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Case Report

Retrospective Analysis of Non-Contact ACL Injury Risk: A Case Series Review of Elite Female Athletes

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ABSTRACT

Background: Literature on ACL injury is limited when assessing for the presence and interaction of multiple risk factors simultaneously. Identifying risk factor interaction may increase the impact of prevention programmes to target ACL injury reduction. The aim of this study was to retrospectively assess ACL injured female athletes to identify which modifiable and non-modifiable risk factors were present at the time of injury.

Method: Seventeen female athletes who had sustained a non-contact ACL injury were interviewed retrospectively to assess for the presence of reported risk factors for ACL injury.

Result: This retrospective analysis ACL injury cases highlighted a number of factors which were present with high frequency across this group of cases. All had non-contact ACL injury occurring during cutting or landing, which suggests a predisposing deficit in neuromuscular control. This poor neuromuscular control could be exacerbated by the presence of fatigue identified within the cohort. This poor control could be further influenced by the fact a majority of athletes had another significant injury in the 12 weeks prior to ACL injury. The restriction to training could have either decreased fatigue resistance, or potentially changed their movement pattern because of the method of injury management undertaken.

Conclusion: This case series provides insight into the interaction of risk factors for ACL injury in sportswomen, with the presence of another injury disrupting training, decreasing the athletes work capacity and fatigue resistance, being compounded perceived or actually elevated levels of fatigue, leading to the potential for abhorrent movement patterns and increased injury risk.

INTRODUCTION

Anterior cruciate ligament (ACL) injuries continue to be one of the most debilitating injuries, in terms of the time lost from sport participation [1], the significant ongoing comorbidities which can be developed [2] and the heighten risk of further ACL injury [3]. Approximately 70% of ACL tears occur from a noncontact mechanism [4] with the research literature identifying both modifiable and non-modifiable risk factors predisposing the individual to increased risk of non-contact ACL injury [5,6]. Identifying the presence and significance of non-modifiable risk factors may increase the impact of prevention programmes which aim the target the modifiable risk factors or allow other interventions to be undertaken to try and mitigate risk. Currently literature is limited on assessing for the presence and interaction of multiple risk factors simultaneously [5,6].

The classification of risk factors into modifiable and non-modifiable may be expanded upon further by considering if the individual risk factor as either an extrinsic

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or intrinsic one. Intrinsic variables include those inherent to the individual athlete, such as sex, hormonal milieu, genetic factors, neuromuscular and cognitive function, anatomic variables (e.g., knee joint geometry, lower extremity alignment, body mass index), and previous injury to the knee or the lower extremity. Extrinsic factors are external to the athlete and may include level and type of activity, type of playing surface and environmental conditions, as well as equipment used. Listing risk factors in this manner may allow the practitioner to start to be able to prioritise factors which can be modified for the individual to reduce overall risk of injury.

A number of studies have looked at manipulating neuromuscular control with training in order to mitigate the risk of ACL injury, as this would appear to be the most obvious factor to change; these studies have met with some notable successes [1]. These programmes may prove even more effective if they are targeted at those of highest risk, as it would appear that risk factors interact to increase likelihood of injury [5]. Those at heightened risk would appear to be female athletes, those with previous ACL injury, family history of ACL history and have generalised laxity [5,6].

Alongside these factors others also appear to have the potential to have a significant impact on injury risk. For example, prior injury to the hamstring muscles [7] or patellofemoral joint [8] have both been speculated to predispose the individual to ACL injury. This relationship might be due to the detraining effect of the previous injury or the prior injury itself might more directly impact on the neuromuscular control of the limb, directly through changes in movement patterns as a result of the injury or indirectly as a result of muscle inhibition and weakness created. It may though in fact be difficult truly ascertain if it is the injury itself which predisposes to an ACL or the common risk factors between problems such as patellofemoral joint pain and ACL injury [8].

Fatigue has been shown to significantly impact on neuromuscular performance especially females [9], though the impact of fatigue through increased competition or training loads on ACL injury rates appears not to have been considered in the literature. Being in competition as opposed to training is another factor which heightens risk [10]; again here this might be to the intensity of the physical activity and/or the accumulation of fatigue because of either the intensity of performance or having to perform on multiple occasions in a short space of time as with tournament play.

Cognitive stress-fatigue is a relatively under researched area in relation to predisposing athletes to injury. It is know that disturbance to normal sleep patterns can affect performance [10] this disturbance to sleep could be from changes in circadian rhythm, due to changing time zones, long haul travel, or from cognitive stress. Cognitive stress, expressed through sleep disturbance, anxiety and depression has been associated with significant musculoskeletal injuries in professional footballers [11], though this has not been investigated specifically for ACL injury or in female athletes.

The aim of this study was to assess retrospectively previously ACL injured elite female athletes to identify which potential extrinsic and intrinsic modifiable and non-modifiable risk factors for ACL injury, were present at the time of injury and were common across the group. Then from this information attempt to identify specific factors or behaviours which may place an individual at higher risk.

METHOD

Participants

Seventeen female athletes (20±4.8 years) who all sustained a non-contact ACL injury were recruited. The injury was diagnosed from MRI and orthopaedic surgeon assessment. The injuries all occurred during competitive play, involving either landing onto the leg or cutting on the leg which was injured. All subjects were national-international level full time athletes from the following sports: Soccer (n=4); Taekwondo (n=4); Netball (n=9). The participants were initially selected from the medical records database of the English Institute of Sport if they had a diagnosis of ACL rupture, subjects were then excluded if the injury was not managed surgically and if the injury had not occurred in competition. By taking athletes injured in competition only this allows some control over the environmental factors such as training-competition load, playing surface, travel stress and general levels of competitive stress levels. The group of athletes then left were approached to see if they wished to participate in the study. The study had approval by University research ethics committee and all participating athletes gave written consent.

Procedures

Information was either collected directly from a semi-structured interview of the athlete or from their medical records in order to answer the questions found in table 1.

RESULTS

Table 2 displays the full results of the retrospective audit. Fourteen out of the 17 athletes audited (82%) had a score of 4 or higher on the Beighton hypermobility scale. A similar number had genu recurvatum present prior to ACL rupture. Eight out of the 17 (47%) had history of previous ACL rupture of the same or other limb. Five out of the 17 (29%) had familial history of ACL rupture (sibling or parental). Thirteen out of the 17 (77%) had had an injury which disrupted and restricted training in the 12 weeks prior to rupturing the ACL (Table 3). Fourteen out of the 17 athletes audited (82%) had a fatiguing event either physical or cognitive at some point in the 7 days prior to rupturing their ACL (Table 4).

DISCUSSION

It has been previously reported that generalised laxity, previous ACL injury and family history of ACL injury all heighten the risk of sustaining an ACL injury [5,6], the findings of this retrospective audit of injured athletes support this previous work.

Table 1: Information extracted by the audit.

Information sort	Source	Question asked at interview
Beighton Hypermobility Score[1]	Subjects medical records	Not applicable
Significant Genu Recurvatum[2]	Subjects medical records	Not applicable
Previous ACL injury	Subjects medical records & athlete interview	Have you previously damaged your ACL in either leg?
Family history ACL injury	Athlete interview	Has anyone in your direct family (siblings or parents) ever damaged their ACL?
Other injury[3] within 12 weeks of ACL injury	Subjects medical records & athlete interview	Have you had any lower limb injury which disrupted your training or restricted your ability training in the last 3 months?
Physical or cognitive fatiguing event in week prior injury	Athlete interview	In the week prior to your ACL injury did any of the following happen: • Long haul flight • Significant increase in training load • Participate in a multi-match tournament • Change time zones • Significant (greater than 2 nights) disruption to sleep • Increase cognitive stress[4]

[1]Assess using the rating scale reported (27)
[2]Greater than 10 degrees of knee hyperextension (28)
[3]An injury when caused greater than two days missed training or competition (29)
[4]Increased cognitive stresses included; relationship issues, performance issues (identified by coach or perceived by player), abnormally high performance anxiety

Table 2: Summary of athlete reported risk factors.

Risk Factor	Athlete																
Beighton Score	8	8	8	6	5	4	4	4	4	5	9	0	4	4	0	0	5
Genu Recurvatum	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	No	yes	yes	no	no	yes
Previous ACL injury*	no	yes	yes	no	yes	no	no	yes	yes	no	yes	yes	yes	no	no	no	no
Family history ACL injury	no	no	no	yes	no	no	no	no	yes	no	yes	no	no	no	no	yes	yes
Injury within last three months	yes	yes	yes	yes	yes	yes	yes	no	no	yes	yes	no	yes	no	yes	yes	yes
Fatigue event in week prior injury (training, long haul flight, time zone, cognitive stress)	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	no	yes	yes	no
Sport	Tkd	Tkd	NB	NB	Tkd	FB	FB	FB	FB	Tkd	NB	NB	NB	NB	NB	NB	NB

Key: Tkd Taekwondo NB netball FB football (soccer)
*Previous ACL 7 of the 8 were contralateral one was ipsilateral

Table 3: Injuries in the preceding twelve weeks to ACL injury.

Injury	Number of athletes (n=13)
Grade 1 or 2 disruption anterior talofibular ligament at the ankle	**8**
Patellofemoral joint pain	**2**
Hamstring muscle injury (grade 1)	**1**
Gastrocnemius muscle injury (grade 1)	**1**
Patella Tendinopathy	**1**

Table 4: Factors creating fatigue in seven days prior to ACL injury.

Factor creating fatigue	Number of athletes (n= 14)
Long haul flight in preceding 7 days	18% (3 out of 17)
Participation in multiple competition matches in preceding 7 days	77% (13 out of 17)
Disturbed sleep (greater than 2 nights) in preceding 7 days	65% (11 out of 17)
Significant increase in acute training load in preceding 7 days	77% (13 out of 17)
Performance anxiety	29% (5 out of 17)
Performance issues	35% (6 out of 17)
Relationship issues	12% (2 out of 17)

Note athletes have reported more than one factor occurring simultaneously

Significant numbers of these female athletes had positive findings for these injury risk characteristics. Though the numbers with previous contralateral or ipsilateral ACL injury are greater than those previously reported for an athletic female population [3], these findings do fit with the contention that the greater the level of sporting activity the patient returns to the greater the risk of further injury [12]. A genetic or familial relationship has been proposed in the aetiology of ACL [6] this study would support that contention of a potential link.

This to our knowledge is the first study to report on the potential association between perceived physical or cognitive fatigue and ACL injury, the relationships found, are an interesting finding which would appear to be worthy of further and far more detailed study than the open ended questions used in the present study. This injury audit found 14 out of the 17 athletes audited (82%) had a fatiguing event, either physical or cognitive at some point in the 7 days prior to rupturing their ACL (Table 4). The fatiguing events inquired after in this study were: physical, such as a significant increase in training load or the participation in a multi-event competition; environmental, here athletes were questioned if they had changed time zones and undertaken long haul travel along with any consistent (greater than two nights) disturbance of sleep; and finally questioning related to cognitive stress (load) which included issues related to relationship issues, performance issues (identified by coach or perceived by player) and abnormally high performance anxiety. Saw et al. [13] found in their systematic review that athlete reported subjective information was highly sensitive to changes in athlete workload and physiological and psychological stress, so it is likely that these findings have some validity in demonstrating the athletes loading environment. Increases in acute training loads have been reported to significantly impact on the rate of injury [14]. This study has indicated that not on physical but cognitive loads should possibly be accounted for when assessing acute loading stress on the athlete.

The relationship of fatigue to ACL injury is a speculative one; it is based on the hypothesis that fatigue will impair the athlete's ability to move optimally, and therefore be more likely to adopt movement strategies associated with the increase the risk of injury [9,15]. There are a number of studies which have shown fatigue to create suboptimal movement patterns which have been associated with ACL injury [9,15]. There is some supporting evidence of how fatigue may increase the risk of injury. Studies have shown that muscle fatigue reduces the neuromuscular systems adaptability to external perturbations [16], so the athlete may be less able to react to altered loading when landing or changing direction during a game. The neuromuscular and perceptual fatigue created by consecutive days of tournament play can create impairments in sprinting and jumping ability, and biochemical markers of muscle damage and reduced mood states [17], all of which may reduce the athlete's ability to move and land optimally. Similarly, in relation to more cognitive factors, mental fatigue has been shown to impair intermittent running performance [18], with depressive symptoms and daytime sleepiness positively associated with musculoskeletal injury [19]. Furthermore, sleep disturbance was found to be significantly related to work related injuries by Uehli et al. [20].

Thirteen out of the 17 (77%) had had an injury which disrupted and restricted training in the 12 weeks prior to rupturing the ACL (Table 3). A consistent finding within the literature is that history of previous injury appears to predict future injury [21]. Furthermore, prior injury to the hamstring muscles [7] or patellofemoral joint [8] have both been speculated to predispose the individual to ACL injury. This relationship may be related to lost training time reducing the capacity to perform at high intensity for prolonged periods, the lack of fatigue resistance leading to a greater propensity to develop abnormal and potentially injurious movement patterns [15]. Interestingly, the most common injury sustained in this group was a lateral ligament injury of the ankle (8 of the 13) (Table 3), there might be a number of reasons why this type of injury could predispose the athlete to an ACL injury. Bullock-Saxton [22] reported significant decreases in gluteal muscle EMG activity following ankle ligament injury, gluteal muscle activity would appear critical in controlling the valgus collapse of the knee [23] which has been linked to ACL injury [1]. Evidence exists that postural control and balance are altered after ankle ligament injury [24] this again could lead to abnormal and potential injurious movement patterns. A final potential reason why ankle ligament injury could create movement patterns which could predispose the athlete to ACL injury is the typical way these injuries are managed. First line treatment for ankle ligament injuries is often to use tape to restrict movement to protect the damaged ligaments [25]. Limitation of ankle dorsi-flexion range of movement has been shown to be linked to increased knee valgus during a variety of functional tasks [26] which could predispose the individual to ACL injury.

This retrospective analysis of a series of ACL injury cases highlighted a number of potentially modifiable factors which were present with relatively high frequency across this group of cases. The athletes within this group all had a non-contact ACL injury occurring during cutting or landing, which suggests a predisposing deficit in neuromuscular control. This poor neuromuscular control could be exacerbated by the presence of fatigue identified within the cohort. The poor control could be further influenced by previous injury either decreasing work capacity and fatigue resistance or changing movement pattern because of the method of injury management undertaken. The findings of this study might have an impact on those working to prevent ACL injury, especially in elite sport. It would appear that risk could be heightened if the non-modifiable factors such as hypermobility and family history occur in an athlete who also has poor neuromuscular control; this has already been identified to a degree in the literature [5]. This study has added to this combination of factors, identifying that likelihood of injury could possibly be increased further if the athlete has an injury which restricts training in the period prior to the ACL injury, with ankle ligament injury seeming to be significant amongst these. The presence of another injury might disrupt training, decreasing the athletes work capacity and fatigue resistance, if the athlete then has perceived or an actual elevated level of fatigue, this may compound the situation further, with the greater the levels of fatigue the greater the potential for abhorrent movement patterns and injury risk. When returning an athlete following an injury which has disrupted training, consideration should be given not only to them being asymptomatic and being able to pass appropriate fitness tests, but also that they have recovered their chronic training capacity, so they are able to cope with acute increases in load better [14].

The study lacks a control group to compare the factors found in the injured group too; this could be regarded as a potential weakness in the study. What must be taken into account here is that these athletes were all national-international athletes participating in very structured training and competitive programme; so many elements are common to all participating athletes. It is likely that what is being seen in the athletes who get injured is a multiplier effect were a number of factors interact. The assessment and understanding of how these interactions create injury is beyond the scope of this case series and certainly requires further prospective study. What is apparent from this case series is ACL injury is unlikely to be related to a single factor, but a critical tipping factor might be loss of chronic training capacity or a perceived or actual increase in acute physical load [14].

This case series has shown that a number of previously reported factors potentially interact to create ACL injury. The risk might be elevated if the athlete lacks chronic training capacity, in these cases through either injury in the period prior to the ACL injury and then an increased acute load [14]. Those working with female elite athletes should consider the level of chronic load the tissues and athlete has been exposed in comparison to the acute load requirements of return to competition, attempting to minimise the mis-match to minimise injury risk. In a similar vein, those working with these athletes should attempt to minimise large increases in acute load real or perceived to also reduce the risk of injury.

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