

PREDICTING PATIENT FUNCTION AND JOINT LOADING POST-TOTAL KNEE REPLACEMENT USING MUSCLE ACTIVATION PATTERNS

Gillian Hatfield¹, Cheryl Hubley-Kozey^{1,2}, Michael Dunbar³.

Schools of Physiotherapy¹, Biomedical Engineering,² and the Department of Surgery³, Dalhousie University, Halifax, NS, Canada. Email: GHatfield@dal.ca

INTRODUCTION

Knee osteoarthritis (OA) is a leading cause of chronic disability, resulting in huge economic costs (Sharma et al. 2006). The prevalence of OA is expected to increase in North America as the population ages, resulting in increased demand for total knee replacements (TKR) (Sharma et al. 2006, Health Canada 2003).

Better functional outcomes after TKR surgery have been linked to higher pre-operative functional scores (Lingard et al. 2004) and quadriceps strength (Mizner, 2005), but these studies did not examine the change in function. Given that muscle activation patterns are altered in those with severe knee OA (Hubley-Kozey et al., 2008), this study aimed to examine the relationship between pre-TKR muscle activation patterns and changes in objective measures of function (velocity) and knee joint loading (knee adduction moment). We hypothesized that pre-TKR electromyographic (EMG) patterns could predict changes between pre-and post-TKR walking velocity and knee adduction moment (KAM).

METHODS AND PROCEDURES

Forty-five participants (65 ± 7 years of age) with severe knee OA were tested within one week prior to TKR surgery, and one year post-TKR surgery. After standard skin preparation Ag/AgCl surface electrodes (0.79 mm) were placed in line with the muscle fibres of the lateral (LG) and medial gastrocnemius (MG), rectus femoris (RF),

vastus lateralis (VL), vastus medialis (VM), and lateral (LH) and medial hamstrings (LH).

EMG signals from an eight channel surface EMG system (AMT-8™ Bortec, Inc., Calgary, Alberta) were collected at 1000 Hz. Three-dimensional motion (Optotrak™) and ground reaction forces (AMTI™) were also collected while the participants walked at their self-selected velocity. After the walking trials, maximum voluntary isometric contraction (MVIC) exercises were completed for amplitude normalization. The EMG signals were full-wave rectified, low pass filtered at 6 Hz then amplitude normalized to MVIC. The KAM was calculated using an inverse dynamics and was amplitude normalized to body mass. The EMG and moment waveforms were time normalized to 100% of the gait cycle.

Pattern recognition techniques determined the principal amplitude and shape characteristics in the EMG and KAM waveforms. Principal components (PC) were extracted which explained over 95% of the variance, and PC scores were calculated for each subject's original waveforms. These scores for each PC were then used in the statistical analyses.

Paired Student's t-tests ($\alpha = 0.05$) were used to detect significant pre to post-TKR differences in the gait velocity and knee adduction moment PC scores. Step-wise regression models ($\alpha = 0.1$) determined which pre-TKR EMG PCs best predicted pre to post-TKR changes in gait velocity and the KAM PC scores.

RESULTS

The mean gait velocity significantly increased from 0.93 to 1.09 m/s ($p < 0.001$). Three PC scores explained 36% of the variance in the change. Prolonged activation of the LH (Figure 1, PC2, 17%) and high activity of the RF in stance (PC3, 13%) were positively correlated with the change in gait velocity. High MG amplitude (PC1, 6%) was negatively correlated with the change.

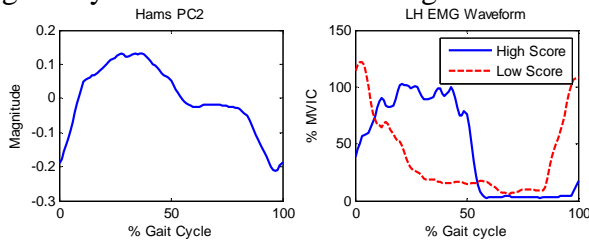


Figure 1: Left: PC2 for the hamstrings, capturing prolonged activation. Right: Waveforms for two participants with high and low scores for PC2.

The first two PCs for the KAM explained 97% of the variance in waveforms. PC1 captured the overall magnitude, and PC2 captured the magnitude of the KAM during mid-stance. There was no significant difference in PC1 scores from pre to post-TKR ($p > 0.05$). The PC2 scores significantly decreased ($p = 0.002$), showing a decrease in the magnitude of the mid-stance KAM. Five PC scores explained 58% of the variance in the change in midstance loading (PC2). Similar to velocity, prolonged LH activation (PC2) explained 31% of variance, and high RF activity in stance (PC3) explained 8%.

DISCUSSION

Prolonged LH activation (PC2) was the greatest predictor of changes in velocity and loading. This PC has been reported for participants with severe knee OA and is associated with antagonist co-activation (Hubley-Kozey et al. 2008). The KAM PCs from this study are similar to those in the literature for participants with knee OA

(Landry et al. 2007). As the KAM has been linked to medial compartment loading (Schnitzer et al, 1993), a change in the magnitude of the midstance moment (PC2) may indicate reduced loading of the joint.

These results provide evidence that patients with more typical EMG profiles have less improvement in objective measures of function and loading post-TKR, whereas those with altered profiles have greater objective improvement. This contrasts previous studies linking higher pre-TKR function to higher post-TKR function (Lingard et al. 2004, Mizner, 2005).

SUMMARY

Pre-TKR EMG patterns predicted pre- to post-TKR changes in gait velocity and the KAM during mid-stance. Participants with greater alterations pre-TKR have a greater improvement in function, and a greater decrease in medial compartment joint loading post-TKR. Potential implications of these results are in triaging surgical waiting lists and in pre-operative management.

REFERENCES

- Health Canada (2003). *Arthritis in Canada*. Ottawa: Health Canada.
- Hubley-Kozey et al. (2008). *Clin Biomech* **23**,71-80.
- Landry S et al. (2007) *J Biomech.***40**,1754-1761
- Lingard E et al. (2004). *J Bone Joint Surg Am.* **86**, 2179-2186.
- Mizner R et al. (2005). *J Rheumatol* **32**, 1533-1539
- Schnitzer et el. (1993). *Arthritis Rheum* **41**,1233-1240
- Sharma L et al. (2006). *Curr Opin Rheumatol* **18**, 147-156

ACKNOWLEDGEMENTS

CIHR and NSERC for funding