

# A retrospective study of mechanisms of anterior cruciate ligament injuries in high school basketball, handball, judo, soccer, and volleyball

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## Abstract

The purpose of this study was to analyze the mechanism of anterior cruciate ligament (ACL) injuries among male and female high school students across several different sports to understand ACL injury trends.

A total of 1000 cases involving high school students who suffered ACL injuries during school activities (soccer, basketball, volleyball, handball, and judo) and who received insurance benefits through the Injury and Accident Mutual Aid Benefit System, were included to clarify the various mechanisms of ACL injuries. The mechanism of ACL injury was divided into contact and non-contact injuries. Contact injuries were further divided into direct and indirect contact injuries. Non-contact ACL injuries were also further divided into landing injuries, which involved jump-landing movements, and cutting and stopping injuries, which involved movement with a change of direction and deceleration.

Overall, 99.0% of judo ACL injuries were categorized as contact ACL injuries. With regards to ball sports, the number of non-contact ACL injuries among basketball, volleyball, and handball players was significantly higher than the number of contact injuries (67.0%, 86.5%, and 68.5% respectively). With regards to female soccer and basketball players, the number of indirect ACL injuries was higher than direct injuries (72.2% and 76.7%, respectively).

Volleyball was associated with a higher rate of non-contact injuries. Soccer, basketball, and handball were associated with more or similar rates of indirect and non-contact injuries than direct injuries. Judo was associated with a higher rate of contact injuries.

**Abbreviations:** ACL = anterior cruciate ligament, JSC = Japan Sports Council.

**Keywords:** ACL, basketball, football (Soccer), judo, team handball, volleyball

## 1. Introduction

Anterior cruciate ligament (ACL) injuries are one of the most serious sports injuries. Previous studies have investigated various aspects of ACL injury including incidence rates, severity, epidemiological factors, mechanisms of injury, and the effect of programs to prevent ACL injuries in athletes.<sup>[1-6]</sup> Recently, prevention has been especially focused on sports medicine and sports-related injury prevention models generally contain 4 steps in the research design.<sup>[7,8]</sup> This model has been used for assessing many sports-related injuries, especially in ACL injury prevention. In some sports, prevention studies revealed effective results.<sup>[4]</sup> However, subjects in previous studies were often used combina-

tion of some prevention measures to the number of causes. Therefore it is unknown whether prevention procedures based on mechanisms of ACL injury in each sport are effective or not.

Many existing ACL injury prevention programs focus on non-contact-related injuries. For example, many programs teach appropriate movement patterns such as jump-landing techniques<sup>[9,10]</sup> because movements such as inappropriate cutting and stopping motions also cause ACL injuries.<sup>[11,12]</sup> However, the mechanisms of the cause of ACL injuries are not limited in noncontact injuries. Therefore, in creating injury prevention programs, it is important to acknowledge and understand the difference in preventing contact and non-contact ACL injuries. Additionally, contact ACL injuries can be further divided into direct injuries that involve direct trauma to the knee and indirect ACL injuries that involve direct trauma to the other body parts. Previous researches focusing on indirect ACL injuries are limited and therefore future research is required. In addition, specific mechanisms of ACL injury differ within each sport; very few studies have investigated mechanisms of injury cross-section using larger cohorts. Previous research also revealed that high school students have a high rate of ACL injuries compared to junior high school age groups.<sup>[13]</sup> Therefore, it is necessary to investigate mechanisms of ACL injury among high school students within each sport to gain a better understanding of ACL injury patterns and injury prevention.

In Japan, the Japan Sports Council (JSC) operates a program called the Injury and Accident Mutual Aid Benefit System. All applicable schools report all injuries involving students under the supervision of the school and all medical expenses are covered by

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the insurance through the program. In order for students to receive the insurance, schools need to report detailed information regarding the incidence. This information is available for analysis to understand how the specific injury occurred during the specific sports activity. Identifying how injury happens is useful for the creation of an effective injury prevention program.

The purpose of this study was to analyze the mechanism of ACL injury among high school students across each sport and with regards to sex to understand the injury trend and mitigate the modifiable risk.

## 2. Materials and methods

### 2.1. Research design

The present study was a retrospective epidemiological study. This study design was approved by Ethics committee of Japan Institute of Sports Sciences. Because the personal information of subjects was not identified on the database of the Injury and Accident Mutual Aid Benefit System, informed consent by each subject was not conducted.

### 2.2. Participants (target population)

In previous a study,<sup>[13]</sup> we reported that athletes who play soccer, basketball, judo, handball, and volleyball had a high incidence of ACL injury. In the present study, a total of 1000 cases, involving high school students who suffered ACL injuries during school activities and who received insurance through the Injury and Accident Mutual Aid Benefit System, were utilized to clarify the mechanisms of ACL injury in these sports. The 1000 cases included the first 100 male and female high school students who injured their

ACL playing soccer, basketball, judo, handball, or volleyball. All ACL injury data were collected retrospectively from January 2016.

### 2.3. Categorization

The mechanism of ACL injury was divided into contact and non-contact injuries. Contact injuries were further divided into direct and indirect contact injuries. Direct contact involved direct contact to the knee. Indirect contact involved contact to other body parts at the moment of injury and before the injury. Any type of contact for which it was difficult to differentiate between direct or indirect contact was categorized as an unknown injury and removed from the analysis. Non-contact ACL injuries were also further divided into landing, which involved jump-landing movements, cutting, and stopping, which involved movement with a change of direction and deceleration, and other, which included non-contact ACL injuries that did not fall into the other 2 categories. If the mechanism of ACL injury was unclear from the description on the insurance form, the cases were excluded from analysis.

### 2.4. Statistical analysis

Mechanisms of ACL injury for each sport and the ratio between sexes were analyzed using the  $\chi^2$  test ( $\alpha=0.05$ )

## 3. Results

### 3.1. Inclusion and exclusion criteria

A total of 40 unknown ACL injuries (9 males and 31 females) were reported and were excluded from the analysis (Fig. 1).

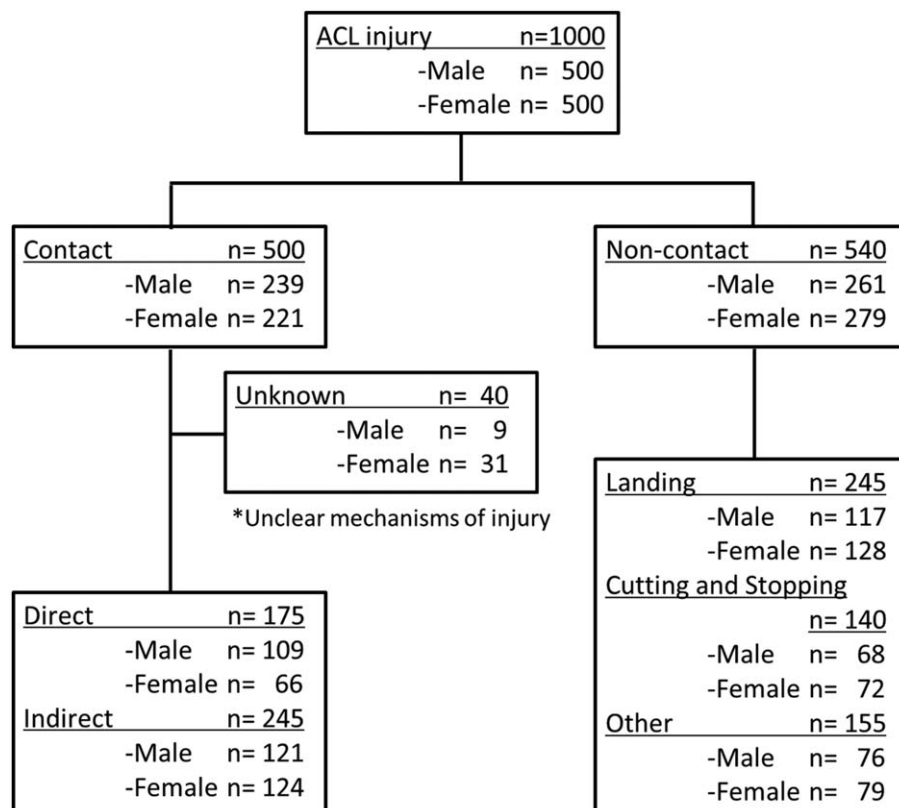


Figure 1. Inclusion and exclusion flowchart.

**Table 1**  
Descriptive data of athletes of ACL injury across sports.

Sports	Male			Female		
	n	Age	Period	n	Age	Period
Soccer	100	16.6 ± 0.9	2015-2016	100	16.4 ± 0.9	2014-2016
Basketball	100	16.4 ± 0.8	2015-2016	100	16.4 ± 0.6	2015-2016
Volleyball	100	16.5 ± 0.9	2011-2016	100	16.2 ± 0.8	2015-2016
Handball	100	16.4 ± 0.8	2014-2016	100	16.4 ± 0.8	2015-2016
Judo	100	16.4 ± 0.8	2015-2016	100	16.4 ± 0.9	2014-2016
Total	500	16.4 ± 0.8	2011-2016	500	16.5 ± 0.9	2014-2016

ACL = anterior cruciate ligament.

### 3.2. Descriptive data

The age of participants and the data collection period are described in Table 1. Age across the sexes and sports was similar. As there were limited data on male volleyball ACL injuries, data for this group were collected before the period between 2016 and 2011.

A total of 1000 cases were divided into contact and non-contact ACL injuries (Table 2). Overall, 99.0% of judo ACL injuries were categorized as contact ACL injuries. With regards to ball sports, the number of non-contact ACL injuries among basketball, volleyball, and handball players was significantly higher than the number of contact injuries (67.0%, 86.5%, and 68.5%, respectively). The number of contact ACL injuries among male soccer players was higher than the number of non-contact injuries (59.0%) and the number of non-contact ACL injuries among female soccer players was higher than the number of contact injuries (53.0%). There was no statistically significant difference between male and female contact and non-contact ACL injuries.

### 3.3. Contact injury: direct contact or indirect contact

Contact injuries were divided into direct and indirect injuries (Table 3). There were no statistically significant differences in the number of direct and indirect ACL injuries in male athletes. With

regard to female soccer and basketball players, the number of indirect ACL injuries was higher than the number of direct injuries (72.2% and 76.7%, respectively) and the total female athlete showed a similar tendency. The ratio of direct and indirect ACL injuries was significantly different between male soccer players and female players.

### 3.4. Non-contact injuries: landing, cutting, and stopping

Non-contact ACL injuries were divided into landing, cutting and stopping, and other. All injuries categorize as "other" were removed from the analysis (Table 4). For all male and female athletes, the number of landing-related injuries was significantly higher than the number of cutting- and stopping-related injuries (44.8% and 45.9%, respectively). With regard to female soccer and basketball players, the number of cutting- and stopping-related ACL injuries was significantly higher than the number of landing-related injuries (44.8% and 45.9%, respectively). The number of landing-related ACL injuries was significantly higher among both male and female volleyball players and female handball players.

Each category of injury for all 5 sports is described in Figure 2. Contact ACL injuries accounted for most of the judo ACL injuries. Other than judo, soccer players generally had a higher number of contact injuries than non-contact injuries. The number

**Table 2**  
Contact or Non-Contact.

Sports	Male				Female				P (male-female)
	n	Contact	Non-contact	P	n	Contact	Non-contact	P	
Soccer	100	59	41	.07	100	47	53	.55	.09
Basketball	100	31	69	<.001	100	35	65	<.001	.55
Volleyball	100	17	83	<.001	100	10	90	<.001	.15
Handball	100	32	68	<.001	100	31	69	<.001	.88
Judo	100	100	0	—	100	98	2	<.001	.50
Total	500	239	261	.36	500	221	279	<.001	.25

**Table 3**  
Direct versus indirect contact injuries among the male and female athletes.

Sports	Male				Female				P (male-female)
	n	Direct	Indirect	P	n	Direct	Indirect	P	
Soccer	55	27	28	.90	36	10	26	<.01	.04
Basketball	28	10	18	.13	31	8	23	<.01	.41
Volleyball	15	7	8	.80	6	1	5	.10	.34
Handball	32	12	20	.16	27	10	17	.18	.97
Judo	100	53	47	.55	90	37	53	.10	.10
Total	230	109	121	.43	190	66	124	<.001	<.01

**Table 4**  
**Non-contact injuries: landing, cutting, and stopping.**

Sports	Male				Female				P (male-female)
	n	Landing	Cutting and stopping	P	n	Landing	Cutting and stopping	P	
Soccer	41	8	13	.28	53	6	21	<.01	.23
Basketball	69	27	20	.31	65	18	33	.04	.03
Volleyball	83	57	6	< .001	90	73	4	<.001	.35
Handball	68	25	29	.59	69	30	13	.01	.02
Judo	0	0	0	—	2	1	1	—	—
Total	261	117	68	<.001	279	128	72	<.001	.88

of direct injuries was very small with basketball and handball players and a similar proportion of indirect, landing-, cutting-, and stopping-related injuries was reported.

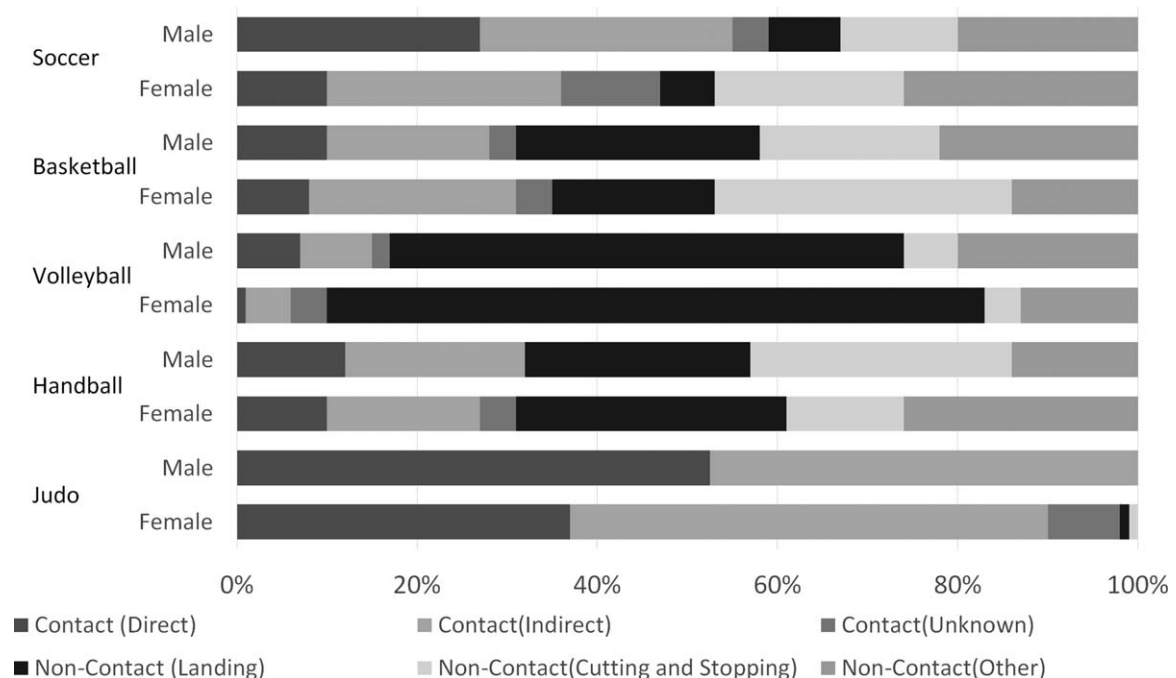
**4. Discussion**

The purpose of this study was to investigate the mechanisms of ACL injury among high school athletes within each sport on a large scale. Many researchers<sup>[14–16]</sup> have investigated mechanisms of ACL injury using medical questionnaires; however, no studies have been as large scale as this study. These studies have reported the mechanisms of ACL injury by contact injury or non-contact injury.<sup>[14–16]</sup> Although some studies<sup>[17,18]</sup> have reported on indirect contact injuries associated with body parts other than the knee, the ratio of indirect to direct contact ACL injuries is still unknown. For the present study, contact injuries were divided into direct and indirect injuries and the ratio of direct to indirect injuries was calculated. As a result, among the contact ACL injuries, this study showed that half of the male contact ACL

injuries and two-thirds of female contact injuries were indirect injuries. This suggests that indirect injuries account for a significant portion of all ACL injuries.

There were no differences in the ratio of contact and non-contact ACL injuries both in male and female athletes; however, the ratio of indirect ACL injuries was higher than direct ACL injuries among female soccer players. Kaneko et al<sup>[14]</sup> suggested that movements such as pressing, dribbling, trapping, kicking are the most common mechanisms of ACL injuries among female soccer players and most of the injuries were categorized as non-contact or indirect injuries. In a male soccer player’s study,<sup>[19]</sup> pressing, kicking, and landing after a jump also accounted for most of the non-contact-related ACL injuries. Another common mechanism of direct ACL injuries reported was tucking into the knee from the behind.<sup>[19]</sup> The aggressive nature of male soccer players who utilize more tackling techniques than female soccer players explains the number of contact and indirect ACL injuries among the male soccer players.

**Mechanism of Injury**



**Figure 2.** Direct contact or indirect contact, landing, cutting, and stopping.

The number of non-contact ACL injuries was higher than the number of contact ACL injuries among male and female basketball players. With the female basketball players, indirect ACL injuries were more common than direct ACL injuries. Krosshaug et al<sup>[17]</sup> reported a higher incidence of non-contact ACL injuries than contact ACL injuries with video analysis, which agree with our findings in this study. They also pointed out that most of ACL injuries of female athletes happened right after contact with another player.<sup>[17]</sup> This supports the results of this study that indirect injury was more common in female. These findings suggest that addressing the indirect mechanisms of ACL injuries is necessary to prevent ACL injuries among female basketball players. Previous research<sup>[17]</sup> has suggested that landing is one of the most common mechanisms of ACL injury. In comparison, our research determined that cutting and stopping were the most common non-contact ACL injury mechanism. This could be a characteristic finding among Japanese female basketball players.

The number of non-contact ACL injuries was higher than the number of contact ACL injuries with male and female volleyball players. Devetag et al<sup>[20]</sup> reported that non-contact ACL injuries accounted for the majority of female ACL injuries, which is consistent with our findings. They also reported that landing from a jump attack was a major mechanisms of ACL injury among female volleyball players<sup>[20]</sup> and this contributed to an increase in the number of female volleyball players who suffered from non-contact ACL injuries. Another characteristic finding among female volleyball players was that more athletes suffered ACL injuries of the left leg and spikers suffered more ACL injuries than other players.<sup>[20]</sup> It is important to understand these characteristics to help prevent ACL injuries among volleyball players.

With regard to handball players, the number of non-contact ACL injuries was higher than the number of contact injuries, and the number of direct and indirect ACL injuries was similar. According to Myklebust et al,<sup>[16]</sup> most of the handball-related ACL injuries reported in their study were non-contact. Another study by Olsen et al<sup>[18]</sup> suggested that 6 of 20 cases of ACL injury were indirect and 1 of 20 were direct. Our results, compared to previous studies, showed a high percentage of direct and indirect ACL injuries among handball players. With regard to details of non-contact injuries, the number of landing, cutting, and stopping was similar among male handball players; however, the number of landing-related ACL injuries was higher than the number of cutting and stopping injuries among female handball players. Future research utilizing video analysis is necessary to better understand the sex difference in mechanisms of injury among handball players.

Most of the ACL injuries among both male and female judo athletes were contact-related injuries and the ratio of direct and indirect ACL injuries was similar. Most of the contact ACL injuries happened when the athlete was attacked by another judo athlete utilizing skills known as "Osotogari" and "Kosotogari."<sup>[15]</sup> The number of indirect ACL injuries is similar to the number direct ACL injuries within this group; however, more data for future research are necessary to evaluate indirect ACL injuries.

#### 4.1. Limitations and other considerations

This investigation has limitations. First, the information in the database regarding the incidence was dictated by the school

nurse. Therefore, the injury descriptions were somewhat lacking in information and at times inaccurate. Second, information such as play situation, game versus practice situation, or athlete position was not collected through the program. Although our study has these limitations, this research was based on a large-scale epidemiological study, which made it possible to understand the mechanisms of ACL injuries within each sport. This information can therefore be a basis for future studies and provide a foundation for injury prevention models.

#### Author contributions

**Data curation:** Saeko Takahashi, Yosuke Kido.

**Formal analysis:** Saeko Takahashi.

**Investigation:** Saeko Takahashi.

**Methodology:** Saeko Takahashi, Yasuharu Nagano, Toru Okuwaki.

**Project administration:** Saeko Takahashi.

**Supervision:** Toru Okuwaki.

**Validation:** Yasuharu Nagano.

**Writing – original draft:** Saeko Takahashi, Yasuharu Nagano, Wataru Ito.

**Writing – review & editing:** Yasuharu Nagano, Yosuke Kido.

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