Cross-correlation study of coupled motion in the lumbar spine during walking.

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Introduction

Since the pioneer work of Lovett in 1903 [1], it is generally assumed [1,2,3] that lumbar spine lateral bending is coupled with heterolateral rotation and *vice versa*. Authors [2,3] compared either the spinal column to a rubber rod or deduced physiological motion from pathological conditions as scoliosis. The latter approach can be criticised from an epistemological point of view. Several studies investigated coupling patterns during single plane motion [4-6]. Results are not always clear and consistent [7].

We investigated the coupled motion at lumbar level during walking. This study mainly consists in a re-interpretation of data from a previous presentation [8].

Methods

Twenty-two healthy volunteers walking on a treadmill at four walking velocities (0.8, 1.1, 1.4 and 1.7 m/s) participated (mean age: 34 years, range: 15 to 57 years, 9 females -13 males). They were allowed to practice on the treadmill in order to be acquainted with this way of walking. 3D motion between lower trunk and pelvis was tracked using an instrumented spatial linkage (CA 6000 Spine Motion Analyzer, USA) with 6 degrees of freedom. The linkage was fixed on the subject using a pelvic and a thoracic harness. Sampling rate was set to 100 Hz. Seven to 12 walking cycles were averaged.

Results

A phase lag exists between rotation and lateral bending (Figure 1). Cross-correlation analysis indicates two lags: 1) zero rotation follows zero lateral bending by 0.28 s (r=0.88); 2) next zero lateral bending follows zero rotation by 0.16s (r=0.89). The sum of both lags

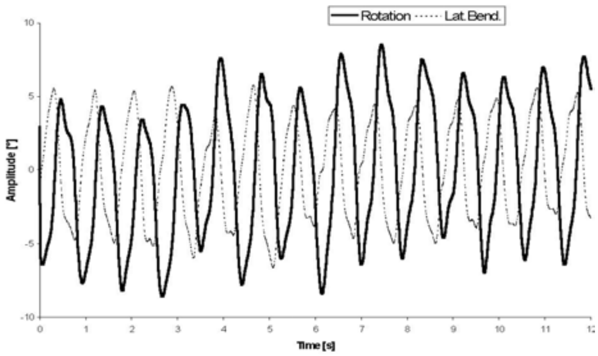

Figure 1: Typical recording at 1.7 m/s.

corresponds to half of the mean duration of a walking cycle. Another interpretation of these lags is shown in figure 2 together with the coupling pattern. This pattern changes four times over a walking cycle. The lags indicate the mean duration of each pattern. Figure 3 shows a schematic phase diagram at different velocities. As velocity influences stride duration, phase lags differ too.

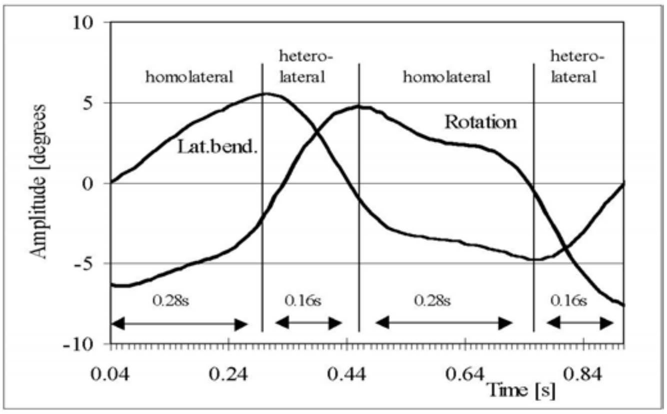

Figure 2: Phase lag and coupling pattern during one cycle.

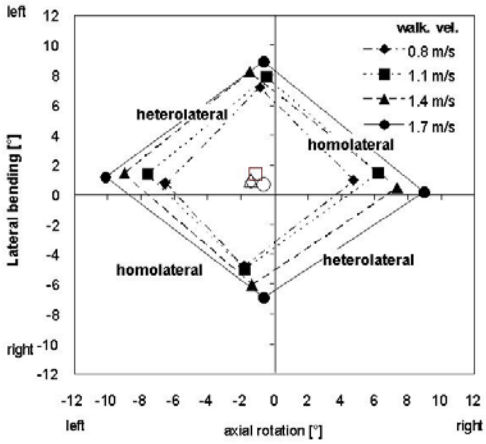

Figure 3: Phase diagram at different walking velocities.

Discussion and Conclusions

3D lumbar motion during walking was already analysed by similar studies [8,9]. To our knowledge, lumbar motion coupling was not yet investigated such as in the present study. This study shows good agreement with data concerning inter- and intra individual variations. While intra-individual differences are relatively low and are mainly a function of walking velocity, inter- individual differences are much greater.The present results suggest that during walking, the lumbar spine undergoes four changes in the coupling pattern between axial rotation and lateral bending. These findings are not in agreement with common adopted coupling patterns at this part of the spine. As one motion component is maximal when the other one is minimal, the stress on the spine is minimized.

References

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