LIGAMENTS DEGENERATION MAY AFFECT BODY SWAY IN THE ELDERLY

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Introduction

Human postural control (PC) under dynamic conditions (e.g. quiet stance) is regulated by human motor-control integrating somatosensory system signals and producing appropriate feedback torque to keep the body center of mass inside the base of support (BOS). As human ages, PC from the ankle joint is shifted to the hip and/or lumbar region due to a decrease of cutaneous tactile senses (Kenshalo 1986). In balance control of the upper body (UB), spine ligaments with intrinsic stiffness provide an additional torque to toque generated by the human motor-control to counter the gravitational torque produced due to small body deviation from a vertical position. Aging is associated with degeneration of the spinal ligaments. There is significant evidence that ligamentous elastic modulus of the main substance of the spinal ligaments (Ferguson & Steffen 2003) increases. Yet, there is no clear evidence of how changes of ligament stiffness affect the sway trajectories when the motor-control system in humans is considered. The existence of the neutral zone (NZ) in the lumbar spine suggests that the motor-control integration of spinal stabilization in human is based on an intermittent control strategy. Knowing that existence of gain shows effectiveness of motor-control in regulating human stance, we investigated biomechanical effect of ligaments stiffness on human trajectories with presence of human motor-control in a vertical stance setup. In the present study, we hypothesize that stiffer ligament will decrease range of motion, indicating an important biomechanical factor in sway measurement.

Methods

A double inverted pendulum feedback control model rotating about the L4/L5 and ankle joints along with feet representation was developed using ADAMS (MSC.Software®, Santa Ana, U.S.A). The intermittent proportional and derivative control is implemented on each joint independently based on (Asai et al. 2009) and delay of 180 ms. The numerical simulation was run to estimate the gain required to minimize the angular position error about L4/L5 in the sagittal plane for less-stiff ligament. With the same gain value the ligament stiffness were increased to twice the original value reported by (Goodworth & Peterka 2009). For both settings the trajectories in the phase plane are reported.

Results

Figure 1 depicts a trajectory of the upper pendulum rotating about L4/L5 joint for stiff and less-stiff ligaments. The rotational trajectory with stiffer ligament about L4/L5 joint indicates a smaller deviation from an upright position.

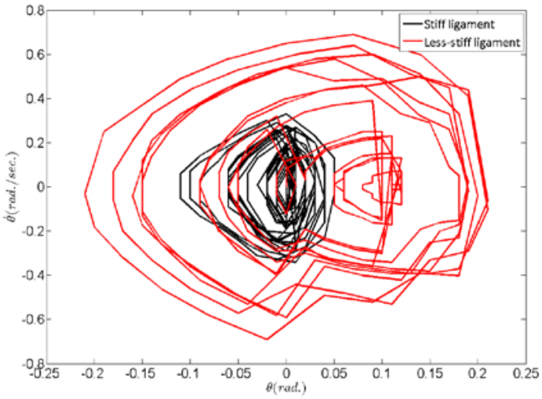

Figure 1: Trajectories in the phase plane with less-stiff and stiffer ligament.

Discussion

The numerical simulation of upper body trajectories in sagittal plane and consideration of the intermittent motor-control using an inverted pendulum model indicates that the model with the less-stiffer ligament has a larger deviation from equilibrium point confirming our hypothesis. In older adults, the local ligament stiffness increases resulting in a smaller trajectory sway or decreasing of flexibility at joint. This study reveals firstly, biomechanical factor may have a decisive role in measuring elderly's sway. Secondly, lack of flexibility may translate to a factor in elderly's fall. Thirdly, exercises aiming to increase properceptive senses in the spinal column can be an aid to improve postural control in the elderly.

References

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