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Effects of lumbar lordosis on spine loads during seating: a simulation study

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1. Introduction

Lumbar spinal joint loading is an important factor contributing to low back pain (Coenen et al., 2013; Griffith et al., 2012) and could be an indicator of seating discomfort. A previous simulation study, using radiologically measured lumbar lordosis (LL) during standing posture, indicated that a larger LL led to a lower spinal compression force, and its influence on shear force varied by the intervertebral level (Müller et al., 2021). However, the relationship between LL and the spinal loads has not been investigated in a seated posture.

As a sitter can vary the posture by changing the spinal curvature in a same seat configuration, a distribution ratio between thorax-pelvis and pelvis-thighs angles, called the thigh-thorax rhythm, is needed to position a model on a seat for simulation, as Rasmussen et al. (2009). In the present work, we investigated the effects of LL on the lumbar spinal joint loads by varying the thigh-thorax rhythm.

2. Methods

2.1 Musculoskeletal model

The "SeatedHuman" musculoskeletal model (height: 175cm, mass: 75kg) from the AnyBody Managed Model Repository v. 3.0.0, including a pelvis, lower and upper extremities, a pelvis, along with a generic spine model comprising 5 lumbar vertebrae, a sacrum, and a lumped thoracic segment (de Zee et.al, 2007) was used in this study.

2.2 Seat model

The seat model's backrest reclination and the seat pan inclination angles were set to 110 and 0 degrees, respectively, with respect to the horizontal direction, corresponding to a daily used seat configuration. The orientation and position of the thigh and thorax segment was controlled via the kinematic links between body and seat model (Fig. 1A) as Rasmussen et al. (2009). The thigh-thorax angle was therefore fixed.

2.3 Kinematics

The thigh-thorax rhythm distributes the fixed thorax-thigh angle (θ) into the thorax-pelvis angle and the pelvis-thigh angle in sagittal plane using a predefined ratio (R), described in Equations (1&2).

$$\theta_{thigh-thorax} = \theta_{pelvis-thigh} + \theta_{thorax-pelvis} \quad (1)$$

$$R_{thigh-thorax} = \frac{\theta_{pelvis-thigh}}{\theta_{thorax-pelvis}} \quad (2)$$

The pelvis-thigh angle to thorax-pelvis angle ratio varied from 1.5 to 7.0 in a step of 0.25 in this study, covering the range of variation observed by Bell & Stigant (2007).

Seven joints between the thorax and pelvis (L1~S1) shared the thorax-pelvis angle following a lumbar spine rhythm (Rasmussen et al., 2009). Thus, the LL was calculated by the sum of the intervertebral joint angles from T12L1 to L5S1 in the sagittal plane.

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2.4 Kinetics

The body model was supported by contact points between the body and the seat model generating normal and shear reaction forces on each contact surface (Fluit et al., 2014).

The muscle recruitment problem was solved through static optimization, minimizing the sum of the cubed muscle activations, computing muscle, joint reaction as well as the contact forces between the human and seat. All simulations were performed in the AnyBody Modelling System v. 8.0.1 (AnyBody Technology A/S, Aalborg, Denmark).

3. Results and discussion

The rhythm variation resulted in the variation of LL from 36 to 54 degrees (Fig.1). The L5S1 compressive and shear forces decreased from 392 to 295N (25%) and from 200 to 154N (23%) respectively, until lumbar lordosis (LL) reached 48 degrees (Fig. 1B&C). The erector spinae muscle force dropped from 70 to 37N (47%) before 44 degrees, then rebounded to 98N (Fig. 1D). The psoas major muscle force gradually decreased from 115 to 18N (84%) (Fig.1E).

A higher LL resulted in lower spinal loads before reaching a minimum LL angle (48 degrees) as well as reduced psoas major and erector spinae muscles forces. This could reduce cumulative spinal compression during prolonged seating and the risk of low back pain (Coenen et al., 2013) as well as delay muscle fatigue and discomfort (Theodorakos, Savonnet, Beurier, & Wang, 2019). Previous studies found a positive correlation between spinal compression and seating discomfort (Eklund & Corlett, 1987; Theodorakos et al., 2019), but further investigation is needed to fully understand if and how spinal loads are linked to seating discomfort.

4. Conclusions

Our preliminary simulations show that a larger lumbar lordosis before 48 degrees resulted in lower compression and shear forces at L5S1 during a seating posture, probably leading to less seating discomfort.

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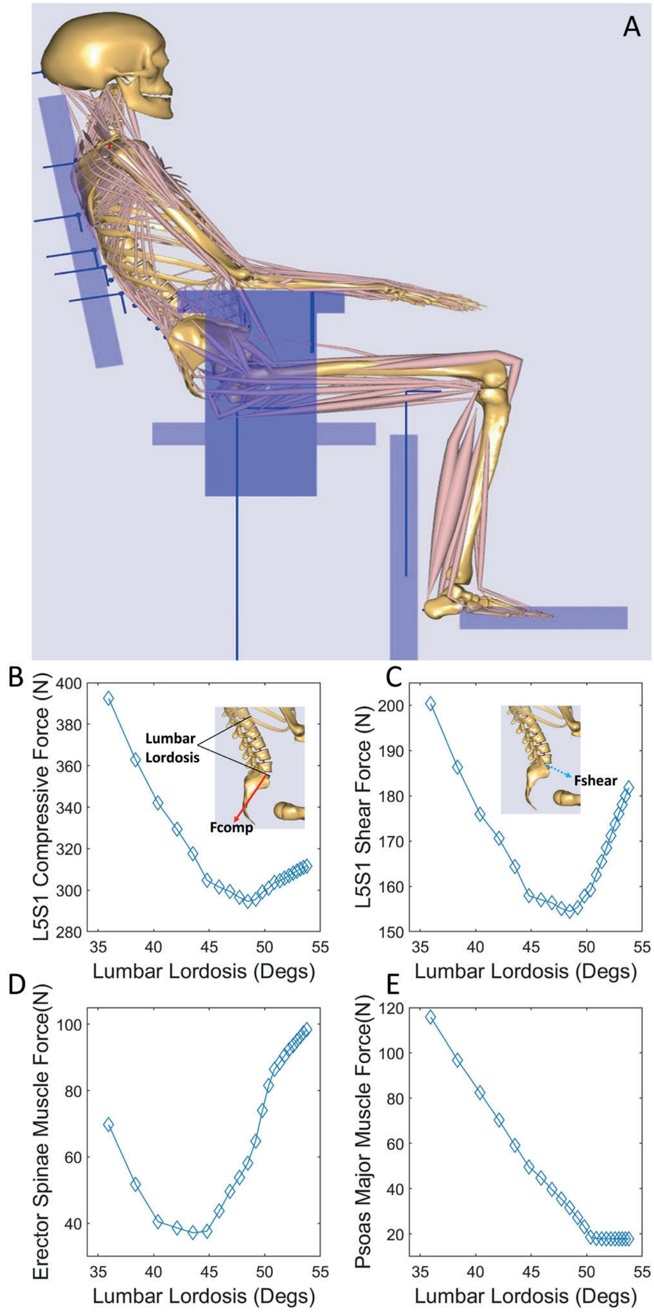

Fig. 1. (A) The body and seat model view. The influence of lumbar lordosis on the (B) L5S1 compressive force, (C) L5S1 shear force, (D) erector spinae force, and (E) psoas major muscle force. Bold blank lines indicate the lumbar lordosis angle.

A red arrow indicates the direction of the compressive force at L5S1, and a blue dashed arrow indicates the direction of the shear force at L5S1.

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