dynamic scanning system

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Summary

3D dynamic scans of 6 women with and without scoliosis were used to analyze the rotations of their vertebrae from C7 to L5 during level gait. This method was capable of distinguishing angular variations between subjects and groups at different vertebral levels, with accuracy comparable to state-of-the-art tools, and the added advantage of not needing physical markers to locate landmarks and being independent of the direction of motion or the subject's position.

Introduction

Radiography is considered the gold standard to assess spinal deformities. Surface topography (ST) is a non-ionizing alternative, which avoids radiation exposure when monitoring disease progression. However, ST also has some limitations: since it is based on the triangulation of a projected structured-light pattern on the back, certain clinical tests that imply motion in varying directions cannot be performed. Additionally, ST requires the manual identification of anatomical landmarks to construct the spinal model, which may introduce interobserver variability in the results.

This study presents a methodology to measure spine motion during gait using a 4D scanning system. This procedure is fully automatic and can be applied to any movement, overcoming the limitations of existing technologies.

Methods

6 female volunteers (3 with diagnosed scoliosis and 3 control) aged between 24 and 39 years were measured in 6 repetitions of level gait with Move4D [1], walking in alternate directions. The spinal midline was reconstructed at each instant through the topological analysis of the back surface, with anatomical landmarks approximated as vertices of the 3D mesh [2,3,4], and the positions and orientations of the vertebrae from C7 to L5 along the spine were estimated at each frame [4,5].

Vertebral lateral flexion (LF) and axial rotation (AR) were analyzed for 6 gait cycles of each subject [6]. Mean angles and angular ranges of motion (ROM) were compared to the between- and within-subjects variability, which was estimated by a linear mixed model using the group as fixed factor, and the subject identity as random effect.

Results and Discussion

The positions and orientations of all vertebrae were identifiable through the whole gait cycles, with consistent results for both walking directions. The variability between gait cycles (from 0.3º to 2.4º for mean angles, 0.4º to 3.3º for ROM) was smaller than the between subjects of the same group (0.5º to 9.8º for mean angles, 0.2º to 6.4º for ROM).

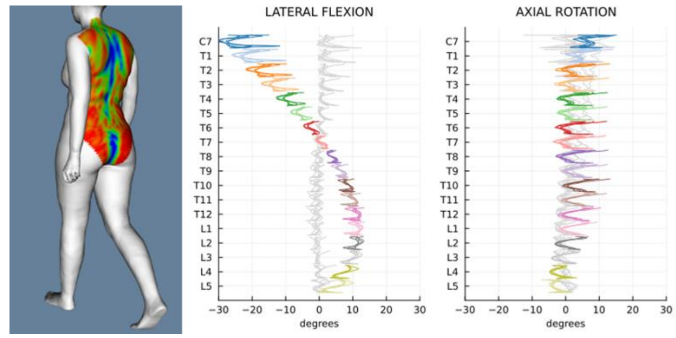

Figure 1: Left: 3D representation of back mean curvature [3] in gait. Right: examples of vertebral angle curves in gait [6], for a control subject (gray curves) and a subject with scoliosis (colored).

The only significant difference between groups was observed in the LF angle; the greatest difference was at the level of C7, (10.3º on average for the people with scoliosis vs. 0.5º for controls), with a tendency of lower vertebrae rotating in the opposite direction (Figure 1).

The angular ROM were the variables with greatest values; ROM varied from 4.6º on average at T7-T8 to 18.4º at C7 for LF; and from 6.4º at L4 to 22.1º at C7 for AR, without significant differences between groups.

Conclusions

This study used an approach similar to [6] to measure spine rotations in gait, during level walk instead of on treadmill, and involving patients with scoliosis. The method had sufficient precision to capture the differences between subjects, which were greater than within-subjects variability for all variables. The few differences found between groups (only in mean LF) are related to the relatively large ranges of motion, which were greater than the deviations observed in the sample of patients. This methodology does not require manual identification of anatomical landmarks and does not depend on the plane of motion, making it an efficient and objective tool for the modelling and analysis of spine motion.

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