ORIGINAL ARTICLE

Tennis specific limitations in players with an ACL deficient knee

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Background: Complete rupture of the anterior cruciate ligament (ACL) causes significant alteration of knee joint kinematics. Untreated patients often develop joint instability, chronic articular degeneration, and knee dysfunction. Demands on the ACL produced by playing tennis have not been investigated.
Objective: To identify subjective sport-specific limitations in tennis players with isolated unilateral ACL deficiency.
Study design: Prospective case–control study.
Methods: 16 players (mean (SD) age, 39.9 (2.3) years; 14 men) with a chronic unilateral ACL deficient knee and 16 healthy controls (38.25 (8.47) years; 14 men) were recruited. ACL deficiency was confirmed by clinical and magnetic resonance imaging. A Lysholm score was obtained in all patients, together with subjective evaluation of their current tennis performance compared with pre-injury levels, applying a 0–100% visual scale. Both groups completed a questionnaire on tennis specific abilities.
Results: Lysholm scores were: 85.6 (10.3) points in the study group and 100 (0) points in the control group ($p<0.001$, *t* test for independent samples). Injured players evaluated their current tennis performance as 66.8 (15.2)% compared with 100% pre-injury level ($p<0.005$, *t* test for dependent samples). Abilities affected in the ACL deficient group were landing after a smash stroke ($p<0.001$); stopping abruptly and changing ($p<0.001$); playing a three set singles match ($p<0.05$); and playing on a hard court surface ($p<0.001$, Kolmogorov-Smirnov test).
Conclusions: There are specific limitations associated with complete isolated ACL rupture, including subjective tennis performance impairment, limitations landing after a smash, stopping and changing step direction, difficulties playing a three set singles match, and playing on hard court surfaces.

Of all the ligaments of the knee, the anterior cruciate (ACL) is the one that most commonly suffers complete disruption. Untreated, this injury can cause potentially debilitating consequences including meniscus tears, anterior and rotational instability, and early onset osteoarthritis.[1 2] Consequently, most orthopaedic surgeons advocate surgical reconstruction of the ACL for patients seeking to take part in activities that exert high functional demands on this ligament. However, demands made on the ACL from tennis playing remain unknown, and ACL insufficiency in tennis players has generated little research interest, with only limited references in the sports medicine literature.

ACL rupture is not a common injury during tennis playing. Kühne *et al*[3] have reported a 1.8% overall ACL rupture incidence from tennis related injuries. Nevertheless, many people play tennis after suffering cruciate ligament rupture during other activities, mainly contact sports. These patients often seek medical advice about potential limitations of practising tennis with an ACL deficient knee.

Our aim in this study was to identify specific subjective limitations in tennis players with unilateral ACL deficiency.

METHODS

Sixteen tennis players (mean (SD) age, 39.93 (2.33) years; two women, 14 men) with a unilateral ACL deficient knee and 16 healthy players as controls (mean age 38.25 (8.47) years; two women, 14 men) were analysed in a prospective study. Inclusion criteria for the patients were: age 18 years or older; unilateral isolated ACL deficient knee confirmed by clinical and magnetic resonance imaging (MRI); regular tennis practice (at least once a week) at any level; no previous lower limb surgery or major trauma; and ACL rupture at least six months prior to the study period. For the controls the inclusion criteria were: age 18 or older; tennis practice on a regular basis at any level; no prior lower limb surgery or major trauma; and stable knees. Subjects in the control group were matched with the study group for age, sex, and tennis participation.

The clinical diagnosis of ACL deficiency was supported both by history and by physical examination, using commonly accepted anterior knee instability tests (Lachman test, pivot-shift tests, anterior drawer test). Physical examination revealed no evidence of additional knee joint instability (that is, medial or posterolateral instability).

MRI evidence of ACL rupture was based on primary and secondary signs following the guidelines of Vahey *et al*.[4]

Knee function evaluated by modified Lysholm score[5] generated numbers from 0–100 (highest) based on a series of questions pertaining to knee function. All 16 patients were asked to evaluate their tennis performance subjectively in relation to their preinjury level on a 0–100% visual scale.

Both groups responded a questionnaire on tennis specific abilities, adapted from Mont *et al*.[6] Each ability was evaluated using a scale of 1 to 5: 1, "cannot do it"; 2, "extremely difficult" (pain and instability); 3, "difficult" (instability only and slight pain); 4, "able to do it with some instability and no pain"; 5, "able to do it with no pain and no instability". Any playing technique changes generated because of mistrust, fear of knee giving way, or other joint related complaints were graded as 1.

For simplification, the knee on the same side as the arm used for the serve was considered "dominant". For statistical significance, α error was calculated as 0.05 and β error as

Abbreviation: ACL, anterior cruciate ligament

0.20. Power analysis was estimated using software.[7] The Kolmogorov-Smirnov test for non-parametric variables of small independent samples was used for tennis abilities analysis. A standard statistical package (Statistics for Windows, StatSoft Inc, Tulsa, Oklahoma, USA) was used to generate all statistics.

RESULTS

The right knee was affected in five players (31%) and the left knee in 11 (69%); five knees were dominant and 11 were non-dominant. ACL injury was caused by soccer (n = 10), skiing (n = 2), tennis (n = 1), paddle tennis (n = 1), rugby (n = 1), and others (n = 1).

Lysholm scores were 85.6 (10.3) points in the study group and 100 (0) points in the control group ($p \ll 0.001$, *t* test for independent samples).

Injured players evaluated their tennis performance as 66.9 (15.3)% compared with 100% preinjury levels (p = 0.0014, *t* test for dependent samples).

Abilities significantly affected in the ACL deficient group were: landing after a smash stroke ($p<0.001$); stopping abruptly and changing direction ($p<0.001$); playing a three set singles match ($p<0.05$); and playing on hard courts ($p<0.001$). No other abilities investigated showed statistically significant differences. All tennis ability assessments are shown in table 1.

No significant relation between limitations in baseline side movements (right, left) and the ACL deficient knee was found in this group of tennis players.

Time elapsed between ACL injury and return to tennis averaged 6.4 (9.8) months; time elapsed between ACL injury and study assessment averaged 40.2 (47.0) months. Only one patient used a rigid knee brace for playing tennis. All players played at recreational level.

Table 1 Subjective evaluation of tennis abilities (adapted from Mont *et al*[5])

Ability	ACL deficient knee*	Control	p Value†
Bending to hit a shot at knee level	4.81 (0.75)	5.00 (0)	p>0.10
Shifting weight in forehand	4.43 (1.03)	5.00 (0)	p>0.10
Shifting weight in backhand	4.43 (0.89)	5.00 (0)	p>0.10
Shifting weight in first serve	4.62 (0.71)	5.00 (0)	p>0.10
Shifting weight in second serve	4.75 (0.68)	5.00 (0)	p>0.10
Shifting weight in volleys	4.68 (0.79)	5.00 (0)	p>0.10
Shifting weight in smash	2.68 (1.66)	5.00 (0)	p<0.001
Moving to right side on the baseline	4.43 (0.81)	5.00 (0)	p>0.10
Moving to left side on the baseline	4.37 (0.88)	5.00 (0)	p>0.10
Moving forward to reach a drop-shot	4.50 (1.09)	5.00 (0)	p>0.10
Moving forward after serve to volley	4.75 (0.44)	5.00 (0)	p>0.10
Stopping abruptly and turning direction	3.50 (1.15)	5.00 (0)	p<0.001
Hitting a ground stroke on the run	4.68 (0.70)	5.00 (0)	p>0.10
Playing a 3-set match of singles	3.93 (1.38)	5.00 (0)	p<0.05
Playing a 3-set match of doubles	4.68 (1.01)	5.00 (0)	p>0.10
Playing on hard court	3.62 (1.54)	5.00 (0)	p<0.005
Playing on clay court	4.81 (0.50)	5.00 (0)	p>0.10

*Graded scale: 1, cannot do it; 2, extremely difficult (pain and instability); 3, difficult (instability only and slight pain); 4, able to do it with some instability and no pain; 5, able to do it with no pain and no instability.
†p values obtained by Kolmogorov-Smirnov test for non-parametric variables of small independent samples.

DISCUSSION

The results of this study identified subjective limitations of subjects with ACL deficient knees during tennis movements. Tennis players did not admit to significant impairment when performing the majority of tennis strokes such as forehand, backhand, volleys, and serves. The major limitation referred to was landing after hitting a smash. This task has often been perceived by ACL deficient subjects as being difficult to carry out with confidence.[8] Many players from the study group referred avoiding the smash entirely.

Interesting information was obtained about displacement while playing tennis. Injured players did not have significant impairment in forward running such as in ''serve and volley'' or ''reaching a drop shot'' movements. This finding was in agreement with previous studies—for example, Czierniecki *et al* found that running in a straight line may not generate sufficient rotational torque to initiate rotational instability in the cruciate deficient knee.[9] In contrast, ACL deficient players show major limitation when trying to ''stop suddenly and change direction''. This type of stressful deceleration creates high anterior loading on the tibiofemoral joint.[10] Both external varus-valgus and internal-external rotation place increased load on the knee joint during cutting movements compared with normal running.[11] Varus-valgus and internal-external rotational movements are believed to be responsible for increasing knee joint ligament risk of injury. External flexion loads, valgus and internal rotation during side-stepping all have the potential to increase ACL and medial collateral ligament load substantially.[11] The ability of normal subjects to undertake deceleration tasks without ACL rupture or giving way of the knee is attributed to the coordinated interactions among the ligamentous and other soft tissue passive restraints, joint geometry and congruency, friction between cartilage surfaces, active muscular control, and tibiofemoral joint compressive forces.[10] Approximately 86% of shear forces are considered to be restrained by the ACL[12]; however, in ACL deficient knees these loads must be restrained by the articulating surfaces and the surrounding soft tissues.[10]

Most ACL injuries are indirect in nature yet occur during contact sports. Tennis involves tremendous forces during cutting, pivoting, and sudden deceleration manoeuvres; nevertheless ACL injuries are less common in tennis than in contact sports.[13,14] In this series, most injuries occurred during contact sports such as soccer or rugby, but the exact mechanism (direct *v* indirect) was not determined. Sallay *et al*[13] hypothesised that a tennis player is not as likely to sustain an ACL injury because of the ability of the neuromuscular system to coordinate muscular function in anticipation of each movement, with little surprise effect. Many investigators have indicated that anticipating a movement can change reflex responses and postural adjustments to minimise forthcoming perturbation and maintain appropriate posture. Besier *et al*[15,16] were able to confirm previous hypotheses indicating that knee joint moments increase under unanticipated conditions compared with preplanned manoeuvres, primarily because of a large increase in varus-valgus and internal-external rotational moments under unanticipated conditions. It is believed that unanticipated movement alters the external moments applied to the knee by reducing the time to implement appropriate postural adjustment strategies. Tennis may cause a low incidence of indirect ACL injury owing to the absence of frequent complete twisting manoeuvres and high jumping, as well as enough time for the player to anticipate strokes, especially from the baseline.

ACL injured players described significant impairment of their recreational tennis performance compared to preinjury level. Results from the present study may support the need for surgical treatment for competitive tennis players with ACL deficiency. Further studies are needed to determine the true incidence of ACL injuries in tennis, to analyse tennis motion knee biomechanics, and to establish the degree of improvement in tennis ability after ACL reconstruction.

Tennis players with an ACL deficient knee showed a clear incapacity to play on hard courts, where demanding eccentric deceleration motions occur. Frontal and rotational knee moments are thought to be increased when playing on hard surfaces owing to greater friction between the foot and the ground.[11 17] Clay courts seem to be a better option for ACL deficient players.

Limitations of this study include problems associated with questionnaires, and shortcomings related to retrospective determination of the preinjury performance level.

In summary, complete rupture of the ACL is a debilitating injury that causes significant alteration of knee joint kinematics. Untreated patients have joint instability, chronic articular degeneration, and knee dysfunction. Tennis specific limitations related to complete isolated ACL rupture were clearly identified. Tennis players with an ACL deficient knee showed significant impairment of subjective sport performance, limitation in landing after smashing, limitation in stopping and changing direction, limitation when playing a three set singles match, and limitation in playing on a hard court surface compared with healthy controls.

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