HAMSTRING CONTRACTILE TIMING IN ANTERIOR CRUCIATE LIGAMENT DEFICIENT PATIENTS

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The purpose of this research is to examine contractile timing of the hamstrings in patients with anterior cruciate ligament (ACL) deficient knees. Ten patients were tested for hamstring contractile timing using Electromyographic (EMG) recordings during gait speeds of 3km/h and 5km/h on both a level and ten degree incline. An ANOVA analysis was used to demonstrate timing onset differences between the deficient and normal leg for each test condition and muscle onset timing was related to the Lysholm scale for perceived knee function. Significant interaction differences were found for legs and speed variations plus a negative correlation between functional scores and hamstring timing onset.

KEY WORDS: anterior cruciate, hamstrings, electromyography, gait.

INTRODUCTION: Estimations on debilitating knee injuries indicate that 60 % to 70 % are related to ACL injuries (Brant, 1989). One of the functional roles of the hamstring musculature during gait is to prevent excessive anterior translation of the tibia when body weight forces and shear forces in the anterior cruciate are maximal. The timing of hamstring contraction onset therefore plays a dominant protective role in patients who are ACL deficient and require muscular support to maintain the integrity of the joint (Tibone and Antich,1988).Although rehabilitation techniques promote tensile strengthening of the hamstrings and quadriceps muscle groups, the timing of the contraction plays a critical role and has been shown to adjust in ACL patients who have chosen a non-surgical treatment approach (Beard,1993;1994).The significance of this research is to gain an understanding of the degree of muscular control that a patient may have developed in order to control joint stability and prevent further injury. In addition, the ability of the patient to perceive and control the adaptations will be investigated. The research provides information that might support viable alternatives to reconstructive surgery using muscular retraining, muscle stimulation or proprioceptive techniques. The purpose of the study is to measure whether ACL patients do in fact adapt their hamstring onset timing under variable gait conditions and if the adaptations are related to knee function symptoms perceived by the patient.

METHODS: Ten male and ten female patients between the ages of 18 and 40 who were ACL deficient and had chosen a non- surgical reconstruction option for rehabilitation were screened for subject selection. Subjects were a minimum of two years post injury due to the average length of the rehabilitation programs, the full recovery time, and the period required for neurological adaptation (Gauffin and Tropp,1992). Subjects were examined originally arthroscopically and diagnosed with a full rupture of the anterior cruciate ligament but were able to walk without a visible limp at the time of testing. All pretesting was performed by an experienced, certified physiotherapist .The clinical pretests for both legs included; the straight leg raise for hamstring tightness, Ober's test for iliotibial band tightness, valgus and varus pressures for knee ligament laxity and the Anterior Draw and Lachman Drawer tests. The pretests were used to ensure that there was a positive ligament deficiency causing anterior tibial translation in the injured knee. Subjects who did not display obvious signs of anterior cruciate deficiency were not considered for the study. Evidence in the literature indicates that there may be some muscular reprogramming adaptation in the contralateral leg of ACL patients (Andriacchi, 1990). Based on the obvious functional differences between the two legs, demonstrated by arthroscopic surgery and joint stability tests, the non-injured leg was used as a control measure. The interview process included a history of injuries to the lower extremity and the treatment, recovery and functional activity levels of each patient over the previous three months. Patients who had experienced additional complicating injuries or difficult rehabilitations plus those who had practiced extreme lifestyle activities were excluded from the subject sample. A Lysholm Knee Scoring Scale was completed during the pretest period (Tegner and Lysholm,1985; McGinnis,1984). The scale provided an indication of the subject's self perceived knee function using a series of questions relating to symptoms which might effect knee function including pain, swelling, instability, locking and support levels. The objective was to relate the scores to muscular timing patterns in order to demonstrate a relationship to perceived function. Bipolar surface EMG electrodes were placed over the medial aspect of the hamstring group, semimembranosus and semitendinosus, in order to minimise cross talk from the vastus lateralis (Basmajian, 1980; Kalund et al.,1990). Foot heel switches recorded heel strike and raw EMG muscle action potentials on a Bortec, 8 channel EMG system equipped with shielded leads and a filtered signal to provide a noise free baseline. The raw EMG recordings were recorded at 1000 Hz over a band width of 10 to 1000Hz.The signal was recorded and time values (ms) values assessed using Global Lab data analysis software (Global Lab.1991). Each subject walked on a treadmill at 3 kmlh and 5 kmlh on both a level and 10 degree inclined treadmill. Three five second recordings were taken at equal intervals during a continuous walking gait test so that a series of three gait cycles were captured. The mean time interval for the three trial intervals was then calculated for each test condition. Walking gait was selected as the most repetitive normal motion to assess muscular timing changes. Two different gait speeds were used to provide variable anterior tibial translation forces and the slope provided an additional timing adjustment created by the shortened distance for heel strike. More aggressive tests to evaluate abnormal knee rotation were avoided due to the potential risk for further injury and the difficulty controlling the motion. Timing values were based on the heel strike to heel strike gait cycle as 100% with hamstring contraction onset presented as a percentage of that period. The hamstring contraction was initiated immediately prior to heel strike and muscle contraction was defined as the first bipolar increase in amplitude more than one standard deviation above 15 msec of baseline activity (Tokuhiro et al,1985). The timing was normalised as a percentage of the gait cycle for comparative purposes. EMG results were analysed using an ANOVA 2x2x2 design to show differences in hamstring timing for injured and uninjured legs at 3k/h and 5k/h speeds for flat and inclined gait conditions. The Lysholm functional scoring scale was correlated to the hamstring timing results to indicate the relationship between perceived knee function and hamstring timing.

RESULTS: Descriptive data for interaction and main effects for hamstring onset timing intervals are presented in Table 1.The ANOVA statistical analysis indicated significant main effects ($p<.05$) for Leg ($F = 893.49$, $df=1, p<.000$) and Speed ($F= 47.82, df=1, p<.000$) plus two interaction effects for Leg/Speed and Incline/Speed. The Leg/Speed main effect was significant ($F= 18.05, df=1, p<.000$) and indicated that the hamstrings onset was earlier for both the 3km/h and 5km/h speeds for both legs and occurred earlier at the higher speed. The Incline/Speed differences were significant ($p<.05$) and ($F= 9.41, df=1, p<.002$) and indicated onset timing to be earlier as speed increases on flat surfaces only. No significance was shown for the Incline main effect, the Incline/Leg interaction or the Incline /Leg/Speed three way interaction. The Pearson Correlation indicated a negative relationship ($r= -0.6$) between hamstring timing onset scores and the Lysholm functional scores.

DISCUSSION: The literature supports the theory that hamstring coordination reflex may help protect the ACL from anterior shear forces during heel strike. The reflex has been demonstrated in static and dynamic movement both during weight bearing and non -weight bearing (Beard and Kyberd, 1993; Osternig,1995). The results for the leg main effects reflect these findings as they demonstrate earlier hamstring onset in the ACL deficient leg compared to the uninjured leg.

Table 1 Group data for Hamstring Onset time (ms). Main effects (M) and Interactions (I) between Injured **(IN)and** Uninjured (UN) Legs for **Speed(S)** and Slope (SL)

GRP- I	MEAN	ST.DEV	ST.ERR	GRP-M	MEAN	ST.DEV	ST.ERR
SUS	ms	ms	ms	Leg	ms	ms	ms
Flat/3km	6.0	4.38	.354	IN	11.61	4.84	.24
Flat/5km	9.09	5.82	. 373	UN	3.97	1.71	.08
10°/3km	7.06	4.51	.329	S			
10°/5km	8.08	5.34	.337	3km	6.59	4.48	.24
SL/Leg				5km	8.58	5.6	.25
Flat/IN	12.21	4.97	.362	SL			
Flat/UN	3.969	1.829	.127	Flat	7.9	5.52	.28
10°/IN	11.113	4.681	. 311	10°	7.65	5.02	.24
10°/UN	3.9691	3.9691	.1083				
Leg/S							
UN/3km	9.97	4.23	.334				
IN/5km	12.64	4.924	.3083				
UN/3km	3.58	1.724	.1281				
UN/5km	4.250	1.64	.1062				

The theories in the literature which explain these differences are still unclear and range from muscle spindle and Golgi organ stimulation to a pre-programmed, leamed protective response. The main effects also indicate earlier hamstring onset with speed increases possibly due to the adjustment required for the higher tibial translation forces and earlier preparation for heel strike. The expected differences due to the ten degree slope were not significant perhaps due to the decreased level of anterior tibial translation adjustment required for the incline slope. A decline test would have promoted more tibial translation but was avoided due to the safety element. The interaction of incline and speed were not consistent for fast and slow speeds. Earlier contraction was significant at the slow speed but not at the higher speed with the incline. This result was not consistent as it was expected that both speeds would have similar result as in the speed main effect. The effects of incline, shorten the gait cycle and decrease anterior tibial translation but this would not be expected to change with an increase in speed. Results from Kalund et. al. (1990) indicate significant differences in hamstring timing from flat to incline however this result only supports a difference for incline at the lower speed. The adaptations for an ACL deficiency are possibly learned responses resulting from joint instability and the protective response. The moderate negative correlation for the functional scores and timing scores indicates that as hamstring timing onset occurred earlier self reported knee function decreased. This is supported by Beard and Kyberd (1993) and indicates that earlier contraction relates to a lower perceived score. Possible explanations are that early onset contraction may be a deficiency linked to the tissue damage within the knee or, alternatively, it may be an adaptation or protective mechanism which is not sufficient to effect the subjects perception of stability as measured by the Lysholm scale. The suggestion then is that patients may not be directly aware of the functional problem to the extent that they can consciously control the contractile process. Patients, however, may develop a natural unconscious protective response which could be maximized through a variety of retraining responses.

CONCLUSION: The results support early contraction of the hamstrings in ACL deficient knees plus earlier onset timing with increases in gait speed. This trend was not maintained for slope and faster gait speeds. The patient did not perceive greater function due to the earlier onset of hamstring contraction. Early contraction onset in the hamstrings is probably the result of a learned adaptation however the nature of the proprioceptive mechanism during walking with combinations of slope and speed is not consistent. Learning may improve timing adaptations with specific training on a variety of slopes and speeds. The recommendation is for further timing studies using training combinations of different gait speeds and slope variations. Failure to find the expected differences in some interactions may be corrected by introducing a control group to account for contralateral differences. Further muscle timing studies on the effects of muscle stimulation and muscle retraining techniques will provide reinforcement for effective rehabilitation and a non-surgical approach to ACL injuries.

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