Three-dimensional kinematics of the lumbar spine during treadmill walking at different speeds

V. Feipel[1], T. De Mesmaeker[1], P. Klein[2], M. Rooze[1]

[1]Laboratory for Functional Anatomy, [2]Research Unit on Manual Therapies, University of Brussels, Belgium.

Introduction

Walking is for humans one of the most natural activities. However, although it is well known that the lumbar spine is of primary importance in gait [1,2], little is known about the kinematical behaviour of the lumbar spine during this daily activity. The resultant forces on lumbar discs and facet joints during walking have been measured during gait [3,4]. In this study, three-dimensional motion of Th12 to the sacrum was sampled using a 3D electrogoniometer in 22 subjects walking on a treadmill at different walking speeds. In particular, the coupling between axial rotation and lateral bending was analysed.

Materials and methods

Twenty-two volunteers participated in this study. Their mean age was 34 years (range: 15 to 57 years). Nine were female and 13 males. Three-dimensional motion between the sacrum and Th12 was tracked using an instrumented spatial linkage (CA 6000 Spine Motion Analyzer, O.S.I., USA), with 6 degrees of freedom. The linkage was mounted on the subject using a pelvic and a thoracic harness. Sampling rate was set to 100 Hz. Global lumbar spine motion was sampled during elementary movements (flexion-extension, lateral bending and axial rotation of the trunk) and during walking on a motorised treadmill at 4 walking velocities (0.8, 1.1, 1.4 and 1.7 m/s). Seven to 10 walking cycles were averaged. The parameters considered were (1) maximal motion ranges (ROM) in each plane, (2) coupling of lateral bending and rotation, (3) peak motion velocities in each plane.

Results

Average sagittal ROM during walking was 11% (SD 3%) of elementary active flexion-extension ROM. Frontal plane (21%, SD 6% of maximal active lateral bending) and transverse plane (26%,SD 8% of elementary maximal axial rotation) ROM during walking significantly increased with walking velocity. Maximal motion velocity (table 1) was approximately similar in each plane and significantly increased with walking speed in the frontal and transverse planes.

Table 1. Average (SD) lumbar maximal velocities (in °/s) during walking at different velocities.

Velocity (m/s)	0.8	1.1	1.4	1.7
sagittal	50 (16)	59 (19)	67 (21)	76 (22)
frontal	48 (11)	60 (15)	69 (19)	83 (26)
transverse	43 (12)	58 (16)	72 (20)	90 (31)

There was a significant direct linear correlation between ROM and maximal velocity in each plane. The average maximal envelope of frontal and transverse plane ROM during walking is presented in figure 1, showing the increase of ROM with walking velocity.

Coupling of rotation and bending was not constant over the population (figure 2). Homolateral and heterolateral coupling patterns were observed. These coupling characteristics could not be correlated to any of the parameters sampled during gait nor during elementary movements.

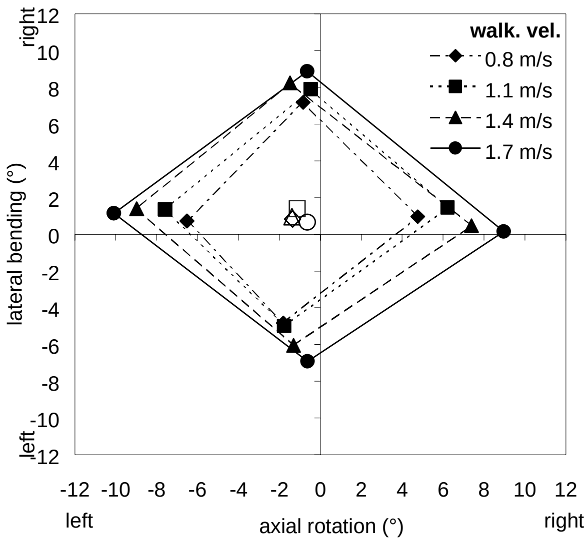

Figure 1. Average maximal envelope and centre of gravity (clear markers) of bending as a function of rotation during walking at different speeds.

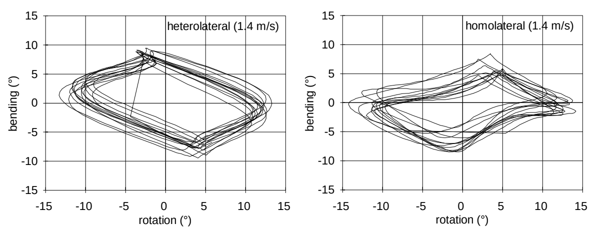

Figure 2. Bending versus rotation at 1.4 m/s. Examples of heterolateral (left) and homolateral (right) coupling.

Discussion and conclusions

The results of this study showed that global lumbar spine ROM during walking does not exceed one fourth of maximal lumbar ROM during elementary trunk movements. Frontal and transverse plane ROM and velocity significantly increase with increasing walking velocity, a finding that was not obtained for sagittal plane parameters. The direction and magnitude of rotation and lateral bending coupling displayed individual variations during walking. Observations suggesting the existence of a preferred, individually varying, walking velocity, complete our findings.

References

[1] S. Gracovetsky (1985) J Biomed Eng 7: 205-16. [2] H. Preuschoft, S. Hayama and M.M. Gunther (1988) Folia Primatol 50: 42-58. [3] A. Cappozzo (1984) J Orthop Res 1: 292-301. [4] C.K. Cheng, H.H. Chen, C.S. Chen, S.J. Lee (1998) Biomed Mater Eng 8: 155-65.