Introduction

Several features characterize the gait of ACL reconstructed (ACLr) patients within the first year after surgery. Among those features are reduced stride frequencies (cadence) and stride lengths; decreased stance phase knee range of motion (ROM); and increased hip and decreased knee extensor torque and power (Bush-Joseph et al., 2001; Devita et al., 1992, 1997, 1998; Ernst et al., 2000; Kowalk et al., 1997). The persistence of these gait adaptations may predispose this population to long term quadriceps strength deficits, anterior knee pain and other orthopedic problems. The developmental period of gait adaptations, after ACL reconstruction, has been reported to be relatively long (Devita et al., 1997) and strongly influenced by appropriate rehabilitation techniques such as gait re-training (Noyes et al., 1996). Gait re-training programs that facilitate the attainment of a pre-injured stride frequency may enhance gait recovery as the return of a normal gait frequency is concurrent with increases in lower extremity joint ROM and moments after ACL reconstruction (Devita et al., 1997; Snyder-Mackler et al., 1991).

Based on a minimum metabolic cost paradigm, several studies have predicted the optimal stride frequency to occur at the preferred stride frequency (Cavagna et al., 1992; Zarrugh et al., 1974). Predictive pendular models have been used to successfully explain the mechanical underpinnings of these findings. At freely selected gait speeds, it has been shown that the selection of a preferred stride frequency is predictable by the resonant frequency of the limbs, modeled as force driven harmonic oscillators (FDHO) (Holt et al., 1990, 91a; Kugler & Turvey, 1987; Schot & Decker, 1998). Compared to other frequencies, walking at the resonant frequency requires the minimum amount of muscle force to maintain leg oscillations and maximizes gait efficiency (Holt et al., 1991b, 1995). This resonance formula has been empirically shown to accurately predict the preferred stride frequency with a mean prediction error near 1% (Holt et al., 1990). Since the resonance formula is based on leg anthropometrics, the close correspondence between the preferred stride frequency and that predicted by the model indicates that humans are sensitive to the mechanical attributes of their own limbs when adopting a natural gait frequency (Holt et al., 1991a).

Sensitivity to resonance is lost soon after ACL injury and subsequent bone-patellar tendon-bone reconstruction (Decker et al., 1999). Thus, the purpose of this study was to examine the therapeutic effects of two gait re-training protocols on the gait patterns of bone-patellar tendon-bone ACL reconstructed patients: a protocol designed with the resonant frequency of a modified FDHO model, and a protocol utilizing the patient’s preferred stride frequency. It was hypothesized that gait re-training with the resonant frequency would facilitate greater gains in knee ROM, knee torque and power, and reductions in hip torque and power, as compared to gait re-training with the preferred stride frequency.

Methods

Sixteen bone-patellar tendon-bone ACLr subjects, and eight healthy control subjects, participated in this study. The ACLr group was randomly sub-divided and given different walking protocols lasting 6 weeks (6 to 12 weeks post-op). Group 1 walked with a metronome at a stride frequency predicted from the resonant frequency of a modified force driven harmonic
oscillator model (FDHO) (Holt et al., 1990). Group 2 walked at their preferred stride frequency without a metronome. Each group walked 20-40 minutes, three to five times a week for the duration of the protocol. Gait tests were performed with self-selected velocities and preferred stride frequencies at 6 and 12 weeks post-op.

Three-dimensional kinematics (60 Hz) and force plate data (1200 Hz) were combined in an inverse dynamics solution to calculate sagittal plane internal joint moments and powers. Within subject time effects (paired t-test), group effects at each time period (one way-ANOVA) and rate of recovery effects (two-way mixed factor ANOVA) were contrasted for all dependent variables (alpha=0.05).

Results & Discussion

Significant improvements over the 6-week treatment sessions were recorded for both groups, but there were trends to suggest that the two gait re-training protocols facilitated different gait strategies. At 6 weeks after surgery, both ACLr groups utilized reduced stride frequencies and stride lengths; decreased stance phase knee ROM; and increased hip and decreased knee extensor torque and power compared to the healthy control group (all p<0.05). Within the 6-week treatment period for Group 1, significant improvements in knee ROM and knee extensor torque and power (all p<0.05); and reductions in hip and ankle extensor torque (both p<0.05) demonstrated gait patterns that were nearly identical to the healthy control group. Within the 6-week treatment period for Group 2, no significant changes were found for knee ROM, knee extensor and ankle plantarflexor torque or power (all p<0.05), but hip power was significantly larger compared to the healthy group (p<0.05). The gait adaptations observed for this group has been previously observed for ACL reconstructed patients (Devita et al., 1997, 1998). Although gait recovery at twelve weeks after surgery was similar between ACLr groups, gait re-training with the resonant frequency of a FDHO model was the only training mode that significantly improved gait function between 6 and twelve weeks after surgery.

This study found that gait re-training with the preferred or resonant frequency demonstrated similar results in the gait patterns of ACLr patients, twelve weeks after surgery. Although gait recovery was similar between ACLr groups, gait re-training with the resonant frequency was the only training mode that significantly restored the natural walking frequency of the limbs and improved gait and quadriceps function (as noted by increased knee ROM and knee extensor torque) during the treatment period. Gait re-training with the preferred stride frequency did little to restore a normal gait, and perhaps may have even accentuated the gait adaptations that were present 6 weeks after surgery. This study provides evidence that the gait and quadriceps function of ACLr patients can be improved with the addition of focused gait re-training protocols.

References


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