Joint position sense and rehabilitation in the anterior cruciate ligament deficient knee

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Abstract

Background—Impaired joint position sense (JPS) has been shown in anterior cruciate ligament (ACL) deficient and osteoarthritic knees. The relation between JPS and function is uncertain. The aim of this study was to determine further if ACL deficient knees show abnormal JPS and the effect of exercise therapy on JPS, and also to assess the relation between JPS, functional stability, and strength.

Methods—Fifty patients (46 men and four women, mean age 26.3 years) with unilateral ACL deficient knees were assessed on admission and after rehabilitation (5 hours a day for four weeks). JPS was assessed by reproduction of passive positioning using a visual analogue incorporating a goniometer. Knee stability was analysed by self report questionnaire (score 0–280) and functional activity test (single leg hop and figure of eight run). Isokinetic dynamometry was performed to evaluate quadriceps and hamstring peak torque strength. Controls were either age and sex matched individuals or the contralateral knee. Statistical analysis was by Wilcoxon signed rank test and Spearman rank order correlation coefficient.

Results—JPS was impaired in ACL deficient knees. The mean (SD) errors in reproducing angles were 9.4 (3.1)° and 7.1 (2.3)° for the ACL deficient knee and control knee respectively ($P < 0.0005$). There was no improvement in JPS after rehabilitation (9.4 (3.1)° and 8.5 (3.2)° before and after rehabilitation respectively, $P = 0.14$). There was improvement as ascertained from the questionnaire (on admission 202 (32.1), after rehabilitation 243 (25.4), $P < 0.0001$) and functional activity testing (hop: on admission 148.7 (37.3) cm, after rehabilitation 169.8 (31.1) cm, $P < 0.0005$; figure of eight: on admission 48.4 (16.6) seconds, after rehabilitation 41.6 (3.4) seconds, $P < 0.0001$). Quadriceps strength improved (peak torque on admission 198.5 (58.9) Nm, after rehabilitation 210.5 (54.2) Nm, $P < 0.05$), but not hamstring strength (peak torque on admission 130.6 (28.1) Nm, after rehabilitation 135.5 (27.7) Nm, $P = 0.24$). JPS did not correlate with the functional activity tests (hop and figure of eight run), the responses to the questionnaire, or strength. There was no correlation between the responses to the questionnaire and functional activity tests or muscle strength.

Conclusions—JPS was impaired in ACL deficient knees. Although knee stability improved with exercise therapy, there was

no improvement in JPS. The role of JPS in the stability of ACL deficient knees remains unclear.

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Keywords: knee; anterior cruciate ligament; joint position sense; rehabilitation

Injuries to the anterior cruciate ligament (ACL) are common in servicemen. The Defence Services Medical Rehabilitation Unit (DSMRU) at Headley Court admits about 400 patients with ACL deficient and ACL reconstructed knees per year for rehabilitation.

Specialised mechanoreceptors found in and around the knee joint capsule have also been shown in the ACL.¹ Rupture of the ACL has been demonstrated to impair proprioception and increase the latency of reflex hamstring contraction.^{2–5} Impaired proprioception is cited as a major factor predisposing to degenerative joint disease and ongoing instability in the ACL deficient knee.^{2–6–7} It has been suggested that dynamic joint control training may improve stability, perhaps by improving joint position sense (JPS).⁸ The effect of proprioceptive training on JPS has, however, not been reported.

Our study sought to check further whether the ACL deficient knee shows abnormal JPS and to assess the response to exercise therapy. We sought also to show the relation between JPS and knee function as measured by self report questionnaire, functional activity test, and muscle strength.

Subjects and methods

Fifty consecutive patients admitted to the Defence Services Medical Rehabilitation Unit (DSMRU) were invited to participate in the study. The inclusion criteria were: (a) 18 years or older; (b) arthroscopically proven ACL tear; (c) injured knee must not have been reconstructed; (d) contralateral knee must have no history, or signs, of injury. Additional intra-articular damage such as collateral ligament or meniscal damage did not prevent inclusion. Royal Air Force Headley Court is a tertiary referral centre. In those subjects who had concomitant meniscal damage, it is assumed that these lesions had been adequately treated before referral from the orthopaedic centres at which they had undergone arthroscopy.

On admission each patient completed the following: (a) consent form; (b) knee stability questionnaire; (c) JPS testing; (d) functional activity tests (figure of eight run and single leg hop); (e) isokinetic dynamometry of quadriceps and hamstring strength.

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QUESTIONNAIRE

The questionnaire used has validity.⁹ This assesses subjective stability and other aspects of knee function by use of visual analogue scales for 28 questions of knee symptoms and function. Each visual analogue scale is divided into 10. A maximum score (greatest stability) is thus 280 out of 280.

JPS TESTING

Both legs of each subject were tested, the contralateral (normal) knee serving as an internal control. The subject was seated on the isokinetic dynamometer. The equipment was adjusted for each subject's leg size. Each knee in turn was moved passively to positions between 0 and 90° flexion. The knee was hidden from the subject's view by a screen. The subject was then asked to reproduce the knee position using a visual analogue of a leg incorporating a goniometer. Each knee was tested in five positions. The dynamometry operator was blind to which was the ACL deficient knee. The mean error of angle detection between actual and perceived knee flexion for the five positions was then calculated.

FUNCTIONAL ACTIVITY TESTS

These activities were devised to simulate components of high level exercise activity (sport/military fitness). Each subject completed two tests. The figure of eight run involved each subject completing five timed circuits of a figure of eight constructed by placing cones at each corner of a rectangle 8 m by 5 m in the gymnasium. Each subject was asked to complete the circuits in as quick a time as possible within their capabilities. Controls were 23 age and sex matched individuals. The single hop test involved each subject making a maximal single measured hop. The best attempt of three hops was recorded. No prior practising was permitted. The best of three hops in the contralateral leg served as control.

ISOKINETIC DYNAMOMETRY

On admission each subject underwent peak torque assessment of quadriceps and hamstring strength by dynamometry testing, on the Lidoactive model (Loredan Inc). Maximum torque (Nm) was measured at 60 degrees/second. The contralateral knee served again as internal control. The dynamometry operator was blind to which was the ACL deficient knee.

REHABILITATION

After initial assessment each subject undertook a programme of intensive residential rehabilitation. This involved muscular and proprioceptive training according to ability and requirement. Each subject completed five hours training per day for five days per week for four weeks (100 hours). Training was performed in groups and supplemented by physiotherapy and occupational therapy as required.

After this rehabilitation programme, each subject was reassessed in the same way as on admission, with the questionnaire, JPS testing, functional activity testing and isokinetic dynamometry.

Table 1 Causes of anterior cruciate ligament injury

Cause	No
Football	22
Rugby	10
Skiing	3
Running	3
Basketball	2
"PT"	2
Motor-cycle accident	2
Military duties	1
Other sports	5
Total	50

Table 2 Concomitant injury to other knee structures

Structure	No
Medial collateral ligament	10
Lateral collateral ligament	4
Posterior cruciate ligament	1
Medial meniscus	15
Lateral meniscus	9
Medial femoral condyle	6
Lateral femoral condyle	0
Chondromalacia patellae	3
Total	48

STATISTICAL ANALYSIS

Data were analysed using the Statsview Student for Apple-MacIntosh. The Wilcoxon signed rank test was used throughout for comparing means. The Spearman rank order correlation coefficient was used for correlation analysis.

Results

Of 50 consecutive patients (service personnel) the vast majority were men (46). The mean age on admission was 26.3 years (range 19–44). The mean duration between injury and admission was 19.8 months (range 2–60). Table 1 shows the causes of injury. All but three cases were due to sporting activities.

ACL rupture occurred as an isolated injury in only 16 cases. Concomitant injury to other knee structures occurred on 48 occasions in 34 knees (table 2).

Table 3 shows the results of JPS, functional activity tests, and isokinetic dynamometry on admission. The contralateral (unaffected) knee served as control for all but the figure of eight run. The control group for the figure of eight run were 23 age and sex matched members of staff at Headley Court.

Significant differences were noted in JPS ($P<0.0005$), single hop ($P<0.0005$), quadriceps strength ($P<0.0005$), and hamstring strength ($P<0.0005$).

No differences were recorded between figure of eight run on admission and controls ($P = 0.13$).

After a programme of exercise therapy as rehabilitation there were significant improvements in knee function as measured by self report questionnaire ($P<0.0001$), single hop ($P<0.0005$), figure of eight run ($P<0.0001$), and quadriceps strength ($P<0.05$).

There were no significant changes in function as measured by JPS or hamstring strength (table 4).

Correlation studies did not show any correlation between JPS and subjective stability, functional capacity, or muscle strength. In

Table 3 Results for joint position sense (JPS), functional activity tests, and isokinetic dynamometry on admission. Results are mean (SD)

Test	Value	P value
JPS (degrees error)		
ACL	9.42 (3.14)	
Control	7.1 (2.32)	< 0.0005
Single hop (cm)		
ACL	148.7 (37.3)	
Control	175.3 (29.8)	< 0.0005
Quadriceps strength (Nm)		
ACL	130.6 (28.1)	
Control	261.7 (53.3)	< 0.0005
Hamstring strength (Nm)		
ACL	130.6 (28.1)	
Control	144.8 (29.4)	< 0.0005
Figure of eight run (seconds)		
ACL	48.4 (16.6)	
Control	42.4 (4.3)	0.13

ACL, anterior cruciate ligament.

Table 4 Results before and after rehabilitation. Results are mean (SD)

Test	Value	P value
Questionnaire (max.280)		
Before	201.6 (32.1)	
After	243 (25.4)	< 0.0001
Single hop (cm)		
Before	148.7 (37.3)	
After	169.8 (31.1)	< 0.0005
Figure of eight run (seconds)		
Before	48.4 (16.6)	
After	41.6 (3.4)	< 0.0001
Quadriceps strength (Nm)		
Before	198.5 (58.9)	
After	210.5 (54.2)	< 0.05
JPS (degrees error)		
Before	9.42 (3.14)	
After	8.54 (3.24)	0.14
Hamstring strength (Nm)		
Before	130.6 (28.1)	
After	135.5 (27.7)	0.24

JPS, joint position sense.

addition, there was no correlation between subjective stability and functional stability or muscle strength.

A relation was, however, noted on correlation analysis between functional activity scores and muscle strength before rehabilitation (table 5) and between functional activity scores and quadriceps strength after treatment (table 6).

Discussion

In this study we have further shown abnormal JPS in the ACL deficient knee, as detected by a method of passive joint position setting and analogue reproduction using a goniometer.

Table 5 Relationship between functional activity scores and muscle strength before rehabilitation

		Z	P
Single hop	Quadriceps strength	2.69	< 0.01
	Hamstring strength	2.97	< 0.005
	Figure of eight run	-4.4	< 0.0001
Figure of eight run	Quadriceps strength	-2.5	< 0.02
	Hamstring strength	-2.2	< 0.03

Table 6 Relationship between functional activity scores and muscle strength after treatment

		Z	P
Single hop	Quadriceps strength	2.37	< 0.02
	Hamstring strength	0.69	0.48
	Figure of eight run	-4.08	< 0.0001
Figure of eight run	Quadriceps strength	-1.16	0.25
	Hamstring strength	-0.95	0.34

This method has been used, with reproducible results, in other studies.^{5 6 10} JPS has been assessed by other methods including threshold of detection of movement,⁵ and measurement of hamstring contraction latency.⁴ This study now adds to the weight of evidence that ACL deficient knees show abnormal JPS.³⁻⁵

Other studies have shown a correlation between JPS and assessments of knee stability.⁴ We did not observe such a correlation. The reasons for this deserve to be explored. In part, it may be due to the other structures around the knee which are also involved in JPS.

Those specialised mechanoreceptors found in the ACL that are thought to permit a proprioceptive role are also present in the joint capsule.² It may be that interruption of these fibres that occurs with joint damage and swelling contributes to abnormal JPS. Studies on cats have suggested that proprioception in the normal knee is derived from sensory afferent activity from receptors in the posterior capsule¹¹ and from the peripatellar plexus.^{12 12a} Episodic joint instability leads to joint capsule laxity and a subsequent reduction of afferent activity. This may contribute to impaired JPS. If this were so, then with each episode of instability that causes joint swelling one might expect a difference in the threshold of response from capsule receptors in acute and chronic lesions. Barrack and workers,² however, found no such difference. This may further imply that proprioceptive loss in the ACL deficient knee is a cause rather than a consequence of increased joint laxity.¹³ A proprioceptive role has been confirmed, however, in the ankle joint by showing the loss of JPS after injection of local anaesthetic into the joint.¹⁴ Other studies report the preservation of JPS in locally anaesthetised joints.¹⁵ This suggests a role also for muscle spindles in joint proprioception. It is considered that muscle spindles may provide crude awareness of joint position whilst joint receptors are responsible for fine tuning.¹⁶ It is not possible with this method of JPS quantification to account for the contributions of these other structures. All may be altered after the injury causing ACL rupture and also with subsequent episodes of "giving way".

In addition, this method is a static one. The programme of proprioceptive rehabilitation is dynamic. Further to this, questions of stability in the self report questionnaire and the functional activity tests are also dynamic. These factors may account for the lack of improvement in JPS despite functional gains.

On initial assessment, single hop for distance and quadriceps and hamstring peak torque were also significantly reduced compared with controls. There was no statistical difference with the figure of eight run. This may be because the control group was relatively small (23). Our study has shown that quadriceps peak torque was reduced by 24% and the hamstring peak torque by 10%, in the ACL deficient knees. This degree of loss of muscle power is considerably greater than that found in other studies (10% for quadriceps and 4% for hamstrings) but in almost identical proportions.¹⁷ Military personnel undergo ex-

tensive physical training and regular fitness tests. The 2.5 fold fall in peak quadriceps and hamstring torque may be accounted for by relatively stronger contralateral (control) knees.

The single hop for distance and figure of eight run have been validated as tests of functional stability.¹⁸⁻²⁰ An increasing number of studies report the importance of the hamstring muscle group in knee joint stability.²¹⁻²⁴ Several authors have documented a positive correlation between isolated quadriceps isokinetic peak torque and functional manoeuvres such as running, cutting, and hopping.^{18 20 24-26} Our findings are consistent with this. As hamstring contraction is synergistic with the normal biomechanics of the ACL,²⁷ it has been advocated that hamstring strengthening exercises be implemented for the ACL deficient and reconstructed knee.^{8 28-30} It is interesting to note that studies do not show a correlation between hamstring peak torque and functional stability.^{26 31} This is not our experience in that there is significant correlation between figure of eight run, single hop for distance, and hamstring peak torque.

After a programme of exercise therapy as rehabilitation which involved open and closed kinetic chain muscular training and proprioceptive work, there was improvement in subjective feeling of stability, hop, figure of eight, and quadriceps peak torque. The positive correlation between quadriceps strength and functional stability, after treatment, is retained. This is in keeping with previous studies.^{21-23 27 32} The correlation with hamstring torque is, however, lost. Further to this, there was no change in hamstring strength. It may be that hamstring function as measured by peak isokinetic torque is inappropriate and that latency of contraction,⁴ quadriceps to hamstring peak torque ratio,¹⁵ or hamstring muscular endurance are better measures, when one bears in mind that most episodes of instability occur during sporting activities. Even in individuals who have not undertaken a formal rehabilitation programme, the hamstrings in ACL deficient knees develop faster contractions, and this may be further enhanced by joint control training.^{8 16}

In summary, this study provides further evidence that ACL deficient knees show abnormal JPS. We have also shown that, with muscular and proprioceptive training, subjective and functional stability improve, whereas JPS remains unchanged. The role of JPS in the ACL deficient knee therefore remains uncertain. Further studies are required. Assessing joint proprioception in a dynamic and hence functional setting may provide more accurate results. In addition, JPS testing in individuals with ACL rupture at different periods after injury may help to define the natural history of position sense awareness of the knee.

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The increasing numbers sitting the examinations have encouraged BASM to organise a course directed towards preparing candidates for this exam. It will take place on 23-25 March 1998 and is restricted to a maximum of 24 participants to ensure the quality of teaching.

President of the RSM sports medicine section

Dan Tunstall Pedoe, who has in the past been acting editor of the Journal and is a member of the editorial board, is the current president of the section of sports medicine of the Royal Society of Medicine. We wish him well and look forward to even stronger links among all those organisations interested in the future of sports medicine.

AIDS in sport

FIMS recently released a statement on AIDS in sport. This document highlights the problems and difficulties of dealing with competitors with AIDS and efforts being made to protect the public and participants. They intend to circulate this document as widely as possible and full text is available on the FIMS home page on the world wide web at <http://cac.psu.edu/~hgk2/fims>

Growth hormone

The Journal always highlights the importance of research as one of the foundation stones of our discipline and congratulates the team at UMDS for their challenging research programme investigating the use and detection of growth hormone and other peptide hormones. This is one of the most exciting new pieces of research in the field of drugs in sport. Many athletes have formed part of this anonymous random sample and medical officers world wide are encouraged to allow their athletes to participate.

CALENDAR OF EVENTS

RSM sports medicine section

2 April 1998; Arthroscopy in the management of sporting injuries
6.00 pm, Royal Society of Medicine, London
Further details: Neela Lubojacky. Tel +44 (0)171 290 2987

Radiology 1998: Imaging, science, and oncology

1-3 June 1998, International Conference Centre, Birmingham, UK

Topics include interventional radiology, *info* RAD, quality in diagnosis and imaging, dosimetry, nuclear medicine, targeted radiotherapy, imaging and brachytherapy, information technology applied to health care and training, magnetic resonance spectroscopy, and medical imaging.

Further details: Ms June Clark, Conference Manager, Radiology Secretariat Office, 36 Portland Place, London W1N 4AT. Tel +44 (0)171 436 7807. Fax +44 (0)171 255 3209

9th British Association of Day Surgery annual meeting

4-6 June 1998; Harrogate International Centre

The meeting will cover the surgical, anaesthetic, nursing and managerial aspects of day surgery practice

Further details: Kite Communications, The Silk Mill House, 196 Huddersfield Road, Meltham, W Yorks HD7 3AP. Tel +44 (0)1484 854575. Fax +44 (0)1484 854576. Email info@kitecomms.co.uk

International conference on "Hydration throughout life"

9-12 June 1998; Palais des Congrès Vittel, France

The scientific programme, which will provide an overview of current basic and clinical research advances in the field of hydration, is intended for basic and clinical researchers and physicians as well as other health care professionals

Further details: Perrier Vittel Water Institute, Conference Secretariat, BP 101 - 88804, VITTEL Cedex. Tel +33 (0)3 29 08 70 41. Fax +33 (0)3 29 08 70 49. Email instieau@worldnet.fr

Third annual congress of the European College of Sports Medicine

15-18 July 1998; Manchester, England

Further details: The Third Annual Congress of the European College of Sports Medicine, Conference Secretariat, HIT Conferences, Cavern Walks, 8 Mathew Street, Liverpool L2 6RE, UK. Tel +44 (0)151 227 4423. Fax +44 (0)151 236 4829. Email ecss@hit1.demon.co.uk

Correction

Joint position sense and rehabilitation in the anterior cruciate ligament deficient knee (Carter ND, Jenkinson TR, Wilson D, Jones DW, Torode AS. 1997;31:209-12)

We regret that an editorial error occurred in table 3 of this article. The value for the entry Quadriceps strength (Nm), ACL should have been 198.5 (58.9).

Errors may occur in the journal from time to time but we would like to assure readers that a correction will always be printed when requested.