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Mechanisms of the noncontact anterior cruciate ligament (ACL) injury in some male sports activities

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Key words: Anterior Cruciate Ligament, sport activities, injury.

doi: <http://dx.doi.org/10.12692/ijb/3.9.329-337>

Article published on September 25, 2013

Abstract

In this research tried to examine ACL injury mechanisms in some sports men. Of course an understanding of the noncontact ACL injuries mechanism has lagged behind diagnosis and treatment. However, a growing research implicates hormonal, anatomic, environmental, and biomechanical factors that may predispose athletes to these injuries. For this study selected 839 athlete for assess ACL injury mechanism by two different method: (A) Questionnaire and (B) Interview that information collected among athlete who were play soccer, volleyball, futsal, basketball, wrestling, ski and gymnastics. Our results indicate 52.6% of injuries occur during practices and 47.4% during competition. It also became clear that 72.3% of injuries are due to noncontact mechanism, 4.7% by accidents and 23% with unknown mechanism. Furthermore Dynamic alignment at the time of the injury included: Knee-in & Toe-out 47.1%, Knee-out & Toe-in 17.7%, and Hyperextension 11.4%. The ACL prevents the femur from moving forwards during weight bearing. It also helps to prevent rotation of the joint. Injury of the ACL most often occurs when an athlete is pivoting, decelerating suddenly or landing from a jump. The injury can also be caused by another player falling across the knee. ACL injuries are, probably, the most common devastating knee ligament injuries amongst sports persons. Usually these injuries are isolated, mainly in noncontact sports, but may often be a part of more complex ligamentous injuries. They occur more often in contact sports, such as football, and road traffic accidents. These injuries are most likely to lead to the need for surgery. So that's why it seems necessary to understand the ACL mechanism injury.

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Introduction

The anterior cruciate ligament (ACL) is the primary passive restraint against anterior tibial translation and hyperextension of the knee. As a secondary stabilizer, it restrains the varus and valgus as well as internal and external stresses on the knee (Butler *et al.*, 1980). It acts like a guide rope during knee extension from flexion (roll-and-glide mechanism of the knee). It averages 31-38 mm in length and 8-11 mm in width (Girgis *et al.*, 1975) and is not a single cord but a collection of fascicles that fan out over a broad flattened area, with a wider and stronger tibial than femoral attachment (Furman *et al.*, 1976). The injury of the ACL is a typical injury of the knee joint that occurs during sports activities (Arendt *et al.*, 1995; Bjordal *et al.*, 1997; Gray *et al.*, 1986). Anterior cruciate ligament (ACL) is a common injury among young sportsmen and sportswomen, with a reported annual incidence in the general population of 0.8 per 1000 (Potter *et al.*, 2012), but as high as 100 per 1000 in professional footballers (Lohmander *et al.*, 2007). The anterior cruciate ligament (ACL) is frequently ruptured in European team handball, US college and high school sports (basketball, soccer, and gymnastics), and other sports and levels (Arendt *et al.*, 1999; Arendt *et al.*, 1995; Hutchinson *et al.*, 1995; Myklebust *et al.*, 1997; Myklebust *et al.*, 1998). ACL injuries are most commonly sustained with the noncontact loading of a valgus knee while twisting in the opposite direction producing a forced internal rotation of the tibia (Shin *et al.*, 2011). The risk factors for an ACL injury have been reported from the standpoints of the environment, anatomical structure, hormones, and biomechanics (Anderson *et al.*, 1987; Arendt *et al.*, 1995; Boden *et al.*, 2009; Chaudhari *et al.*, 2007). Anterior cruciate ligament (ACL) injuries are common among athletes and occur primarily in individuals involved in sports with knee pivoting movements such as soccer, football, team handball, basketball and alpine skiing. ACL injuries are functionally disabling and their natural history is unclear. They predispose the knee to subsequent injuries and the early onset of osteoarthritis (Beynon *et al.*, 2005). Due to the fact that female athletes are 4-6 times more likely to sustain an ACL injury than

their male counterparts when participating in the same sports, most studies evaluating risk factors focus on females (Hewett *et al.*, 2005; Hewett *et al.*, 2006). Approximately 70% of all ACL injuries are non-contact injuries (Griffin *et al.*, 2000). Risk factors for an ACL non-contact injury can be divided into environmental, anatomic, hormonal and biomechanical. Environmental or extrinsic factors refer to how the friction between shoes and the playing surface has implications for the risk of sustaining an ACL injury (Strand *et al.*, 1990; Olsen *et al.*, 2003). The dimensions of the intercondylar notch have been extensively studied in relation to ACL injuries. Due to the different methods employed to obtain data on notch width, results are difficult to interpret. It has been demonstrated that the notch width measurement of bilateral knees with ACL injury is smaller than that of unilateral knees with ACL injury, and notch widths of bilateral and unilateral knees with injury to the ACL are smaller than those of normal controls. This implies a strong association between notch width and ACL injury (Griffin *et al.*, 2006). Hormonal differences between men and women could to some extent explain the discrepancy in injury rates. The risk of an ACL injury seems to be higher in the preovulatory than the postovulatory phase of the menstrual cycle (Wojtys *et al.*, 1998; Zazulak *et al.*, 2006; Beynon *et al.*, 2006). Results from measurement of estrogen, progesterone and luteinizing hormone metabolites levels at the time of the anterior cruciate ligament tear have indicated that women had a significantly greater than expected percentage of anterior cruciate ligament injuries during midcycle (ovulatory phase) and a less than expected percentage during the luteal phase of the menstrual cycle (Wojtys *et al.*, 2002). Also recent research in the area of ACL injury risk factors has centered on neuromuscular performance. Neuromuscular control of the knee involves a complex interplay between the neurologic system and the muscles that cross the knee joint. Perhaps in noncontact ACL injury, expected motor recruitment patterns that control the knee are altered, which lead to injury. This aberration may result in a faulty or delayed neurologic signal to the knee instead of a

protective muscle response. The balance of muscle power and recruitment pattern between the quadriceps and the hamstring muscles is crucial to functional knee stability. The quadriceps, as ACL antagonists, may contribute to ACL injury. Some researchers have reported that quadriceps contraction increases ACL strain between 10° and 30° of knee flexion (Torzilli *et al.*, 1994; Arms *et al.*, 1984; Shoemaker *et al.*, 1993; Draganich *et al.*, 1990). ACL injuries often occur when landing from a jump, cutting or decelerating. A combination of anterior tibial translation and lower extremity valgus are probably important components of the injury mechanism in these athletes. It has been demonstrated that most non-contact ACL injuries occurred when the frontal knee valgus angle increased abruptly from 3 to 16° during 30-40 ms (Krosshaug *et al.*, 2007). Approximately 30% of all ACL injuries result from direct contact with another player or object (Malinzak, unpublished data, 1999). Although several authors have speculated on the etiology of the 70% of ACL injuries that do not result from direct contact, the basic mechanism for this injury still eludes us.

Materials and methods

Information on injury mechanisms was collected in 2 different ways, from the questionnaire (n=634) and through interviews with injured players (n=205). Information was collected prospectively through the 2010-2013. The sport activities that were considered for the study included: soccer, volleyball, futsal, basketball, wrestling, ski and gymnastics (Table1).

All injured players were interviewed during the 2010-2013 to compare player recall with the questionnaire. The interview data were also used to check whether the questionnaire we obtained was a representative sample. The entire athletes were diagnosed as having an ACL injury confirmed by magnetic resonance imaging (MRI) and/or an arthroscopic procedure. Approximately seventy five percent of the subjects visited the clinic within one month, and 25 percent of the subjects visited the clinic within one week after an ACL injury incident. We classified the activity of the

subject at the time of the ACL injury in two categories (A) competitions (B) practice. Also we classified the injury mechanism. In three categories (A) Noncontact: No contact with another person or things at the time of the injury (B) Accident: Particular situations during sports activities such as skiing and (C) Unknown: The injury mechanism data missing in medical records, and dynamic alignment at the time of the injury. We classified the dynamic alignment at the time of the injury into six categories (Kawano *et al.*, 1998).

- (1) Knee-in & Toe-out: Knee valgus and foot abduction position
- (2) Knee-out & Toe-in: Knee varus and foot adduction position
- (3) Hyperextension: Hyper-extended knee position
- (4) Unclear: Injury mechanism that was not expressed clearly by the patients
- (5) Unknown: The injury mechanism data missing in medical records
- (6) Other

Results

Activity at the time of the injury (Table 2), the number of subjects who had the injury during "Practice" was the largest (441), accounting for 52.6% of all the subjects. The number of subjects who had the injury during "Competition" accounted for 47.4 % (398). No significant difference was found between sports activities.

We obtained the information of the injury mechanism from 839 subjects (Table3). The number of "Noncontact" cases was 607, "Accident" cases were 39 and unknown cases were 193. Our results indicate that the number of noncontact injury among soccer and futsal was largest (248).

We investigated the dynamic alignment at the time of the injury in 839 subjects (Table4). Among all the subjects, the number of the subjects with the alignment of Knee-in & Toe-out was the largest (395), Knee-out & Toe-in was (148) and Hyperextension was (96), Unclear was (107), Unknown was (52) and Others was (41). We found no significant difference in

the dynamic alignment at the time of the injury between sport activities.

The results of this study showed that regardless of the Activity at the time of the injury (practice, Competition), Injury mechanism at the time of the injury and Dynamic alignment at the time of the

injury, the most ACL injuries occur in ski. Although the skiers in study were just 54, but 41 of them had an ACL injury (76%). ACL injury among volleyball was lowest with only 69 of 183 people have an ACL injury (37.8%). In Figure 1 are shown sport activities and percent of ACL injury.

Table 1. Male Sports activities participation (n = 839).

Sport	N	Rate(%)	Height(m)	Weight(kg)	Age(yrs)
Soccer	268	32	1.73	72.3	24.7
Volleyball	183	21.8	1.96	89.6	21.5
Futsal	126	15	1.71	71.8	23.9
Basketball	96	11.4	1.88	86.9	21.8
Wrestling	88	10.5	1.68	70.3	25.2
Ski	54	6.4	1.74	72.5	22.4
Gymnastics	24	2.9	1.67	65.4	19.5

Table 2. Activity at the time of the injury .

Time of injury	Total(839)	Rate(%)
Practice	441	52.6
Competition	398	47.4

Table 3. Injury mechanism at the time of the injury.

Injury mechanism	Total(839)	Rate (%)
Noncontact	607	72.3
Accident	39	4.7
Unknown	193	23

Table 4. Dynamic alignment at the time of the injury.

Position	Total(839)	Rate (%)
Knee-in & Toe-out	395	47.1
Knee-out & Toe-in	148	17.7
Hyperextension	96	11.4
Unclear	107	12.7
Unknown	52	6.2
Others	41	4.9

Discussion

The function of the ACL is to stabilize the knee joint, prevent abnormal movements, and steer the movement of the knee (Nordin *et al.*, 2001). The ACL prevents forward translation of the tibia relative to the femur, and cadaver studies have shown that at 30° of knee flexion the ACL represents 85% of the total capsular and ligamentous resistance (Butler *et al.*, 1980). An ACL tear is most often a sports-related injury. ACL tears can also occur during rough play, motor vehicle collisions, falls, and work-related injuries. About 80% of sports-related ACL tears are "non-contact" injuries. This means that the injury

occurs without the contact of another athlete, such as a tackle in soccer. Most often ACL tears occur when pivoting or landing from a jump. The knee gives-out from under the athlete when the ACL is torn. Our result showed an ACL injury occurred more often during a practice than during competition. The situations during a competition and a practice are different in many respects. Athletes usually spend a much longer time in practice than in competition. Along with longer commitment, athletes usually challenge new team formation and technique during a practice rather than during a competition, which might increase the risk of injury. However, a more

stressful situation might be imposed on the athletes during a competition than during a practice both physically and mentally. The current result might reflect the increased physical and mental stress during competitions but with regard the time of practice longer than competition, there is a greater risk of injury during practice. The current result also showed that noncontact cases were the most common in soccer. The investigation on the dynamic alignment at the time of the injury revealed that the knee-in & toe-out alignments were most often reported. In retrospective interviewing studies, the subjects often encounter difficulty in recalling the dynamic alignment at the time of the injury, which may be related to the passage of time between the injury and the interview. The interview was usually held long after the injury occurred; for example, (Boden *et al.*, 2000) reported that the interview was held 3.4 years after the injury on average. In addition, whether the information obtained is accurate or not may depend on how the subject described the dynamic alignment at the time of the injury. Therefore, there might be questions about the accuracy of the information obtained in the retrospective interviewing study (Krosshaug *et al.*, 2005; Shimokochi *et al.*, 2008).

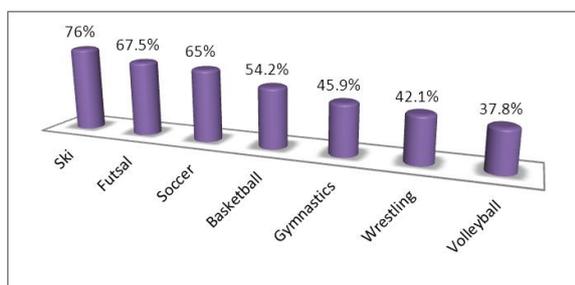


Fig. 1. Rate of ACL injury among some male sport activities.

This study with the results obtained from interview also showed that gaining a better understanding of ACL injury mechanism provides greater insight into possible predisposing factors (McNair *et al.*, 1990; Feagin *et al.*, 1985). Noncontact ACL injuries typically occur during deceleration and change of direction with the foot fixed. Knee torsion that results from making a sudden directional change on a planted foot has been implicated as a cause of ACL tears. We confirmed that the data from both sources

(questionnaire and interview) exactly matched each other. If the data was unmatched, we regarded the description of the ACL injury mechanism as an “unclear” dynamic alignment. The subjects at the interview were able to recall the mechanism of their ACL injury. A noncontact mechanism was described in 24.5% of the athletes via interview. Data such as contact versus noncontact, position of the knee and lower leg, direction of knee collapse, direction of body twisting, and other events were recorded. The number of variables an athlete must respond to in team sports may explain the higher incidence of injuries in sports such as soccer, futsal, volleyball and basketball. Though the exact moment of injury was impossible to determine from interview, the position of the leg before collapse in most of noncontact injuries was near foot strike with the knee in slight flexion. None were associated with a sharp, pivoting motion of the body around a planted leg or varus collapse of the knee. Valgus collapse of the knee in varying degrees was noted in most injuries. These findings have several important implications. Sharp changes in direction, landing, and rapid deceleration are normally repeated thousands of times in athletic endeavors without injury. The difference for athletes who sustain ACL injuries may be that abnormal motor patterns cause the quadriceps to preferentially activate before the hamstrings. (Simonsen *et al.*, 2000) found that even with maximal contraction of hamstrings, the muscles were not able to reduce the forces on the ACL during cutting movements in young, well-trained team handball players. Some researchers discussed the mechanical stress imposed on the knee joint on the basis of the MR images after an ACL injury (Fayad *et al.*, 2003; Viskontas *et al.*, 2008). Due to these previous findings and our current finding we speculated that the “valgus knee” observed in an action with “Knee-in & Toe-out” is related to the occurrence of a noncontact injury and that both internal and external rotations of the tibia may occur at the time of an ACL injury. Although knee external rotation is often described in the mechanisms for ACL injuries, the literature indicates that knee internal rotation may be an equally, if not more important, motion to protect the ACL. Further, the application of

knee valgus loading during a sudden decelerating, weight-bearing task, such as landing, may also increase ACL loading (Withrow *et al.*, 2006). Because a combination of knee external rotation and valgus motions may impinge the ACL against the femoral intercondylar notch (Fung *et al.*, 2003) and because these motions have been often observed during noncontact ACL injury, knee external rotation remains an important consideration for ACL injury. (Ferretti *et al.*, 1992; Olsen *et al.*, 2004). Also, the mechanism of ACL injury in skiing is different from that in jumping, running, and cutting sports such as football, soccer, basketball and volleyball. In skiing, most ACL injuries result from internal rotation of the tibia with the knee flexed greater than 90°, a position that results when a skier, falling backward, catches the inside edge of the tail of the ski (Ettliger *et al.* 1995).

There is a pressing need to improve public and participant awareness of the risk of ACL injury and the possibilities for prevention. The morbidity from ACL injuries in the athletic population is of great concern. Furthermore, the economic impact of these injuries adds significantly to our rising medical costs. Therefore, efforts to prevent or at least decrease the rate of occurrence of these injuries seem prudent. Until recently, attempts to develop prevention programs centered on first clearly defining risk factors and injury mechanisms. Although these research efforts have yielded much information, they have not, with the exception of research efforts in some sport activities, resulted in a clear understanding of the cause of non-contact ACL injuries. So it seems, according to the findings of this study should be planned prevention programs to reduce ACL injury. Prevention programs designed to increase neuromuscular control, improve balance, and teach avoidance strategies for at risk situations appear to be effective in decreasing injury rates.

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