

# Anterior cruciate ligament injury in the female athlete: risk and prevention

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## Summary

**Background:** The anterior cruciate ligament (ACL) injury of the knee is the second most common sports injury after the ankle sprain. It causes knee instability and impacts sport performance. Knowing what predisposes this injury is important to prevent it, specially in women, where the rate is higher. This paper presents the ACL injury epidemiology, making reference to the underlying risk factors and its preventive programmes. The aim of this study was to show the risk factors that predispose to a higher incidence of anterior cruciate ligament injury, as well as to present the effectiveness of the prevention programs.

**Methods:** A literature review through PubMed, Cochrane and UpToDate has been performed including the meta-analysis or clinical trials published over the past 10 years.

**Results:** The injury incidence rate is three times higher in women than in men. It specially develops in sports like football and basketball, i.e., sports where pivoting, sharp running direction changes or abruptly stopping exercises are more common. The risk factors are multifactorial; and the only adjustable ones are the biomechanical risk factors. Prevention programmes are focused in these factors, trying to enhance strength and biomechanical proprioception.

**Conclusions:** After the review we can conclude that ACL injuries are more frequent in women. Prevention programmes focus on neuromuscular training (strengthening exercises, proximal control and plyometric exercises) and they reduces significantly the injury for football and handball players, but not for basketball ones. The programmes focus on strengthening exercises, proximal control and plyometric exercises.

## Key words:

Anterior cruciate ligament. Prevention. Athlete. Risk factors.

## Rotura del ligamento cruzado anterior en la mujer deportista: factores de riesgo y programas de prevención

### Resumen

**Objetivo:** La lesión del ligamento cruzado anterior de la rodilla (LCA) es la segunda lesión deportiva más frecuente tras el esguince de tobillo. Provoca inestabilidad de la rodilla y afecta al rendimiento deportivo, por lo que es importante saber qué lo favorece y cómo lo podemos evitar. En este trabajo se expone la epidemiología de la lesión del LCA haciendo referencia a los factores de riesgo predisponentes y a los programas preventivos de la misma. El objetivo de este trabajo ha sido mostrar los factores de riesgo que predisponen a una mayor incidencia de lesión del ligamento cruzado anterior, así como presentar la efectividad de los programas de prevención de la misma.

**Método:** Se ha realizado una revisión de la literatura a través de PubMed, Cochrane y UpToDate incluyendo los metanálisis o ensayos clínicos publicados en los últimos 10 años.

**Resultados:** La incidencia de lesión es mayor en la mujer que en el hombre con una relación 3:1, y sobre todo se produce en deportes como el fútbol y el baloncesto, donde se realizan ejercicios como pivotar, cambio brusco de dirección en la carrera o frenar de forma brusca. Los factores de riesgo son multifactoriales, entre ellos los únicos modificables son los factores de riesgo biomecánicos y es en ellos donde se centran los programas de prevención.

**Conclusiones:** Las mujeres tienen una mayor incidencia de lesión de LCA. Los programas de prevención se centran en factores de riesgo modificable, principalmente en el entrenamiento neuromuscular y disminuyen de forma estadísticamente significativa tanto en el fútbol como en el balonmano, pero no en el baloncesto. Estos programas se centran en ejercicios de fortalecimiento, control proximal y ejercicios pliométricos.

## Palabras clave:

Ligamento cruzado anterior. Prevención. Deportistas. Factores de riesgo

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## Introduction

The anterior cruciate ligament of the knee (ACL) injury rate varies depending on gender, sport, and prevention programmes<sup>1</sup>. It is higher in women than in men, and a higher rate is seen in sports such as football and basketball<sup>1</sup>. ACL injury is the second most frequent sporting injury after ankle sprain<sup>2</sup>, which is why it is important to establish the risk factors, paying attention to those that can be modified, as this is the main focus of prevention programmes.

## Epidemiology of ACL injury

### Rate

The anterior cruciate injury rate varies in the different studies published, possibly due to the different physical activity performed by the study participants. It is essential to highlight that the data published is heterogeneous, and that the injury rate depends to a great extent on sporting performance<sup>1,2</sup> and therefore on neuromuscular control, which should be considered upon analysing the results.

The female:male ratio of ACL injuries has recently generated considerable attention. In the study by Prodromos *et al.*<sup>1</sup>, the ACL tearing rate (female:male) by sport was: basketball, 3.5:1; football, 2.67:1; hockey, 1.18:1. According to the level of female athletes: in secondary school it was 0.09, whilst in men it was 0.02, and the female:male ratio was 4.5:1. At university, the rate was 0.29 for women and 0.08 for men, with a female:male ratio of 3.63:1, and on a professional level it was 0.20 for women and 0.21 for men, with a female:male ratio of 0.95:1. According to this data, as female athletes become more elite, the injury rate reduces to almost the same as the rate for males.

### Risk factors

To understand why this injury is more frequent among women and as a means of preventing it, it is important to identify the risk factors. The cause of the increase in ACL injury is multifactorial, and the risk factors have been categorised into: environmental, anatomical, hormonal and biomechanical<sup>3</sup>.

#### Environmental factors

Surface temperatures, friction between materials, and the design of footwear soles can be a risk factor in ACL injury<sup>3</sup>. These factors affect both men and women equally, which is why there is not a higher rate among women.

#### Hormonal factors

Proof of the effect of sex hormone effects on connective tissue is limited and the results of some studies are inconsistent. However, the synthesis of collagen could be reduced up to 40% due to physiological oestrogen levels, and up to 50% induced by pharmacological oestrogen levels<sup>3</sup>.

### Anatomical factors

The anatomical difference between men and women could be a factor that contributes to a heightened ACL injury rate. However, these factors cannot be modified, therefore preventive measures cannot be applied to them.

- The breadth of the intercondylar notch in women is smaller than in men, however no differences in the risk of ACL injury have been revealed<sup>3</sup>.
- The cross-sectional area of the ACL is greater in men<sup>3</sup>, which suggests that a smaller diameter of the ACL in women could be a tearing risk factor.
- The Q angle, whose normal value is from 8 to 17°, is greater in women. This increase is because generally the female pelvis is wider and the femur is shorter<sup>3</sup> or that a high Q angle increases the medial stress on the ligaments of the knee<sup>3</sup>.
- The angle between the patellar tendon and the tibia affects the shearing force applied.

### Biomechanical factors

The quadriceps muscle displays its greatest muscular activity during knee flexion exercises, whilst the hamstrings tend to relax; moreover, when inducing muscle fatigue and performing sporting manoeuvres in female athletes such as landing on just one leg or changing running direction, a reduction in the hip flex occurs, as well as an increase in the internal rotation of the hip, an increase in knee valgus and an external rotation of the tibia, which leads to less stability in the knee joint<sup>3</sup>. In men, all of this is less frequent because they have greater muscle control. The lack of this control in women, especially in adolescence, causes a greater predisposition to slipping of the femur over the tibia and greater stress on the ACL.

Biomechanical risk factors are the only ones considered to be modifiable, and this is why prevention programmes focus on this area. Greater neuromuscular control leads to a reduced risk of ACL injury, which explains why as the sporting level increases and training demands are higher, female:male injury ratios are nearly 1:1

### Prevention programmes

Biomechanical and biomuscular components are the only modifiable elements. Recent studies reveal that certain risk factors such as an increase in knee valgus, limited hip flex or the internal rotation of the hip predispose the individual to a greater risk of ACL tearing<sup>4,5</sup>. The magnitude of these movements can be controlled by increasing supporting muscle and by alternating this with sporting technique, all through the use of preventive neuromuscular training programmes (PNMT). A recent meta-analysis assessed the overall effectiveness of PNMT and revealed that these programmes reduce ACL injuries in young women<sup>4</sup>.

Training promotes muscle development, improves movement patterns and protects from ACL injury; however, it is not clear which

kind of exercises are the most effective in preventing this injury. Upon assessing the different studies, in which the groups included are not homogeneous<sup>6-8</sup>, it is vital to establish which kind of exercises included in PNMT significantly reduce ACL injury.

A meta-analysis published by Sugimoto *et al.*<sup>4</sup> aimed to establish the exercises that had the greatest prophylactic effect on reducing ACL injury. They examined four exercise categories: balance, plyometric exercises, strength training and proximal control. The results revealed a statistically significant lower number of ACL injuries ( $p = 0.001$ ) with PNMT that focused on strength, proximal control and plyometric exercises.

Neuromuscular risk factors can be modified through training, leading to better sporting performance. Furthermore, given that the majority of ACL injuries occur in non-contact situations, it is necessary to consider the different biomechanical demands of the different sports, as well as to work on the sporting motion depending on the sport.

Different training programmes have been described that reduce the ACL injury rate<sup>9-10</sup>. The most important are included in the systematic

review published by Michaelidis *et al*<sup>9</sup> in which 12 PNMT are proposed, which despite their differences, focus their training plan on neuromuscular development and include the types of exercises that have revealed statistically significant reductions in ACL injury.

### Training programmes

Different prevention programmes have been proposed with the aim of reducing the ACL injury rate in female athletes. The characteristics and exercises of each of these programmes are summarised in Table 1. To establish whether or not they are effective, they have been assessed using studies with a control group. Below are the main studies used to assess these programmes.

#### Sportsmetrics

A prospective study to assess the effect of PNMT on the knee injury rate of female athletes. They compared athletes following the

**Table 1. ACL injury prevention programmes in female athletes.**

Programme	Sport	Characteristics
<b>SPORTSMETRICS</b>	Football Volleyball Basketball	- Session: 60-90 min - Frequency: 3 days/week - Total time: 6 weeks (only pre-season)
<b>FATP</b>	Football	- Session: 75 min - Frequency: 3 days/week - Total time: 7 months
<b>PEP</b>	Football	- Session: 20 min - Frequency: 2-3 days/week - Total time: 12 weeks
<b>KLIP</b>	Football	- Session: 20 min - Frequency: 2 days/week - Total time: 4-5 months
<b>FIFA 11</b>	Football	- Session: 15 min - Frequency: 1 day/week - Total time: 7.5 months
<b>SÖDERMAN</b>	Football	-Session: 10-15 min -Frequency: 3 days/week -Time: 6 months
<b>MYKLEBUST</b>	Handball	- Session: 15 min - Frequency: 1 day/week - Total time: 5 months
<b>OLSEN</b>	Handball	- Session: 15-20 min - Frequency: 1 day/week - Total time: 5 months
<b>PETERSEN</b>	Handball	- Session: 10 min - Frequency: 1 day/week - Total time: 8 weeks
<b>PASANEN</b>	Hockey	- Session: 20-30 min - Frequency: 2-3 days/week (intense) alternated with 1 day/week (maintenance) - Total time: 6 months
<b>WALDEN</b>	Football	- Session: 15 min - Frequency: 2 days/week - Total time: 7 months
<b>HTP</b>	Football	- Session: 20-25 min - Frequency: 2 days/weeks (pre-season) / 1 day/week (season) - Total time: 9 months

programme to those without a specific training programme, as well as to a group of male athletes with no training in the different sports (football, volleyball and basketball). The injury rate in the female athletes was not significantly lower than in untrained male athletes; however, a significant difference was observed in the reduction of the ACL injury rate in women to which a PNMT was applied compared to those that did not follow a training programme. This prospective study revealed a lower knee injury rate in women after following a specific plyometric training programme<sup>11</sup>.

#### *Frappier Acceleration Training Programme (FATP)*

The aim of the study by Heidt *et al.*<sup>12</sup> was to establish the effect achieved with a training programme in the pre-season among female football players compared to those that did not follow a programme. This study led to the conclusion that in this demographic, injuries were more frequent in the lower limbs and that the trained group had a statistically significant lower injury rate. Despite a statistically significant conclusion not being observed, they concluded that the trained group had a lower ACL injury rate. For all of the above, they concluded that physical conditioning entails a reduction in the injury rate of female football players.

#### *Prevent Injury and Enhance Performance programme (PEP)*

A clinical trial was carried out in which female football players were randomly separated into a study group and a control group. The aim was to identify the PNMT that reduced non-contact ACL injury rates. The conclusion reached was that with the PEP programme, the ACL injury rate was lower, including among athletes that had a previous history of ACL injury<sup>13</sup>.

#### *Knee Ligament Injury Prevention (KLIP)*

A prospective study carried out over two years to assess the effects of preventive programmes on female footballers, basketball players and volleyball players at secondary school. The results suggested that a programme focusing on plyometric exercises in which the jump landing mechanism and rapid deceleration were assessed does not reduce the injury rate in female athletes if it is carried out twice a week for 20 minutes<sup>14</sup>.

#### *FIFA 11 Injury Prevention Programme*

The aim of this randomised controlled clinical trial was to research the effect of the combination of plyometric, strength, balance and proximal control exercises on the risk of injury in adolescent female footballers. No difference was found in the general injury rate between the intervention and control group, or in the rate of any kind of injury. The outcome of the study, in which no effect was found upon applying the exercises, could be due to the poor fulfilment of the prevention programme by the study group<sup>15</sup>.

#### *Söderman*

Prospective study based on balance exercises. The aim was to establish whether performing these kinds of exercises within a PNMT

could reduce lower limb injuries in female footballers compared to those that did not follow the programme. It was established that there were no differences in the study groups, either in terms of the injury rate or the type of injury<sup>16</sup>.

#### *Myklebust*

A prospective study that assessed the application of a training programme in which the balance exercises used focused on neuromuscular control and landing abilities. Upon finishing the study, a reduction was seen in the injury rate in elite female athletes that had completed the programme compared to those that had not followed it. It was concluded that it is possible to prevent ACL injury with the right PNMT<sup>17</sup>.

#### *Olsen*

A randomised controlled clinical trial, which assessed the efficiency of a warm-up programme in reducing the rate of knee and ankle injuries in female handball players. The warm-up programme aimed to improve the landing technique, neuromuscular control, strength and balance. It was observed that it prevented injuries and therefore it was established that it should be introduced as part of the PNMT<sup>18</sup>.

#### *Petersen*

A retrospective study that assessed the effects of PNMT on ankle and knee injury rates, applied to female handball players. It was concluded that neuromuscular training is appropriate and effective in preventing knee and ankle injuries in female handball players<sup>19</sup>.

#### *Pasanen*

A PNMT that aimed to improve motor skills, body control, as well as to prepare and activate the neuromuscular system. The aim was to prevent non-contact knee injuries, applying the study to female hockey players. After performing the study, the conclusion was reached that the preventive programme is effective and can be recommended in the weekly training routines of these athletes<sup>20</sup>.

#### *Walden*

A randomised clinical trial that assessed a preventive programme focusing on proximal control exercises, balance and the correct alignment of the knee in football players. It concluded that the warm-up programme statistically significantly reduced the ACL injury rate<sup>21</sup>.

#### *"Harmoknee" training programme (HTP)*

A clinical trial was carried out on a multifaceted preventive programme in football players. It was concluded that the knee injury rate among young football players was reduced with physical exercise, if this was applied alongside an appropriate sporting education<sup>22</sup>.

Furthermore, in a study recently published by Zebis *et al.*<sup>23</sup>, the reduction of the ACL injury rate was assessed upon performing rapid direction changes, by applying preventive programmes. A clinical trial was performed with a sample group of 40 female basketball or handball players, aged between 15-16 years, in which 20 were randomly assigned

to a control group and the remaining 20 to a neuromuscular training group. The preventive programme consisted of warm-up exercises, analysing the activity (isometric contraction) of the vastus lateralis (VL), of the semitendinosus (ST) and of the biceps femoris using an electromyography (EMG) for 12 weeks. Differences were observed between the follow-up groups in VL-ST activity (43% of difference between the groups; CI 95%, 32% to 55%)<sup>23</sup>.

## Conclusions

Female athletes suffer from approximately 3 times more ACL injuries in basketball and in football than male athletes. However, female athletes that perform sports to a high performance level have less frequent injuries as they have better neuromuscular control over their lower limbs.

Prevention programmes focus on neuromuscular training and have been shown to cause a statistically significant reduction in injury rate in both football and handball. However, reductions in injury rates in basketball are not statistically significant. Current analyses of sub-groups indicate that strength programmes, proximal control exercises and plyometric exercises increase the effectiveness of ACL injury reduction among female athletes.

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