MUSCLE FORCES AT THE KNEE DURING WALKING AND RUNNING IN PATIENTS WITH PATELLOFEMORAL PAIN

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INTRODUCTION

It is commonly believed that stresses placed on the patellofemoral (PF) joint are responsible for eliciting a pain response and the development of PF pain syndrome. Testing this hypothesis requires knowledge of the articulating geometry of the PF joint as well as the forces acting on the patella.

Quadriceps muscle forces play a crucial role in determining the medial-lateral force balance of the patella and the associated contact force and pressure distribution (Elias et al., 2006; Dhaher & Kahn, 2002). However, direct measurement of muscle forces in a subject population is not currently feasible, so it remains to be seen if the distribution of muscle forces in a group of patients with PF pain is different to those who are pain-free.

The purpose of this study was to use an electromyographic (EMG)-driven musculoskeletal model of the knee (Lloyd & Besier, 2003) to estimate muscle forces in a group of patients with PF pain and compare these with a group of pain-free controls. Of particular interest were the individual contributions from the quadriceps to the knee extension moment during walking and running.

METHODS

Twenty-seven individuals with PF pain (16 female; 11 male) and 16 pain-free controls (8 female; 8 male) participated in this study. Subjects performed various tasks in a motion capture laboratory, including walking and running, stair climbing, and static and dynamic squatting. Segmental kinematics and ground reaction force data were collected and inverse dynamics used to calculate the net flexion-extension (FE) moment at the knee joint. Surface EMG recordings were taken from the following muscles: vastus lateralis, vastus medialis, rectus femoris, biceps femoris, semimembranosus, medial and lateral gastrocnemius.

Joint kinematics and EMG were input to an EMG-driven model of the knee (Figure 1). Muscle tendon lengths and FE moment arms were calculated for each task using a scaled anatomical model (Delp et al., 1990). A modified Hill-type muscle model was used to estimate muscle forces.

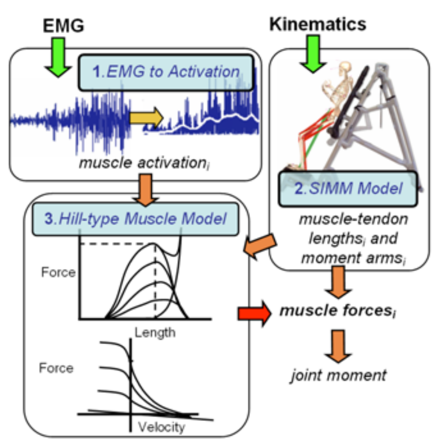

Figure 1. Schematic of the EMG-driven model.

Subject-specific models were calibrated by adjusting muscle and activation parameters to improve the model estimates of the net joint moment during a walk, run, and static squat trial. Following calibration, muscle forces were normalized using each muscles maximum isometric force to enable comparison across groups. The contributions from each of the quadriceps muscles to the total extension moment produced were then calculated.

RESULTS AND DISCUSSION

Following calibration, the EMG-driven model estimated FE joint moments close to those estimated using inverse dynamics (walking: r^2=0.81±0.09 & running: r^2=0.89±0.07). Normalized muscle force profiles were similar between PF pain and control subjects, during both walking and running, with no difference in the magnitude of normalized forces across groups.

During walking and running, the quadriceps produced an extension moment at the knee greater than the net joint moment (Figure 2a). This was due to the moments produced by the hamstring and gastrocnemii muscles during stance. The magnitude of the peak difference between the quadriceps moment and the net joint moment was similar across PF pain and control groups, suggesting similar levels of co-contraction for a given joint moment.

The contribution from each quadriceps muscle were also similar across subjects for walking and running, although patients with PF pain displayed slightly greater standard deviations than controls. During early stance, or weight acceptance (WA) and at peak knee extension (PKE), vastus lateralis provided the largest contribution (~45±10%), followed by vastus intermedius (~29±3%), and vastus medialis (~26±7%). Rectus femoris contributed only ~5±2%. These relative contributions were consistent across the stance phase during walking and running (Figure 2).

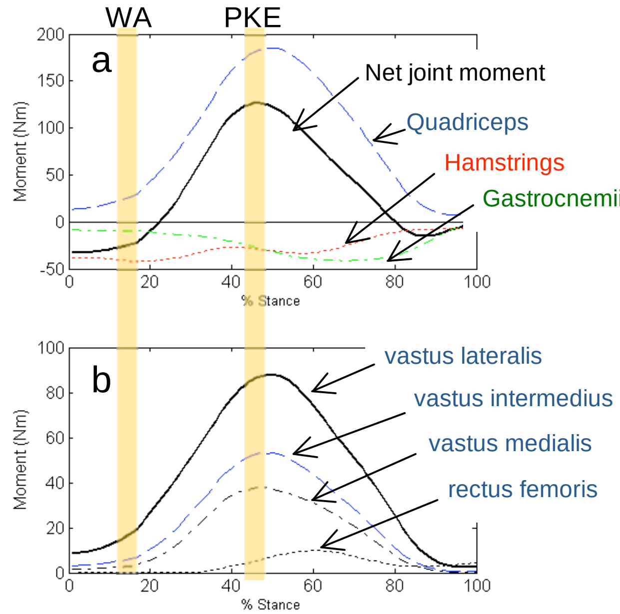

Figure 2. Knee joint moments produced by muscles during a run. Note the extension moment produced by the quadriceps exceeds the net joint moment, due to co-contraction of the hamstrings and gastrocnemii (a).

SUMMARY/CONCLUSIONS

Relative to the net knee joint moment, patients with PF pain appear to produce the same magnitude and distribution of forces as those who are pain-free during walking and running.

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