MONTE CARLO SIMULATION OF AN EQUILIBRIUM CONDITION OF THREE DIMENSIONAL SPINAL ISOMETRIC EXERTION AT L3 LEVEL

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INTRODUCTION

Prediction of spinal loading during occupational activities such as lifting and lowering is significant in assessment of risk of low back pain and injury in the workplace using biomechanical modeling. Due to the existing variability of the input parameters (i.e. anthropometric measures such as moment arm, cross sectional area and line of actions of muscles) different muscle forces are expected for a certain external load. Hughes et al. [1] used the Monte Carlo simulation to consider moments arm variations in a planar model of shoulder. Application of this method is extended to isometric exertion of trunk muscles to explore the variability of predicted muscle forces and compressive loads on spine.

METHODS

A static biomechanical equilibrium model is used that included ten muscles at L3 level: right and left Latissimus dorsi, Erector spinae, Rectus abdominis, External oblique, Internal oblique [2]. Muscles forces are determined by optimizing cubic stresses:

$$\text{Minimize} \quad \sum_{i=1}^{10} \left(\frac{|F_i|}{a_i} \right)^3$$

$constraints$:

$$|F_i| > 0 \ , \quad \sum_{i=1}^{10} |F_i| U_i \times R_i = M_{ext} \ , \ |F_i| < 60 * PCSA_i$$

Where $|F|$ is magnitude of muscle force, a stands for PCSA, U is line of action, R is the vector of moment arms for each muscle and M_{ext} is the vector of external moments. Mean values of muscle line of actions of [2] and PCSAs [4] without using their standard deviations, while sagittal and coronal moment arms and their standard deviations were taken from [3]. At each iteration, muscle moment arms are sampled from related Normal distributions in sagittal and coronal planes to form a moment arm vector, the values of this vector were used in the optimization procedure to predict muscle forces and related compressive force. This procedure is repeated 20,000 times and the descriptive statistics of the outputs are reported for further analysis. Although our model is 3D, the results of a simulation against 50 Nm of sagittal external moment are reported.

RESULTS AND DISCUSSION

Distribution of predicted Left Erector Spinae is depicted in Figure 1, indicating the unimodal distribution. Box plot of all muscles and their resulting compressive force are shown in Figure 2. Slight differences between left and right muscles forces are due to the small bilateral PCSA differences [4]. This study indicates that we must take into account one component of variability in prediction may be due to variance in the estimation of the inputs. Although our optimization algorithm is deterministic the consideration of Monte Carlo simulation allows us to predict a variable output based on the variance of moment arms reported in the literature. In future, the variation of line of action and PCSA could be easily included in our model. One limitation of this study, is that we have modeled moment arms of muscles as independent normally distributed variables, while if we had access to raw data of [4] we could have used covariance matrix between variables using multivariate normal distribution theory.

REFERENCES

1. Hughes RE, et al. *IEEE Eng in Med and Bio*. **35**: 544-548, 1997.
2. Hughes RE, et al. *J of Biomechanics*. **28**(7): 875-878, 1995.
3. Jorgensen MJ, et al. *Clinical Biomecanics*. **16**(3): 182-193, 2001.
4. Jorgensen MJ, et al. *Clinical Biomecanics*. **16**(1): 38-46, 2001.

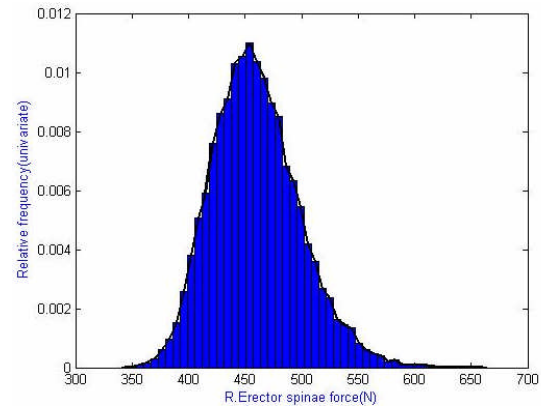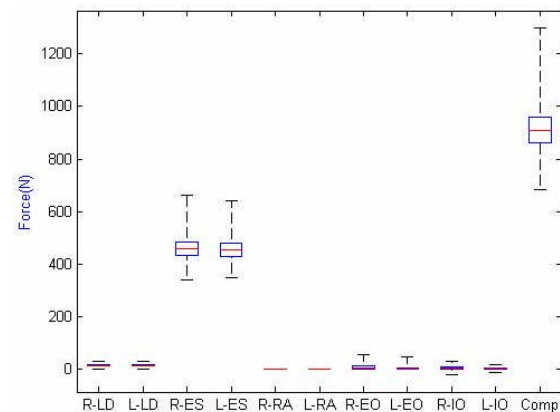**Figure 1**: Distribution of Predicted Left Erector Spinae Force.

Figure 2: Box plot of Trunk Muscle Forces and The Resulting Compression Force (N)