Introduction

Unanticipated cutting tasks have been shown to increase the varus/valgus (VV) and internal/external rotation (IE) moments at the knee as much as 200% compared with cutting manoeuvres that are pre-planned (Besier et al., 2001). These loads coupled with an external flexion moment during stance phase are hypothesised to be responsible for non-contact knee ligament injuries. Muscles have the potential to support these moments and reduce ligament load, however, whether they are activated to do so during cutting tasks remains to be seen. The purpose of this study was to use an EMG-Driven musculoskeletal model [2] to estimate the muscular support and soft tissue loading at the knee during pre-planned (PP) and unanticipated (UN) cutting manoeuvres.

Methods

Ten male subjects performed five PP and UN sidestepping and crossover cutting manoeuvres at 3 m/sec in our gait laboratory. The UN condition was simulated using a set of target LED's, such that the subjects had to make a split-second decision regarding which direction to move. Joint kinematics and kinetics were collected using a VICON motion analysis system (Oxford Metrics) in conjunction with an AMTI force plate. Activation of ten muscles surrounding the right knee were estimated using surface EMG collected at 2000 Hz. The FE, VV and IE external joint moments at the knee were determined using inverse dynamics.

Kinematic and EMG data were used as input to the EMG driven dynamic knee model [2], which estimated individual muscle forces and subsequent flexion/extension (FE), VV, and IE joint moments produced by the muscles. The potential for VV soft tissue load was calculated by subtracting the externally applied VV moment (from inverse dynamics) from the internal VV moment generated by muscle (from the model) (Lloyd and Buchanan, 1996). If the moment generated by muscle matched that the applied external VV moment, then no contribution from other soft tissue structures was assumed. However, if the externally applied VV moment was greater than the VV moment generated by muscle, then soft tissue loading may be required to close the joint and a ‘residual load’ was calculated.

Results and Discussion

There appeared to be a general increase in all muscle activity during the stance phase of the cutting tasks, with no selective activation of muscles with medial or lateral moment arms. This neural strategy was adequate to stabilise the joint during the PP tasks with more than 90% of the external VV moments supported by muscle. However, under UN conditions, the net muscle activation increased by only 20%, which was not adequate to support what was sometimes a 200% increase in VV and IE joint moments.

Following calibration to the individual subject the EMG driven dynamic knee model validity proved to be very high. This model predicted the FE moments at the knee (as measured from inverse dynamics) with an average R-squared of 0.9. Thus we can have confidence that the muscles forces estimated are a reliable estimation of those the subjects are generating. Subsequently, the potential for soft tissue loading could be well estimated.

For the run and sidestep tasks, the VV moments generated by muscles nearly matched the external moment applied to the knee, thus minimal soft tissue loading was required. However, the large varus moments measured during the crossover exceeded the contribution from muscles. The UN crossover produced the highest potential for soft tissue load, with a residual varus moment of over 1 Nm/kg (Figure
A lack of muscular stabilisation when performing the crossover in UN condition indicated that the ligamentous and meniscal tissues were at greater risk of injury when performing this task.

In summary, during PP cutting manoeuvres, muscle activation strategies were effective in reducing the potential load on ligaments at the knee. However, UN conditions required greater contribution from ligaments to support the external loads applied to the knee, which was especially the case in the crossover manoeuvre. These findings have important implications for the aetiology and prevention of knee ligament injuries in sport.

References

