Can muscle activation patterns be retrained during dynamic deceleration?

Implications for ACL injury.

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Introduction
Rupture to the anterior cruciate ligament (ACL) is the most frequently occurring and debilitating of knee injuries (Johnson, 1983; Malone et al., 1993). Non-contact ACL injury commonly occurs in tasks involving rapid changes in direction (Bartold, 1997), abrupt deceleration (Miller et al., 1995), and landing, commonly in conjunction with poor landing technique (Hopper et al., 1993; Hume et al., 1997; Otago et al., 1997). Whilst the ACL provides primary restraint to anterior tibial translation, the hamstring muscles act as synergists, recruited on demand when the ACL is excessively loaded (Solomonow et al., 1987). Therefore, the integrity of the ACL is highly dependent on proper lower limb muscle coordination, particularly of the hamstring and quadriceps muscles. Kain et al. (1988) suggested that a muscle recruitment strategy, whereby the hamstring muscles contract prior to the quadriceps, offered optimal protection to the ACL. Despite extensive research pertaining to ACL injury prevention, no research was located which investigated whether simple verbal instructions may be effective in changing the muscle activity displayed by athletes during dynamic landing. Therefore, the purpose of the present study was to investigate whether simple verbal instructions could alter landing muscle activation patterns.

Methods
Twenty four A-grade female netball players (mean (SD) age = 21.9 (4.8) years) with no history of lower limb injury, trauma or disease were chosen as experimental subjects for the study. For data collection, subjects were required to run forward for approximately three paces, to leap from their non-dominant leg, and to land on their dominant (test) limb in single-limb stance, with their foot centrally located on a force platform whilst catching a chest-height pass. This task was performed for 10 trials under four test conditions: (i) normal landing (N); (ii) repeat normal landing (R); (iii) landing after an instruction to increase knee flexion (K), and (iv) landing after an instruction to recruit the hamstring muscles earlier (M). The deceleration task was chosen for the study as abrupt landing has been suggested to be a typical ACL injury mechanism (Otago et al., 1997).

Ground reaction force data and surface EMG data for rectus femoris (RF), vastus lateralis, biceps femoris (BF), and semimembranosus (SM) were sampled (1000 Hz) for each subject’s dominant limb. Muscle activity analysed during the deceleration task included the burst immediately prior to IC for each of the four muscles. The raw signal was filtered using a fourth-order zero-phase-shift Butterworth high pass filter (Winter, 1990; \( f_c = 15 \) Hz) to eliminate any movement artefact. To assess the temporal characteristics of the muscle bursts, the filtered EMG data was full-wave rectified and low pass filtered \( (f_c = 20 \) Hz) to obtain linear envelopes, and subsequently screened with a threshold detector (7 % of maximum burst amplitude). The calculated values were visually inspected to confirm the results truly represented the temporal characteristics of each muscle burst.

The following temporal variables were then calculated for each of the four muscles from the processed EMG data: (i) duration of the muscle burst (ms); (ii) timing of the onset of muscle activity relative to IC (ms); and (iii) timing of the peak muscle activity relative to IC (ms). These variables were calculated to provide an indication of the effect of the verbal instructions on the sequence and timing of the hamstring and quadriceps muscle contractions during the deceleration task.
Results & Discussion
Repeated measures ANOVA results indicated there were no significant ($p<0.05$) differences in any of the temporal variables analysed for the hamstring muscles amongst the four test conditions. However, RF onset relative to IC was significantly ($p<0.001$) earlier during the M condition (Fig. 1; mean (SD) =110 (53) ms) compared to the other three conditions (N = 83 (33) ms; R = 77 (27) ms; K = 72 (34) ms).
As no significant differences were found in timing of the SM and BF muscles amongst the four conditions it is suggested that subjects were not able to selectively alter the time at which they recruited their hamstring muscles when only given verbal instructions without prior muscle recruitment training. In their attempt to do so, they actually recruited an antagonist muscle, the RF, significantly earlier prior to IC. Results of this study suggested that subjects were unable to selectively change the way they activated their quadriceps and hamstring muscle groups following verbal instruction. In fact, although instructed to alter hamstring muscle activity in the M condition, subjects generated earlier onset times of the antagonistic quadriceps muscles prior to landing, thereby imposing a greater risk of injury to the ACL during landing. Therefore, to alter the activity of specific muscle groups during dynamic landing to better protect the ACL, subjects may require more specialised muscle activation training. Further research is therefore warranted to investigate whether lower limb muscles can be retrained to alter landing technique, so that safer landing practices can be adopted in the future.

References

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RF muscle burst onset time relative to initial contact (IC).

-200 -180 -160 -140 -120 -100 -80 -60 -40 -20

Muscle Instruction (M)
Knee Instruction (K)
Repeat Landing (R)
Normal Landing (N)

* denotes a significant difference between the M and remaining three conditions.

Figure 1: RF muscle burst onset time relative to initial contact.