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# Preliminary study of angular velocity vs. angular position phase diagram of the thoraco-pelvis joint with ambulatory lumbar traction exoskeleton

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## 1. Introduction

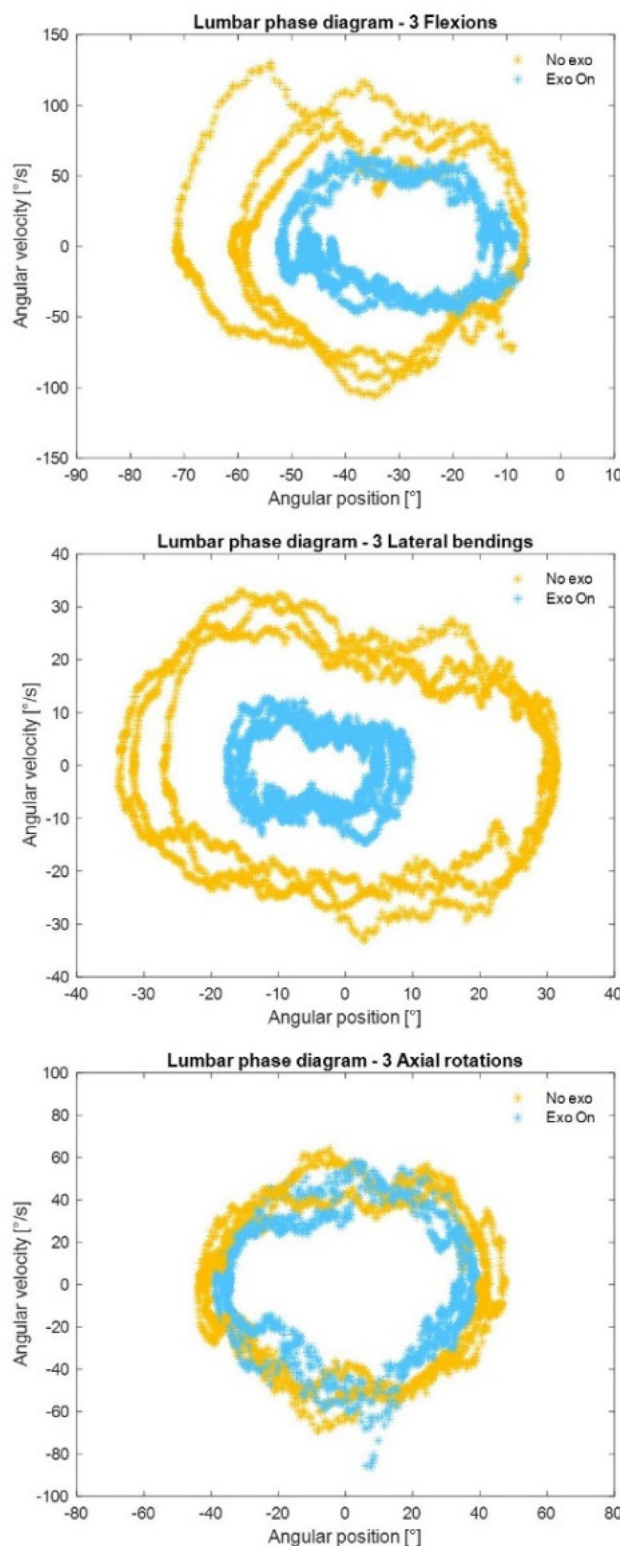
Musculoskeletal disorders (MSDs) are a scourge in businesses, with very high costs (Parker et al. 2014). The use of a dedicated exoskeleton possibly provides a solution to reduce mechanical joint stresses. However, the biomechanical impact of an exoskeleton is complex to quantify (Vignais et al. 2013). The purpose of this study is to assess the effect of an ambulatory lumbar traction exoskeleton on kinematics on the thoraco-pelvis joint.

## 2. Methods

Laboratory motion capture session was performed on 10 asymptomatic subjects (3♂ and 7♀, mean ± std, age: 20.2 ± 1.2 years, mass: 69.1 ± 10.9 kg, height: 1.76 ± 0.09) with a sequence of movements (Sghaier et al. 2019). The sequence of movements is as follows: trunk frontal bending, trunk lateral bending, trunk axial rotation, walking, walking carrying a 5 kg box,



**Figure 1.** Transfer of a 5 kg box from one table to another (transfer movement).



**Figure 2.** Phase diagram (angular velocity vs. angular position) for the simple trunk movements: flexion, lateral bending and axial rotation. The yellow curves are the result 'NO EXO' and the blue one the 'EXO ON'. However, we noticed the exoskeleton did not affect the axial rotation movement.

free lifting a 5 kg box (the subject can freely choose his lifting technique), squat lifting a 5 kg box (the subject must bend the knees with the trunk straight) and transferring a 5 kg box, according to 2 randomized conditions: (i) without an exoskeleton labelled 'NO EXO', and (ii) with the exoskeleton (Japet.W, Japet Medical Devices®) set on a lumbar traction of 8 kg labelled 'EXO ON' (Figure 1). All movements are repeated 3 to 5 times. Between the passage of the two conditions, each subject has a resting time of 5 min. 'NO EXO' data shall be considered as the reference data. On the basis of the data collected with the motion capture phase diagram, relative rotations between the trunk and the pelvis were computed (Burgess-Limerick et al. 1993).

### 3. Results and discussion

The preliminary results show a clear difference in amplitude and angular velocity according to the different conditions for the flexion and lateral bending (Figure 2).

### 4. Conclusions

The analysis of joint kinematics using the angular velocity vs. angular position phase diagram explores not only a quantification of kinematic parameters, but also more information available from muscle receptors (Burgess-Limerick et al. 1993). As a result, this representation enables greater sensitivity to the environmental change effect in terms of neuromechanical muscle coordination (Burgess-Limerick et al. 1993). Here, in our case, it is, indeed the wearing of the exoskeleton that influences the movement's biomechanics of the lumbar complex.

In our study, because of the movement's amplitude decrease by  $-45^\circ$  in flexion and  $20^\circ$  in inclination, the lumbar traction exoskeleton limits the trunk motion angular range in an area considered to be at moderate risk by ergonomics (Sghaier et al. 2019).

Furthermore, for these movements, it also decreases the angular speeds, consequently reducing the operator's production rate with the counterpart of a long-term endurance increase (Vignais et al. 2013).

This preliminary study demonstrated the relevance of a phase diagram analysis for quantifying the biomechanical impact of a lumbar-drawn exoskeleton.

The perspective of this work is now to conduct a clinical study with a larger population to confirm the subject's benefit to the wear such an exoskeleton.

### Disclosure statement

No potential conflict of interest was reported by the authors.

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**KEYWORDS** Musculoskeletal disorder (MSD); motion capture; exoskeleton; biomechanics

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