BIOMECHANICS OF THE LUMBAR SPINE IN STANDING

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INTRODUCTION

Aspects of standing posture have been studied and documented over a number of years. Many early biomechanical studies were limited to static analyses, these works established that the ankle joint line of gravity (LOG) typically lies about 5cm anterior to the joint and therefore requires postural activity in the ankle plantarflexors. The knee joint LOG typically lies just anterior to the joint requiring an internal flexion torque for stabilisation. The hip joint LOG lies just posterior to the hip joint requiring an internal flexion torque. However there has been no consensus on the location of the LOG relative to the lumbar spine.

Recent textbooks reflect the lack of consensus and selectively cite relatively old and methodologically limited studies to indicate that the LOG lies either anterior (Lindh, 1989) or posterior (Levangie & Norkin, 2001) to the lumbar spine, requiring either an internal flexion or extension torque respectively to maintain postural stability. Many of these texts cite, either directly or indirectly, work performed some 50 years ago in Denmark that is summarized by Asmussen & Klausen (1962). This body of work and others have inferred the location of the LOG relative to the lumbar spine using one of a variety of methods including balance boards, EMG, or the 'ideal' LOG as identified by a vertical line descending from the external auditory meatus. Asmussen & Klausen observed that there was a distribution of both postures within the population. However the different elements of their data were not collected on the same subjects. The lack of consensus for the location of the LOG may be a consequence of the LOG lying close to joint centres in the lumbar spine. This is further compounded by body sway which wasn't considered in earlier studies.

Postural studies have shown that the positions of the body centre of mass (COM) and centre of pressure (COP) fluctuate during quiet standing due to postural sway. The LOG is dependent on segment COM position, thus it is expected that the LOG will also change position with sway.

Thus for this study a dynamic approach was adopted to obtain the L4/L5 joint LOG for quiet standing. EMG for flexor and extensor muscles about the lumbar spine was measured and the sagittal plane L4/L5 intervertebral joint muscle moment (M) was calculated.

METHOD

Five male and five female college age (19.4 ± 2.2 years) subjects were observed for a period of 120s while quietly standing. Data was acquired at a rate of 50 Hz using a Vicon 512 motion analysis system, Kistler 9281B force plate and a Motion Labs MA100 EMG system. Two trials per subject were used for analysis.

M was calculated using an inverse dynamic solution. A seven segment model of the pelvis and lower limbs was used for the analysis (McConville, 1980; Young, 1984).

Position of the L4/L5 joint centre was determined using an X-ray technique (Pearcy & Bogduk, 1998). The LOG was calculated by subtracting the COM of the pelvis and lower limbs from the whole body COM. The whole body COM was estimated by filtering the body COP with a rectangular filter of width 1.2s (Benda, 1994).

EMG's were measured for the rectus abdominus, internal oblique, external oblique and erector spinae muscles.

Mean values of LOG, M and EMG were analysed using a repeated measures two-way ANOVA. Dynamic relationships between LOG, M and EMG were analysed using cross-correlations.

RESULTS

EMG showed co-activation of flexor and extensor muscles for all subjects. All but one subject (male) had a posteriorly located LOG. The mean LOG for all participants was 0.031m posterior to L4/L5 and required a mean flexor M of $0.306 N.m.kg^{-1}$ (Table 1).

	Trial	LOG (SD) (m)	M (SD) (N.m/kg)
Males	1	-0.012 (0.029)	-0.227 (0.170)
	2	-0.011 (0.029)	-0.212 (0.190)
Females	1	-0.054 (0.023)	-0.381 (0.042)
	2	-0.045 (0.023)	-0.399 (0.075)
All	all	-0.031 (0.031)	-0.305 (0.152)

Table 1: LOG and M values. LOG -ve: posterior; M -ve: flexor moment.

ANOVA for LOG showed significant difference between trials ($p<0.05$), approached significance for differences between gender ($p=0.06$) and a significant interaction between trial and gender ($p<0.01$).

LOG and M had a strong positive correlation across all trials (typical values or range). Cross-correlations between M and the activity of individual muscles varied in magnitude and sign between and within subjects.

DISCUSSION

For the second trial the mean LOG shifted anteriorly. Females exhibited a more posteriorly located LOG. The significant interaction between trial and gender is consistent with the relatively constant LOG between trials for males (0.012m trial 1, 0.011m trial 2) and the anterior shift for females (0.053m trial 1, 0.045m trial 2).

Cross-correlations for the dynamic results lead to the proposal of three strategies for lumbar spine musculature.

1. As the flexor M increases then flexor muscle activity increases ($r<0$) while extensor activity decreases ($r>0$).

2. As the flexor M increases then flexor muscle activity increases ($r<0$) while extensor activity remains relatively constant (r is small).

3(a). As the flexor M decreases then both flexor and extensor muscle activity increases ($r>0$).

3(b). As the flexor M increases then both flexor and extensor muscle activity increases ($r<0$).

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