 INTRODUCTION

Within the sport disciplines, there is a plethora of epidemiological evidence that contends that 54 – 71% of all injuries occur late in competitions or practices [1, 2]. Equally important is the notion that 58% of these injuries are caused by some noncontact mechanism [2]. The deleterious outcomes elicited by fatigue are typically related to altered biomechanics or motor control strategies [3]; however, studies predicting such effects may use inadequate techniques to fatigue subjects relative to author’s conclusions. Perhaps, future studies could be refined by understanding differences in fatigue methodology. The purpose of this study was to compare the effects of intense exercise-induced fatigue on quadriceps/hamstring torque production and EMG using a functional fatigue protocol (FFP) and an isokinetic fatigue protocol (IFP).

METHODS

Twenty healthy subjects (10 male, 10 female; age: 21.4±3.5 yrs.; height: 169.8±7.3 cm; mass: 72.0±18.8 kg) volunteered for the two sessions comprising this investigation. Inclusion criteria were: (1) subject deemed healthy by the Physical Activity Readiness Questionnaire; (2) subject was free from illness/injury; and (3) subject was physically able to complete the FFP/IFP.

In both sessions, subjects completed isokinetic strength testing for knee flexion (KF) and extension (KE) on the KinCom 125AP Dynamometer. Both concentric (CON) and eccentric (ECC) actions were recorded at a rotational velocity of 180°/sec. Simultaneously, surface EMG was recorded from Vastus Medialis (VM), Vastus Lateralis (VL), Biceps Femoris (BF) and Semitendinosus (ST).

In the first session, subjects were fatigued using the FFP (Figure 1), which consisted of a series of time sprinting, cutting, and jumping tasks. For each repetition, subjects were asked to perform at maximal effort and render a Borg Rating of Perceived Exertion (RPE) score at the end. After a one month washout period, subjects reported for the second session incorporating the IFP. In the IFP, subjects performed CON KF and CON KE at various velocities, starting at 240°/sec and decreasing by 30°/sec intervals. Subjects continued to exercise in either fatigue protocol with intermittent 20-second rest periods until the termination criteria were met. Upon conclusion, subjects were immediately re-tested for isokinetic strength.

RESULTS AND DISCUSSION

Isokinetic peak torque (PT) and average torque (AT) data were extracted for both CON- and ECC-KF and KE. Root Mean Square Amplitude (RMS) and Median Spectral Frequency ($F_{med}$) values were extracted from EMG data for each muscle. All data were visually inspected and analyzed using custom software. Comparisons were made using a mixed-model repeated measures analysis of variance (ANOVA) where ($P<0.05$).

There were statistically significant differences in both PT and AT for the KE muscle group pre- to post-fatigue for the FFP and IFP (see figure 2). Interestingly, for the KE muscle group, significant decreases in PT and AT were only evident pre-
post-fatigue for the FFP (see Figure 3). The FFP appeared to universally target the musculature of the lower extremity, while the IFP did not. It is perceived as easier to pull with the line of gravity while on the dynamometer; hence subjects may not have been contracting their hamstrings with maximal intensity during the down phase of the IFP.

**Figure 2:** Quadriceps (KE) data prior to and following both the FFP and the IFP. * P<0.05; Significant decreases occurred from pre- to post-fatigue strength measures. ** P<0.05; Significant differences in change scores occurred between the IFP and FFP. † P= 0.064; Trend towards significance for concentric peak torque change scores between the IFP and FFP.

The EMG data yielded mixed results. For the KE muscle group, there were significant differences in \( F_{\text{med}} \) across protocols. VL CON and VL ECC yielded changes where \( P<0.0001 \) and \( P=0.002 \) respectively and VM CON yielded changes where \( P<0.0001 \). VM ECC tended towards significance where \( P=0.059 \). The quadriceps yielded no significant changes across any EMG RMS variables. The KF muscle group also exhibited significant changes across protocols in \( F_{\text{med}} \). ST CON and ST ECC rendered changes where \( P=0.008 \) and \( P=0.011 \) respectively and BF CON and BF ECC both yielded changes where \( P=0.001 \). EMG RMS for ST CON and ST ECC also showed a significant change where \( P=0.003 \) and \( P=0.004 \) respectively. Follow up t-tests revealed that more pronounced changes were evident for KE following the FFP where \( F_{\text{med}} \) decreased in VM CON (pre-/post-IFP: 20.67±11.12 to 20.25±10.84; pre-/post-FFP: 38.47±5.32 to 33.87±2.83; \( P=0.007 \)), VM ECC (pre-/post-IFP: 26.22±12.89 to 32.06±19.11; pre-/post-FFP: 36.02±5.01 to 33.78±3.96; \( P=0.039 \)) and VL ECC (pre-/post-IFP: 37.08±20.62 to 39.33±21.15; pre-/post-FFP: 57.48±15.12 to 50.17±14.27; \( P=0.021 \)).

The reductions in EMG \( F_{\text{med}} \) confirm that fatigue was achieved in the observed muscle groups. Other authors have demonstrated a left-hand shift in medial spectral frequency following exhaustive exercise [4]. It appears as though the FFP had a greater effect on the quadriceps than the IFP. In general, the data did render the changes in EMG RMS values consistent with fatigue; research suggests that RMS Amplitude values decrease following fatigue when maximal contractions are performed [5], however only the ST data demonstrated significance.

**CONCLUSIONS**

While both fatigue protocols caused a similar effect on the quadriceps’ force production, the FFP had a greater effect on the hamstrings. Additionally, the deficits in quadriceps and hamstring activation evident with the FFP are suggestive of a more proximal (central) fatigue mechanism. Since greater forces are needed under dynamic conditions to avoid noncontact injuries, it is important to appropriately address methodology in the application of the results of fatigue studies. This FFP is a valid protocol for use in research targeting sports biomechanics.

**REFERENCES**