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INJURY HISTORY AND PERCEIVED KNEE FUNCTION AS RISK FACTORS FOR KNEE INJURY IN YOUTH TEAM-SPORTS ATHLETES

ABSTRACT

Background: The identification of risk factors for sports injuries is essential before injury prevention strategies can be planned.
Hypothesis: Previous acute knee injury and lower perceived knee function measured by Knee and Osteoarthritis Outcome Score (KOOS) will increase the risk of acute knee injury in youth team-sports athletes.
Study design: Prospective cohort study.
Level of evidence: Level 3.
Methods: At baseline, youth (≤ 21 years) male and female basketball and floorball athletes completed a questionnaire on previous acute knee injuries and perceived knee function (KOOS). A total of 211 male and 183 female athletes were followed for an acute knee injury up to three years. Unadjusted and adjusted Cox regression models were used in risk factor analyses.
Results: In males, previous acute knee injury and lower KOOS Pain-, Activities of Daily Living-, Sport and Recreation- and Knee-Related Quality of Life- subscale scores increased the risk of acute knee injury in the unadjusted analyses. Adjusted analyses for male injuries were not performed due to low number of acute knee injuries (n = 18). In females, previous acute knee injury increased the risk of acute knee injury when adjusted for athletes' age and body mass index (hazard ratio 2.6 [95% confidence interval, 1.3 to 5.2]). In females, none of the KOOS subscale scores were associated with the increased risk of acute knee injury in the adjusted analyses.
Conclusion: Previous acute knee injury was associated with the risk of new acute knee injury in youth male and female athletes. In youth male athletes, also lower perceived knee function in 4 out of 5 KOOS subscale scores were associated with the increased risk of new acute knee injury.
Clinical relevance: The treatment and rehabilitation of the present acute knee injury and secondary prevention of re-injury should be emphasized in youth team-sports athletes.

Keywords: SPORT INJURY; INJURY RISK; YOUTH SPORT

INTRODUCTION

Basketball and floorball are both fast-paced indoor team-sports with the similar incidence of acute knee injury in youth athletes.[28,30] These injuries are more common in youth female than in male athletes.[6,24,33,39] The majority of acute knee injuries occur in non-contact situations and are often severe causing a long absence from sports.[2,11,30] Furthermore, severe knee injury is a common cause of early osteoarthritis.[35]

In order to prevent sports injuries, knowledge of injury risk factors is essential.[40] After identifying injury risk factors, an attempt to ameliorate the effects of these risk factors can be done by introducing appropriate injury prevention strategies.[23] For example, the use of proprioceptive balance board program have been shown to reduce the risk of new ankle sprains in volleyball athletes with a history of previous ankle sprains.[41] Sports injuries are thought to be caused by complex interactions of many risk factors.[23] However, the measurement of non-modifiable risk factors such as anatomy[37] or modifiable risk factors such as muscle strength[18] and sport specific skills[21] requires health professionals and clinical testing equipment, which are rarely available especially for non-professional and youth athletes. Therefore, only less sophisticated injury screening tools might be available for these athletes. If questionnaires could identify athletes who are at increased injury risk, they would be simple, feasible and time-saving instruments.

Previous knee injury and lower scores in one or more Knee and Osteoarthritis Outcome Score (KOOS)[34] subscales have been found to increase the risk of any type of knee injury in youth soccer athletes.[8,19,38] However, in the studies of Steffen et al[38] and Kucera et al,[19] athletes' exposure time in trainings and matches was collected on a team level. Exposure time is recommended to be collected on an individual level in studies investigating relationship between injuries and individual risk factors.[16] Clausen and colleagues[8] registered individual exposure times but included also overuse knee injuries in the analyses. Considering the fact that time-loss based injury definition substantially tends to underestimate the number of overuse injuries[4] it is possible that the total number of new knee injuries have been underestimated in relation to the previous knee injuries. According to Clarsen and study group,[7] time-loss based injury definition is better applicable for registering acute injuries. In addition, to our knowledge, there are no previous studies investigating the association between KOOS subscale scores and knee injury risk in youth male athletes.

The purpose of this 3-year prospective study was thus to investigate previous acute knee injury and perceived knee function as potential risk factors for an acute knee injury in youth team-sport athletes. We hypothesized that previous acute knee injury and lower perceived knee function will increase the risk of new acute knee injury.

METHODS

Study design and participants

This study is part of the Predictors of Lower Extremity Injuries in Team Sports (PROFITS) study. [31] The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee (ETL-code R10169). The participants signed a written informed consent before entering the study (including parental consent for participants under the age of 18).

Junior-aged (≤21 yrs) basketball and floorball athletes were recruited from 9 basketball and 9 floorball teams from 6 sports clubs from Tampere city district. All athletes played at the two highest junior league levels. Inclusion criteria were: 21 years of age or younger and official team member. Altogether 214 male (102 basketball and 112 floorball) and 189 female (107 basketball and 82 floorball) athletes entered the study during the preseason (April-May) in 2011, 2012 or 2013. Each athlete completed a baseline questionnaire including questions about age, sex, playing experience, playing level, knee injury history and knee function (KOOS). Standing height (cm) and weight (kg) were recorded. After baseline, prospective injury registration continued until the end of April 2014. The complete data were obtained from a total of 211 male and 184 female athletes. One female athlete did not participate in the follow-up leading to a total of 211 male and 183 female athletes in the final analysis (**FIGURE 1**).

Previous acute knee injury and KOOS questionnaire

A previous acute knee injury was recorded if an athlete had ever sustained one or more sport-related knee injury resulting in a specific identifiable event leading to absence from trainings and matches at least the following 24 hours. Acute knee injuries during the previous 12 months as well as previous anterior cruciate ligament (ACL) injuries were also recorded. The KOOS is a self-administered knee-specific questionnaire comprising of five subscales: Pain, Symptoms, Activities of Daily Living (ADL), Sport and Recreation (Sport/Rec) and Knee-Related Quality of Life (QOL). Each item is scored from 0 (no problems) to 4 (extreme problems) using a Likert scale. A normalized score from 0 to 100 is then calculated for each subscale where 0 indicates extreme problems and 100 no problems.[34] KOOS subscale scores were recorded for both knees separately.[13,38] Missing data was handled according to the recommendations from the KOOS Users Guide.[1] The Finnish-translated KOOS version has demonstrated good validity according to

Spearman's Correlation Coefficients 0.48-0.81 between KOOS subscales and subscales from other self-administered knee-specific outcome measures and good to excellent test-retest reliability with Intraclass Correlation Coeffients 0.73-0.86 for all KOOS subscales.[25]

Injury and exposure registration
During a follow-up period (May 2011–April 2014), all acute knee injuries were registered. Two study physicians contacted the teams once a week to check possible new injuries and after each injury reported, the injured athlete was interviewed by telephone using the structured questionnaire including for example questions about injury date, injury situation, injured body part and injury diagnosis given by a physician. Injury definition was adapted from definition by Fuller and colleagues.[16] An injury was recorded if the athlete was unable to fully participate in matches or training at least the following 24 hours regardless of the injury diagnosis or given medical treatment. Only time-loss injuries and injuries which occurred in teams' scheduled training sessions or matches were included in this study. The injuries were classified as contact (ie. direct contact or strike to the involved knee) or non-contact (ie. no direct contact to the involved knee). If an injury had not diagnosed by the physician, the study physician made the diagnosis in telephone without seeing the injured athlete. All ACL, posterior cruciate ligament and meniscal injuries were verified by magnetic resonance imaging.

During the follow-up, the coach of each team recorded athletes' participation in trainings and matches. Athlete attendance in a training session (yes/no), duration of a training session (h) and attendance in each period of a match (yes/no) were recorded individually on a team diary. The diaries were returned after each follow-up month and the individual monthly exposure time (h) were registered for all athletes. If an acute knee injury occurred, the total exposure time from the beginning of the follow-up to the injury date was calculated. Injury incidences were calculated as the number of injuries per 1000 player-hours and reported with 95% CIs: ([*Incidence rate* – 1.96 * *Standard error of incidence rate*] * 1000 hours) to ([*Incidence rate* + 1.96 * *Standard error of incidence rate*] * 1000 hours). Recurrent injuries were included in incidence calculations.

Sample size
According to Bahr and Holme,[5] the sample size needs to be 20-50 injuries to detect moderate to strong associations between risk factors and injury risk. Estimates based on previous studies suggest that 0.1-0.2 acute knee injuries occur per athlete per year in basketball and floorball.[24,29] Therefore, we estimated that if we recruited 400 athletes during the 3-year study and if the mean follow-up period in athletes would be one year, 40 to 80 acute knee injuries will appear among athletes.

Statistical analysis
Descriptive data are presented as the mean ± standard deviation (SD) or the median and interquartile range (IQR). An independent-samples *t* test was used to compare group differences between sports for normally distributed variables and the Mann-Whitney *U* test for non-normally distributed variables. Fisher's exact test was used to compare group differences for categorical variables. Relative risks with 95% CIs[10] were calculated to measure the association between previous and new acute knee injury. Unadjusted mean differences for the KOOS subscale scores between previously injured and uninjured knees were analyzed according to the mixed linear models (gamma distribution). To correct potential dependence between right and left knee, an athlete was considered as a cluster with two knees.

Because athletes' individual playing and training times were recorded, Cox mixed effect regression models were calculated for risk factors.[5] The primary outcome was a new acute (contact or non-contact) knee injury and a secondary outcome a new acute non-contact knee injury. The athlete was a unit of analyses in the models analysing previous acute knee injury. In the models analysing KOOS subscale scores, the knee was the unit of analyses.[13,38] In all models, sports club was considered as a cluster,[21] because playing and training styles may differ between the clubs. In the models analysing KOOS subscale scores, also the athlete was considered as a cluster. Unadjusted and adjusted models were made separately for males and females, respectively.[40] The adjustment factors that might mostly influence to the risk of injury based on previous studies[9,26] were chosen and included in the models according to the number of injuries in each model, following the recommendation of at least 10 injuries needed per included variable.[32] The adjustment factors were age and body mass index (BMI) in the models analysing previous acute knee injury and previous acute knee injury, age and BMI in the models analysing KOOS subscale scores.

Cox hazard ratios (HRs) with 95% CIs were calculated for risk factors. *P* value < 0.05 were considered significant. A receiver operating characteristics (ROC) curve analysis were calculated to assess the combined sensitivity and specifity of a risk factor in cases where significant associations between the risk factor and the outcome were found. The combined sensitivity and specifity was defined as “excellent” (0.90–1.00), “good” (0.80–0.89), “fair” (0.70–0.79), “poor” (0.60–0.69) and “fail” (0.50–0.59).[36] Statistical analyses were conducted in Statistical Package for the Social Sciences (v.20.0.0; SPSS), except the regression models, which were conducted in R (v3.1.2; R Foundation for Statistical Computing).

RESULTS

Cohort baseline characteristics

Complete data were obtained from 211 (99%) male and 183 (97%) female athletes. The median follow-up period was 1.0 (0) and 1.0 (1.0) years in males and females, respectively. As seen in **TABLE 1**, significant group differences between basketball and floorball athletes were observed in age and match exposure in both sexes, in playing experience and KOOS Symptoms-subscale score in males as well as in height, training exposure and total exposure in females.

Previous injury characteristics

Fifty-three male and 46 female athletes reported one or more previous acute knee injury. Both knees had injured in 18 male and in 13 female athletes. Twenty-nine males and 23 females reported that last acute knee injury had occurred during the previous 12 months. Previous ACL injury had occurred in 7 male and in 6 female athletes. As shown in **TABLE 2**, all five KOOS subscale scores were significantly lower in previously injured knees compared to uninjured knees in both sexes at baseline. The highest mean KOOS subscale scores were observed in ADL- and the lowest in Symptoms-subscales in both previously injured and uninjured knees at baseline regardless of sex **(TABLE 2)**.

Injury characteristics

A total of 18 male and 32 female athletes had a new acute knee injury during the follow-up. Five female athletes had both knees injured (**TABLE 3**). In addition, two male and three female athletes had one re-injury to the same knee. Fifty percent of acute knee injuries in males and 32% in females were diagnosed by study physician in telephone.

Risk factor analysis: previous acute knee injury

Both male and female athletes with previous acute knee injury were more likely to sustain a new acute (any type or non-contact) injury compared to previously uninjured athletes (**FIGURES 2 & 3**). In male athletes, previous acute knee injury was associated with 5.8-fold increase in risk of any type of acute knee injury (HR 5.8 [95% CI, 2.2 to 15.3]) in the unadjusted risk factor analyses

(**TABLE 4**). In males, acute knee injury during the previous 12 months and previous ACL injury were also associated wih the increased risk of any type of acute knee injury (HR 8.4 [95% CI, 3.1 to 22.3] and 5.6 [95% CI, 1.2 to 25.2], respectively) in the unadjusted analysis (**TABLE 4**). Due to low number of acute knee injuries in males (n = 18) adjusted analyses were not performed.

In female athletes, previous acute knee injury increased the risk of any type of acute knee injury by 2.6-fold (HR 2.6 [95% CI, 1.3 to 5.2) in the adjusted risk factor analyses (**TABLE 4**). Females with a previous acute knee injury, a probability of having a new acute knee injury was 30.4% (95% CI, 21.0 to 41.9%). Correspondingly, in those who did not have a previous injury, the probability was 13.1% (95% CI, 9.9 to 17.2). However, ROC curve analysis showed AUC of 0.61 indicating "poor" combined sensitivity and specifity of previous acute knee injury. In females, previous acute knee injury also increased the risk of acute non-contact knee injury (HR 2.4 [95% CI, 1.1 to 5.0]) in the adjusted analysis (**TABLE 4**). In addition, acute knee injury during the previous 12 months was associated with the increased risk of any type of acute knee injury in females (HR 2.6 [95% CI, 1.1 to 6.1]) in the adjusted analysis, but no associations were found between previous ACL injury and new acute knee injury (**TABLE 4**).

Risk factor analysis: KOOS

Significantly lower scores in injured compared to uninjured knees were observed in KOOS Pain-, ADL-, Sport/Rec- and QOL-subscales in male and in Pain-, ADL- and QOL-subscales in female athletes with any type of acute knee injury **(APPENDICES 1 & 2).** In addition, male athletes with acute non-contact knee injury had significantly lower scores in all KOOS subscales in their injured knees compared to uninjured knees (**APPENDIX 1**).

In male athletes, lower KOOS Pain-, ADL-, Sport/Rec- and QOL-subscale scores increased the risk of any type of acute knee injury in the unadjusted risk factor analysis. The same risk factors were also associated with the increased risk of acute non-contact knee injury in the unadjusted analyses (**TABLE 4**). In female athletes, lower KOOS ADL-subscale score increased the risk of any type of acute knee injury in the unadjusted analysis. The trend was similar in the adjusted analysis, but the observed HR was not statistically significant (**TABLE 4**).

DISCUSSION

The main finding of this study was that previous acute knee injury increased the risk of sustaining a new acute knee injury by 2.6-fold in youth female and 5.8-fold in youth male athletes. Secondly, in youth male athletes, the unadjusted risk factor analyses showed that lower KOOS Pain-, ADL-, Sport/Rec- and QOL-subscale scores increased the risk of acute knee injury, but in females, none of the KOOS subscale scores were associated with the increased risk of acute knee injury in the adjusted risk factor analyses.

The risk factors and male injuries

In the present study, previous acute knee injury was associated with the increased the risk of new acute knee injury in youth male athletes. Previous knee injury has also shown be associated with an increased risk of any type of knee injury in intercollegiate male basketball (RR 4.23 [95% CI, 2.07 to 8.67])[22] and knee sprain in elite male soccer athletes (OR 4.6 [95% CI, 1.6 to 13.4]).[3] Hagglund et al[17] found that elite male athletes with having an acute knee injury had 3-fold (HR of 3.1 [95% CI, 1.3 to 7.6] in the unadjusted analysis) increase in risk of new acute knee injury in the following season. Considering that Hagglund and colleagues[17] registered also only acute knee injuries, the injury risk associated with having a previous injury, was considerably higher in the present study. This may be due to the recall bias related to the athletes' retrospective reporting of previous acute knee injuries in our study. Kucera et al[19] studied youth (<18 years) soccer athletes and presented also a nearly 6-fold increased risk for acute knee injury in previously knee-injured compared to uninjured athletes. Although the study group in Kucera and colleagues[19] study included both sexes, the study supports our finding of high re-injury risk of acute knee injury in youth male athletes. Consistently, young age has previously been found to be a risk factor for secondary ACL injury, especially in males.[43,44]

We found that previous ACL injury was also associated with the increased risk of acute knee injury in youth male athletes. This finding is in line with the previous study in Swedish elite soccer athletes.[42] Walden and colleagues[42] reported 2.7-fold increase in risk of acute knee injury in athletes with the history of ACL injury compared to athletes without ACL injury in history.

In the present study, 4 out of 5 KOOS subscale scores were associated with the increased risk of new acute knee injury. In contrast to our study, Engebretsen et al[13] reported that only lower KOOS Pain-subscale score was associated with the future acute knee injury in the unadjusted risk factor analyses and no associations were found in the adjusted analyses. However, the athletes in their study were considerably older (mean age 24 years) compared to our study. It is likely that adult athletes with longer sports careers are more likely to have sustained previous knee injuries compared with younger athletes. In addition, rehabilitation of previous injuries may also be more successful in experienced adult athletes and due to drop out of severe cases they may have less knee problems and thus higher KOOS subscale scores in previously injured knees.[3,17,22]

The risk factors and female injuries

The findings concerning injury history correspond with previous findings from two Scandinavian studies in youth female soccer athletes.[8,38] Steffen et al[38] found that history of previous knee injury increased the risk of any type of injury to the same knee by 40%. Clausen and study group[8] reported an over 3-fold increase in risk of sustaining any type of knee injury in previously injured compared to uninjured athletes. In contrast to our study, Faude and colleagues[14] studied a cohort of elite female soccer athletes (mean age 22 years) and found that athletes with previous knee sprain did not have a significantly higher risk of the same injury. This may be due to the drop out from the sports of those with severe or multiple injuries in younger age.

In contrast to youth male athletes, we found no association between previous ACL injury and the risk of new acute knee injury in youth female athletes. However, this finding should be interpreted with caution, because the mean age of female athletes in the present study was 15 ± 2.0 years and only 6 athletes had previous ACL injury.

In the present study, none of the KOOS subscale scores were associated with the increased risk of acute knee injury in youth female athletes. Steffen and study group[38] found that lower scores in all KOOS subscales and Clausen and colleagues[8] that in Sport/Rec-, QOL- and ADL-subscales were associated with the increased risk of any type of knee injury. However, in contrast to our study, previous injury was not treated as a confounder in the analyses in these studies. As presented in our study, strong associations exist between previous acute knee injury and all KOOS subscale scores in both sexes. Surprisingly, only lower KOOS ADL-subscale score was associated with the increased risk of acute knee injury in youth female athletes in the unadjusted risk factor analysis in the present study. Clausen et al[8] reported also the high risk for future knee injury in athletes with lower KOOS ADL-subscale score (RR 5.38 [95% CI, 1.73 to 7.46] for score < 80 compared to score ≥ 80). However, we found the mean difference of only 1.5 in the ADL-subscale scores between injured and uninjured knees in youth female athletes, limiting the clinical relevance of the finding. In addition, the mean ADL-subscale scores in the present study were over 95 in both previously injured and uninjured knees in both sexes indicating that difficulties with ADL-functions are typically mild in adolescence.[15]

We found that in female athletes, as in male athletes, mean scores in KOOS Symptoms-subscale were considerable lower compared to other KOOS subscales in both previously injured and uninjured knees. Steffen et al[38] reported also the mean KOOS Symptoms-subscale scores of 58.6 ± 12.9 and 67.1 ± 10.1 in previously injured and uninjured knees, respectively. The reasons for low scores in KOOS Symptoms-subscale compared to other KOOS-subscales in youth athletes are unclear. In contrast to youth male athletes, apart from ADL-subscale, we found no associations between lower KOOS-subscale scores and the risk of new acute knee injury in youth female athletes even in the unadjusted analyses. However, it should be noticed that we investigated only acute knee injuries. The incidence of overuse knee injuries in youth basketball and floorball athletes is remarkable high especially in females[20] and these injuries might have also affect the KOOS scores.

Clinical implications

The strong association between previous and future acute knee injury in youth male and female athletes suggests that treatment and rehabilitation of the present acute knee injury and the secondary prevention of re-injury should be emphasized in these athletes. Neuromuscular injury prevention programs have shown to be effective in the prevention of acute knee injuries in youth athletes[12,27] and they are recommended to be included in regular training. Considering the findings of the present study, especially athletes with previous acute knee injuries, should be motivated for neuromuscular training to prevent re-injuries. This study also gives evidence that KOOS Pain-, ADL-, Sport/Rec- and QOL-subscale scores may be useful when identifying youth male athletes with increased risk of acute knee injury, but further studies are needed.

Regardless of significant associations between previous and new acute knee injury in youth female athletes in the adjusted analyses, the combined sensitivity and specifity of previous acute knee injury in predicting future acute knee injury was classified as “poor” according to ROC curve analysis. We found that history of previous acute knee injury can correctly classify only 61% of injured and uninjured female athletes. Therefore, in clinical practice, previous acute knee injury cannot be recommended alone to predict the future acute knee injury in youth female athletes. However, while we cannot predict future injury it may be still useful to determine youth athletes who might be at increased risk for future acute knee injury by recording previous injuries and focus neuromuscular training especially for athletes with previous acute knee injuries.

Study strengths and limitations

This study had several strengths including the relatively long follow-up, large sample size and low drop-out rate. Also, prospectively collected injury and exposure data enabled the use of Cox regression models. In addition, risk factors presented in our study are easily available, simple and fast to use in clinical practice.

This study also had limitations. Originally, KOOS has been developed for studies concerning treatment of knee injuries and for long-term follow-up of patients with osteoarthritis.[34] Therefore, it may have limited value for the assessment of knee function in youth and mainly knee-healthy athletes. Also, self-reported injury history relies on athletes recall and therefore some previous injuries may have gone unreported. However, we believe that using only previous acute knee injury in the analyses minimized the risk for recall bias. In addition, despite the 3-year follow-up, the incidence of acute knee injury especially in male athletes was relatively low limiting the statistical power of the study. Thus, small group differences and risk estimates might not have been detected[5] and adjusted risk factor analyses for male injuries were not able to be performed.

CONCLUSION

Our prospective study showed that previous acute knee injury increased the risk of new acute knee injury in youth female and male athletes. In youth male athletes, lower perceived knee function measured by KOOS Pain-, ADL-, Sport/Rec- and QOL-subscale scores increased the risk of new acute knee injury. In females, none of the KOOS subscale scores were associated with the increased risk of acute knee injury.

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Table 1. Demographic data, match, training, and total exposure times, previous acute knee injuries, and KOOS subscale scores in male and female athletes

	Male				Female			
	All (n = 211)	Basketball (n = 100)	Floorball (n = 111)	P^a	All (n = 183)	Basketball (n = 103)	Floorball (n = 80)	P^a
Age, y[b]	16.1 ± 1.7	15.2 ± 1.6	17.0 ± 1.3	<**0.001**	15.5 ± 2.0	14.6 ± 1.6	16.5 ± 1.9	<**0.001**
Height, cm[c]	179.0 ± 8.1	179.4 ± 9.5	178.6 ± 6.5	0.48	167.6 ± 6.3	168.4 ± 6.5	166.5 ± 5.7	**0.04**
Weight, kg[c]	69.6 ± 11.1	69.0 ± 13.3	70.2 ± 8.7	0.45	61.1 ± 8.6	60.9 ± 9.4	61.3 ± 7.6	0.75
BMI, kg/m[2c]	21.7 ± 2.7	21.3 ± 3.1	22.0 ± 2.3	0.08	21.7 ± 2.8	21.4 ± 2.9	22.1 ± 2.6	0.10
Playing experience, y[c]	8.1 ± 3.1	7.3 ± 3.2	8.7 ± 2.8	**0.001**	6.4 ± 2.6	6.5 ± 2.6	6.2 ± 2.6	0.42
Match exposure, h[d]	10.0 (9.4)	7.3 (6.4)	12.5 (9.0)	<**0.001**	10.1 (15.7)	7.5 (9.0)	19.7 (25.3)	<**0.001**
Training exposure, h[d]	274.1 (243.9)	286.5 (165.1)	267.7 (298.8)	0.79	246.8 (346.5)	201.4 (123.0)	468.9 (431.8)	<**0.001**
Total exposure, h[d]	287.1 (248.6)	291.7 (155.3)	280.8 (304.7)	0.98	254.7 (354.0)	214.0 (125.7)	485.0 (466.7)	<**0.001**
Previous acute knee injury, n[e]	53	30	23	0.15	46	20	26	0.06
KOOS[f]								
Pain	94.9 ± 8.3	94.4 ± 9.0	95.4 ± 7.7	0.20	95.3 ± 7.3	95.5 ± 7.8	95.1 ± 6.6	0.16
Symptoms	64.3 ± 8.6	62.5 ± 9.7	65.9 ± 7.0	<**0.001**	64.0 ± 8.8	63.4 ± 8.4	64.7 ± 9.2	0.65
ADL	98.3 ± 4.8	97.9 ± 6.0	98.6 ± 3.3	0.12	98.3 ± 4.1	98.2 ± 4.9	98.5 ± 2.9	0.41
Sport/Rec	90.5 ± 15.6	89.5 ± 16.9	91.3 ± 14.4	0.25	91.8 ± 13.3	91.5 ± 14.2	92.2 ± 12.1	0.62
QOL	92.6 ± 13.1	92.6 ± 13.7	92.5 ± 12.7	0.97	92.9 ± 12.3	93.4 ± 12.3	92.3 ± 12.3	0.39

ADL, Activities of Daily Living; BMI, body mass index; KOOS, Knee Injury and Osteoarthritis Outcome Score; QOL, knee-related Quality of Life; Sport/Rec, Sport and Recreation.
[a]Significant between-group differences are marked in boldface.
[b]Age at the start of the follow-up. Values are presented as mean ± SD.
[c]Values are presented as mean ± SD.
[d]Values are presented as median (interquartile range).
[e]Values are presented as total number of injured athletes.
[f]Values are presented as mean ± SD.

Table 2. KOOS subscale scores in previously injured and uninjured knees in male and female athletes at baseline[a]

	Male			Female		
	Previous Acute Knee Injury (n = 71), Mean ± SE	No Previous Acute Knee Injury (n = 351), Mean ± SE	Mean Difference (95% CI)	Previous Acute Knee Injury (n = 59), Mean ± SE	No Previous Acute Knee Injury (n = 307), Mean ± SE	Mean Difference (95% CI)
Pain	89.7 ± 1.0	95.6 ± 0.1	**−5.6 (−7.8 to −3.9)**	89.9 ± 0.9	96.1 ± 0.5	**−6.2 (−8.1 to −4.3)**
Symptoms	60.4 ± 0.9	64.5 ± 0.6	**−4.0 (−5.8 to −2.2)**	58.4 ± 1.0	64.4 ± 0.7	**−6.0 (−7.8 to −4.1)**
ADL	96.2 ± 0.6	98.6 ± 0.4	**−2.4 (−3.5 to −1.2)**	96.2 ± 0.5	98.6 ± 0.3	**−2.4 (−3.5 to −1.4)**
Sport/Rec	79.7 ± 2.0	90.9 ± 1.3	**−11.2 (−15.2 to −7.2)**	82.7 ± 1.8	92.7 ± 1.0	**−10.0 (−13.7 to −6.3)**
QOL	82.2 ± 1.6	93.7 ± 1.0	**−11.5 (−14.8 to −8.2)**	82.8 ± 1.5	94.0 ± 1.0	**−11.2 (−14.2 to −8.2)**

ADL, Activities of Daily Living; KOOS, Knee injury and Osteoarthritis Outcome Score; QOL, knee-related Quality of Life; Sport/Rec, Sport and Recreation.
[a]Significant between-group differences are marked in boldface. Athlete considered as a cluster with 2 knees.

Table 3. The number of injured athletes and knees as well as injury diagnoses and incidences of acute knee injuries in male and female athletes

	Male		Female	
	Any Type of Acute Injury	Noncontact Injury	Any Type of Acute Injury	Noncontact Injury
Injured athletes[a]	18	10	32	28
Injured knees[a]	18	10	37	30
Injury diagnoses[a]				
Bone bruise	5	—	8	2
Joint or ligament sprain[b]	5	3	6	6
Meniscal lesion	4	3	1	1
ACL injury	1	1	16	15
PCL injury	—	—	1	1
Patellar dislocation	1	1	—	—
Intra-articular fracture	1	1	—	—
Unspecified knee injury	1	1	5	5
Injury incidence[c]	0.3 (0.2-0.4)	0.2 (0.1-0.3)	0.6 (0.5-0.8)	0.5 (0.3-0.7)

ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.
[a]Values are presented as total number of new injuries.
[b]Excluding ACL and PCL injuries.
[c]Values are presented as total number of injuries per 1000 player-hours. Values in parentheses are 95% CIs.

Table 4. Unadjusted and adjusted HR with 95% CIs for previous acute knee injury and KOOS subscale scores for acute knee injury in male and female athletes[a]

	Male (n = 211)		Female (n = 183)			
	Any Type of Acute Injury (n = 18)[b]	Noncontact Injury (n = 10)[b]	Any Type of Acute Injury (n = 32)[b]		Noncontact Injury (n = 28)[b]	
	HR (95% CI)	Adjusted HR (95% CI)	HR (95% CI)	Adjusted HR (95% CI)	HR (95% CI)	Adjusted HR (95% CI)
Previous acute knee injury[c]	**5.82 (2.21-15.27)**	**7.19 (1.84-28.04)**	**2.67 (1.33-5.37)**	**2.58 (1.28-5.21)**[d]	**2.40 (1.13-5.07)**	**2.35 (1.11-4.97)**[e]
During previous 12 months	**8.35 (3.13-22.28)**	**7.42 (2.09-26.32)**	**2.32 (1.01-5.36)**	**2.60 (1.11-6.11)**	2.21 (0.90-5.45)	2.40 (0.96-5.96)
Previous ACL injury	**5.58 (1.23-25.23)**	**12.74 (2.42-67.18)**	1.81 (0.55-6.01)	1.46 (0.42-5.09)	2.12 (0.63-7.11)	1.90 (1.56-2.31)
KOOS[f]						
Pain	**1.76 (1.25-2.49)**	**2.31 (1.47-3.64)**	1.26 (0.94-1.68)	1.12 (0.80-1.56)[g]	1.14 (0.81-1.61)	0.97 (0.65-1.45)[h]
Symptoms	1.10 (0.68-1.80)	1.30 (0.74-2.31)	1.25 (0.93-1.67)	1.12 (0.82-1.52)[g]	1.15 (0.83-1.61)	1.01 (0.71-1.43)[h]
ADL	**1.50 (1.20-1.89)**	**1.64 (1.26-2.15)**	**1.29 (1.03-1.62)**	1.22 (0.97-1.54)[g]	1.23 (0.95-1.60)	1.13 (0.85-1.49)[h]
Sport/Rec	**1.76 (1.26-2.46)**	**2.04 (1.30-3.18)**	1.27 (0.95-1.68)	1.15 (0.84-1.58)[g]	1.25 (0.92-1.70)	1.13 (0.80-1.58)[h]
QOL	**1.94 (1.38-2.73)**	**2.33 (1.40-3.90)**	1.34 (1.00-1.79)	1.16 (0.84-1.60)[g]	1.33 (0.98-1.81)	1.19 (0.84-1.67)[h]

ACL, anterior cruciate ligament; ADL, Activities of Daily Living; HR, hazard ratio; KOOS, Knee Injury and Osteoarthritis Outcome Score; QOL, knee-related Quality of Life; Sport/Rec, Sport and Recreation.
[a]Significant results are marked in boldface.
[b]The number of injured athletes.
[c]Athlete as a unit of analysis. Club considered as a cluster.
[d]Adjustment factors: age and body mass index.
[e]Adjustment factor: age.
[f]Knee as a unit of analysis. Club and athlete considered as clusters. HR per 1 SD decrease.
[g]Adjustment factors: previous acute knee injury and age.
[h]Adjustment factor: previous acute knee injury.

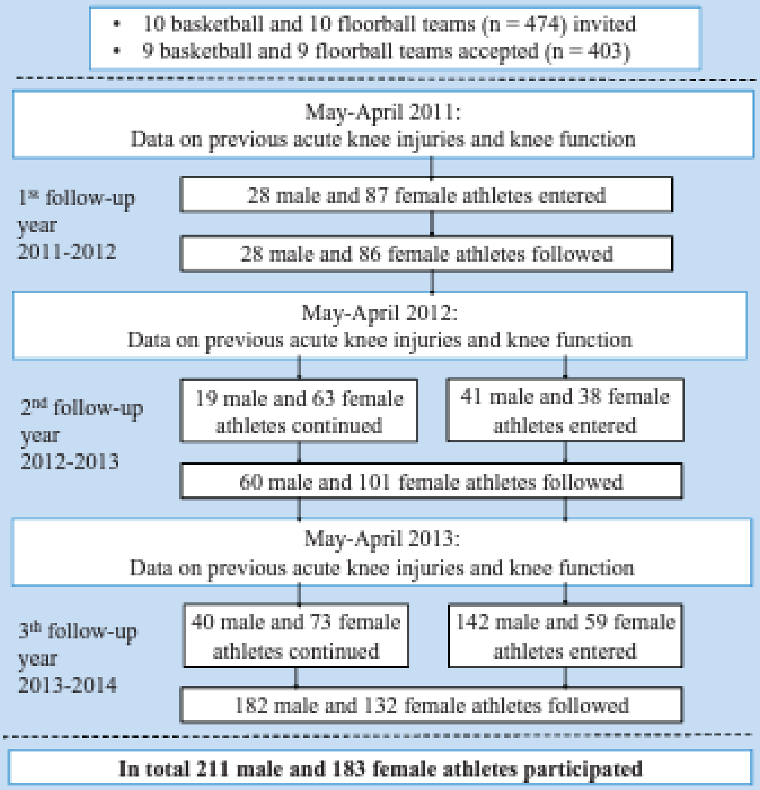

Figure 1. The flow of athletes in the study.

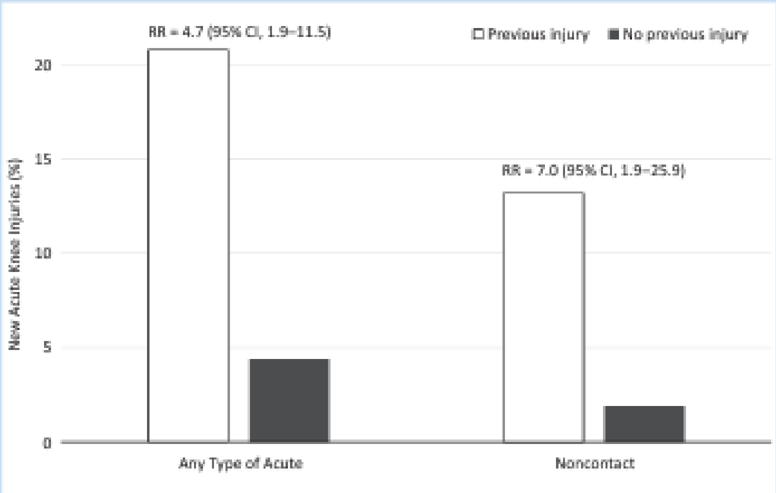

Figure 2. Risk of any type of acute (n = 18) and noncontact (n = 10) knee injury for male athletes with previous acute knee injury. RR, relative risk.

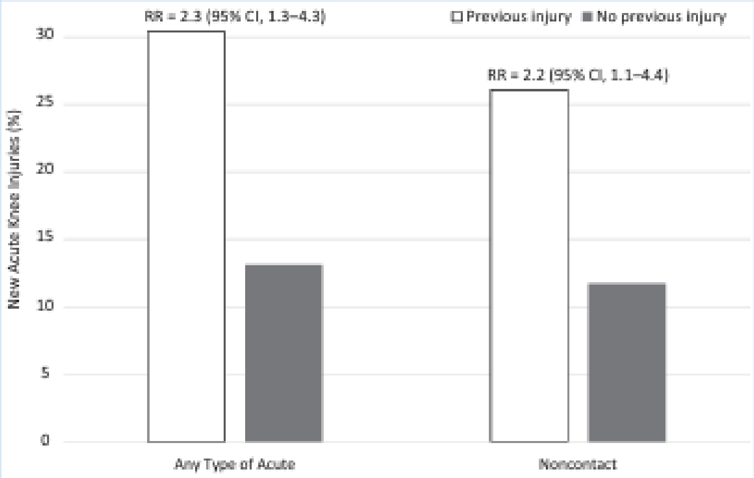

Figure 3. Risk of any type of acute (n = 32) and noncontact (n = 28) knee injury for female athletes with previous acute knee injury. RR, relative risk.