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Original Research

Risk Estimation of Anterior Cruciate Ligament (ACL) Injury in East Java Puslatda Pencak Silat Athletes

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ABSTRACT

Background: Dr. Soetomo General Hospital Sports Clinic Surabaya reported that the incidence of knee injuries was rather high, particularly in martial art athletes. Injuries in pencak silat athletes are dominated by Anterior Cruciate Ligament (ACL) injuries (16.7%) Several risk factors are thought to influence ones' propensity for these injuries.

Aim: To analyze risk estimation between intrinsic and extrinsic factors in the occurrence of ACL injury in East Java Puslatda Pencak Silat Athletes.

Material and Methods: This study was an analytic observational study with a case control design involving 18 pencak silat athletes from East Java Regional Training Centre. Age, gender, body mass index, previous ACL injury, range of motion, laxity, and flat foot were included as intrinsic factors; while duration of each training, training frequency, and sparring frequency were included as extrinsic factors. Data analysis was done using the Chi-Square Test. Odds Ratio was calculated through cross-tabulation.

Results: It was found that 3 of 18 athletes (16.7%) had ACL injuries. None of the intrinsic and extrinsic factors significantly affected the incidence of ACL injury ($p > 0.05$). However, the odds ratio calculation showed that adult athletes older than 25 years-old (OR = 1.4), male (OR = 1.667), obese (OR = 1.4), with laxity (OR = 2.5), and flat foot (OR = 1) had higher risk in having ACL injury.

Conclusion: Adult athletes, male, obese, with laxity, and flat foot had a higher risk of ACL injury.

Keywords: *anterior cruciate ligament, injury, obese, range of motion, laxity, flat foot*

Introduction

Injury is a disruption of muscles, tendons, ligaments, joints and bones functions due to excessive movements or physical accidents marked by sensations of pain, heat, redness, and swelling in the structures involved. Injuries can be acute or chronic.[1]

Dr. Soetomo General Hospital Sports Clinic Surabaya reported that the incidence of knee injuries was rather high, particularly in martial arts athletes. Pencak silat is a contact sport which makes it a high risk of injuries. Injuries met from Pencak silat athletes at Dr. Soetomo General Hospital Sports Clinic Surabaya were dominated by Anterior Cruciate Ligament (ACL) injuries (16.7%). Several risk factors are thought to influence one's propensity for these injuries. In 2014 East Java *Pekan Olahraga Pelajar Daerah* (POPDA) Regional Competition, injuries on legs and feet in pencak silat athletes consist of bruises (30.43%), abrasions (28.26%), strains (23.91%), sprains (8.70%), dislocations (4.35%), and others (4.35%). There were no fractures found.[2]

ACL injuries in international athletes recorded occurred mostly in soccer (53.3%), followed by martial arts (26.7%), and in other sports (20%).[3] More than 120,000 ACL injury incidents occur each year in United States, with a predominance in school and college ages.[4] Studies in Norway, Denmark, and Sweden in 2004-2006 found that the highest incidence of ACL injury occurred in female teenagers aged 15-19 years-old.[5] A study in West Point England also reported that ACL injury occurred more in female (3.5%) than male (3.2%) athletes over a 4 years-period.

The rate of injury in female athletes is 2 to 6 times higher than in male athletes, depending on the type of sport.[6]

Intrinsic factors, extrinsic factors, and inciting events can affect the incidence of ACL injury. If not treated properly, ACL injuries can disrupt footwork stability that lead up to a reduced quality of performance during a match. Athletes who experience injuries during training and competitions require treatments from both medical and therapeutic perspective to restore maximum quality of performances.[7]

The risk estimation of ACL injury particularly in pencak silat athletes can provide information about the causes of ACL injuries. Results of the study can be used as a basis to determine preventive workups and also be a source of information for athletes and coaches to reduce the number of ACL injuries during training and competitions. Studies providing this information were still limited. This study was aimed to analyze risk estimation of intrinsic and extrinsic factors in the occurrence of ACL injury. Risk estimations were done towards intrinsic and extrinsic factors that will be explained in the method section. The hypothesis of this study found >0 Odds Ratio calculation results between the factors mentioned in the method towards the occurrence of ACL injury.

Material and Methods

This was an analytic observational study with a case control design to analyze the estimated risk of ACL injury in pencak silat athletes in East Java Regional Training Centre.

Case group consisted of athletes with no history of previous ACL injury, while the control group was athletes with previous history of ACL injury. The diagnosis of ACL injury was made by clinicians working at Dr. Soetomo General Hospital Sports Clinic Surabaya.

Population and sample included pencak silat athletes who attended medical screenings at Dr. Soetomo General Hospital in 2014 and 2017. The inclusion criteria included athletes in East Java Regional Training Center, with a fit condition, agreed and had signed the consent agreement to participate in this

study. The exclusion criteria included athletes with histories of another musculoskeletal injury in lower extremities except ACL injury that occurred less than 3 months before the data collection. Variables analyzed consisted of intrinsic and extrinsic factors. Age, gender, body mass index, previous ACL injury, range of motion, laxity, and flat foot were included as intrinsic factors; while duration of each training, training frequency, and sparring frequency were included as extrinsic factors. Data was processed and analyzed using Chi-Square Test in SPSS v23. Odds Ratio was calculated through cross-tabulation. Results are presented in tables and diagrams.

Results

General Characteristics of Pencak Silat Athletes

There were 18 samples found with 10 samples from 2014 and 8 samples from 2017. Current ACL injuries were found in 3 (16.7%) pencak silat athletes. Current ACL injuries were ACL injuries that were found during data collection. Age distribution of the subjects were found to be 10 athletes aged 17-25 years (55.5%), 7 athletes (38.9%) aged 26-35 years, and 1 athlete aged 36-45 years (5.6%). The average age was found to be 26.389±5.1807 years old. Most subjects were male, 12 of 18 athletes (66.7%). Body Mass Index (BMI) of the athletes were classified as severely underweight (<17 kg/m^2), underweight (17- 18.4 kg/m^2), normal (18.5-25 kg/m^2), overweight (25.1-27 kg/m^2), and obese (>27 kg/m^2). 16 athletes (88.8%) had normal BMI and 2 athletes were obese (11.2%). There were no athletes found in the underweight and overweight category. The average BMI was 26.239±5.309 kg/m2. No athletes were found with previous ACL injury. All athletes were found with normal range of motion. There were 3 (16.7%) athletes found with laxity and 6 (33.3%) athletes found with flat foot. All athletes got the ideal duration of ≤150 minutes and frequency of ≤10 times per week training.

Risk Estimations of Pencak Silat Athletes

There were 2 athletes aged 17-25 years old (20%) and 1 athlete aged 26-35 years old (14.2%) found with a current ACL injury. No significant relationship found between age and ACL injury incidence. Odds ratio showed that age was a risk factor for ACL injury (95% CI = 0.042-7.740; p = 0.857; OR = 0.571). Pencak silat athletes aged 17- 25 years old (95% CI = 0.316-2.027; p = 0.857; OR = 0.8) had a relatively lower risk to suffer from ACL injury than athletes aged 26-35 years (95% CI = 0.259-7.582; p = 0.857; OR = 1.4).

There were 3 male athletes who experienced ACL injuries (25%), while all female athletes were found with no ACL injuries. There was no relationship between gender and ACL injury incidence (p = 0.18). The odds ratio calculation showed that the male athletes had a 1.667 times higher risk to suffer from ACL injury compared to female athletes (95%CI = 1.103-2.519; p = 0.18; OR = 1.667).

There were 2 athletes with a normal BMI (12.5%) and 1 athlete with an obese BMI (50%) found with a current ACL injury. There was no relationship between BMI and ACL injury incidence (p = 0.18). The odds ratio showed that BMI was a risk factor for ACL injury (95% CI = 0.302- 162.202; p = 0.18; OR = 7). Athletes with normal BMI (95% CI = 0.017-2.386; p = 0.18; OR = 0.2) have a relatively lower risk to suffer from ACL injury than athletes with obese BMI (95% CI = 0.622-3.152; p = 0.18; OR = 1.4).

No athletes were found with previous history of ACL injury. There was no relationship between previous ACL injury and current ACL injury incidence. P-value cannot be calculated due to zero frequency in one category.

Table 1. General Characteristics

Characteristics	n	%
ACL Injury		
Yes	3	16.7
No	15	83.3
Age (years)		
17 – 25	10	55.5
26 – 35	7	38.9
36 – 45	1	5.6
Mean ± SD	26.389±5.1807	
Gender		
Male	12	66.7
Female	6	33.3
Body Mass Index (kg/m^2)		
Normal	16	88.8
Obese (>27)	2	11.2
Mean ± SD	26.239±5.309	
Previous ACL Injury		
Yes	0	0
No	18	100
Range of Motion		
Normal	18	100
Abnormal	0	0
Laxity		
Yes	3	16.7
No	15	83.3
Flat Foot		
Yes	6	33.3
No	12	66.7
Duration of Training		
Ideal (≤150 minutes)	18	100
Not ideal (>150 minutes)	0	0
Frequency of Training		
Ideal (≤10 times per week)	18	100
Not ideal (>10 times per week)	0	0
Frequency of Sparring		
Ideal (1 times per week)	18	100
Not ideal (>1 times per week)	0	0
TOTAL	**18**	**100**

Source: Research Data, Processed

There were 3 athletes with normal range of motion (16.7%) suffering from ACL injuries. There was no relationship between range of motion and ACL injuries incidence. P-value cannot be calculated due to zero frequency in one category.

There was 1 athlete with joint laxity (33.3%) and there were 2 athletes with no joint laxity (13.33%) suffering from ACL injury. There was no relationship between laxity and the incidence of ACL injury. The odds ratio showed that laxity was a risk factor for ACL injury (95% CI = 0.193-54.777; p = 0.396; OR = 3.25). Athletes with joint laxity had a relatively higher risk to suffer from ACL injury (95% CI = 0.320-19.529; p = 0.396; OR = 2.5) than athletes with no joint laxity (95% CI = 0.337-1.754; p = 0.396; OR = 0.769).

There was 1 athlete with flat foot (16.7%) and there were 2 athletes with no flat foot (16.7%) suffering from ACL injury. There was no relationship found between flat foot and the incidence of

ACL injury. The odds ratio showed that flat foot was not a risk factor for ACL injury (95% CI = 0.072-13,868; p = 1,000; OR = 1). Both athletes with (95% CI = 0.173-5,772; p = 1,000; OR = 1) and without flat foot (95% CI = 0.416-2.403; p = 1,000; OR = 1) have a relatively same risk of suffering from ACL injuries.

Though in Chi-square analysis, the p-value of flat foot against the occurrence of ACL injury was found not significant, but the OR value was found >0. Then it can be concluded that athletes with flat feet had a higher risk for having an ACL injury in the future, so that flat foot can be included as a risk factor for ACL injury.

All athletes had the same training duration and there were 3 athletes suffering from ACL injuries (16.7%). There was no relationship between the duration of training and the incidence of ACL injuries. P-value cannot be calculated due to zero frequency in one category.

All athletes also had the same training frequency and there were 3 athletes suffering from ACL injuries (16.7%). There was no relationship between the duration of training and the incidence of ACL injuries. P-value cannot be calculated due to zero frequency in one category.

All athletes had the same sparring frequency and there were 3 athletes suffering from ACL injuries (16.7%). There was no relationship between the duration of training and the incidence of ACL injuries. P-value cannot be calculated due to zero frequency in one category.

Discussion

The incidence of ACL injuries tends to increase in late adolescence towards early adulthood. Fernández-Jaén et al., also found that the median age of athletes with ACL injuries tended to be older than athletes without injuries.[8] Beynnon et al., also found that athletes in early adulthood (college) had a greater risk of ACL injury than athletes in late adolescence (school).[9] It can be explained that the lower prevalence of ACL injuries at younger ages could be due to the lesser frequency of matches. Young athletes tend to have a lesser play-time and difficulty level than the senior athletes. However, this study found no significant relationship between age and the risk of ACL injury (p = 0.954) that is similar to other studies.[8,9]

Older athletes had a two-fold increased risk of ACL injury, although the results were insignificant. A higher prevalence at older age is associated with puberty, particularly in girls. A decrease in neuromuscular control of the knee and a greater medial knee movement during the vertical jump test tends to be experienced by female athletes' after the puberty period. Post-pubertal greater knee abduction angles and moments are also thought to be associated with the risk of future ACL injury.[10] Webster et al., showed that age was a risk factor for ACL injury (95% CI = 1.6-5.9; OR = 3.1). The study found that patients under 20 years of age had a relatively higher risk of ACL injury. This was due to higher intensity of activities of patients under the age of 20.[11]

ACL injuries are 25% higher in male athletes, although there was no significant relationship between gender and the incidence of ACL injury found in this study (p = 0.18), similar to results of Poosamsai et al.[12]. Fernández-Jaén et al. also showed that ACL injuries were more common in male athletes (61.5%) compared to female athletes (50.6%), especially in athletes over 18 years-old.[8] Insignificant relationship between gender and ACL injury incidence could be due to a lack of female athlete participants. The evaluation was not optimal.[12] Inadequate neuromuscular control in female athletes in central coronal plane was also thought to be the risk, increasing the abduction torque in the knee which could lead to ACL injury.[8]

Table 2. Risks Estimation

Characteristics	ACL Injury		%		P-value
	Yes	No	Yes	No	
Age (years)					
17 – 25	2	8	20	80	0.857
26 – 35	1	6	14.2	85.8	
36 – 45	0	1	0	100	
Mean ± SD	26.389±5.1807				
Gender					
Male	3	9	25	75	0.18
Female	0	6	0	100	
Body Mass Index (kg/m^2)					
Normal	2	14	12.5	87.5	0.18
Obese (>27)	1	1	50	50	
Mean ± SD	26.239±5.309				
Previous Injury					
Yes	0	0	0	0	
No	3	15	16.7	83.3	.[a]
Range of Motion					
Normal	3	15	16.7	83.3	
Abnormal	0	0	0	0	.[a]
Laxity					
Yes	1	2	33.3	66.7	0.396
No	2	13	13.3	86.7	
Flat Foot					
Yes	1	5	16.7	83.3	1.000
No	2	10	16.7	83.3	
Duration of Training					
Ideal (≤150 minutes)	3	15	16.7	83.3	
Not ideal (>150 minutes)	0	0	0	0	.[a]
Frequency of Training					
Ideal (≤10 times per week)	3	15	16.7	83.3	
Not ideal (>10 times per week)	0	0	0	0	.[a]
Frequency of Sparring					
1 times per week	3	15	16.7	83.3	.[a]
TOTAL	**18**		**100**		

Source: Research Data, Processed

A narrower intercondylar notch in female athletes also makes it more likely for female athletes to experience ACL injuries. The narrower the intercondylar notch, the shorter the ACL.[8] Alicia et al. stated that the odds ratio value for gender showed that gender was a risk factor for ACL injury (95% CI = 1.31-1.75; p = 0.01; OR = 1.51) and female athletes have a relatively higher risk to suffer from ACL injury (95% CI = 1.61-2.20; p = 0.01; OR = 1.88) than male athletes (95% CI = 0.69-1.11; p = 0.01; OR = 0.87).[13]

Uhorchak et al. found that the mean BMI was higher in athletes with ACL injuries compared to athletes without ACL injuries. In that study, a significant relationship was found between BMI and the incidence of ACL injury (p = 0.002), but in regression with gender, a significant result was only found between female athletes (p = 0.008) and not in male athletes (p = 0.137).[14] Hägglund and Markus Waldén, also showed that the mean BMI was higher in athletes with ACL injuries and no significant relationship found between BMI and ACL injury incidence (p = 0.064).[10]

The relationship between BMI and ACL injury can be due to the association between BMI and physical fitness. BMI as a risk factor for ACL is also influenced by other factors such as the intercondylar notch index and joint laxity, so that further regression analysis must be carried out to evaluate the interdependency.[14] Insignificant relationship between BMI and the incidence of ACL injury found in this study could be due to other factors that could influence the BMI that were not analyzed in this study. Bojicic et al. showed that the odds ratio value for BMI was 0.973 (95% CI = 0.908-1.042) meaning that athletes with a higher BMI has a relatively higher risk for ACL injury.[15]

There were no athletes with previous ACL injuries in this study. Wiggins et al. showed that athletes who have a previous history of ACL injury have a 15% higher potential to suffer from ACL injury.[16] Results in this study are similar to Lundblad et al study result on 101 football players with a history of previous injury, indicating that there was no association between history of ACL injury and the incidence of ACL injury ($p = 0.65$).[17] In contrary, Allen et al. study on 90 female athletes with history of ACL injury showed that injury history had a significant effect on the incidence of ACL injury ($p = 0.04$). Athletes who had a history of ACL injury and returned to play had a 15% higher risk to suffer from ACL injury than athletes who did not return to play.[18]

Tainaka et al., showed that athletes with increased degrees of internal and external hip rotation during active range of motion to body weight had a relatively lower risk for ACL injury compared with athletes with limited internal and external hip rotation.[19] This limited range of motion affects the ACL condition, it is often accompanied by a decrease of hamstring muscles strength, causing athletes more prone to genu hyperextension.[16,19] ROM restriction in hip joint especially during rotation will increase knee pressure, making the ACL more prone to injury. ACL tear occurs when the maximum pelvic range of motion has reached.[20] The strength of pelvic abductor and extensor muscles greatly affects the degree of range of motion. If those muscles are not strong enough during dynamic movement, the ACL will be susceptible to injury.[21]

There were no athletes with abnormal range of motion in this study. This may be due to inaccurate focus on certain joints. Although the injury occurs in the knee joint, the most influence comes from the hip joint. It is necessary to classify a more specific range of motion between joints.

ACL injuries were higher in athletes with laxity (33.3%). In this study, there was no significant relationship found between laxity and the incidence of ACL injury ($p = 0.396$). The odds ratio showed that laxity was a risk factor for ACL injury (95% CI = 0.193-54.777; OR = 3.25). Athletes with laxity have a relatively higher risk to suffer from ACL injury (95% CI = 0.320-19.529; OR = 2.5). Uhorchak et al., showed similar results that athletes with a joint laxity of 1 SD above average had a higher prevalence of ACL injury, although a significant relationship was found ($p = 0.001$) in KT-2000 arthrometer test against ACL with loads of 111 N, 134 N, 156 N, and 178 N ($p = 0.048$; 0.034; 0.023; 0.016). However, there was no significant association found with a lighter load of KT-2000 arthrometer, of 45 N, 67 N, 89 N ($p = 0.611$; 0.301; 0.159).[14] Ramesh et al., also found that the prevalence of ACL injuries was higher in athletes with joint laxity (42.5%) and found a significant relationship between joint laxity and the risk of ACL injury ($p = 0.001$).[22]

Uhorchak et al., explained that although joint laxity can be found to significantly increase the risk of ACL injury, it is not accurate because it tends to overlap with other risk factors including a

narrow intercondylar notch index and higher BMI, so that further regression analysis is needed.[14] Vaishya and Hasija study on 190 men and 110 women, and 135 men and 75 women who had ACL injuries found that athletes with laxity had a relatively higher risk of ACL injury (95% CI = 2.58-7.71; p = 0.01; OR = 4.46).[23]

Boden et al. found that all athletes who had an ACL injury first touched the ground with their back foot or foot flattened and reached an average flat foot position 1.5 feet faster than athletes without an ACL injury. Athletes with an ACL injury also perform plantarflexion in the ankle joint at a smaller angle during injury.[24] Olsen et al. also found that 63% of athletes with ACL injuries used the plant-and-cut maneuver with the knee almost fully extended and the foot firmly planted outside the area immediately below the center of movement that commonly leads to ACL injury.[25]

Almost all of the studies of flat foot at the time of ACL injury found a significant association between flat foot position and risk of ACL injury. Flat foot has a significant effect especially on non-contact injuries when injury does not occur due to physical contact, but as result of the athletes' movements.[24,25] Cowan et al. showed that the odds ratio value for BMI was 0.973 (95%; CI = 0.908-1.042). Athletes who has a higher body mass index has a relatively higher risk of ACL injury.[26]

In this study, all athletes had an ideal training duration in accordance with the coaches' direction. However, there was no variation in the duration of the training, so the p-value couldn't be calculated. The longer the duration is, the longer the exposure of the athletes is in a prone-to-injury condition. A long duration of training can also cause fatigue in athletes, making them prone to injury. The highest risk of injury was found during the last 15 minutes or in the second half of matches in several studies that were associated with fatigue and decreased focus of athletes in the game.[27]

The frequency of training showed a single variation of time. No athletes with a not ideal training frequency were found. The p-value couldn't be calculated.

In previous studies, observations of training frequency are usually combined with observations of training duration. Although in several studies observing ACL rupture prevention programs, it was found that the frequency of exercise no more than 3 times a week reduced the incidence of ACL injury.[28] The ideal frequency not only prevents fatigue, but also keeps the athlete in optimal physical condition so that they are less prone to ACL injury.[27] The application of the ideal training frequency also serves to optimize the increase in athletes' potential in each exercise including the strength, speed, and agility of the athletes in the match.[28]

All athletes in this study had an ideal and similar sparring frequency so the p- value could not be defined. The higher the frequency of sparing performed, the higher the exposure to prone-to-injury conditions is. The frequency of sparring must also be adjusted to frequency and duration of training with a higher ratio of training compared to sparring. In previous studies, it was shown that ACL injuries occur more during matches or sparring than during training.

Data retrieval of sparring frequency in this study could not be optimally evaluated because of limitation on data collection via questionnaires and not through continuous observation. The data obtained was a rough estimate of actual training exposure. Variations in the duration of each sparring in each season and the type and intensity of athletes' participation in competitions were not observed.[27]

Conclusion

Athletes with male gender, adult

age, obese, experiencing laxity and experiencing flat foot have a higher risk of ACL injury.

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