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Bilateral accommodations to anterior cruciate ligament deficiency and surgery

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Abstract

Objective. To determine bilateral lower extremity joint accommodations during gait in anterior cruciate ligament deficient subjects and uninjured controls.

Design. Gait testing of 10 chronic anterior cruciate ligament deficient subjects prior to and 3 months following reconstructive surgery, and 10 uninjured controls.

Background. It is possible that bilateral joint accommodations could occur as a result of anterior cruciate ligament injury and in response to surgical repair. Few studies have investigated bilateral joint accommodations to anterior cruciate ligament injury and there is little consistency in the reported results.

Methods. Bilateral lower extremity kinematic and kinetic data were collected from 12 walking trials and inverse dynamics calculations were made to estimate bilateral knee and hip joint angle, moment, and power patterns during the stance phase of gait.

Results. Control subjects exhibited asymmetrical hip but symmetrical knee joint moment and power patterns. In contrast, the anterior cruciate ligament deficient subjects exhibited symmetrical hip and asymmetrical knee joint moment and power patterns prior to and following reconstructive surgery.

Conclusions. Gait asymmetry in healthy subjects should not be considered pathological. In addition, chronic anterior cruciate ligament injury results in joint specific, bilateral lower extremity accommodations in gait mechanics. These accommodations persist 3 months following surgical repair.

Relevance

Often times, the contralateral, non-injured limb is used as the clinical criteria for rehabilitation progression and return to full activity. However, gait adaptations to the contralateral limb following chronic deficiency and surgery remain unclear. This information may aid in the rehabilitation of anterior cruciate ligament injured and reconstructed patients.

Keywords: Anterior cruciate ligament; Surgery; Biomechanics; Gait accommodations

1. Introduction

Successful locomotion requires a complex interaction between the central nervous system and various muscles to maintain balance, support of the body against gravity, and propel the body forward in a smooth and rhythmical manner (Sadeghi et al., 1997, 2000; Winter et al., 1990). Smooth and rhythmical gait is often associated with gait symmetry while gait asymmetry is commonly associated with gait pathology and injury (Sadeghi et al., 2000). However, while gait symmetry has been reported in the literature (Hamill et al., 1984; Menard et al., 1992), evidence exists suggesting that asymmetrical gait, even in healthy populations, is a common occurrence (Allard et al., 1996; Sadeghi et al., 1997, 2000).

Among the few studies that have investigated bilateral joint accommodations to anterior cruciate ligament

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(ACL) injury, there is little consistency in the reported results (Berchuck et al., 1990; Ernst et al., 2000; Rudolph et al., 1998; Tibone and Antich, 1993). Tibone and Antich (1993) evaluated 18 ACL deficient patients during walking and reported no significant differences in joint angles or ground reaction force (GRF) variables between limbs. However, Rudolph et al. (1998) reported that the ACL deficient limb exhibited lower peak vertical GRF, a greater knee flexion angle, a reduced knee extensor moment, and reduced knee power absorption compared to the contralateral uninjured limb. In addition, Berchuck et al. (1990) examined chronic ACL deficient subjects during walking and reported a bilateral increase in the hip extensor moment during normal gait as compared to controls. These authors also reported that the ACL injured knee exhibited a sustained flexor moment during midstance compared to the uninjured limb and controls. Thus, the bilateral accommodations that ACL deficient subjects undergo remain unclear and no studies have investigated possible bilateral accommodations following ACL reconstructive surgery.

The contralateral limb is often used for comparison as either a method to determine progression during rehabilitation or as the criteria to determine when the patient is ready to return to full activity. It is possible that bilateral, as well as unilateral joint accommodations could occur as a result of ACL injury and in response to surgical repair (Berchuck et al., 1990; Rudolph et al., 1998; Tibone and Antich, 1993). If so, this information may aid in the rehabilitation of ACL deficient and reconstructed patients. Therefore, the purpose of this investigation was to determine the effect of chronic ACL deficiency and subsequent reconstructive surgery on bilateral lower extremity joint kinematic, moment, and power patterns in chronic ACL deficient subjects prior to and 3 months following surgical repair and in healthy uninjured subjects.

2. Methods

2.1. Participants

Based on a priori power analyses ($\beta = 0.20$; $P = 0.05$), 20 subjects participated in this investigation. Ten (five males and five females) ACL deficient individuals were compared with 10 (five males and five females) healthy uninjured age and gender-matched control subjects. All subjects were physically active, participating in regular activity at least three times per week. The mean age, body weight, and body height of the ACL deficient subjects were 27.7 (SD 9.1) yr, 79.1 (SD 13.8) kg, and 166.1 (SD 20.2) cm, respectively. The ACL deficient subjects had sustained an isolated unilateral ACL injury confirmed by an orthopedic surgeon and had sustained the injury more than 2 yr prior to testing (mean = 5.7, SD 5.1 yr). Prior to surgery, all subjects exhibited full knee joint range of motion, no joint swelling, and no pain during ambulation. However, all subjects exhibited at least one episode of knee joint instability ("giving way") prior to surgery which was the main impetus for undergoing reconstructive surgery. The subjects had undergone arthroscopically assisted, endoscopic, bone-patellar tendon-bone reconstruction using the central one-third of the patellar tendon. All subjects were compliant with a conservative rehabilitation program and no subjects exhibited dysfunction at any other lower extremity joint on either the ipsilateral or contralateral limb. Following surgery, all subjects exhibited full knee joint range of motion, minimal joint swelling, and no pain during ambulation. No episodes of knee joint "giving way" were reported by any subject. The ACL deficient subjects were tested immediately prior to and 3 months following reconstructive surgery.

The mean age, body weight, and body height of control (CON) subjects were 24.4 (SD 3.1) yr, 67.2 (SD 10.7) kg, and 170.1 (SD 9.3) cm, respectively. The control subjects did not have a history of lower extremity infirmity or pathology that may have affected the ability to perform the experiment. Prior to participation, each subject signed a consent form approved by the University's Human Subjects Compliance Committee Institutional Review Board.

2.2. Protocol

The subjects walked along a 5 m wooden walkway in which a force plate was embedded. The subjects walked at a self-selected comfortable pace that was maintained throughout data collection via a metronome. Subjects were instructed to look straight ahead as to avoid any 'targeting' of the force plate. Each subject began walking at a sufficient distance from the force plate so that the self-selected pace was attained prior to the foot of the test limb making contact with the center of the force plate. Joint kinematic and kinetic data were collected for a 5-s period, which included the step prior to, during, and following contact with the force plate. Twelve trials of data were recorded for both limbs of each subject.

2.3. Instrumentation

A 6-degree of freedom custom force plate (Institute of Neuroscience Technical Service Group, University of Oregon, Eugene, OR, USA) equipped with strain gauges mounted underneath the four corners was used to measure the vertical (*Fz*), horizontal antero-posterior (*Fx*), and medio-lateral (*Fy*) ground reaction forces. Kinetic data were recorded at 1200 Hz for a 5-s duration via the Associated Measurements Laboratory (AMLAB Inc., Sydney, Australia) system. Prior to analysis, kinetic data were low-pass filtered between 4 and 10 Hz using a fourth order dual-pass Butterworth filter. Selected filter frequencies were determined for each force signal based on specifications from the manufacturer.

Kinematic data were collected using a PEAK Performance Technologies Real-Time Data Acquisition System (Peak Performance Inc., Denver, CO, USA). Four cameras were positioned 4 m from the sagittal plane along the progression plane of the subject's gait path. The pre-determined criterion for tolerable error in space calibration was set at 0.2% (2 mm maximum error for a 1-m long object). Five kinematic reflective markers were placed on the skin overlying the base of the fifth metatarsal, lateral malleolus, lateral condyle of the femur, greater trochanter of the femur, and acromion process of the scapula. A reflective marker was also placed on the force plate to serve as the point of reference for transformation of local center of pressure (CoP) coordinates to global kinematic coordinates. Kinematic data were collected at 120 Hz for a 5-s duration with each of the four cameras synchronized with the AMLAB system. Data were then digitized for the entire collection period. The digitized position data for all markers were then low-pass filtered between 4 and 8 Hz using a fourth order dual-pass Butterworth filter. Optimal filter frequencies were determined for each force signal based on power spectral analyses wherein 90% of the raw signal was retained after the filtering process. Linear and angular position, velocity and acceleration data were then calculated and exported for further analysis.

2.4. Inverse dynamics calculations

The magnitudes of the segmental masses along with their moments of inertia were estimated using data reported by Dempster (1959) and individual subject anthropometric data. CoP was calculated from the ground reaction force data within the force plate local coordinate system. Joint moments were calculated through an inverse dynamics analysis using a custom written MATLAB (The MathWorks, Inc., Natick, MA, USA) computer program combining the anthropometric, kinematic, and kinetic data. Knee and hip joint moments were expressed as a reaction moment to all external moments and represent the internal moments normalized to subject mass. All joint moments were expressed as positive values for extensor and plantarflexor moments. Extensor angular impulse was calculated from the positive area under the joint moment curve. Joint powers were calculated as the product of the joint moments and angular velocities and normalized to subject mass and positive work was calculated from the positive area under the joint power curve. The variables of interest were knee and hip joint moments, powers, and angles and were assessed from individual trials. Prior to analysis, each trial was partitioned for the stance phase of the gait cycle (heel strike to toe off), interpolated as a percent of stance, and an ensemble average was created by averaging the 12 trials.

2.5. Statistical analysis

Point-by-point Pearson product–moment correlation coefficients over the entire stance period of gait were calculated between corresponding data points of bilateral lower extremity joint kinematic, moment, and power ensemble curves for each group. A minimum correlation of 0.75 was used to indicate similarities in temporal characteristics between patterns. Derrick et al. (1994) introduced this curve correlation technique and reported that similarities in temporal characteristics result in a high correlation. However, high correlations do not necessarily provide information on amplitude differences. As such, in order to measure amplitude differences and provide further criteria to determine bilateral joint symmetry, extensor angular impulse, positive work, and average joint angle were analyzed using a two-way (group × limb) ANOVA. Therefore, r-values greater than 0.75 and no differences in magnitude measures would indicate joint symmetry and either r-values less than 0.75 or significant differences in magnitude measures would indicate joint asymmetry. The independent variables were group (ACL deficient, ACL reconstructed, and controls) and limb (injured, non-injured, left, right). The dependent variables were bilateral joint extensor angular impulse, positive work, and average joint angle for the knee and hip. Tukey post-hoc analyses were performed to detect differences between contralateral limbs and between groups when appropriate. A maximum α level of 0.05 was used to indicate statistical significance.

3. Results

There were no differences ($P > 0.05$) in total time of stance between limbs for the control (right: 863.06, SD 77.27 ms; left: 856.93, SD 75.94 ms), ACL deficient (injured: 865.08, SD 52.22 ms; non-injured: 838.97 SD 62.47), and ACL reconstructed (injured: 853.22, SD 72.33 ms; non-injured 858.00 SD 77.39 ms) groups. There were no significant ($P > 0.05$) differences in total time of stance between the three groups. Table 1 presents bilateral knee and hip joint extensor angular impulse, positive work, and average angle for each of the three groups.

3.1. Joint kinematics

The bilateral knee position curves for each of the three groups were highly correlated (range 0.93–0.99) and no between-limb differences in average knee angle

Table 1
Bilateral means (SD) for average angle (Ang; [a]), extensor angular impulse (EAI; [b]), and positive work ([c]), and for the knee (K) and hip (H) of control (CON), anterior cruciate ligament deficient (ACLD), and anterior cruciate ligament reconstructed (ACLR) subjects

Variable	CON		ACLD		ACLR	
	Left	Right	INJ	NON	INJ	NON
Knee angle	12.97 (0.87)	15.22 (1.92)	14.79 (4.57)	18.92 (2.62)$*_{l}$	17.63 (4.42)$*_{l}$	18.74 (3.91)$*_{l}$
Hip angle	10.32 (2.71)	11.24 (2.63)	14.65 (2.17)$*_{lr}$	15.71 (1.82)$*_{lr}$	15.85 (2.19)$*_{lr}$	15.95 (2.95)$*_{lr}$
Knee EAI	4.22 (1.20)	3.44 (0.49)	6.97 (2.68)	15.46 (3.30)$*_{lr}$+	9.92 (3.34)$*_{r}$	15.83 (4.81)$*_{lr}$+$\#_{i}$
Hip EAI	9.98 (4.57)	12.93 (5.30)	16.15 (8.05)	13.42 (6.79)	11.36 (5.82)	8.51 (4.63)
Knee work	8.57 (2.84)	6.30 (2.47)	14.37 (9.53)	22.38 (6.62)$*_{lr}$+	10.24 (4.46)$*_{r}$	19.08 (6.53)$*_{lr}$+
Hip work	16.80 (4.65)	23.77 (5.31)+	28.32 (15.61)	23.38 (11.67)	22.64 (8.21)	17.34 (6.50)

+ Significantly different than opposite limb ($P < 0.05$);
$*_{l}$ Significantly different than CON left limb ($P < 0.05$);
$*_{r}$ Significantly different than CON right limb ($P < 0.05$);
$\#_{i}$ Significantly different than ACLD injured limb ($P < 0.05$).
[a] Values indicate flexion (deg).
[b] Values indicate extensor moments (N m/kg).
[c] Values indicate power generation (J).

were observed indicating bilateral knee joint symmetry within each group (Table 1; Fig. 1). However, differences in average angle were observed between groups as the ACL deficient group exhibited significantly ($P < 0.05$) greater non-injured knee flexion and the ACL reconstructed group exhibited significantly ($P < 0.05$) greater non-injured and injured knee flexion compared to the control group's left limb (Table 1; Fig. 1). The bilateral hip position curves for each of the three groups were highly correlated (range 0.86–0.96) and no between-limb differences in average hip angle were observed indicating bilateral hip joint symmetry within each group (Table 1; Fig. 2). However, differences in average angle were observed between groups as the ACL deficient and ACL reconstructed groups exhibited significantly ($P < 0.05$) greater bilateral hip flexion compared to the control group (Table 1; Fig. 2).

3.2. Joint moments

Similar to the position data, the bilateral knee moment curves for the control group were highly correlated (0.96) and no between-limb differences in knee extensor angular impulse were observed further suggesting bilateral knee joint symmetry. However, while the bilateral knee moment curves for the ACL deficient group were highly correlated (0.94), these subjects demonstrated significantly ($P < 0.05$) greater non-injured knee extensor angular impulse compared to the contralateral injured knee indicating bilateral knee joint asymmetry (Table 1; Fig. 3). In addition, the ACL deficient group demonstrated significantly ($P < 0.05$) greater non-injured knee extensor angular impulse compared to the control group (Table 1; Fig. 3). Following surgery, the bilateral knee moment curves for the ACL reconstructed group were highly correlated (0.94)

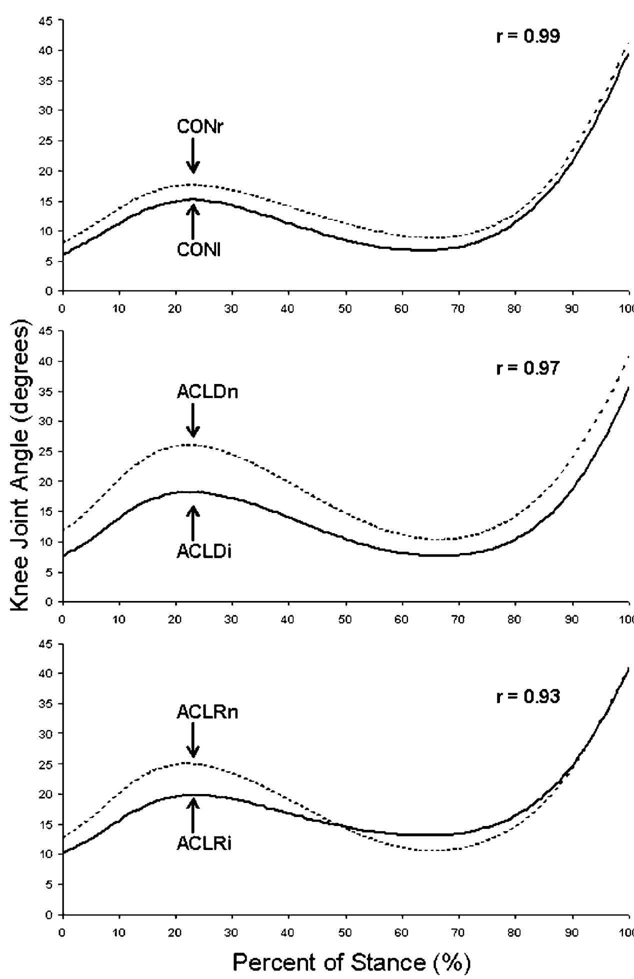

Fig. 1. Bilateral knee joint position curves and r-values for control (CON) left (l) and right (r) limbs, ACL deficient (ACLD) and ACL reconstructed (ACLR) injured (i) and non-injured (n) limbs. Positive values indicate flexion, negative values indicate extension.

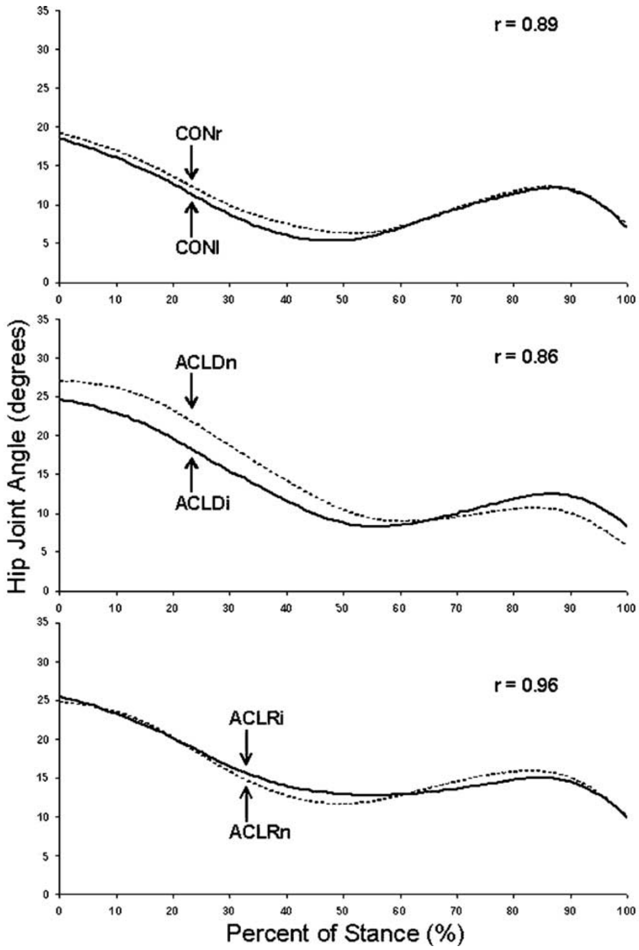

Fig. 2. Bilateral hip joint position curves and *r*-values for control (CON) left (l) and right (r) limbs, ACL deficient (ACLD) and ACL reconstructed (ACLR) injured (i) and non-injured (n) limbs. Positive values indicate flexion, negative values indicate extension.

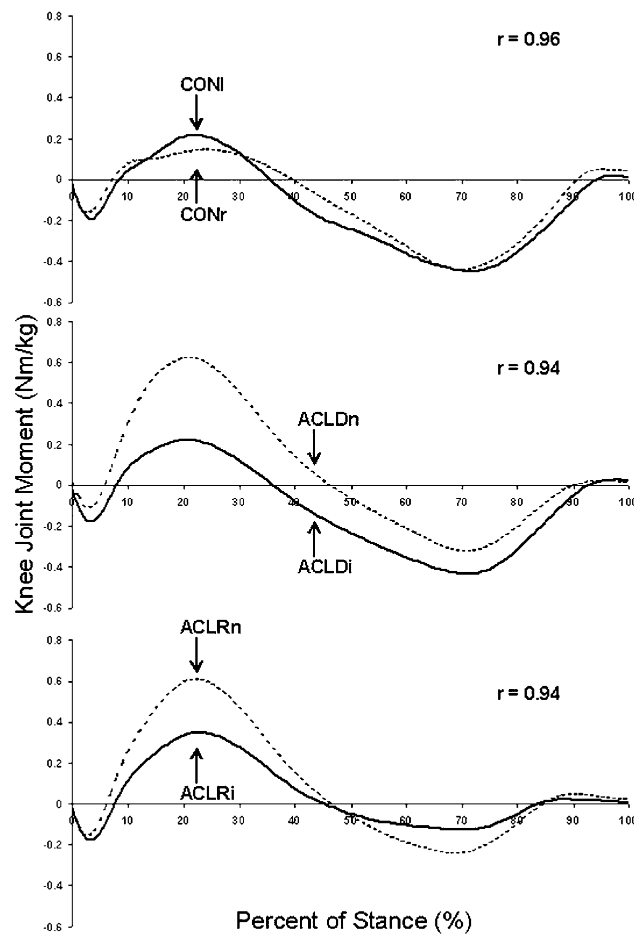

Fig. 3. Bilateral knee joint moment curves and *r*-values for control (CON) left (l) and right (r) limbs, ACL deficient (ACLD) and ACL reconstructed (ACLR) injured (i) and non-injured (n) limbs. Positive values indicate extensor moments, negative values indicate flexor moments.

but significantly ($P < 0.05$) greater non-injured knee extensor angular impulse was observed compared to the contralateral injured knee indicating bilateral knee joint asymmetry (Table 1; Fig. 3). In addition, the ACL reconstructed group exhibited significantly ($P < 0.05$) greater non-injured knee extensor angular impulse compared to the injured limb prior to surgery and the control group (Table 1; Fig. 3). The bilateral control group hip moment curves did not meet the minimum *r*-value of 0.75 ($r = 0.72$) and no differences in hip extensor angular impulse were observed suggesting hip joint asymmetry. In contrast to the control group, the bilateral ACL deficient (0.89) and ACL reconstructed (0.94) hip moment curves were highly correlated and no significant ($P > 0.05$) differences in hip extensor angular impulse were observed between limbs suggesting bilateral hip joint symmetry (Table 1; Fig. 4). No between-group differences in hip extensor angular impulse were observed ($P > 0.05$; Table 1).

3.3. Joint powers

The bilateral control group knee power curves were highly correlated (0.93) and no significant ($P > 0.05$) differences in knee positive power were observed further suggesting bilateral knee joint symmetry (Table 1; Fig. 5). In contrast, the bilateral ACL deficient were only moderately correlated (0.68) and the non-injured knee produced significantly ($P < 0.05$) more positive work compared to the contralateral injured limb indicating knee joint asymmetry (Table 1; Fig. 5). In addition, the ACL deficient non-injured knee produced significantly ($P < 0.05$) more positive work compared to the control group (Table 1; Fig. 5). The ACL reconstructed knee power curves were highly correlated (0.79) but the non-injured knee produced significantly ($P < 0.05$) more positive work compared to the contralateral injured limb suggesting bilateral knee joint asymmetry. In addition the ACL reconstructed non-injured and injured

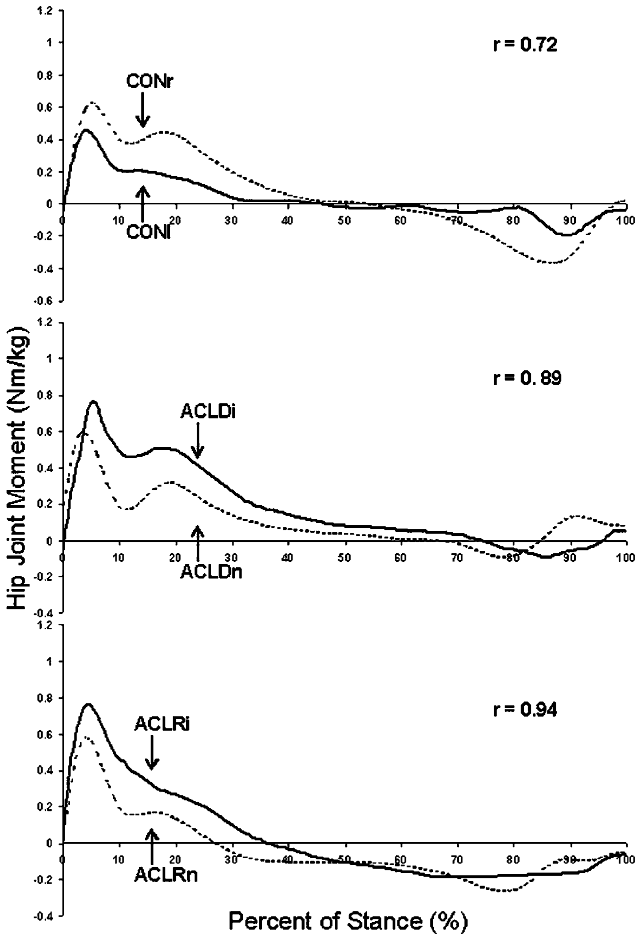

Fig. 4. Bilateral hip joint moment curves and r-values for control (CON) left (l) and right (r) limbs, ACL deficient (ACLD) and ACL reconstructed (ACLR) injured (i) and non-injured (n) limbs. Positive values indicate extensor moments, negative values indicate flexor moments.

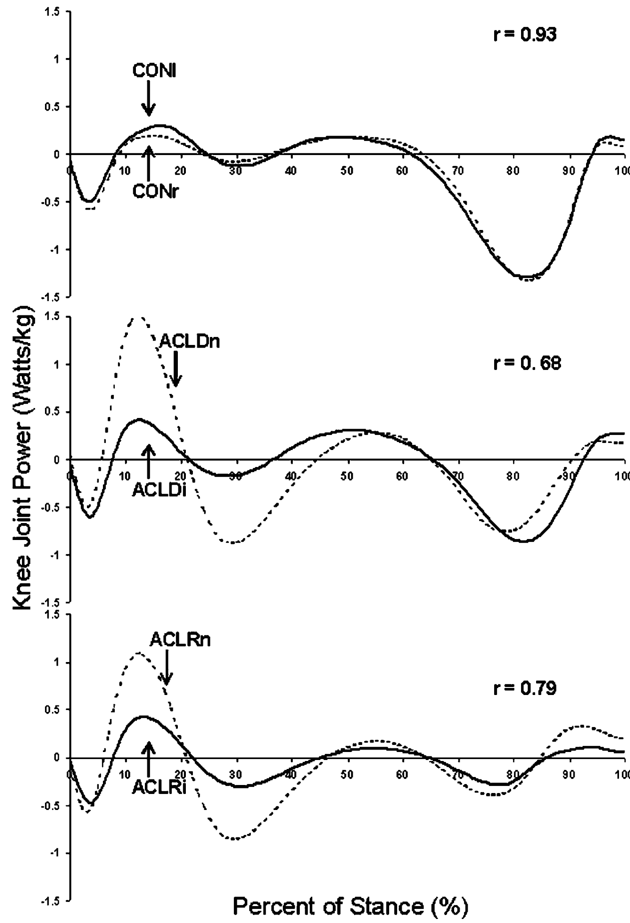

Fig. 5. Bilateral knee joint power curves and r-values for control (CON) left (l) and right (r) limbs, ACL deficient (ACLD) and ACL reconstructed (ACLR) injured (i) and non-injured (n) limbs. Positive values are energy generation, negative values are energy absorption by the muscles.

knee produced significantly ($P < 0.05$) more positive work compared to the control group (Table 1; Fig. 5). The bilateral control hip power curves were poorly correlated (0.42) and significantly ($P < 0.05$) more right hip positive work was produced compared to the left hip indicating bilateral hip joint asymmetry (Table 1; Fig. 6). In contrast, the ACL deficient (0.80) and ACL reconstructed (0.75) bilateral hip power curves were highly correlated and no significant ($P > 0.05$) differences in bilateral differences in hip positive work were observed indicating bilateral hip joint symmetry. No significant ($P > 0.05$) between-group differences in hip positive work were observed (Table 1; Fig. 6).

4. Discussion

The purpose of this study was to determine the effect of chronic ACL deficiency and subsequent reconstructive surgery on bilateral lower extremity joint kinematic, moment, and power patterns in chronic ACL deficient subjects prior to and 3 months following surgical repair and in healthy uninjured subjects. Biomechanical adaptations to chronic ACL injury and reconstructive surgery depend on several factors including rehabilitation protocol, patient compliance, and surgical procedure. The present results may apply only to chronic ACL injured individuals who demonstrate similar characteristics as patients involved in this study. As well, the subjects involved in the present investigation would be classified as non-copers since each reported at least one episode of giving way prior to surgery (Rudolph et al., 1998). ACL injured subjects who are able to cope with their injury may not exhibit similar bilateral lower extremity joint accommodations.

Torry et al. (2000) suggested many gait adaptations reported in previous ACL investigations may be the result of intra-articular knee effusion. They reported that artificially-induced knee joint effusion resulted in a decreased peak knee extensor moment in healthy

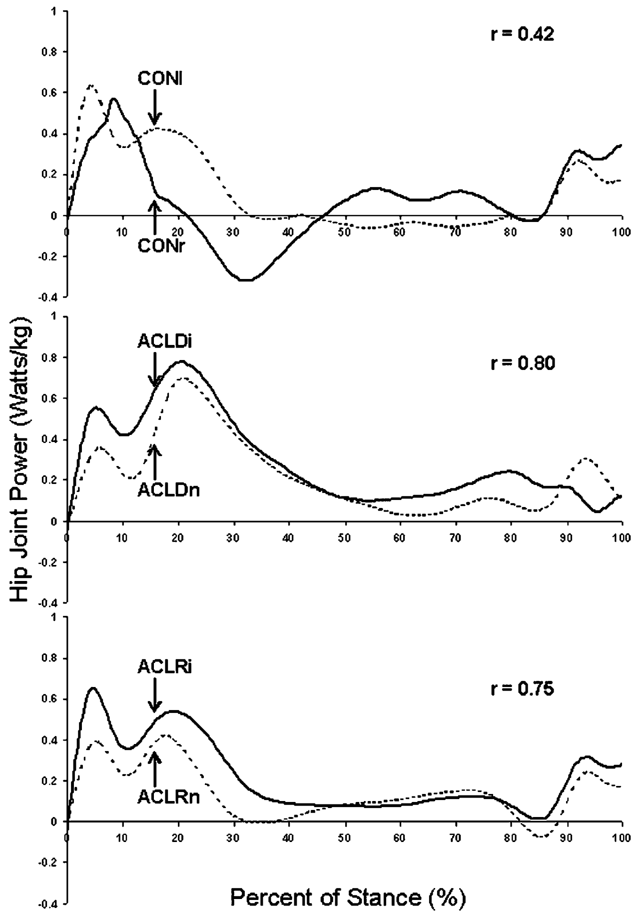

Fig. 6. Bilateral hip joint power curves and r-values for control (CON) left (l) and right (r) limbs, ACL deficient (ACLD) and ACL reconstructed (ACLR) injured (i) and non-injured (n) limbs. Positive values are energy generation, negative values are energy absorption by the muscles.

individuals. In the present investigation, the ACL injured subjects exhibited minimal, if any, knee joint effusion prior to or following surgery but it is possible that effusion was present but not readily noticeable. Similar to the results of Torry et al. (2000), the reduced knee extensor angular impulse in the ACL deficient and ACL reconstructed injured knee compared to the non-injured knee observed in the present investigation may have been the result of such effusion.

In the present study, the control group exhibited hip joint asymmetry as significant bilateral differences in hip positive work and low to moderate between-limb correlation coefficient values for the hip moment and power curves were observed. It has been previously reported that hip power patterns in healthy individuals were asymmetrical due to different limb functions during stance (Allard et al., 1996; Sadeghi et al., 1997, 2000). Allard et al. (1996) reported total lower extremity joint symmetry for positive work during gait but significantly greater peak muscle power generation in the right limb of subjects. These authors speculated that the between-limb asymmetry should be interpreted as gait adjustments and could be attributed to different limb functions during gait. Sadeghi et al. (1997, 2000) supported these findings and suggested that the lead leg was primarily used for propulsion while the trail leg was used for balance control. The results of the present investigation are in agreement with those of Allard et al. (1996) and Sadeghi et al. (1997, 2000) and suggest that gait asymmetry in healthy subjects should not be considered pathological. In addition, the results of the present study suggest that pooling left and right limb data when making comparisons to other populations may mask differences between groups.

Contrary to the control group, the ACL deficient and ACL reconstructed groups exhibited hip joint symmetry in terms of no between-limb differences in hip positive work and extensor angular impulse and high between-limb correlation coefficient values for hip moment and power patterns. Berchuck et al. (1990) reported that chronic ACL deficient subjects demonstrated a bilateral increase in hip extensor moments compared to healthy adults. The data from the present study support those of Berchuck et al. (1990) and suggest that ACL deficient and ACL reconstructed subjects demonstrated hip joint symmetry, possibly in response to ACL injury.

In the present study, the control group exhibited knee joint symmetry since no significant between-limb differences in knee positive work and extensor angular impulse were observed and the bilateral knee moment and power curves were highly correlated. In contrast, the ACL deficient and ACL reconstructed groups exhibited knee joint asymmetry in both moment and power patterns. Specifically, between-limb differences in positive work and low to moderate correlation coefficients for knee power patterns were observed. In addition, while the ACL deficient and reconstructed groups exhibited moderate to high between-limb correlation coefficient values for knee moment patterns, significant between-limb differences in extensor angular impulse magnitude were also observed. Derrick et al. (1994) reported that high correlations indicate similarities in the temporal relationship between two curves but that these measures are not sensitive to amplitude differences. Thus, joint symmetry was defined as high correlations and no between-limb differences in the discrete measures. In the present study, the ACL group's non-injured knee produced significantly more extensor angular impulse and knee work compared to the contralateral injured knee prior to and following surgical repair suggesting bilateral joint asymmetry. These findings are in support of Rudolph et al. (1998) who also reported knee joint asymmetry in terms of significantly different between-limb peak knee extensor moments.

The results of the present study suggest that ACL deficient subjects exhibit bilateral and unilateral joint accommodations in gait mechanics that persist up to 3 months following surgery. The ACL deficient and reconstructed groups also demonstrated significantly greater bilateral hip joint flexion throughout stance compared to the control group. These results are in agreement with previous investigations that have reported that ACL deficient subjects were more flexed at the hip and exhibited a greater hip extensor moment during stance (Berchuck et al., 1990; Devita et al., 1997; Ferber et al., 2002; Roberts et al., 1999; Wexler et al., 1998). The ACL deficient and reconstructed groups also exhibited bilateral hip joint symmetry and bilateral knee joint asymmetry. It is possible that symmetrical hip moment and power patterns were an adaptation to asymmetry exhibited in the ACL deficient and ACL reconstructed group knee moment and power patterns. It has been suggested that there is a reciprocal trade-off between the hip and knee joints such that dynamic balance and control of the head–arm–trunk segment occurs via a coordination between posterior muscles (hip extensors/knee flexors) and anterior muscles (hip flexors/knee extensors) acting at either joint (Winter, 1987, 1990). Winter (1987, 1990) also suggested that this reciprocal trade-off between the knee and hip moments may be necessary to maintain forward progression during ambulation.

Often times, the contralateral limb is used for comparison to determine progression during rehabilitation or as the criteria to determine when the patient is ready to return to full activity. The results of the present investigation suggest that the use of the contralateral, non-injured limb as the basis for comparison for the injured limb may not be sufficient as adaptations to injury and surgery may occur bilaterally. As was previously noted, all subjects in the present study exhibited full knee joint range of motion, no to minimal joint swelling, no pain during ambulation, and the subjects did not walk with any obvious gait abnormalities. However, the results of the present study suggest that gait adaptations were apparent prior to surgery and that these adaptations persisted up to 3 months following surgery.

Most clinicians do not have access to motion analysis equipment and cannot therefore determine gait adaptations in a similar manner. The clinical tests most often used for comparing the injured and non-injured limb are generally such tests as ACL laxity, joint range of motion, isokinetic strength testing, hop tests and other athletic activities, and Knee Outcome Survey-Activities of Daily Living Scale (KOS-ADLS) and Global Rating self-report of function questionnaires (Chmielewski et al., 2002; Irrgang et al., 1998; Rudolph et al., 1998). However, it is unknown whether bilateral accommodations in gait mechanics would also be apparent during such clinical rehabilitation activities. Future studies investigating bilateral differences in common clinical rehabilitation techniques and during gait may be useful to determine the best clinical criteria to use with ACL deficient and reconstructed patients.

5. Conclusions

The present study investigated bilateral symmetry in healthy and chronic ACL injured subjects prior to and 3 months following reconstructive surgery. The control subjects demonstrated asymmetrical hip patterns and symmetrical knee patterns. However, ACL injured subjects exhibited symmetrical hip but asymmetrical knee joint mechanics prior to and following reconstructive surgery. These findings suggest that ACL injury result in joint specific, bilateral lower extremity accommodations and persist up to 3 months following reconstructive surgery.

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