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KNEE FUNCTION OF CHRONIC ACLD PATIENTS DURING STATIC KNEE LAXITY ASSESSMENT AND DYNAMIC DECELERATION

A thesis submitted in fulfilment of the
requirements for the award of the degree

DOCTOR OF PHILOSOPHY

from

UNIVERSITY OF WOLLONGONG

by

JULIE R STEELE BPE (Hons) DipTch

DEPARTMENT OF BIOMEDICAL SCIENCE

1997

Declaration

The work presented in this thesis is original work of the author except as acknowledged in the text. I hereby declare that I have not submitted any of the material presented in this thesis, either in whole or in part, for a degree at this or any other institution. Copies of the original data analysed in the four studies conducted within this thesis are held by the Department of Biomedical Science, University of Wollongong.

Julie Robyn Steele

Dedication

To Bruce, Jessica, and Harrison.

I dedicate this thesis to you. I am indebted to your unending love, patience, and understanding, without which this thesis would never have been completed. You have sacrificed much to let me achieve my goals.

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Publications

The following publications and presentations have arisen directly from the work conducted for this thesis. Other related publications completed by the author are included in the reference list.

Publications in Refereed Journals

Steele, J.R., Roger, G.J., & Milburn, P.D. (1994). Reliability of knee laxity assessment using the Dynamic Cruciate Tester [abstract]. *Medicine and Science in Sport and Exercise*, **26**(5), S62.

Steele, J.R., Roger, G.J., & Milburn, P.D. (1995). Tibial translation and hamstring activity during active and passive arthrometric assessment of knee laxity. *The Knee*, **1**, 217-223.

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Steele, J.R., & Roger, G.J. Reproducibility of knee laxity results using the Dynamic Cruciate Tester. *Australian Journal of Science and Medicine in Sport* (accepted for publication pending minor revision).

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Steele, J.R., & Brown, J.M.M. Effects of chronic ACL deficiency on muscle activation patterns during an abrupt deceleration task. *Clinical Biomechanics* (invited submission as a finalist in the Clinical Biomechanics Award, International Society of Biomechanics; in review).

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Steele, J.R., Milburn, P.D., & Roger, G.J. (1993). Effect of torso position on measurement of knee laxity and hamstring muscle activity [abstract]. In S. Bouisset, S. Métral, & H. Monod (Eds.), *Abstracts of the International Society of Biomechanics XIVth Congress* (pp. 1282-1283). Paris, France: Société de Biomécanique.

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Other International Conference Presentations

Steele, J.R. (1994). Functional adaptations in the ACL deficient knee: performance of a deceleration task. *The New Zealand Federation of Sports Medicine Annual Scientific Conference.* April 15-18, Nelson, New Zealand (Invited Presentation).

Steele, J.R. (1994). Arthrometric testing of the ACL deficient knee. *The New Zealand Federation of Sports Medicine Annual Scientific Conference.* April 15-18, Nelson, New Zealand (Invited Presentation).

Steele, J.R., Brown, J.M.M., & Milburn, P.D. (1997). Effect of chronic ACL deficiency on tibiofemoral joint forces and knee moments of force during an abrupt deceleration task. *XVth International Symposium of Biomechanics in Sport*, June 21-24, Denton, Texas (accepted for presentation).

Steele, J.R., & Brown, J.M.M. (1997). Effects of chronic ACL deficiency on muscle activation patterns during an abrupt deceleration task. *XVIth International Society of Biomechanics Congress*, August 25-29, Tokyo, Japan (accepted for presentation and selected as a finalist in the Clinical Biomechanics Award, International Society of Biomechanics).

Abstract

Treatment of anterior cruciate ligament deficient (ACLD) patients is complicated by difficulty in accurately predicting those patients who will be functionally impaired by ACL rupture and those who will have minimum symptoms. Although the effects of ACL rupture on knee function during locomotor tasks have been studied, no research was located which examined whether the use of compensatory adaptations by ACLD subjects to perform dynamic tasks could be associated with knee function during knee laxity assessment. Therefore, the purpose of the thesis was to establish the relationship between knee function during arthrometric knee laxity assessment and knee function during a dynamic movement known to stress the ACL, namely abrupt deceleration. To achieve this three studies were conducted to establish a standardised arthrometric knee laxity assessment protocol using the Dynamic Cruciate Tester (DCT) and to verify reliability of the protocol (Experimental Section A). In Study 1 active and passive knee laxity was assessed for 10 uninjured subjects before and after the subjects cycled for 10 minutes and then performed hamstring stretches. As there were no significant differences between anterior tibial translation (ATT), knee extension force, or hamstring activity pre- compared to post-warm up it was concluded that a warm up suitable for use with ACLD patients was not required before arthrometric knee laxity assessment. In Study 2 active and passive knee laxity of 12 controls and 12 ACLD subjects was assessed with the subjects in three torso positions: vertical, reclined, and supine; while electromyographic (EMG) data were collected for the hamstring and quadriceps muscles. Although there was no significant difference in mean ATT as a function of torso position, subjects displayed significantly greater hamstring activity when seated vertically or reclined compared to when supine. As torso position also significantly affected knee extension force, it was recommended patients be supine during arthrometric knee laxity assessment to minimise muscle guarding. In Study 3 reproducibility of ATT and knee extension force data were examined for 13 ACLD subjects and 16 controls. The ATT and knee extension force results were found to be highly reproducible between and within test days. However, as a significant main effect of trial was found on ATT, a pretrial was recommended before knee laxity assessment to enhance reproducibility of the results. It was concluded that, following the standardised protocol, the DCT was a reliable tool to characterise ATT and isometric knee extension deficits and to monitor hamstring guarding by chronic ACLD subjects during active and passive arthrometric knee laxity assessment.

Once the arthrometric assessment protocol was established, a kinematic, kinetic, and neuromuscular analysis was conducted of 11 chronic functional ACLD subjects and 11 matched controls performing a deceleration task (landing in single-limb stance after catching a ball) after each subject's lower extremity strength and knee laxity were assessed (Experimental Section B). Compared to the controls, the ACLD subjects displayed: lower

Lysholm knee scores; significantly lower peak knee extension torques assessed isokinetically ($60^\circ \cdot s^{-1}$); no evidence of knee flexion strength deficits and no significant reduction in thigh circumference; a significantly greater mean passive gap but a negligible limb-to-limb difference in active ATT; greater hamstring cocontraction during anterior tibial drawer to restrict excessive ATT; and took longer during active assessment to deactivate rectus femoris and vastus lateralis after reaching their maximal knee extension effort. During the deceleration task no significant alterations were evident in the kinematic parameters analysed at either Initial Contact (IC) or Peak Resultant Ground Reaction Force (PRGRF) or in the ground reaction forces generated by the ACLD subjects. However, compared to the controls, the ACLD subjects displayed: significantly less knee flexion motion from IC to PRGRF; a higher tibiofemoral compressive force (F_c) at IC caused by higher knee flexion moments; a delay in hamstring activation so that peak hamstring activity was more synchronous with IC and with the high tibiofemoral shear forces (F_s) which occurred post IC; but no evidence of quadriceps-avoidance nor any increase in hamstring cocontraction intensity. These between-subject group differences were thought to be functional adaptations employed by the ACLD subjects to stabilise their involved knee against a giving-way episode via increased joint compression and posterior tibial drawer in preparation to withstand, rather than reduce or avoid, the high anterior F_s generated during deceleration.

Landing technique adaptations displayed by ACLD subjects were evident only at IC with the hamstring and quadriceps muscles activated before IC. These findings supported the notion that subjects preprogrammed their deceleration strategy before landing in anticipation of the joint loads. Although increased hamstring guarding during arthrometric knee laxity assessment and restricted knee flexion motion during deceleration were displayed bilaterally, alterations in F_c, knee flexion moments, and hamstring sequencing during deceleration were not transferred to the contralateral limb. It was postulated that task novelty or upper extremity motion involved in catching the ball may have interfered with the ACLD subjects' motor programs developed to control lower extremity muscle function during deceleration.

Thirty five correlations between variables characterising knee laxity and deceleration were significant across the pooled subject group results. However, the correlations were low ($r = 0.299 - 0.483$) such that most of the variance within the variables characterising knee function during deceleration could not be explained by their relationship to the variables characterising knee function during arthrometric knee laxity assessment. Therefore, although providing information pertaining to functional status during a closed isometric knee extension effort or during passive anterior tibial loading, it was concluded that the DCT could not be used to predict knee function of ACLD subjects during an open dynamic deceleration task.

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List of Abbreviations and Notations

Abbreviations and notations used throughout the text of the thesis are defined below. Abbreviations used in tables throughout the thesis are defined within the relevant tables. Symbols used in equations in the thesis are defined below each equation.

Notation	Definition	Notation	Definition
ACL	Anterior cruciate ligament	KSS	Knee Signature System
ACLD	Anterior cruciate ligament deficient	LCL	Lateral collateral ligament
		LH	Lateral hamstrings
A-D	Analog-to-digital	LVDP	Linear voltage differential potentiometer
AIIS	Anterior inferior iliac spine		
ALB	Anterolateral band of the ACL	MCL	Medial collateral ligament
AMB	Anteromedial band of the ACL	MET	Metabolic equivalent
AMI	Arthrogenic muscle inhibition	MH	Medial hamstrings
ANOVA	Analysis of variance	M_k	Moment of force about the knee
AP	Anterior-posterior		
ATT	Anterior tibial translation	MVIC	Maximal voluntary isometric contraction
BF	Biceps femoris		
BrF	Braking force	PC	Personal computer
BW	Body weight	PCL	Posterior cruciate ligament
CNS	Central nervous system	PLB	Posterolateral band (ACL)
COM	Centre of mass	PNF	Proprioceptive neuromuscular facilitation
COP	centre of pressure		
DC	Direct current	PRGRF	Peak resultant ground reaction force
DCT	Dynamic Cruciate Tester		
df	degrees-of-freedom	RHCL	Reflex hamstring contraction latency
DSP	Digital Signal Processing		
EMG	Electromyography	ROM	Range of motion
f_c	Cutoff frequency	RPM	Revolutions per minute
F_c	Tibiofemoral compressive force	RF	Rectus femoris
		RMS	Residual mean square
F_R	Resultant ground reaction force	SEP	Somatosensory evoked potentials
F_s	Tibiofemoral shear force	SD	Standard deviation
F_x	Anteroposterior ground reaction force component	SM	Semimembranosus
		ST	Semitendinosus
F_y	Vertical ground reaction force component	UCLA	University of California, Los Angeles
F_{y1}	Initial peak vertical ground reaction force component	VGRF	Vertical ground reaction force
		VI	Vastus intermedius
GT	Greater trochanter	VL	Vastus lateralis
HEST	Hall Effect Strain Transducer	VM	Vastus medialis
IC	Initial Contact	VML	Vastus medialis longus
ICC	Intraclass correlation coefficient	VMO	Vastus medialis obliquus
		WASP	Waveform Analysis System Package
IEMG	Integrated electromyography		