Introduction: While reconstruction of the ACL deficient (ACLd) knee remains common practice in the sports medicine profession, it has been reported that a number of individuals with complete ACL ruptures are able to return to high level of activities without surgical reconstruction (Daniel et al., 1994). These individuals have been labeled “Copers” as they have been able to develop mechanisms of compensating for the ACLd knee while experiencing neither instability, loss of function or weakness (Daniel et al., 1994; Rudolph et al., 1998).

In previous studies, ACLd gait compensations have been characterized by an increase in knee flexion angle, an increase in hamstring electromyographic (EMG) activity and by the reduction or elimination (quadriceps avoidance) of the knee extensor moment during the stance phase of the gait cycle. The literature regarding the emergence and presence of quadriceps avoidance gait patterns (defined as a complete elimination of knee extensor moment during stance) in ACL deficiency is confounding. Initially, Berchuck et al, (1990) reported that 75% of test subjects exhibited no knee extensor moment. Noyes et al. (1992) reported 50%, Birac et al. (1991) 80% and Kadaba et al. (1993) reported 22% of their patients exhibited a complete lack of the knee extensor moment during stance. Others have reported only a knee extensor moment reduction (Daniel et al, 1994; Rudolph et al., 1998) in ACLd gait. More recently, Roberts et al. (1999) reported no such changes in the gait patterns of ACLd subjects.

From this review, it is evident that there is little consensus as to whether the quadriceps avoidance gait pattern is a common adaptation observed in most ACLd individuals or if several compensating mechanisms are possible. Thus, the purpose of this study was to corroborate previous studies as to the existence of quadriceps avoidance gait patterns; and to determine, based on the presence, reduction or elimination of the knee extensor moment, if several adaptive strategies exist in compensating for ACL deficiency during gait.

Methods: Surface EMG (vastus medialis, vastus lateralis, rectus femoris, medial hamstrings, biceps femoris, tibialis anterior and gastrocneumius) and three-dimensional kinematic and kinetic gait patterns were recorded for 16 ACLd and 8 healthy subjects during walking at self-selected speeds (ACLd=1.48 m/s, healthy=1.47 m/s). All ACLd subjects had been previously diagnosed with MRI as having a complete and isolated ACL rupture with a mean KT-1000 score of 5.8 mm (range 3.0 to 15.0 mm). The mean time from injury to test date was 8.7 years (range 3.1 to 23.4 years). All subjects had returned to pre-injury levels of exercise and reported no episodes of giving way or associated complications. Stance phase hip, knee and ankle kinematics and internal joint kinetics; average and peak EMG activity and co-contraction ratios (sum of peak EMG amplitudes of quadriceps divided by the sum of peak EMG amplitudes of the hamstrings) were contrasted with a one-way ANOVA and post-hoc tests (p<0.05).

Results: Hip, knee and ankle kinematics and joint moments were not different between groups (p>0.05). However, the ACLd group demonstrated greater biceps femoris EMG activity and support moment indicating an additional neuromuscular strategy during the stance phase. Quadriceps avoidance pattern was not present for any
of the ACLd subjects. Nine of the subjects demonstrated a normal bi-phasic pattern whereas seven demonstrated almost an all extensor pattern without a knee flexor moment during mid-stance. This observation indicates that two different coping mechanisms were present in the group of ACLd subjects. Thus, we sub-divided this group based on the knee joint moment curve and re-analyzed the data. We delineated the ACLd subjects with a bi-phasic knee joint moment as Group 1, and the extensor dominant knee joint moment as Group 2.

The KT-1000 scores between ACLd groups (Group 1=5.8 mm; Group 2=5.9 mm) and gait velocities between all groups were not different (p>0.05). Group 1 utilized a hip ROM and hip extensor moment that was significantly greater than Group 2 and healthy (p<0.05). Group 1 demonstrated knee motion and neuromuscular co-contractions that were not different from normal (p>0.05). However, Group 1 demonstrated a knee extensor moment during the first 50% of stance that was significantly smaller than Group 2 and healthy (p<0.05).

Group 2 demonstrated hip kinematics and kinetics that were not different from healthy (p>0.05), yet maintained the knee in a position that was significantly more flexed at contact and mid stance compared to Group 1 and healthy (p<0.05). This group also demonstrated biceps femoris EMG activity to be significantly greater than Group 1 and healthy (p<0.05). Significantly smaller quadriceps to hamstring co-contraction ratio during mid-stance was found for Group 2 compared to Group 1 and healthy (p<0.05).

**Discussion:** This study did not find any support for the quadriceps avoidance pattern defined as a flexor-dominant, internal knee joint moment. We did, however, have one ACLd group demonstrate a reduced knee extensor moment during the first 50% of stance. The quadriceps avoidance pattern, therefore, may be better defined as a reduction, rather than the elimination, of a net internal knee extensor moment. This study also revealed two distinct styles of compensation for ACL deficiency. Group 1 demonstrated a hip strategy that increased hip extensor output, decreased knee extensor output and allowed normal knee kinematics. Group 2 demonstrated a knee strategy that increased the stiffness (increased hamstrings muscle activity relative to quadriceps muscle activity) of the joint and utilized a flexed knee gait.

The prevalence of multiple adaptive strategies to compensate for ACL deficiency has several important ramifications. First, an ACLd subject pool with mixed compensating strategies may wash out the identification of specific coping mechanisms and account for the confounding results in the literature. Second, the importance of the hip extensors must not be overlooked when studying this population.