Module 3. Prevention of joint injuries

Unit 3.1 Prevention of the most frequent lower limb joint injuries: ACL (Anterior Cruciate Ligament) injury

3.1.1 Injury mechanism

Most ACL injuries are due to strain on the knee, where the foot is firmly planted on the ground. Non-contact mechanisms represent 70% of these injuries (Arendt, 1995). In other words, it is not necessary to collide with another athlete in order for this injury to appear. The force of the body's rotation turning on a fixed joint (with the foot planted on the ground) produces large moments of tension in this ligament (a common movement with unplanned changes of direction). Athletes often say they felt or heard a crack (or a small noise) followed by inflammation of the joint.

ACL injuries probably occur during deceleration actions, with excessive activation of the quadriceps and little co-contraction of the hamstrings, with the knee at near full extension, or with little bending of the hip and knee. The burden on the ACL is increased when an internal and external rotation is added to the conditions previously mentioned, plus a valgus force on the knee. Thus, the combined effects of an excess of valgus force on the weight-bearing knee, with a lower extremity in a position of near extension plus rotational loads, all amount to the actions that most increase stress on the ACL and constitute the most well-documented mechanism of injury (Shimokochi & Shultz, 2008).

In conclusion, the mechanism for tearing the anterior cruciate ligament is the external tibial rotation with the foot planted on the ground and bending at 20° to 30°, a position in which the majority of athletic movements are made.

It is important to highlight that the anteroposterior tension or tension associated with tibial movement that produces the injury is also accompanied by an external tibial rotation and a valgus collapse, thus representing an injury mechanism in the three planes of movement in space.

When the tear is produced by contact, which, as we said, does represent a minority of injuries, the ACL is injured through the application of an external force on the knee, and this type of trauma can involve different structures of the knee. O'Donohue's unhappy triad (ACL, MCL, and medial meniscus) is the classic example for injuries associated with an external trauma on the knee (Prentice, 2001).

3.1.2 Intrinsic risk factors

The analysis of risk factors associated with non-contact mechanisms for ACL injuries is important, because it permits us to deduce those factors that, when an isolated action is performed by an athlete under specific circumstances, can cause an ACL tear, thus showing an injury pattern that is uncommon in stabilizing structures like ligaments.

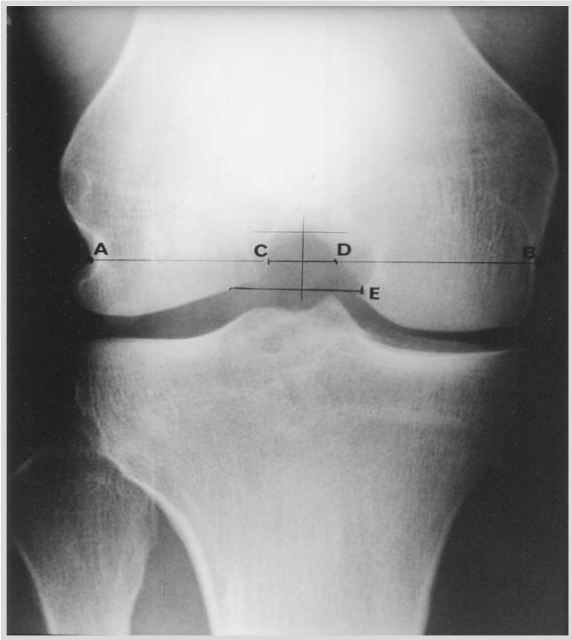
These risk factors can be divided into two groups, as Meeuwisse (1994) shows in his model: extrinsic or intrinsic. Gender, anatomical, neuromuscular, and hormonal elements are among those factors established by two large consensus groups made up of some of the main experts in the field (Griffin LY et al 2006 and, Renstrom, P., Ljungqvist, A., Arendt, E., Beynnon, B., Fukubayashi, T., Garrett, W., & Engebretse, L 2008). In terms of external risk factors, some factors such as the friction coefficient of the shoe-surface interface, or the influence of rules, equipment or weather conditions are taken into consideration.

On this basis, we can focus on the risk factors that are most directly implicated in the matter, that is, on those that can be modified or at least mitigated through the development of prevention models.

Anatomical Factors

The relationship between intercondylar notch width and ACL injuries is among the most often cited anatomical factors in the scientific literature. The intercondylar notch is the arch between the condyles, under the femoral trochlea, where the crossed ligaments of the knee pass through and are contained. This led many authors to presume that if, in a simple frontal X-ray, the relationship between the width of this notch and the bicondylar width were reduced, the risk of sustaining an injury in the anterior cruciate ligament would increase. The argument was that the ligament had less space to pass through and fulfill its stabilizing function; furthermore, they explained that the notch could act to tear the ligaments.

Figure 1: Frontal X-Ray Showing the Relationship between the Bicondylar Width and the Width of the Intercondylar Notch



Source: Myer Gregory et al., 2009, pg. 105.

On this topic, various authors, such as Shelbourne, Davis and Klootwyk (1998); Souryal and Freeman (1993); LaPrade and Burnett (1993), cited in a review by Beynnon, Johnson, Abate, Fleming and Nichols (2005), established that patients with a narrow intercondylar notch, relative to an index correlating intercondylar width with bicondylar width, had a greater risk of sustaining ACL injuries (Figure 1). This fact was included in the latest meeting of the Olympic Committee (Renstrom, P., Ljungqvist, A., Arendt, E., Beynnon, B., Fukubayashi, T., Garrett, W. & Engebretse, L 2008), and was accepted as an important risk factor in the incidence of ACL injuries.

This fact was considered as having equal importance among women and men, but, without a doubt it is an intrinsic risk factor (according to Bahr's model, 2005, expanding upon Meeuwisse's model, 1994) which, taken in conjunction with other risk factors both intrinsic and extrinsic, makes an athlete predisposed and later susceptible to sustain this injury.

Accordingly, the Hunt Valley Committee (Griffin LY et al., 2006), linked various intrinsic risk factors, suggesting that school-aged athletes with a combination of increased body mass index, a narrow intercondylar notch and an increase in joint laxity are more predisposed to sustain this injury.

Gender

It has been proposed that due to diverse anatomical, neuromuscular, and biomechanical features, women have a greater risk of sustaining ACL injuries through non-contact movements in different sports situations.

In that sense, among the many papers that demonstrate this difference in incidences of ACL injuries are those by Bjordal, Arnly, Hannestad and Strand (1997); Agel, Arendt and Bershadsky (2005), and Mihata LC, Beutler AI, Boden BP. (2006), who detected a greater incidence of injuries in female soccer players than in their male counterparts. Different studies have also found this gender discrepancy in the distribution of ACL injuries among handball and volleyball players.

Hormonal Factors

With regard to hormonal differences in gender and their influence on the specific analyses of men and women, there is a clear need to perform research based on hormonal differences to see if any aspect could have an effect on the greater incidence of ACL injuries in women.

In 2005, the Hunt Valley Committee (Griffin LY et al., 2006) reached several conclusions about hormonal risk factors, among which the most noteworthy are:

- There is no consensus in the scientific community about the role that sex-specific hormones play in the incidence of ACL injuries. However, more research is needed in this subject area.
- Hormonal interventions for the prevention of ACL injuries are not currently justified.
- There is no evidence that suggests modifying or restricting women's participation in sports during any given part of their menstrual cycle.
- Even though the role of estrogen or any other hormone is not well-defined in the incidence of ACL injuries, there seems to be an unequal distribution of hormones in the menstrual cycle, which suggests that hormones have some role in the distribution of ACL injuries; although the evidence of hormonal involvement as a risk factor is inconclusive.

Dedrick et al. (2008) researched the effect of sex hormones throughout the menstrual cycle and their connection to neuromuscular control of the lower extremity. In this paper, it was noted that female athletes use different neuromuscular control patterns during drop jump tests when their estrogen levels are high (luteal phase) as compared with when they are low (early follicular phase).

These conclusions were suggested by the delay in EMG (Electromyography) activation of the semitendinosus muscle upon contact with the ground during the luteal phase. This demonstrates a significant difference between the early and late follicular phase, as well as a reduced difference in activation times between the gluteus maximus and the semitendinosus in the late follicular phase. These results ultimately suggest a different behavior of co-contraction between the gluteus and the semitendinosus, which translates into a change in neuromuscular behavior in women according to their menstrual phase. These authors ultimately emphasize that in the drop jump test women seem to use different neuromuscular patterns when estrogen is high than when it is low.

Finally, it is clear that the hormonal factor is still not conclusive, although different authors highlight the presence of certain changes in the menstrual cycle that could influence ACL injuries. Researchers continue to do research in this field with the goal of further clarifying the role that hormones play in the incidence of ACL injuries in women.

Biomechanical and Neuromuscular Factors

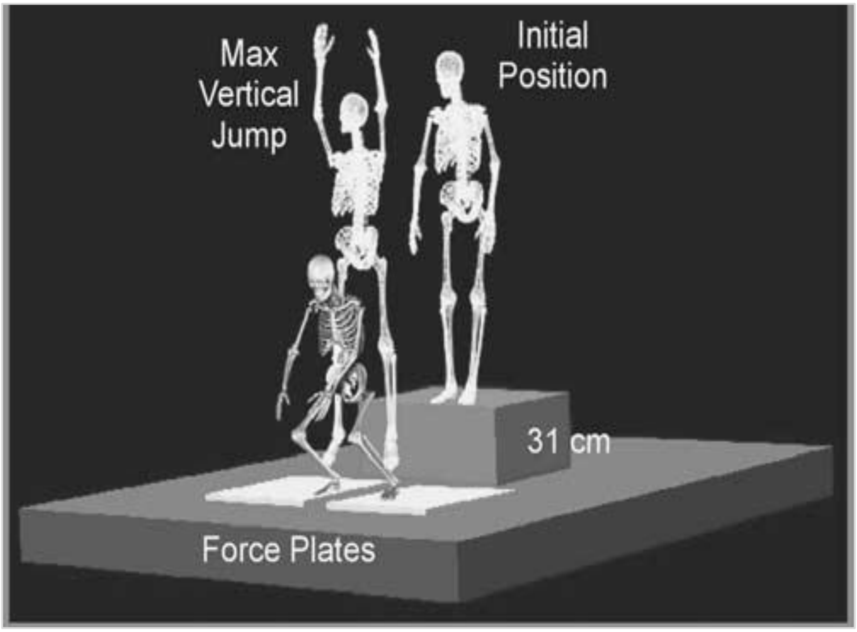
Recent years have seen a growing interest in analyzing neuromuscular patterns of different activities that promote ACL injuries (changes of direction, shock absorption from jumping, braking with change of direction, etc.) among different sexes and ages. These biomechanical analyses began to detect differences and alterations in said actions, which could be considered as risk factors associated with ACL injuries and thus regarded as the main focus in the development of activities that would reduce the incidence of injury. While this research was carried out primarily with women, the connection to men with altered patterns must be taken into account.

In order to explain this topic, we chose a paper by Hewett, Ford and Myer (2005). This choice is based on the fact that these authors are well known researchers in the issue of neuromuscular patterns in women's drop landings and their connection to the high incidence of ACL injuries in this gender. This study concluded that women had a greater dynamic valgus moment than men in this type of activity.

Using the data found by Hewett et al., Noyes, Barber-Westin, Fleckenstein, Walsh and West (2005) designed a testing and assessment model in order to register the distance between the knees in a drop landing, called the Drop Jump Screening Test. While it is clear that this type of assessment via video tracking or motion analysis falls short of the level of precision reached in kinetic and kinematic assessments in laboratory studies, it can still be an interesting, practical method for inferring which of our athletes is at-risk based on weaknesses in this movement, and for monitoring their progress after a corrective program (Figures 2 and 3).

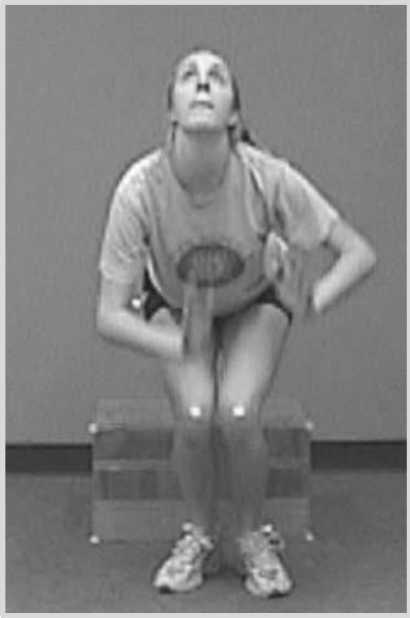
The same authors tested 325 women and 130 men between 11 and 19 years of age. In the video they also measured the distance in centimeters between the hips, knees, and ankles, and standardized these measurements for the distance between the hips (which serves as a fixed reference). They found that the majority of men and women who lacked training showed a valgus alignment during the video test. Later, the University of Cincinnati's Sportmetrics program, designed by Timothy Hewett's group, was performed on 62 female athletes. In this program, the details of landing after a jump were re-examined, showing a significant improvement in the distance between the knees, as standardized by the distance between the hips, and showed a greater alignment of the lower extremity in the drop landing.

Figure 2: Drop Jump Test



Source: [Untitled image of drop-jump test] (n. d.). Taken from http://goo.gl/MJjU3Z

Figure 3: Example of a Drop Jump test



Source: Noyes et al., 2005, pg. 202.

Bing Yu et al. (2005), following Hewett and Noyes' paper, submitted an important study that broadened the spectrum of assessment, revealing neuromuscular patterns in drop landings between genders and among different age groups. They concluded that young recreational female soccer players showed a reduction of hip and knee flexion angles upon initial contact with the ground, as well as a reduction of hip and knee flexion angles in shock absorption from drop landings, as compared with males of the same age. These differences in hip and knee flexion patterns between genders appear after 12 years of age, and increase with age up until 16 years.

Continuing with the confirmation of this trend, Pappas E, Hagins M, Sheikhzadeh A, Nordin M, Rose D. (2007) reported that there was a greater dynamic valgus and greater vertical reaction forces (measured on a force platform) in women at the moment of contact with the ground after a jump, which led them to think that the absorption patter from a drop following a jump are less efficient in women. The authors noted this fact as an important risk factor for ACL injuries.

A study by Quatman, Ford, Myer and Hewett (2006) concluded that the majority of kinematic and kinetic differences between male and female recreational athletes during drop landings in non-fatigue situations were observed in the frontal plane and not in the sagittal plane. Later, in fatigue situations, women are less capable than men of reducing the magnitude of the force of the anterior knee translation, where men reduce this force at the expense of a greater flexion angle in the knee at the moment of absorbing the shock of a jump. This absence of adaptation to fatigue in women suggests an increased risk of knee injuries. The authors suggests that women should train in a fatigued state in order to achieve the same adaptations as men, with the objective of minimizing the effect of the force of the anterior knee translation.

Kernozek, Torry and Iwasaki (2008) propose that neuromuscular fatigue causes significant alterations in drop landings in women when compared with men. Their study evaluated drop landings and the neuromuscular pattern in this movement in women as well as in men, before and after performing a fatigue protocol of parallel squats at 60% of 1 RM (Repetition Maximum) until fatigued. The biggest differences found by this study are that, no matter if both groups increased hip flexion in the post-fatigue landing, men increased peak knee flexion as compared with women, whose peak knee flexion remained unchanged. Furthermore, men had a greater peak knee varus angle, regardless of fatigue, while women had a greater valgus moment in general. Finally, the women had a greater anteroposterior movement force on the post-fatigue knee, as compared to the men. These results support the conclusions reached by the authors.

Insofar as the incidence of anterior cruciate ligament (ACL) injuries continues to be much higher in young female athletes and that female athletes have a much higher incidence of ACL injuries in team sports such as basketball and handball, the IOC (International Olympic Committee) invited a multidisciplinary group of doctors and scientists specializing in the ACL in order to:

1) Review current evidence, including data regarding the new Scandinavian records of ACL injury;
2) critically evaluate studies of the mechanics of injuries;
3) consider the key elements in the success of prevention programs;
4) include a summary of clinical management and surgery as well as protective treatment;
5) identify new areas for research.

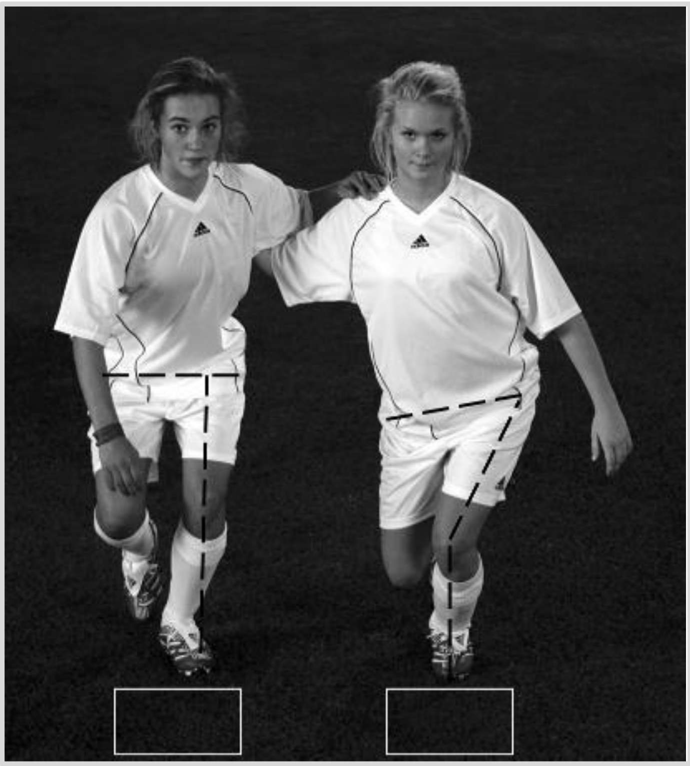
This group determined that risk factors for women who sustain ACL injuries include:

1. Being in the preovulatory phase of the menstrual cycle (compared with the postovulatory phase);
2. Having a narrowed intercondylar notch in a simple X-ray;
3. The presence of an increased knee abduction moment (a valgus intersegmental torque) during impact in the moment of landing after a jump.

They ultimately concluded that well-designed injury prevention programs could reduce the risk of ACL injuries for athletes, particularly for women. These programs attempt to change the dynamic load of the tibiofemoral joint through the training of neuromuscular patterns and optimal proprioception, or at least with the correction of defects.

These authors underscore that proper landing and shock absorption after a jump, as well as techniques for changes of direction are key aspects in the development of these prevention programs. This includes: a smooth landing with the front part of the foot and the rear part of the foot pulling back, the engagement of knee and hip flexion, where possible, landing on both feet, and all while avoiding excessive dynamic valgus in the knee (Renstrom et al., 2008).

Figure 4: Example of Dynamic Alteration of the Lower Extremity that Promotes Dynamic Valgus in the Knee



Source: [Untitled image of dynamic alteration] (n. d.). taken from http://goo.gl/xPf9kV

Givoni, Pham, Allen and Proske (2007) created a report on the effects of exercise on the position and stability of the knee. This paper determined that men had a better capacity for the voluntary muscular co-contraction that increased stiffness in the sagittal plane, or the capacity of muscles to limit the force of the anterior tibial translation, as compared to women. With this, they determined that women had less muscular capacity to protect the ligamentary structures of the knees than did men.

Changes of Direction as a Risk Factor in ACL Injuries

In analyzing changes of direction as risk factors, the focus has been centered on biomechanical features, especially on loads or moments on the knee, in accordance with different changes of direction, such as the side step cut (where the direction of movement is towards the side that is moving, via a pivot on the opposite leg; see Figure

5) or the crossover cut (cutting to the opposite side, where the change of direction is made by pivoting on the foot from the side of the movement's direction; see Figure 6).

On this point, in an interesting paper Lloyd (2001) established that the maneuver that most leads to tension on the ACL was a change of direction pivoting on the opposite side from the direction of the change of movement.

Figure 5: Example of the Sidecut Change of Direction

Source: [Untitled image of Mario Bolatti] (n.d.). Taken from https://goo.gl/iic5z1

In this maneuver, to counteract the flexion forces, the quadriceps should apply large moments of extension that produce an anterior force on the tibia, from approximately 45° flexion to full extension. In this movement, from the moment of assuming the weight to the moment of pushing the leg open, the force of anterior movement produced by the moments of the quadriceps are added to a large internal rotation event of the valgus and tibia, generating significant extension forces on the ACL.

Adding to this is that fact that when planned changes of direction were evaluated against sudden or reactive changes of direction, the valgus or varus forces, that is, the lateral and rotational moments on the knee, increased in reactive maneuvers.

This paper suggests, therefore, that training and progress in abilities for changes of direction should be considered towards the goal of reducing incidence of non-contact ACL injuries. This can be achieved by improving knee positioning in changes of direction in both reactive and planned situations, as well as the reaction times of the hamstrings, with the goal of minimizing the anterior translation forces produced by the quadriceps.

Figure 6: Example of a Crosscut Change of Direction

Source: Adapted from [change of direction]. (n.d.). Taken from http://goo.gl/lXX0kI

Sell (2006) proposes that the direction of the jump and the planned and reactive abilities significantly affect joint angles, vertical reaction forces, as well as knee moments and anterior tibial translation forces. Women show different kinematic, kinetic, and electromyographic features in these activities. Directional jumping significantly influences the biomechanics of the knee, which suggests that lateral jumps are more dangerous to the knee in stop-jump tasks. Reactive or unanticipated jumping was also significantly more dangerous in this type of jump. The results of this study indicate that the direction and reactivity of jumps should be included in research methodologies and in prevention programs.

A paper by Landry, McKean, Hubley-Kozey, Stanish and Deluzio (2007) attempted to assess the differences in gender in kinematics and kinetics, as well as neuromuscular patterns in the lower extremities of adolescent soccer players during the performance of unplanned direction-changing maneuvers. This study was carried out in a laboratory, analyzing change of direction maneuvers via a three-dimensional analysis of the previously outlined features. The most important finding of this study is that women show a greater gastrocnemius muscle activation as compared to men, where this imbalance in gastrocnemius activation is not present. Furthermore, it also showed a greater rectus femoris activation during the whole support phase and observed that women performed this maneuver with less hip flexion.

The clinical relevance outlined by this study is that women showed an increase in gastrocnemius activity, combined with a greater activity in the rectus femoris and less hip flexion than men. These factors play an important role in the increased incidence of ACL injuries in women as compared with men.

3.1.3 Extrinsic risk factors

In the literature on ACL injuries, the most frequently documented and cited extrinsic risk factors are the relationships between footwear and playing surface, or the surface that acts as the support for the athlete playing a sport.

On this subject, some papers have appeared in which the epidemiology of ACL injuries have been analyzed on different playing surfaces, and where there was not found to be any significant differences in risk of injury in soccer between grass, traditional turf or synthetic turfs. However, only one paper studied the features of studs in soccer and the incidence of ACL injuries, suggesting that with the utilization of longer studs, the incidence was greater (Villwock, Meyer, Powell, Fouty, & Haut, 2009).

Ultimately, there seems to be a relationship that links the friction coefficient between the footwear and the playing surface with the incidence of ACL injuries. Therefore, it is logical that all the conditions and elements that raise this friction coefficient will become an extrinsic risk factor that, when affecting athletes with intrinsic risk factors, will increase the risk of sustaining ACL injuries. As concerns this injury, these two points are the most well-studied extrinsic risk factors.

3.1.4 Models for the preventive approach to ACL injuries

Basing their studies on the fact that altered motor control strategies in women increase the risk of non-contact ACL injury, Chappell and Limpisvasti (2008) studied the effects and efficacy of a prevention program based on neuromuscular and plyometric training, in an attempt to correct these motor control patterns. For this study, all the subjects carried out neuromuscular and core stabilization training; later the biomechanics of the knee were analyzed with three-dimensional motion analysis, revealing the kinetics and kinematics of the jumping technique before and after the training. The study proved that six weeks of this type of training produced selective improvements in the performance of jumping techniques among female athletes, and it was concluded that this kind of prevention strategy can be useful in the reduction of incidence of ACL injuries.

Secondarily, analyzing the focus on strength training for muscles that influence knee dynamics as a preventive resource for ACL injuries, Herman et al. (2008) published a paper in which they established that isolated strength training was insufficient for reducing the incidence of ACL injuries. In the study, 9 weeks of strength training did not manage to produce significant differences in kinetic and kinematic patterns in the stop-jump test, as compared with subjects who did not do this training.

This suggests that combined interventions of coordinative or neuromuscular training along with strength training of the antagonistic muscle groups protecting the knee and the stabilizing muscles of the pelvis could be useful in this context. We feel that strength training of weak muscle groups should be integrated into synergistic exercises that also achieve neuromuscular adaptations, thus improving both strength levels as well as kinetic and kinematic patterns in movements that promote ACL injuries.

Included below is a correction guide for altered kinetic and kinematic patterns, prepared by the Hunt Valley Committee in 2005, wherein they show where the technical correction should be targeted, with the goal of reducing a detected risk.

Table 1: Prevention Components

The Risk	The Strategy	How?
Extended Knees	Flexing the Knees	More Shock Absorption from the Drop
Extended Hips	Flexing the Knees	More Shock Absorption from the Drop
Knee Valgus	Minimizing the Valgus	Drop Control
Loss of Balance	Improving Balance	Dynamic Balance Training
Poor Motor Skills	Improving Agility	Abilities Exercises

Source: Adapted from Griffin et al., 2006

By way of expanding the preventive training courses for the ACL, we might cite Zazulack, Hewett, Reeves, Goldberg & Cholewicki (2007). That study reported that core proprioception training, evaluated in active repositioning of the trunk, predicts the risk of ACL injuries in female but not male athletes. This suggests that this type of core training enables a better stabilization of the body's center, so that, from the stable core, the transfer of forces towards the extremities can be carried out in a more coordinated fashion, contributing to neuromuscular training that corrects for technical flaws.

By way of conclusion for this section, it is important to highlight the work done by Mandelbaum et al. (2005), who studied the efficacy of neuromuscular and proprioceptive training for the reduction of incidence of ACL injuries in female soccer players. This non-random, controlled study using a significant sample (1,041 female soccer players in the experimental group and 1,905 females in the control group) performed a follow-up for the implementation of the program over two years, achieving an 88% reduction in the first year and a 74% reduction in the second year, as shown in the table. These authors concluded that the use of neuromuscular and proprioceptive training has a direct influence on the reduction of incidence of ACL injuries in female soccer players (Tables 2 and 3).

Table 2: Rate of Incidence and Relative Risk of ACL Injuries per Total Exposure

	No. of Total Exposure	No. of ACL Injuries	Rate of Incidence	Relative Risk
Year 1				
Trained	37,476	2	0.05	0.114
Without Training	68,580	32	0.47	
Total	106,056	34		
Year 2				
Trained	30,384	4	0.13	0.259
Without Training	68,868	35	0.51	
Total	99,252	39		
Years 1 and 2 Combined				
Trained	67,860	6	0.09	0.181
Without Training	137,448	67	0.49	
Total	205,308	73		
Rate based on injuries per 1,000 hours of exposure				

Source: Adaptation by the author(s) from Mandelbaum et al., 2005.

Table 3: Rate of Incidence and Relative Risk of ACL Injury per Player

	No. of Subjects	No. of ACL Injuries	Resulting Rate per Player	Relative Risk
Year 1				
Trained	1,041	2	1.9	0.114
Without Training	1,905	32	16.8	
Total	2,943	34		
Year 2				
Trained	844	4	4.74	0.259
Without Training	1,913	35	18.3	
Total	2,757	39		
Years 1 and 2 combined				
Trained	1,885	6	3.18	0.1814
Without Training	3,818	67	17.6	
Total	5,703	73		
Total decline in ACL injuries for year 1 (16.8-1.9)/16.8*100= **88 %**				
Total decline in ACL injuries for year 2 (18.3-4.74)18.3*100=**74 %**				
Rate based on injuries per 1,000 players				

Source: Adaptation by the author(s) of Mandelbaum, 2005.

This paper has weak points in its design, such as the use of a non-randomized design employing voluntary enrollment of participants, which could generate bias due to the motivation caused by partiality in the selection of the sample. Furthermore, the fact that athletes were not subject to neuromuscular assessment before and after training could have changed some factors, making uncertain the real efficacy of this risk reduction program for non-contact ACL injuries. Apart from these criticisms, this promising program deserves, at least, a more detailed study.

Contrary to what was found by Mandelbaum et al. (2005) and the program of Hewett et al. (2005), Pfeiffer, Shea, Roberts, Grandstrand and Bond (2006) designed a prospective cohort study using high school female athletes (soccer, volleyball, and basketball players) from 15 schools (112 teams; 1439 players) during two consecutive seasons, dividing them into a control group (862 players) and a training group (577 players). The training group participated in a plyometric training program designed with the goal of correcting drop landing strategies, wherein they performed the program twice a week throughout the whole season, during which time epidemiological surveys were conducted on the rate of ACL injuries in both groups. The study found that this twice-weekly training with a focus on drop landing and deceleration techniques without prior change of direction was not effective in the reduction of incidence of ACL injuries in female adolescents.

Criticism of this paper is based on the fact that the program chosen was most likely not applied correctly, either with insufficient sets or not consistent with the prescribed program. In this respect, programs that have reported success have focused on retraining control strategies for the lower extremities, trunk, and upper extremities. The objective is to use this exercise to retrain the hamstrings, hip muscles, and core areas, with the ultimate objective of achieving a coordinated activation in body alignment during the implementation of these movement strategies; using moderately larger sets (3 times a week for 60 minutes, approximately) and, finally, using certified trainers in the process.

Concluding this section, while the evidence is not entirely convincing regarding whether these strategies can prevent incidence of ACL injuries, the specific training programs that have been documented to be relatively successful are those that attempt a correct alignment of the body in general and of the lower extremities in particular, especially in those movements that pose a risk for the knee joint. The focus is placed on attempts to correct movement coordination and overall body stability in certain actions that promote injuries.

Preventive Actions for the Reduction of Incidence of Injury in the Anterior Cruciate Ligament (ACL)

This section proves to be the most confusing and difficult in the attempt to establish precise instructions for the reduction of incidence of ACL injuries.

The current body of knowledge offers sufficient information about the intrinsic and extrinsic risk factors that increase the risk of ACL injury and addresses preventive measures. However, we still lack larger research projects that would identify organized and effective strategies to this end.

Thus, there are some points that remain less clear. For example, we can infer that Video Screening methods employed to detect flaws in high-risk movements such as the Drop-Jump Screening Test proposed by Noyes et al. (2005) and the recently approved LESS (landing error scoring system) (Padua et al., 2009), are useful for identifying at-risk subjects and, at least as practical tools, for assessing and supervising the progress of corrective neuromuscular techniques that we employ with our athletes.

Figure 7: Drop-Jump Used with LESS Score

Source: [Untitled image of drop-jump] (n. d.). Taken from https://goo.gl/xsz6Tt

It should be acknowledged that, while we know there could be errors or biomechanical deficits in the changes of direction that act as intrinsic risk factors, they can be deduced through these screening tools. Therefore, it is valid to say that these tools are specifically for assessing the biomechanical aspects of jumps, especially in the landing or shock absorption phase.

Thus, we can say that there is no existing field method that establishes biomechanical deficits in changes of direction, which are themselves the riskiest movements in soccer due to their frequent and varied appearance during the course of a soccer match.

We should also consider that the most robust evidence we have to-date about the efficacy of these prevention programs relates to female soccer players (among other sports with similar kinematic and kinetic actions), rather than their male counterparts.

As far as preventive measures are concerned, plyometric training appears to be the most prevalent method, with the main focus on biomechanical modifications in the techniques and strategies for drop landings and changes of direction.

The pioneering papers on this topic come from the research groups of Hewett et al. (1996) and Mandelbaum et al. (2005). The latter study, especially, is focused on the efficacy of neuromuscular and agility training in the reduction of incidence of ACL injuries in female soccer players.

To summarize, we can say with certainty that as concerns the design of prevention programs for the reduction of the incidence of ACL injuries, there exists currently a relative consensus around the following:

- Carrying out specific development strategies and improving the biomechanical aspects of jumps and changes of direction.

- That in this context, neuromuscular (NM), plyometric (PLYO) and agility (AGY) training is the most effective tool, provided it is carried out with supervision and adjustments on the part of those responsible for the program (technique adjustments).

- Aiming at greater shock absorption and lowering the center of gravity in these techniques to promote the hamstring's protection of the ACL (sagittal plane) and the correction of knee abduction moments (dynamic valgus) (adjustment in the frontal plane).

- Doing these programs more than once a week, over a minimum of six weeks to guarantee full effectiveness, as suggested by Hewett et al. (2006).

- The strategies should include single-legged NM and PLYO actions in order to be effective and applicable to the adjustments related to the injury mechanism (Brown, Palmieri-Smith and McLean, 2010).

- The influence of dynamic instability or poor core control is also clear, especially in dynamic actions, in the modification of biomechanical patterns in the lower extremities, and with particular influence on knee and the valgus collapse, as established initially in the paper by Zazulack et al. (2007). For this reason, prevention strategies should include core training (Zazulack et al., 2007).

- Interventions turn out to be significantly more effective with women than men, although they are also beneficial for men with neuromuscular deficits or detected risk factors.

- As suggested by Bahr (2009), interventions for players with risk factors, especially those detected by proven simple screening tools (LESS and Drop Jump Screening Tests) are more effective and efficient than those applied to the whole population. Therefore, it would be interesting to form an intervention subgroup based on the implementation of LESS, for example.

- These interventions should begin at 12 years of age (LaBella et al, 2011), with an emphasis during the sensitive phases, where modifications will be most effective and crucial, on developing patterns and skills related to jumping and changes of direction techniques.

In conclusion, we can organize this intervention subgroup based on the implementation of LESS at the beginning of the season, thus determining the players with biomechanical risk factors for ACL injuries. Subsequently, this subgroup should perform plyometric and agility interventions apart from the rest of the group, at least twice a week over the course of at least six weeks, under the supervision and coaching of motivating strategies related to the techniques for drop landings and changes of direction. Finally, a monitoring system should be set up in order to track the modifications achieved throughout the rest of the season.

The NM, PLYO and AGY interventions should include double-legged and single-legged jumps and landings in different directions, movements with changes of direction at different angles and in different directions (cross cut and side step cut), dynamic stability training and the development of a lower center of gravity. Interventions should also include core training, especially working to make progress with weight-bearing and dynamics exercises.

Figure 8: Sequence of 4 Frames Taken from 30 Analysis Frames for Coaching a Shuttle Run at 100% of VO_2max

Source: Author(s)' own file, unedited [captured or prepared]

Unit 3.2 Prevention of the most frequent upper limb joint injuries (shoulder injuries)

3.2.1 Epidemiology of shoulder injuries in sports and the most common injury mechanisms

Shoulder injuries in sports can be caused by trauma or overuse, and shoulder pain is common in sports, especially in those with a high number of overhead motions of the upper extremities.

While there is ample bibliography regarding the rehabilitation of the shoulder joint, there are few methodologically precise scientific papers (unlike with other injuries) addressing the epidemiology and prevention of injuries in athletes. There should, therefore, be more literature on the subject.

Generally speaking, the team sports that have higher incidence of shoulder pain, presupposing some damage to this joint complex, are: baseball, volleyball, and handball; meanwhile, those individual sports with higher incidences of shoulder pain are tennis and/or other racket sports, as well as swimming.

In a paper by Bonza, Fields, Yard and Comstock (2009), shoulder injuries among high school athletes who practiced different sports were analyzed over the course of two seasons. They found that the most common injuries were produced by contact (dislocations, blunt traumas, acromioclavicular luxations from falls), and only 10% were diagnosed as being caused by overuse. However, one limitation for this type of study is the underestimation of injuries from overuse, due to many participating in games or training despite suffering shoulder pain.

The most easily prevented injuries in these kinds of sports are overuse injuries, fundamentally due to the large amount of movement producing mechanical stress on the shoulder which, in general, consists of overhead motions or those that replicate the motor pattern associated with throwing.

3.2.2 Intrinsic and extrinsic risk factors

There are intrinsic and extrinsic risk factors that contribute to overuse injuries in the shoulder joint complex. The interaction of these factors presumes that the athlete exposed to those risks will be susceptible to an overuse injury, especially in overhead athletes.

Intrinsic Risk Factors

Age

Problems from overuse increase with age among athletes. For example, in pitchers, the incidence of injury is greater among veteran athletes than in young athletes. It is likely that time spent playing a game, and the subsequent accumulation throughout an athlete's career of microtrauma in the shoulder, may be elements that should be regarded as risk factors.

Anatomical Factors

Anatomical variations in the acromion can become an intrinsic risk factor when the subacromial space decreases, and especially in those cases where the acromion is hook-shaped. The reduction of subacromial space due to anatomical factors can be especially risky in tennis players, swimmers, or throwers.

Glenohumeral Internal Rotation Deficit (GIRD) and Posterior Capsule Strain

Posterior capsule strain is a common cause of shoulder pain. It tends to manifest itself as restricted internal rotation and pain.

Among athletes who perform overhead throws, the posteroinferior capsule can undergo strain, causing a loss of internal rotation. The glenohumeral internal rotation deficit (GIRD) is the loss of glenohumeral internal rotation in shoulders performing throws (compared with those that not performing throws) (Burkhart, Morgan, Kibler, 2003).

The relationship between GIRD and shoulder dysfunction in throwing athletes was first demonstrated in 1991. (Birkhart SS, Morgan CD, Kibler WBB, 2003). In said study, 39 professional baseball pitchers who were training with less than 25 degrees total internal rotation (GIRD) and with a loss of internal rotation greater than 35 degrees were assessed during a sports season. 60% of the pitchers developed shoulder problems that forced them to stop pitching over the course of the study (Burkhart SS, Morgan CD, Kibler WBB, 2003).

Capsular retraction in the shoulder produces a rotation of the humeral head, which induces tension in the tissues when the capsule is retracted due to previous surgical interventions. This forces the humeral head to move in the opposite direction of the retracted tissue.

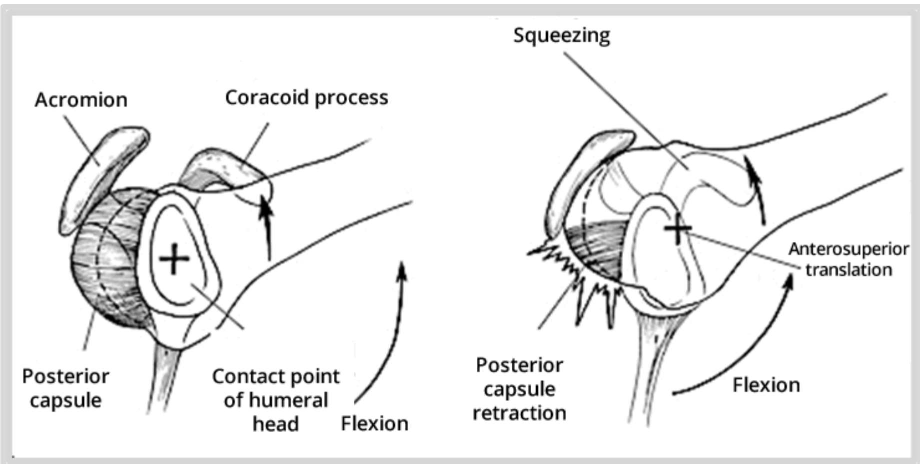
The retraction counteracts the humeral head's weight burden as well as movement, making it so that the head moves into the glenoid cavity, displacing it from its usual position. This phenomenon is called **capsular restriction.**

Similarly, among athletes suffering type II symptomatic injuries of the superior labrum anterior and posterior (SLAP), a significant GIRD in affected shoulders was observed (average 33 degrees, range of loss of internal rotation from 26 to 58 degrees) (Burkhart SS, Morgan CD, Kibler WBB, 2003).

In another study, top-level tennis players were followed on a prospective basis over 2 years; one group performed daily posteroinferior capsular stretches to minimize GIRD, while the control group did not perform these stretches. During the 2 year period of the study, the athletes that performed stretches increased their internal rotation and their total rotation in comparison with the control group. Furthermore, the stretching group showed a 38% reduction in shoulder problems (Burkhart SS, Morgan CD, Kibler WBB, 2003).

Finally, of the 22 pitchers in the first division league who performed daily manual stretches during the 1997, 1998, and 1999 seasons, none demonstrated any intra-articular pathology in the shoulder, nor stopped playing at any point. Nor did they require surgical operations.

Figure 9: Effects of Strain on the Posterior Capsule



Source: adapted from Matsen, Lippitt, Sidles and Harryman, 1994 pg. 40.

A. Normal capsular laxity allows the humeral head to be centered during the raising of the arm. B. Posterior capsular retraction can produce an anterosuperior movement during shoulder flexion.

Scapular Dyskinesis as a Factor Promoting Subacromial Impingement

Scapular dyskinesis (SD) is a disorder in the normal movement of the scapula occurring during coupled scapulohumeral movements, known as **scapular rhythm.** This occurs in various shoulder injuries and commonly arises as a result of inhibition or disorganization of activation patterns in stabilizing muscles of the scapula. SD can increase the functional deficit associated with shoulder injury, disturbing the role of the scapula in the simultaneous and harmonious movement of the scapulohumeral rhythm as a whole (Kibler & McMullen, 2003).

Scapular dyskinesis, as well as the lack of control of normal functioning of the scapula in overhead sports, can be an important cause of shoulder pain. Both reduce subacromial space, disrupt the shock absorption forces necessary in the final phases of throwing, produce nerve entrapment of different parts of the rotator cuffs, a poor centering of the humeral head, among other conditions.

Extrinsic Risk Factors

Exposure to Loads on the Shoulder

The main extrinsic risk factor for injuries in the shoulder-joint complex seems to be a heightened exposure to routines involving stressful movements.

It has been demonstrated that among throwing athletes or those who perform overhead motions (volleyball, handball, pitchers, etc.), as the season progresses and the athletes accumulate large amounts of overhead motions, alterations begin to appear in the shoulder's ROM, especially in internal or external rotation, or in scapular dyskinesis. The aforementioned becomes a source of muscle pain for the athletes (Thomas, Swanik, Swanik & Huxel, 2009).

The sudden increase in the amount of overhead motions at different points during the season or in certain situations can also be associated with an increased risk of muscle pain in tennis players, swimmers, and throwers.

3.2.3 Identifying at-risk athletes

At the beginning of the season, in sports that make continuous demands on the shoulder, there should be an assessment of the functional status of this joint in order to identify possible risk factors that could, over the course of the season, develop into a joint injury.

This assessment should be repeated, as far as possible, in steady cycles throughout the season.

Points to assess in an evaluation of the athletes include:

- **Inspection of thoracic mobility:** inspections should be conducted for mobility of the dorsal column and trunk. Lack of mobility in this region is associated with dysfunctions in the scapulohumeral complex.

- **Postural Evaluation of Shoulder in Resting Position:** observing the position of the resting shoulder can yield information about retracted structures or those structures that tend to retract. Shoulder antepulsion, for example, could mean retraction of the anterior muscles of the shoulder and deficiencies in the centering of the humeral head during rotation and abduction movements.

- **Evaluation of the Posterior Capsule:** Assessment of the posterior capsule's status in the shoulder in resting position, between the dominant and non-dominant limb, can yield information about the condition of the posterior capsule of the shoulder, which, as previously seen, is a strong risk factor for this joint complex.

- **Evaluation of Articular Dyskinesia:** just as with the posterior capsule of shoulder, inspecting the scapular rhythm and the scapula in resting position provides us with information about possible risk factors associated with poor neuromuscular control of the scapula.

- **Evaluation of Shoulder ROM:** assessment of ROM, as well as the stability of the shoulder joint, can provide us with information about the instability of the glenohumeral joint, which becomes a risk factor for this joint.

3.2.4 Model for the preventive approach to shoulder injuries

Taking into consideration everything covered in this unit, any model aiming to reduce the risk of shoulder injuries should include the most relevant aspects of those risk factors mentioned here, especially among athletes with a large number of throwing patterns.

For sports with high-impact on the shoulder joint complex, an exercise program focusing on risk factors should include all elements of a well-balanced routine (flexibility, strength, stability, coordination, and core stability).

Traditional exercise programs for the prevention of shoulder injuries include:

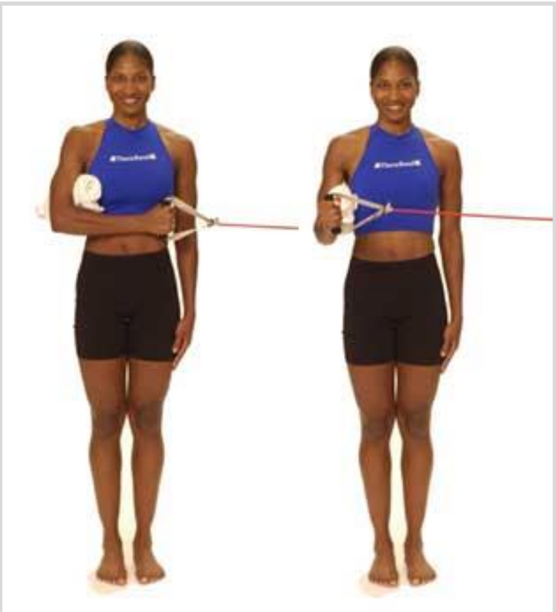
- Glenohumeral stability training: closed kinetic chain exercises that increase coactivation of the antagonist muscles.

Figure 10: Example of Scapular Activation Exercises in a CKC (Closed Kinematic Chain)

Source: [Untitled image of scapular activation exercises] (n.f.). Taken from http://goo.gl/0Ib1Sn

- Strength Training of the Rotator Cuff

Figure 11: Examples of Exercises of External Rotators of the Shoulder in a Neutral Position or 0° ABD (Abduction)



Source: [Untitled image of examples of exercises of external rotators of the shoulders in neutral position or 0° ABD (abduction). (n. d.). Taken from http://goo.gl/kCIb3s

Figure 12: Internal Rotation Exercise

Source: [Untitled image of internal rotation exercise] (n. d.). Taken from https://goo.gl/WHqjHR

- Scapular stability training: serratus anterior and trapezius muscle activation exercises.

Figure 13: Example of Analytic and Comprehensive Exercises for the Serratus Anterior and Trapezius Lower Fibers

Source: Kibler et al., 2008, pg. 1792.

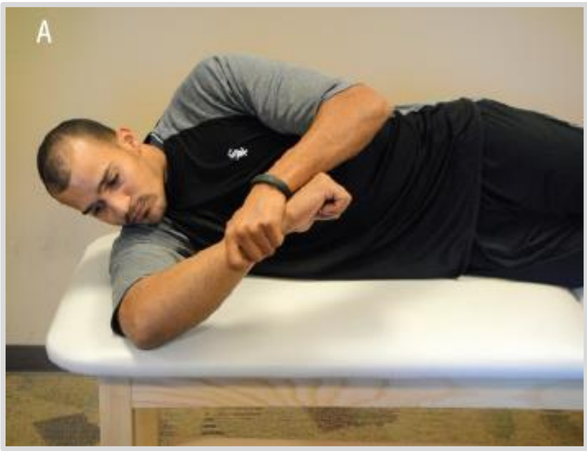
- Thoracic mobility training, especially in extension and rotation.

Figure 14: Example of Mobility Exercises in Thoracic Extension

Source: [Untitled image of example of mobility exercises in thoracic extension]. (n. d.). Taken from http://goo.gl/jC91gL

- Core stability training and the rest of the kinematic chain.
- Prevention of rigidity in:
    - Posterior capsule;
    - rhomboids;
    - latissimus dorsi;
    - pectoralis minor.

Figure 15: An Example of Posterior Capsule Stretching



Source: Wilk Kevin et al., 2013, pg. 892.

Figure 16: Pectoralis Minor Stretching

Source: [Untitled image of stretching]. (n. d.). Taken from http://goo.gl/S7zpkv

Figure 17: Latissimus Dorsi Stretching

Source: [Untitled image of stretching]. (n. d.). Taken from https://goo.gl/v2k93q

In conclusion, it is critical to perform a proper evaluation of overhead athletes and design a program for the protection of the shoulder joint complex, especially during heightened periods of use or exposure to stressful motions. It is crucial to perform an ongoing training plan that will target the most important aspects of the shoulder joint's neuromuscular function.

References

[Untitled image of an example of mobility exercises in thoracic extension]. (n. d.). Taken from http://goo.gl/jC91gL

[Untitled image of an example of scapular activation exercises in CKC (Closed Kinematic Chain)]. (n. d.). Taken from: http://shoulder-pain-case-report.blogspot.com.ar/

[Untitled image of drop-jump test]. (n. d.). Taken from http://4.bp.blogspot.com/-4b5kap718Fk/VJ_px4ONV2I/AAAAAAAAATg/axO79xD2Xas/s1600/ugr%C3%A1s.jpg

[Untitled image of examples of shoulder external rotator exercises in neutral position or 0 degrees ABD (abduction)]. (n. d.). Taken from http://goo.gl/kCIb3s

[Untitled image of internal rotation exercise]. (n. d.). Taken from https://goo.gl/WHqjHR

[Untitled image of pectoralis minor stretching]. (n. d.). Taken from https: http://goo.gl/S7zpkv

[Untitled image of stretching]. (n. d.). Taken from https://lauralovesfitness.files.wordpress.com/2012/02/dsc_37551.jpg
2001;31(11):645-654

Agel, J., Arendt, E. A., & Bershadsky, B. (2005). Anterior Cruciate Ligament Injury in National Collegiate Athletic Association Basketball and Soccer A 13-Year Review. *Am. J. Sports Med, 33*(4):524-30.

Arendt, E., & Dick, R. (1995). Knee injury Patterns among Men and Women in Collegiate Basketball and Soccer: NCAA Data and Review of Literature. *Am J Sports Med, 23*(6), 694–701.

Bahr, R. & Krosshaug, T. (2005). Understanding Injury Mechanisms: a Key Component of Preventing Injuries in Sport. *Br J Sports Med, 39 39* (6):324-9.

Bahr, R. (2009). No injuries, but Plenty of Pain? On the Methodology for Recording Overuse Symptoms in Sports. *Br J Sports Med, 43*(13), 966-972.

Beynnon, B. D., Johnson, R. J., Abate, J. A., Fleming, B. C. & Nichols, C. E. (2005a). Treatment of Anterior Cruciate Ligament Injuries, Part 1. *Am J Sports Med, 33*(10), 1579-1602.

Beynnon, B. D., Johnson, R. J., Abate, J. A., Fleming, B. C. & Nichols, C. E. (2005b). Treatment of Anterior Cruciate Ligament Injuries, Part 2. *Am J Sports Med, 33*(11), 1751-67.

Bjordal, J. M., Arnły, F., Hannestad, B., & Strand, T. (1997). Epidemiology of Anterior Cruciate Ligament Injuries in Soccer. *Am J Sports Med, 25*(3), 341-345.

Bonza, J. E., Fields, S. K., Yard, E. E., & Comstock, R. D. (2009). Shoulder Injuries among United States High School Athletes during the 2005–2006 and 2006–2007 School Years. *Journal of Athletic Training, 44*(1),76-83.

Brown, T. N., Palmieri-Smith, R. M., & McLean, S. G. (2010). Knee Kinematics During Single- and Double-Legged Jump Landings Following Six Weeks of Neuromuscular Training. *Journal of Athletic Training, 45*(5), 522-541.

Burkhart, S. S., Morgan, C. D. & Kibler, W. B. (2003). The Disabled Throwing Shoulder: Spectrum of Pathology. I: Pathoanatomy and Biomechanics. *Arthroscopy, 19*(4), 404-420.

Burkhart, S. S., Morgan, C. D., & Kibler, W. B. (2000). Shoulder Injuries in Overhead Athletes: The “Dead Arm” Revisited. *Clin Sports Med, 19*(1), 125-158.

Chandrashekar N, Slauterbeck J, Hashemi J. (2005) Sex-based Differences in the Anthropometric Characteristics of the Anterior Cruciate Ligament and its Relation to Intercondylar Notch Geometry: a Cadaveric Study. *Am J Sports Med.;33*(10):1492–1498

Chappell, J. D., & Limpisvasti, O. (2008). Effect of a Neuromuscular Training Program on the Kinetics and Kinematics of Jumping Tasks. *Am J SportsMed, 36*(6), 1081-1086.

Dedrick, G. S., Sizer, P. S., Merkle, J. N., Hounshell, T. R., Robert-McComb, J. J., Sawyer, S. F., ... & Roger James, C. (2008). Effect of Sex Hormones on Neuromuscular Control Patterns during Landing. *J Electromyogr Kinesiol,18*(1),68-78.

Givoni, N. J., Pham, T., Allen, T. J., & Proske, U. (2007). The Effect of Quadriceps Muscle Fatigue on Position Matching at the Knee. *J Physiol, 584*(Pt 1),111-119.

Griffin LY, Albohm MJ, Arendt EA, Bahr R, Beynnon BD, Demaio M, Dick RW, Engebretsen L, Garrett WE Jr, Hannafin JA, Hewett TE, Huston LJ, Ireland ML, Johnson RJ, Lephart S, Mandelbaum BR, Mann BJ, Marks PH, Marshall SW, Myklebust G, Noyes FR, Powers C, Shields C Jr, Shultz SJ, Silvers H, Slauterbeck J, Taylor DC, Teitz CC, Wojtys EM, Yu B. (2006) Understanding and Preventing Non-Contact Anterior Cruciate Ligament Injuries: a Review of the Hunt Valley II Meeting, January 2005. *Am J Sports Med. Sep;34*(9):1512-32.

Herman DC, Weinhold PS, Guskiewicz KM, Garrett WE, Yu B, Padua DA. (2008). The Effects of Strength Training on the Lower Extremity Biomechanics of Female Recreational Athletes during a Stop-Jump Task. *Am J Sports Med. Apr;36* (4):733-40.

Hewett, T. E., Ford, K. R., & Myer, G. D. (2005). Anterior Cruciate Ligament Injuries in Female Athletes Part 2, a Meta-Analysis of Neuromuscular Interventions Aimed at Injury Prevention. *Am. J. Sports Med, 34*(3), 490-498.

Kernozek, T. W., Torry, M. R., & Iwasaki, M. (2008). Gender Differences in Lower Extremity Landing Mechanics Caused by Neuromuscular Fatigue. *Am J Sports Med, 36*(3), 554-565.

Kibler Ben W., Sciascia Aaron D. Uhl Timothy L. Tambay Nishin, and Cunningham, Thomas. (2008) Electromyographic Analysis of Specific Exercises for Scapular Control in Early Phases of Shoulder Rehabilitation. *The American Journal of Sports Medicine, 36* (9) 1789-1798

Kibler, B. W., & McMullen, J. (2003). Scapular Dyskinesis and its Relation to Shoulder Pain. *J Am AcadOrthopSurg, 11*(2), 142-151.

LaBella CR, Huxford MR, Grissom J, Kim KY, Peng J, Christoffel KK. (2011) Effect of Neuromuscular Warm-Up on Injuries in Female Soccer and Basketball Athletes in Urban Public High Schools: Cluster Randomized Controlled Trial. *Arch Pediatr Adolesc Med. Nov;165*(11):1033-40. doi: 10.1001/archpediatrics.2011.168.

Landry, S. C., McKean, K. A., Hubley-Kozey, C. L., Stanish, W. D., & Deluzio, K. J. (2007). Neuromuscular and Lower Limb Biomechanical Differences Exist Between Male and Female Elite Adolescent Soccer Players During an Unanticipated Side-cut Maneuver. *Am J SportsMed, 35*(11):1888-900.
Ligament Injuries in Australian Football. *J Orthop Sports Phys Ther.*

Lloyd DG, Buchanan TS, Besier TF (2005). Neuromuscular Biomechanical

Lloyd DG. Rationale for Training Programs to Reduce Anterior Cruciate

Mandelbaum B. R., Silvers, H. J., Watanabe, D. S., Knarr, J. F., Thomas, S. D., Griffin, L. Y. & Garrett W. Jr. (2005). Effectiveness of a Neuromuscular and Proprioceptive Training Program in Preventing Anterior Cruciate Ligament Injuries in Female Athletes. *Am J Sports Med, 33*(7):1003-10.

Meeuwisse W. (1994) Assessing Causation in Sport Injury: a Multifactorial Model. *Clin J Sport Med.;4*(3):166–70

Mihata LC, Beutler AI, Boden BP. (2006). Comparing the Incidence of Anterior Cruciate Ligament Injury in Collegiate Lacrosse, Soccer, and Basketball Players: Implications for Anterior Cruciate Ligament Mechanism and Prevention. *Am J Sports Med. Jun;34*(6):899-904.
Modeling to Understand Knee Ligament Loading. *Med Sci Sports Exerc.;37*(11):1939-1947

Murata, M. (1996). Height Velocity Curve in Childhood and Adolescence. *Obstetrical and Gynecological Therapy, 72*(4), 401-406.

Myer Gregory D, Ford Kevin R, Divine Jon G, Wall Eric J, Kahanov Leamor, and Hewett Timothy E. (2009) Longitudinal Assessment of Noncontact Anterior Cruciate Ligament Injury Risk Factors During Maturation in a Female Athlete: A Case Report. *J Athl Train; 44*(1): 101–109

Noyes, F. R., Barber-Westin, S. D., Fleckenstein, C., Walsh, C. & West, J. (2005). The Drop-Jump Screening Test: Difference in Lower Limb Control by Gender and Effect of Neuromuscular Training in Female Athletes. *Am J Sports Med, 33*(2), 197-207.

Padua, D. A., Marshall, S. W., Boling, M. C., Thigpen, C. A., Garrett, W. E. Jr, & Beutler, A. (2009). The Landing Error Scoring System (LESS) Is a Valid and Reliable Clinical Assessment Tool of Jump-Landing Biomechanics. The JUMP-ACL Study. *Am J Sports Med, 37*(10), 1996-2002.

Pappas E, Hagins M, Sheikhzadeh A, Nordin M, Rose D. (2007) Biomechanical Differences between Unilateral and Bilateral Landings from a Jump: Gender Differences. *Clin J Sport Med.;17*(4):263-268.

Pfeiffer, R.P., Shea, K. H., Roberts, D., Grandstrand, S., & Bond, L. (2006). Lack of Effect of a Knee Ligament Injury Prevention Program on the Incidence of Noncontact Anterior Cruciate Ligament Injury. *J Bone Joint Surgery, 88*(8), 1769-1774.

Prentice, W. E. (2001). *Rehabilitation Techniques in Sports Medicine* (2nd edition). Barcelona: Paidotribo.

Quatman, C. E., Ford, K. R., Myer, G. D., & Hewett, T. E. (2006). Maturation Leads to Gender Differences in Landing Force and Vertical Jump Performance: a Longitudinal Study. *Am J Sports Med, 34*(5), 806-813.

Renstrom, P. et al. (2008). Non-Contact ACL Injuries in Female Athletes: an International Olympic Committee Current Concepts Statement.

Renstrom, P., Ljungqvist, A., Arendt, E., Beynnon, B., Fukubayashi, T., Garrett, W., … & Engebretse, L. (2008). Non-Contact ACL Injuries in Female Athletes: an International Olympic Committee Current Concepts Statement. *Br J Sports Med, 42*(6), 394–412.

Sampietro, M. (2005). Untitled image of an example of a side cut maneuver with change of direction. Author(s)' own file, unedited.

Sampietro, M. (2008). Untitled image of an example of a crosscut maneuver with change of direction. Author(s)' own file, unedited.

Sell TC, Ferris CM, Abt JP, Tsai YS, Myers JB, Fu FH, Lephart SM. (2006) The Effect of Direction and Reaction on the Neuromuscular and Biomechanical Characteristics of the Knee during Tasks that Simulate the Noncontact Anterior Cruciate Ligament Injury Mechanism. *Am J Sports Med.;34*(1):43-54.

Sell, T. C. (2011). An Examination, Correlation, and Comparison of Static and Dynamic Measures of Postural Stability in Healthy, Physically Active adult. *Physical Therapy in Sport, 13*(2), 80-86.

Shimokochi, Y., & Shultz, S. J. (2008). Mechanisms of noncontact anterior cruciate ligament injury. *J Athl Train, 43*(4), 396-408. doi: 10.4085/1062-6050-43.4.396

Thomas, S. J., Swanik, K. A., Swanik, C., & Huxel, K. C. (2009). Glenohumeral Rotation and Scapular Position Adaptations After a Single High School Female Sports Season. *Journal of Athletic Training, 44*(3), 230-237.

Villwock, M. R., Meyer, E. G., Powell, J. W., Fouty, A. J., & Haut, R. C. (2009). Football Playing Surface and Shoe Design Affect Rotational Traction. *Am J Sports Med, 37*(3), 518-525.

Wilk Kevin E, Hooks Todd R., Macrina Leonard C. (2013) The Modified Sleeper Stretch and Modified Cross-body Stretch to Increase Shoulder Internal Rotation Range of Motion in the Overhead Throwing Athlete. *Journal Of Orthopaedic & Sports Physical Therapy. 43* (12) 891-894

Yu, B., McClure, S. B., Onate, J. A., Guskiewicz, K. M., Kirkendall, D. T., & Garrett, W. E). (2005). Age and Gender Effects on Lower Extremity Kinematics of Youth Soccer Players in a Stop-Jump Task. *Am. J. Sports Med, 33*(9):1356-64.

Zazulak, B. T., Hewett, T. E., Reeves, N. P., Goldberg, B., & Cholewicki, J. (2007). The Effects Of Core Proprioception On Knee Injury: A Prospective Biomechanical-Epidemiological Study. *Am J Sports Med, 35*(3), 368-73.