STABILIZING POTENTIAL OF TRUNK MUSCLES

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INTRODUCTION

Without muscle activation, the lumbar spine is inherently unstable and will buckle under compressive loads of approximately 90N (Crisco et al., 1992). Further, it has been hypothesized that coactivation of trunk muscles serves the primary purpose of fulfilling stability requirements of the spine (Gardner-Morse & Stokes, 1998). However, the exact role of particular muscles in this regard is not fully understood. The purpose of this paper is to present a quantitative estimate of the static ability of individual trunk muscles to stabilize the L4-L5 joint about three separate axes.

METHODS

Anatomical data was taken from Cholewicki and McGill (1996). A two-dimensional measure of the stabilizing potential of muscles was taken about each of the flexion/extension (FE), lateral bend (LB) and axial twist (AT) axes. Nodal points were included on muscles where appropriate to present a more realistic view of the function of the spinal musculature about L4-L5. Joints above L4-L5 were considered to be rigid.

The minimum potential energy (V) approach was used to calculate stability. This method states that, in order for a system to be stable, the second derivative of the V of the system must be positive definite (Bergmark, 1989). V for a particular muscle was calculated as the elastic energy stored in the muscle plus the work done by the muscle for small rotations:

$$V_{mi} = \frac{1}{2} k_{mi} dl_{mi}^{\ 2} + F_{mi} dl_{mi} \qquad (1)$$

where: *mi* is a particlar muscle *i*, *k* is the muscle stiffness, *dl* is the small change in muscle length with a small rotation and *F* is the muscle force.

Substituting appropriate muscle length-change relationships into (1), applying a Taylor Series expansion to the second order and twice differentiating with respect to trunk angle yields:

$$\frac{dV_{mi}^{\ 2}}{d^2\theta} = k_{mi} r_{mi}^{\ 2} - \frac{F_{mi} r_{mi}^{\ 2}}{l_{mi}} \qquad (2)$$

where: *r* is the 2Dmuscle moment arm

From Bergmark (1989), we assume:

$$k_{mi} = q \frac{F_{mi}}{L_{mi}} \qquad (3)$$

where: *q* is a dimensionless multiplier and *L* is the entire 2-D muscle length

Substituting (3) into (2) gives:

$$\frac{dV_{mi}^{\ 2}}{d^2\theta} = \frac{qF_{mi} r_{mi}^{\ 2}}{L_{mi}} - \frac{F_{mi} r_{mi}^{\ 2}}{l_{mi}} = S_{mi} \qquad (4)$$

where S_{mi} is a measure of a given muscle's contribution to stability.

In muscles with nodal points, *r* and *l* are calculated based on the vector of the muscle as it crosses the L4-L5 joint.

To determine the stabilizing potential of each muscle, activations are set to 100% of maximum; muscles were assumed to be at resting length; q was set to 10 and the maximum muscle stress was set to 35 N/cm^2.

RESULTS AND DISCUSSION

Total stabilizing potential of the trunk muscles analyzed (N=9) is highest in the AT axis (S_{mN}=1213), followed by the LB axis (S_{mN}=1095) and the FE axis (S_{mN}=728).

Figure 1 shows the stabilizing potential of each muscle normalized to the total stabilizing potential of all muscles examined. External Oblique and Internal Oblique display the highest stabilizing potential in each of the LB and AT axes; while the LES and multifidus show the highest stabilizing potential in the FE axis.

The FE axis appears to be most vulnerable to instability as trunk muscles generally are less capable of stabilizing this axis. However, most industrial tasks, in which FE is the dominant axis of movement, require higher posterior than anterior levels of muscular activation. Thus, it is likely that the critical axis, in which buckling is most likely to occur for a given situation, is dependant on the action being performed.

SUMMARY

Trunk muscles are shown to have a higher stabilizing potential in the AT and LB than in the FE axis. This increased potential may serve to protect against instability in these axes, as the main AT and LB stabilizers (EO & IO) tend to activate to a lesser degree than the main FE stabilizers (erector spinae) in most industrial activities.

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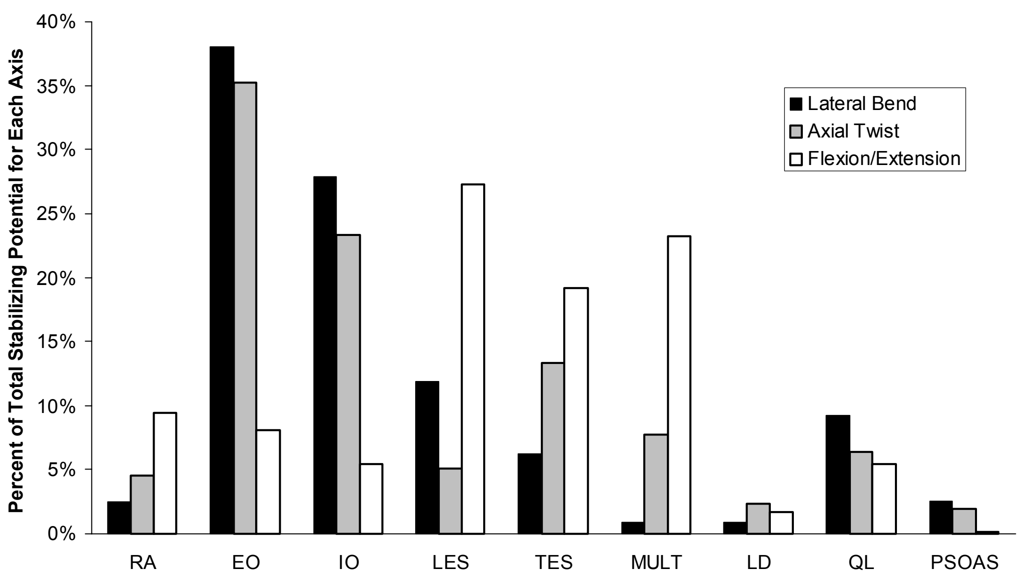

Figure 1. Normalized stabilizing potential, about each axis, for every muscle examined (one side of the body only) relative to the total stabilizing potential about each axis.