AGE-RELATED DIFFERENCES IN MECHANICAL RESPONSE OF LOWER BACK TISSUES AND THE RESULTANT SPINAL LOADS DURING LIFTING

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Introduction

Among identified risk factors for low back pain (LBP), age is becoming increasingly important due largely to the increasing population of older workers in the US. Given the important role of lower back biomechanics in development of LBP, the objective of this study was to investigate differences in the active and passive mechanical responses of lower back tissues and the resultant spinal loads when persons of different age complete the same manual material handling (MMH) task.

Method

Experimental procedure

53 individuals between 22 and 68 years old participated in this study after completing an informed consent procedure approved by the University of Kentucky IRB. During experimental session, participants completed a symmetric MMH task by lowering a 10 lb load from upright standing posture to their knee height and lifting it back to their initial upright posture. Each participant also completed a maximum voluntary isometric trunk extension (MVE) test and a passive trunk stress relaxation test as explained elsewhere [1].

Trunk kinematics and electromyography (EMG) of select trunk muscles were collected using respectively accelerometers (Xsens Technologies, Enschede, Netherlands) and surface electrodes (DE-2.1 Differential EMG sensor, Delsys, Natick, MA). Trunk kinetics during MVE and stress-relaxation tests, was collected using a load cell (Interface, Scottsdale, AZ) while ground reaction force during MMH task was collected using a force plate (AMTI, Watertown, MA). The raw collected data were filtered according to literature recommendations.

Modeling procedure and analysis

Active tissue response to task demand was calculated using a simple EMG-assisted model including a single extensor and a single flexor muscle with respective fix moment arms of 6 cm and 10 cm with respect to L5-S1 joint. Active muscle response was calculated using the following relation

$F_a = \frac{EMG}{EMG_{max}} * G * f(l) * f(v)$ wherein EMG denotes mean EMG of four extensor/flexor muscles, EMG_{max} denotes the maximum mean EMG of the same four muscles during MVE test, f(l) and f(v) represent length-tension and velocity-tension coefficients. G, as a gain factor, is calculated for each person such that the error between the moment of predicted active force and measured moment during MVE is minimized. Passive tissue response at any given angle was considered to be the required force in the extensor muscle of the model such that its moment around L5-S1 to be the same as the measured passive moment for the same angle during stress-relaxation test. The resultant spinal loads (i.e., compression and shear forces) were calculated using both active and responses. A multivariate analysis of variance (MANOVA) was used to determine the effects of age on the maximum values of the ratio of active to passive tissue responses, and estimated compression and shear forces.

Results and discussion

For younger participants, sum of moments from the active and passive responses of lower back tissues with respect to the L5-S1 joint matched well with the net external moment obtained using a link-segment model (Table 1). For older participants, though, the error between the aforementioned moments increased due to inability of our model to account for active response of abdominal muscles; an event that was present at larger trunk flexion of older participants. To account for such contribution from abdominal muscles to active tissue response and the resultant spinal loads, the difference between the aforementioned moments were considered as the contribution of abdominal muscles. Compared to younger participants (Table-1), older individuals (20s, 30s and 40s vs. 50s and 60s) developed higher ratio of passive to active moments in the extensor muscles (P=0.0174). Further, older versus younger individuals completed the task such that a similar compression force (P=0.1286) but higher shearing demands (P=0.0393) were imposed on their lower back.

Increased shearing demand of task with aging was due to higher/lower contribution of pelvis/lumbar spine to trunk flexion among older vs. younger participants and may result in a higher risk of LBP due to excessive pressure on the facet joints.

REFERENCES

1. Toosizadeh N, et al. *PLOS ONE* **7**, e48625, 2012.

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Table 1: The estimated maximum moments at the L5-S1 predicted by the link-segment model (M_S) and EMG-driven model (M_E). AEM/PEM represents active/passive extensor moments

Age range	Segment model	EMG-assisted model				
	M_S (N.m)	AEM (N.m)	PEM (N.m)	PEM/AEM	M_E (N.m)	Error (%)
22-28	96(9)	48(6)	56(7)	1.16(0.15)	92(8)	3
32-38	105(23)	56(14)	75(17)	1.33 (0.23)	111(26)	6
42-48	86(16)	52(11)	59(10)	1.13(0.14)	92(18)	7
52-58	82(18)	42(13)	73(15)	1.74(0.23)	103(24)	26
62-68	90(11)	48(7)	81(9)	1.69(0.20)	113(16)	26

Table 2: Estimated spinal loads

Age range	Moment (N.m)	Compression (N)	Shear (N)
22-28	96(9)	1997(283)	705(105)
32-38	105(23)	2143(308)	609(99)
42-48	86(16)	1877(245)	672(107)
52-58	82(18)	1935(277)	874(142)
62-68	90(11)	2079(301)	866(129)