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Prevention of overuse knee injuries in Basketball athletes

BOOKLET BASED ON SYSTEMATIC LITERATURE REVIEW

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The aim of the thesis was to create a booklet for athletes based on a systematized literature review. The purpose was to gather applicable methods from the literature to prevent overuse knee injuries in male basketball athletes (17-35yo). Thesis will be done for BC Sisu men’s basketball team from Pori.

Evidence was gathered through search of risk factors for patellar tendinopathy and patellofemoral pain syndrome. Majority of the evidence is less than 10 years old and from multiple sources. Due to authors interest a systematized literature review was conducted within 10-year publications from Pubmed. The booklet was based on both Systematized literature review and the theory framework of the thesis.

The result was based on documented risk factors of the conditions, primary & secondary prevention programs such as FIFA 11+ program. The exercise program is a synthesis of the results mimicking the format of the FIFA 11+ program. Current evidence in injury prevention is limited especially for basketball athletes. Another difficulty for prevention is the occurrence of prevalence studies in recent years. Studies conclude that the prevalence of true patellar tendinopathy is much less than suggested previously by athletes, coaches, and clinicians. However, systematized search about basketball players and overuse injuries typically involves mainly patellar tendinopathy.

The main extrinsic risk factor which came up through many different sources is rapid loading or loading over the tissue capacity. Especially for basketball athletes it is important to look at the demand of the sport and increase the physical capacity of the athletes.

Knee joint, Basketball, Primary prevention, Cumulative Trauma Disorders, Resistance Training

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1 INTRODUCTION

Basketball is a sport in which two teams are playing against each other and trying to score more points as the other. Both teams have 5 players on the court, and they are trying to make a basket in the opponent's basket while trying to block the other team scoring a basket to their own. (Suomen koripalloliitto, 2020.)

Basketball has evolved significantly in the last few years. The game has been molded into many other similar sports such as wheelchair basketball, streetball, slamball, show basketball (Harlen globetrotters) and 3v3 Basketball, which just recently got introduced as an Olympic sport. The evolution, rule changes and progress in the sport has increased the demand of athletes. Nowadays basketball is considered as one of the most injury prone ball games. (Laver et al., 2020, p. XVI.)

The most common injuries in basketball are ankle sprains and overuse knee injuries. Acute knee injuries resulted in highest absence from the sport. Basketball in general has a high injury incidence of 9.8/1,000 hours. Contact mechanisms are causing 69,2% of the acute injuries. However, basketball is still considered a non-contact sport. (Cumps, Verhagen, & Meeusen, 2007.) Injury studies typically measure time-loss from activity. Athletes with overuse injuries often continue their activity with symptoms and do not get registered in injury epidemiology. (Hannington et al., 2021.)

There has been a study made in France hope championship league, where they assessed the prevalence of below patella pain. The authors concluded that their study highlights the high frequency of below patella pain in basketball training centers. The questionnaires were also given to coaches and all the coaches were ready to dedicate time to specific training for prevention of jumper's knee prevention. (Caquot et al., 2016.) Anterior knee pain is very common in both males and females in a jumping sport like basketball. The Cause of pain is thought to be both patellofemoral pain and patellar tendinopathy. (Hannington, Docking, Cook, Edwards, & Rio, 2020; Hannington et al., 2021.)

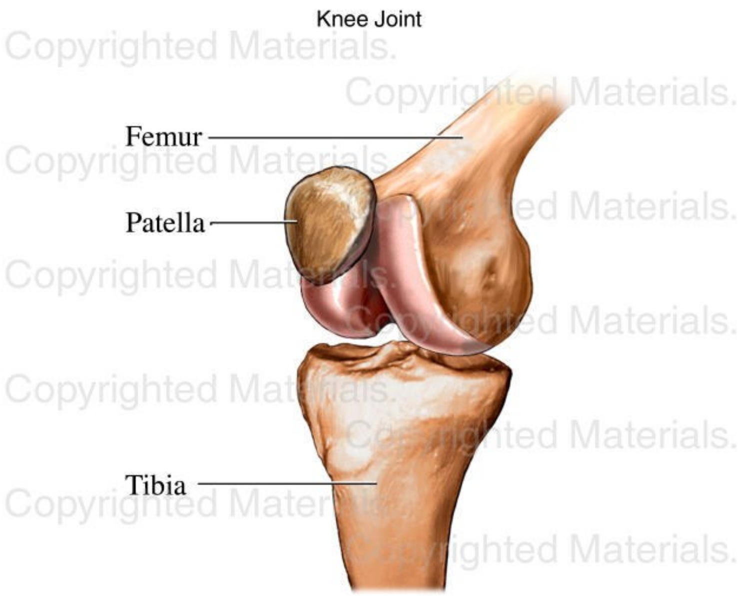
2 KNEE JOINT

2.1 Bony structures

Because the topic of this thesis is covering the overuse injuries of the knee in basketball athletes, this part will only cover the structures affected or closely related to these problems. However, it is important to note, the knee joint has a lot of additional supporting structures. Some of these structures are commonly injured in sports but are considered traumatic injuries instead of overuse injuries. The Overuse injury incidence was 3.8/1000 hours, and the knee is the joint which was the most common site. (Cumps, Verhagen, & Meeusen, 2007.)

Knee joint also referred as tibiofemoral joint. Knee joint has the reputation of being the most complex joint of the human body. Due to its complexity, thesis will be focusing more on the main structures affected by the overuse injuries. Knee joint's primary function is uniaxial hinge movement. However, this movement is produced by three different joints 1. Tibiofemoral between lateral condyle of the femur, lateral meniscus, and lateral condyle of the tibia, 2. Tibiofemoral joint between medial condyle of the femur, medial meniscus, and medial condyle of the tibia. 3. Patellofemoral joint is between the patella and the patellar surface of the femur also referred as patellar groove. (Tortora & Derrickson, 2017, pp. 247-250.)

The knee joint has 4 different bony structures at its proximity which are influencing on the anatomy and physiology of the knee as seen in Picture 1. These bones are from proximal to distal femur, patella, tibia, and fibula. Tibia has also an important role as an attachment point to the patellar tendon which will be in a closer observation in this thesis. (Tortora & Derrickson, 2017, pp. 247-250.)



Picture 1. Bony structures of the knee (Nucleus Medical Media, 2020)

2.2 Muscles

Knee joint is surrounded by many different muscles which are having different roles in terms of force production and stability. The muscles are illustrated in Table 1. For the sake of simplicity, this part will cover the muscles that are either crossing the joint or are in a proximity to it. (Tortora & Derrickson, 2017, pp. 340-346.) There are many other muscles in the hip and foot which have a strong influence on knee function and altered movement in one of the joints effects on the kinematics on the others (Svoboda, Janura, Kutilek, & Janurova, 2016).

The quadricep muscle which has, as the name applies four different muscles, vastus lateralis, - medialis, -intermedialis and rectus femoris is mainly producing force to extend the knee. It is also important in terms of patellar tracking as its insertion is in the proximal part of the patella. (Tortora & Derrickson, 2017, p.341.)

Hamstring muscles are formed of three different muscles which are producing flexion of the knee joint. Bicep femoris with its two heads long and short head, semitendinosus, and semimembranosus. All these muscles have similar action which is flexion of the knee joint and extension of the hip. (Tortora & Derrickson, 2017, p.341.)

Gastrocnemius has an interesting structure and function. The muscles main action is plantar flexion of the foot, but it also flexes the knee joint. This is due to it crossing over two joints and originating from the femur. Plantaris has the same function but originates only from lateral epicondyle of the femur and is significantly smaller than the gastrocnemius. Soleus is producing plantar flexion with gastrocnemius but only crosses the ankle joint compared to gastrocnemius. (Tortora & Derrickson, 2017, pp.342-342.)

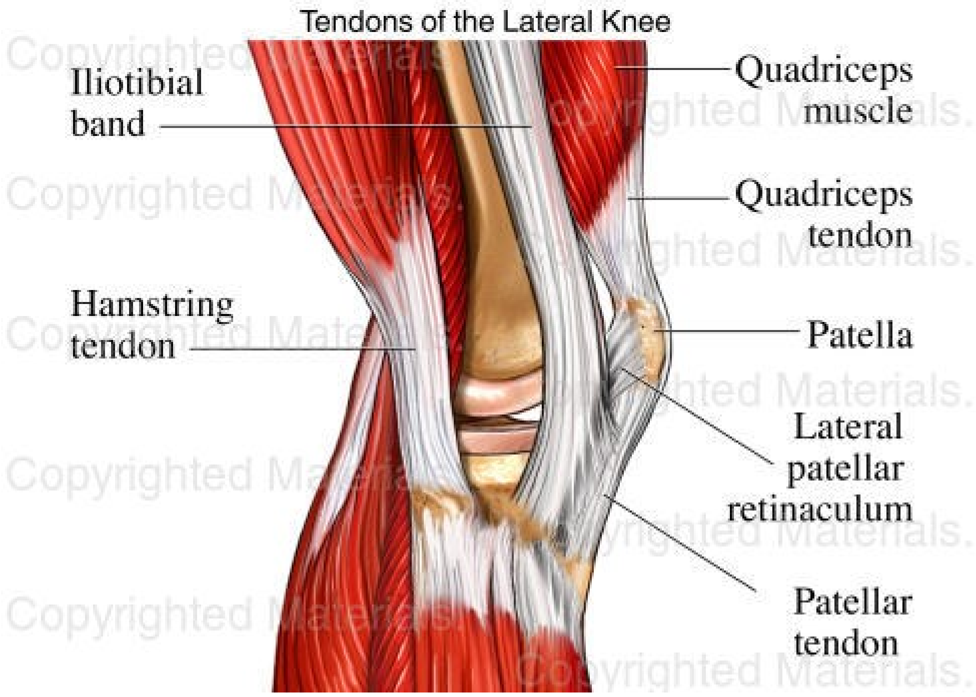
Table 1. Muscles around the knee joint (Tortora & Derrickson, 2017)

Muscle	Origin	Insertion	Action
Quadriceps femoris	Anterior iliac spine, greater trochanter & femur	Patella	Extension of the knee joint & flexion of the hip
Sartorius	Anterior iliac spine	Medial surface of tibia	Flexion of the knee joint & Flexion, abduction, and external rotation of the hip
Hamstrings (semitendinosus, semimembranosus, bicep femoris)	Ischial tuberosity, Femur	Proximal parts of tibia and fibula	Flexion of the knee joint & Extension of the hip
Gastrocnemius & Plantaris	Lateral and medial condyles of the femur	Calcaneus via Achilles tendon	Plantar flexion of the ankle & Flexion of the knee
Soleus	Head of fibula and medial border of Tibia.	Calcaneus via Achilles tendon	Plantar flexion of the ankle
Gracilis	Body and inferior ramus of pubis	Medial surface of the Tibia	Abducts the leg, medially rotates the femur & flexion of the knee

Popliteus	Lateral condyle of the femur	Proximal part of tibia	Flexion of the knee & internal rotation of the tibia

2.3 Tendons & ligaments

Tendons are connecting muscles to bones and ligaments are connecting bone to bone. Every part of the quadricep muscle attaches to the superior pole of patella via quadricep tendon. Often referred to as patellar tendon, it is technically a ligament since it attaches from the inferior pole of patella to the ischial tuberosity. The patella is in the middle of the quad tendon and patellar ligament. Contraction of quadriceps pulls the ischial tuberosity and thus straightens the knee. (Tortora & Derrickson, 2017, pp.247-250.) Tendons are illustrated in Picture 2.



Picture 2. Tendons of the lateral knee (Nucleus Medical Media, 2020)

What we know about tendon adaptation is poorly understood. It is known that tendon responds to tensile, compressive and shear force. Too much or too little loading can cause maladaptive response. How to apply the intervention to achieve tendon adaptation is unknown. High number of asymptomatic tendons suggests that tendons can adapt to function. Thus, pain and tendon damage do not correlate very well. However, tendon pathology probably does not resolve by healing the pathology. Asymptomatic tendons do suggest that we should be more concerned about the function rather than structure. Whether an individual has symptomatic or asymptomatic tendon, it comes down to load capacity of the tendon. By going over the individuals load capacity you likely increase the risk for tendon pain. Tendon pain protocols work to increase capacity gradually. Resting as a mean to decrease pain is not the answer as tendon capacity will go down at the same time as pain goes away. Appropriate load management is important to maintain tendon adaptation/homeostasis. (Docking & Cook, 2019.)

2.4 Biomechanics

The knee joint is very resistant to external stress due to its passive and active stabilizers. It also has a large potential for wide range of motion. The compressive forces are distributed to the articular surfaces and tensile load is absorbed by ligaments and muscles. Correct kinematics in the knee joint load the joint evenly and may prevent compartmental overload which could lead do degenerative changes in the joint. Knee joint has two main movements which are extension and flexion. Full range of motion is about 0 ° to 140 ° depending on the individual and activity. Flexion of the knee joint however includes two different movements to reach the potential of 140 °. Those movements are rolling and sliding over the tibial plate. The combined movement maximizes the range of motion with providing sufficient stability in the knee. The knee joint also rotates internal and external, foot going in and foot moving out. During knee flexion, the femoral condyles internally rotate on the tibial plate which causes slight internal rotation of tibia. Vice versa, during knee extension, there is a small amount of external rotation of the tibia. However, the rotations are in fact much more complex because there is no axis or center of rotation during flexion/extension but rather a semicircular curve in the plane of the femoral condyles. (Affatato, 2015.)

3 BASKETBALL

3.1 Movement in the sport

From the total amount of play, about 45% is short to moderate length bouts of effort (0-20 seconds), continuing with a break of less intense work. About 40% of the time movement is unconventional such as backwards running or defending which is lateral shuffling or running. From the time of efforts during the game, about 10-20% is high intensity. (Sakselin, 2019, pp. 20-22; Forssell, 2016, pp. 12-18.)

Basketball requires many kinds of physical abilities from the athlete such as a high level of maximum strength, speed strength, agility, and low levels of bodyfat. Also, maximal oxygen uptake must be at a sufficient level to guarantee for enough recovery between the burst of activity during the sport. About 40-50 ml/kg/min is considered sufficient. The players usually have a more favorable anthropometry. Basketball athletes are typically taller individuals. It is important to note that the difference in player position effects on the required physical capabilities. Shorter players and guard positions usually run more in higher intensity and the bigger players like forward and center positions usually jump and have more contact situations with other players. (Sakselin, 2019, pp. 20-22; Forssell, 2016, pp. 12-18.)

3.2 Jumping

The athletes are using both one- and two footed jumps during the game multiple times. In terms of knee stress, it is not clear which one is more demanding, since one-footed jumps are highly elastic and use larger joint angles in the hip and knee. The contact time of a one-footed jump is faster, decreasing time under tension, compared to two-foot jumps. The forces on the muscles and tendons are also higher in the one-foot jump. (Vint and Hinrichs, 1996.)

The findings of a 2018 study suggest that the increased takeoff velocity and running speed in one-foot jumps, increases the stiffness of the lower extremity and creating a higher impulse thus creating a more forceful stretch shortening cycle (Tai, Wang & Peng, 2018).

3.3 Landings

Landings with high impact forces have been associated with multiple sports injuries such as ankle ligament sprains, patellar tendon injuries and Anterior cruciate ligament ruptures. Landing task begins when the athlete first contacts the ground and continues until the center of mass of the athlete stops going downwards. At this moment, the momentum is zero. There are studies about landing biomechanics, but the research focuses on tasks that are measurable and can be standardized for example drop landings from a set height. Drop landings rarely happen in sport in a controlled fashion and thus the studies do not have very much transfer to sport. In sport there occurs both one- and two-foot landings and most probably the athlete has another task after the landing such as a another jump right after the foot ground contact and time spent on ground, absorption of force and joint angles are much less than in a biomechanical study in a laboratory. (Joyce & Lewindon, 2016.)

3.4 Change of direction

Basketball requires great levels of agility and change of direction ability to be able to move efficient and quick. Athletes have multiple changes of direction during the basketball game. To achieve good agility, requirements for the athlete are good leg strength, coordination, balance, and sufficient footwork. Elite men and female athletes have been shown to change their movement style every 1-3 seconds. (Sugiyama, Maeo, Kurihara, Kanehisa, & Isaka, 2021.) There have been reported over 1000 changes of movement during one competitive game. The changes of direction are most often also reactive and not planned by the athlete beforehand such as reacting to a opponents move. (Ben Abdelkrim, El Fazaa, El Ati, & Tabka, 2007.) Basketball involves a lot of curvilinear running in situations such as trying to get past a defender (Velocity Sport Performance, 2020).

4 OVERUSE INJURIES OF THE KNEE

4.1 Overuse injuries in the anterior knee

Jumping athletes such as basketball players experience anterior knee pain (AKP) and it is usually due to either patellofemoral pain (PFP) or patellar tendinopathy (PT). However, it is challenging to diagnose which one is the cause of pain. Players have frequent reports of AKP, but the pain presentation in the knee is often diffuse. Pain mapping can thus be useful to differentiate. The demands of basketball physically require different qualities from the athlete such as repeated jumping, landing and multidirectional movement. The required qualities place high loads on the anterior knee and its structures. Injury epidemiology studies typically measure time-loss to dictate how much injuries effect on large amounts of people. Thus, players who suffer from PFP and PT are not registered to the studies, because many players continue their activity with symptoms. PFP and PT get provoked quite similarly, the diagnosis should possibly start using less of yes or no type of testing to get an idea which of the conditions is at hand. Findings in recent studies suggest that jumper’s knee (PT) is not the primary cause of knee pain in elite jumping athletes. (Hannington et al., 2021.)

Self-reported patellar tendinopathy in elite men athletes was studied and they found out that the pain location was not consistent between the reports. The study used focal and load related pain as definition of patellar tendinopathy and found that the PT was not common in the study. They concluded that patellar tendon abnormality was common but did not correlate with symptoms. (Hannington, Docking, Cook, Edwards, & Rio, 2020.)

4.2 Patellar tendinopathy (PT)

Patellar tendinopathy also known as patellar tendinitis or Jumper’s knee is a typical form of overuse injury. It often occurs in jumping athletes for example basketball, volleyball, high jump, tennis, and football. Similarity between the sports is repetitive loading. Typical characteristics are load related and localized pain in the inferior pole of patella. (Malliaras, Cook, Purdam, & Rio, 2015.) Cook & Purdam's (2009) model describes PT as a continuum. First phase is reactive tendinopathy which typically results from a spike of tendon overload, something that often results from not being used to a form of certain exercise. Second phase is called Tendon Dysrepair. At this phase there is an attempt to heal tendon pathology. This phase is typically seen in chronic overload of the tendon. Tendon matrix might be disorganized, and increased vascularization and neural ingrowth can be seen. Third phase is called degenerative tendinopathy. Areas of cell death can be seen with imaging. Tendon matrix has large areas of lack of collagen and increase of vessels. Typically, degeneration can be seen in a more mature person. Pain can be present or absent at any stage.

PT is a maladaptive response to tendon overload. Typically, a high spike in tendon load increases the risk. This type of spike could result from for example a high intensity & high-volume plyometric session performed early in the pre-season. It is a common lower leg injury. Up to 45% of elite jumping athletes such as basketball & volleyball players suffer from PT. One downside athletes suffer, is staying away from their sport. Another is a decrease in athlete's performance and due to these two factors decrease in health benefits gained from physical activity. The cause-effect relationship and pathogenesis of the patellar tendinopathy is still unknown. (Breda et al., 2021.) Athletes with patellar tendinopathy are typically avoiding the tendon load by going through less knee flexion on their jump landings (Pietrosimone et al., 2021).

A well-known significant extrinsic risk factor for especially patellar tendinopathy is repetitive overuse with inadequate recovery time (Maciel Rabello, Zwerver, Stewart, van den Akker-Scheek & Brink, 2019). Another widely agreed risk factor is competing in a jumping sport like basketball or volleyball. Correlations have been made from training load and hard training surfaces. Intrinsic risk factors have been studied quite a lot but there have not been made any consistent correlations with patellar tendinopathy. Quadricep, hamstring and hip range of motion and a knee joint angle during landing have been used as predictors of non-symptomatic tendon abnormality with meaningful results. Quadricep weakness has also been associated with PT. (Laver et al., 2020, pp. 423-426.) Stiffer tendon has been reported to correlate with better performance in movements such as jumping and running. Interestingly, increased stiffness is also associated with higher risk of injury. (Tapio & Vilén, 2020, p. 77.)

4.3 Patellofemoral pain syndrome (PFPS)

Patellofemoral pain syndrome is also known as patellofemoral syndrome or runner's knee, retropatellar pain syndrome, lateral facet compression syndrome or idiopathic anterior knee pain. It is one of the most common causes of anterior knee pain. PFPS is described to be diagnosis after excluding other diagnosis in intra-articular or peripatellar pathologies. The pain is usually located around or behind the patella during loading activities such as squatting, stair ambulation and running. Symptoms are often triggered after long periods of sitting or after stress to the knee joint such as flexing the knee joint. (Bump & Lewis, 2021, p. 1; Collins et al., 2018.)

A well-known risk factor is spike in loading. Rapid increase in volume, duration, and pace in running often results in symptoms. Other intrinsic risk factors stated in the literature are quadricep and gluteus muscle weakness, hamstrings and iliopsoas tightness, and patellar malalignment. Flexibility of the calf and quadricep muscles have also been associated with developing knee pain. (Ramklass, Kunene, & Taukobong, 2018.) The research states that the VMO muscle of the quadriceps is the risk factor, but other studies have shown that the muscle cannot be isolated, so it does not offer very much of practical implication for clinical practice (Mirzabeigi, Jordan, Gronley, Rockowitz, & Perry, 1999). Patellar malalignment and suboptimal patellar tracking in the patellar groove have previously been stated as the reason for pain in the PFPS (Walker, 2014, p.198). Recent studies however show that healthy knees have a big variety of different patellar alignments (Hochreiter et al., 2020). Risk factors and treatment recommendations can be seen on the Table 2 below.

Table 2. Risk factor chart (Bosshardt, Ray, & Sherman, 2021)

Risk factor/Cause	Treatment guidelines
Hip muscle/ Hip abductor weakness	Hip strengthening

Quadriceps weakness	Quadriceps strengthening, blood flow restriction
Delayed VMO activation	Biofeedback
Patellar maltracking or hypermobility	Patellar taping or bracing
Foot overpronation	Core foot strengthening and foot orthosis
Soft tissue inflexibility	Stretching, manual soft tissue therapy
Overtraining	Load management, return to activity plan
Gait deviations	Gait retraining
Non-physical -fear avoidance and catastrophizing	Address beliefs towards pain, unmet expectations, patient engagement

4.4 Management strategies

Management of previously mentioned conditions have general guidelines of treatment strategies. Patellofemoral pain syndrome (PFPS) has 4 different guidelines according to 2021 study. One guideline considered as higher quality, includes examination, interventions, and evaluation processes to assess the effectiveness of interventions. Consistently recommended interventions were exercise therapy (Combining hip and knee exercises were considered better than knee exercises alone), foot orthoses, patellar taping, patient education, and combined interventions. Two of the guidelines which were considered as higher quality did not recommend dry needling, patellar bracing and/or manual therapy in isolation. Interestingly the review also states that clinical physiotherapy management of PFPS may be conflicting with the recommended guidelines. Indicating that clinicians have very different views and approaches. Higher quality studies are still needed. (Wallis, Roddy, Bottrell, Parslow, & Taylor, 2021.) Exercise therapy prescribed has a lot of variances due to the research lacking in reporting prescription. 2018 study assessed frequently missing elements in RTC studies and found that exercise prescription is poorly reported in RTC studies. (Holden, Rathleff, Jensen, & Barton, 2018.) Thus, the reader might ask how can we implement evidence-based exercise therapy? However promising results have been shown with activity modification and load management alone in adolescent (10-14yo) population. (Rathleff et al., 2019.)

Patellar Tendinopathy (PT) treatment can require a lot of time and still be ineffective. The management is thought to be ineffective, due to limited knowledge about the how the condition develops, not understanding the risk factors and the limitation of effective treatment provided. The protocols of PT management are often evidence-based but the evidence is retrieved from other tendinopathies than patellar or quad tendon. There are differences between tendons around the body in their structure and function and it may influence on the optimal management strategies between different tendons. It is thought that the tendinopathy may not ever resolve but the symptoms can be managed quite well. Treatment strategy starts with load management. Active intervention is usually a progressive resistance exercise program, followed with power exercise to work the capacity in the stretch-shortening cycle and return to sport. Active tendinopathy management protocols usually follow the similar principles as listed in Table 3. Some of the treatments seek a short-term quick solution to the problem but it usually stems from false understanding of the pathology and often, the rehabilitation fails. (Cook, Khan, & Purdam, 2001; Rudavsky & Cook, 2014.)

Table 3. Tendinopathy management (Malliaras, Cook, Purdam, & Rio, 2015; Rudavsky & Cook, 2014)

1. Sustained isometric contractions have been shown to have an analgesic effect for about 2 to 8 hours. Dosing is 70% of maximal contraction from 45-60 seconds for 4 times. Isometrics have been shown to decrease pain in-season, where the sport specific exercise is consistent. (van Ark et al., 2016)
2. Isotonic heavy slow resistance training, such as leg extension/press, 6-8 repetitions x 4 sets, 3-5 times per week.
3.Functional strengthening to be more specific with movement patterns, such as walking lunge weighted or bodyweight, stair walking.
4. Progressing to higher intent exercises to increase the speed of the reps to train for power. Exercises such as split squat or stair walking faster.

5. Energy storage and release, which would include gradual progression of plyometric exercise, such as jumping, deceleration and change of direction or sport specific exercises with graded intensities and volumes.
6. Maintenance, which includes management of symptoms and prevention of flare ups. This could include continuing to perform the leg extension exercise, addressing load management and work their flexibility and strength deficits if there are some typically in calf or gluteal area.

There have also been positive outcomes with adding specific supplementation of 15g gelatin and 225 mg vitamin C before training sessions as it has been shown to increase collagen synthesis. The study was done on an elite 21-year-old NBA player. Supplementation could in theory offer an added benefit to the active rehabilitation protocol. (Baar, 2019.) However, as mentioned in the previous chapter, Tendinopathy pathology might not ever resolve but symptoms can be managed, which is conflicting to the other research and thus supplementation probably offers little to no benefit. (Malliaras, Cook, Purdam, & Rio, 2015; Rudavsky & Cook, 2014; van Ark et al., 2016.)

5 INJURY PREVENTION

5.1 What is injury prevention

Injury prevention aims to decrease the number of injuries. However, it is a slightly misleading term as injuries cannot be prevented but rather the risk of injury can be reduced. We have strong evidence that physical activity does reduce mortality. Physical activity on the other hand, introduces the risk of injury. Depending on the activity, we have certain demands and risks. Injury prevention has been growing and we now have a lot of prevention programs with the goal of decrease the risk of injuries people experience. (Spinelli, 2020.)

5.2 Levels of prevention

Primary prevention targets the initial event/accident. In many instances this is not possible because accidents, injuries and events are not predictable. Primary prevention thus tries to prevent the injury before it occurs. Secondary prevention targets to decrease the impact and severity of the injury after it has occurred. Detecting and providing an intervention to an injury as early as possible is one of the key factors. Encouraging personal strategies to decrease the risk of reinjury and returning people to their original health/condition. Prevention has a third level of tertiary prevention. It means managing with the symptoms with a problem which has already occurred. Typically, a serious medical condition that leaves some long term affects, which are managed during tertiary prevention. (Institute for Work & Health, 2015; Pless, 2005.)

5.3 Risk factors

To successfully implement an injury prevention strategy, one must screen for risk factors. There are general and individual risk factors associated. Next, important to notice that injuries can be caused by overload or trauma. Generally, the injury risk increases when the capacity of the player is not enough for the demand of the applied load. That is why the loading of the player (general), and the physical and psychological deficits (individual) characteristics must be assessed. (Laver et al., 2020, pp. 658-659.) It is important to note that, we have strong evidence in psychosocial factors affecting on injuries and that interventions focusing on the psychological factors have been shown to decrease injuries. (Ivarsson et al., 2017.)

Optimal balance of recovery and training is the key to progress without increasing injury risk. Another aspect is external loading i.e., training load. Loading can be also internal. Internal loads can be for example sleep, heart rate, perception of exercise and psychological well-being. As loading is important, factored tools to monitor the combined internal and external loading have been developed. Simple way of assessing athletes rate of perceived exertion (sRPE) is to ask them after training how hard the training was and rate it 1-10. (Laver et al., 2020, pp. 658-659.) ’’Injury prevention programmes could be more effective if greater responsibility over workload regulation was given to athletes themselves. The development of this responsibility should start at an early age, and so pedagogical tools should be created for this purpose.'' (Pol, Hristovski, Medina, & Balague, 2019.)

One of the biggest risk factors is previous injury. A soft tissue injury might have healed, and the pain subsided, but the area of injury has not yet fully regained its strength and capacity needed for sport. For elite players the loading on the court, accumulated fatigue with minutes played compared to recovery and the years of playing in elite level were considered as risk factors. For youth athletes, growth can make tissues vulnerable for injuries. Anatomical and physiological factors should be considered, and Muscle strength and flexibility can play a role as well. Biomechanics should be identified in the sport-specific movements: jumping, landing, chance of direction. (Laver et al., 2020, pp. 658-659.

5.4 Dynamical systems approach

Fairly recent approach has been implemented to understand sports injuries and their complexity. Dynamic systems theory from mathematics has been used to explain injuries and help with rehabilitation and prevention. The approach theorizes, that sensitivity to a musculoskeletal systems injury is resulted from constraints that interact with each other dynamically at different levels and times. For example, A decrease in another muscle, forces another muscle to work more to complete the task, or a small increase in workload, which causes excessive fatigue. Fatigue and extra workload itself effects on many different levels such as strength and impairs motor coordination and the extra workload increases time thus the effect of fatigue multiplies. The risk factors themselves are thought of being insufficient to cause an injury but inciting event such as a motor action, player situation or opponent's behavioral might trigger the risk factor being causal to the injury. (Pol, Hristovski, Medina, & Balague, 2019.)

Variability of movement has been typically stated as bad, but it is important to dictate which kind of variability. End-point variability means how the result of such movement ends such as hitting the nail with a hammer and experts typically have less of end-point variability. Interestingly, coordinative variability, such as different body segments altering between others, has been shown to differ more in experienced movers. The study of dynamical systems approach states that increased biomechanical variability during movement may be functional and healthy and thus not overload specific tissues too much, theoretically decreasing the risk for overuse injuries. (Hamill, Palmer, & Van Emmerik, Richard E. A., 2012.) Movement quality itself does not show injury predictive value. Several studies are showing that movement quality testing such as FMS do not have valid predictability for injuries. (Coogan et al., 2020; Dorrel, Long, Shaffer, & Myer, 2018; Dorrel, Long, Shaffer, & Myer, 2015.)

A problem noticed with injury risk factors is the fact that there are several interactions between individuals risk factors which makes the etiology study of the injury very difficult. Adding to the intrinsic and extrinsic risk factors the inciting event and opponent behavior, the study of injury etiology gets even more complicated. It is difficult to make causal relationships of risk factors and injuries due to the lack of prospective data. (Hamill, Palmer, & Van Emmerik, Richard E. A., 2012.)

5.5 Prevention in basketball

Demands of basketball require many different movement qualities. Movements in vertical and frontal plane are a big part of basketball. Injury prevention programs should be more sport specific to basketball as these multidirectional movements also could have different risk factors and injury mechanisms. Specific basketball injury prevention programs are limited, and the prevention programs are prescribed generally to basketball, volleyball, and football players even though the sports have very different demands. (Taylor, Ford, Nguyen, Terry, & Hegedus, 2015.)

A meta-analysis testing preventive exercise program on female athletes showed to be effective in decreasing the risk of ACL injuries. This meta-analysis concluded that Plyometric and strengthening exercises were an essential part of these programs and balance training exercises were not. (Yoo et al., 2010.) Many of the sports studies have been made in football and one of the most popular and biggest studies in injury prevention was the FIFA 11+ program. The exercises selected have a small amount of balance training, but majority includes plyometric actions and strengthening of the relevant muscle groups. (Sadigursky et al., 2017.)

Neuromuscular interventions are appealing way of preventing injuries because of its easily appliable exercises that require limited equipment (Davis et al., 2020). A study assessing warmup-based program decreased the risk of injuries through scoring Landing errors (The Landing error scoring system). The study demonstrated a decrease in the LESS scores. Results were not statistically significant. The study was performed on female athletes in Division III. In the study they used a standardized 30cm box, 10 feet away from the landing spot and assessed the landings of the athletes. (Scholz, German, Miles, & Payne, 2020.) The landing-based studies have the issue mentioned in the Landings chapter. Landing in a study must be measurable and controlled thus not very sport specific which do not have a direct transfer to sport but provide value for studies. (Joyce & Lewindon, 2016, pp. 121-125.)

5.6 Strength training

Strength training has been proven to have multiple mechanisms to decrease injury risk in acute and overuse sports. It is also very safe way of exercise and results have been shown in multiple different populations. Neuromuscular training is effective but not to the extent as strength training programs. There are more and more good quality studies researching strength training. (Lauersen, Andersen, & Andersen, 2018.) For athletes a very important added benefit is that strength training as a mean to increase athletic performance is well known and documented in the literature (Mcguigan, Wright, & Fleck, 2012). Progressively improving strength training has numerous benefits including positive causations to health and wellbeing such as strengthening of the bones and connective tissue which decreases musculoskeletal injury risk, carbohydrate metabolism, and many other general health adaptations and positive effects on quality of life, mood, self-image, self-esteem, and self-efficacy. Important aspect when considering strength training as a tool to prevent injuries is to make sure total stress of training and other life is not higher than capacity to recover. Thus, it is important to optimize recovery, eating and sleep. (Rytkönen, 2018, p. 20, 41.)

6 AIM AND OBJECTIVES

Aim of the thesis is to help the readers, coaches and athletes gain knowledge about evidence-based methods of knee overuse injury prevention. A systematized literature review will be conducted to gather applicable methods from the literature to prevent overuse knee injuries in male basketball athletes (17-35yo). An exercise-based booklet will be made based on the systematized literature review for BC Sisu men's basketball team from Pori. Research question of my Thesis is "Which are the evidence-based methods to prevent overuse injuries of the knee in Basketball?"

7 THESIS PROCESS

The idea formulated from author's interest in the sport of basketball. After searching information about common injuries and typical problems athletes suffer from via literature, videos, podcasts, and own previous discussions with basketball athletes the topic started to narrow down to knee overuse injuries. Suitable organization for the thesis was found in Pori (Bc Sisu men's team) via personal contacts. Primary plan was to conduct a systematized literature review to learn and go through a systematic process to find out answers. After theory process, an idea of a small exercise-based booklet came up and thus the thesis will have a concrete product for the organization. Meeting with a librarian was held to go over search results, databases and to find a suitable search phrase. Schedule of the thesis is illustrated in Table 4. Main deadlines of the work being Thesis plan presentation December 10th, 2020, and Thesis presentation November 11th, 2020.

Table 4. Thesis process

Thesis idea & search for background information	August (2020) - November (2020)
Finding suitable thesis collaboration organization	August (2020) - November (2020)

Thesis Plan December 10th, 2020	November (2020) - February (2021)
Theoretical background	November (2020) - February (2021)
Carrying out the research about overuse injuries	February (2021) - August (2021)
Writing thesis	February (2021) - August (2021)
Thesis finalizing	August (2021) - November (2021)
Thesis presentation 11.11	August (2021) - November (2021)

8 SYSTEMATIZED LITERATURE REVIEW

This thesis will follow the format of a systematic literature review. However, because Systematic review has clearly defined guidelines which exceed the bachelor level and would require at least two authors, the format of this thesis will be systematized literature review. Systematized literature review is mimicking the format of a systematic review on one or more aspects but is not as thorough with the guidelines and literature search. Systematized literature review must follow strict guidelines. 5 Steps in a systematized literature review (Khan, Kunz, Kleijnen & Antes, 2003; Grant & Booth, 2009.)

Literature review should form a strict question which to follow. Like previously mentioned, research question of my thesis will be: “Which are the evidence-based methods to prevent overuse injuries of the knee?” (Khan, Kunz, Kleijnen & Antes, 2003.)

To form a structured question, modified PICO model will be used.
P=Population=Basketball player, male, 17-35
I=Intervention= Injury prevention
C=Comparison=Comparison group is not relevant to the research question
O=Outcome= Knee pain

The literature search should be thorough. The selected literature should also have inclusion and exclusion criteria. (Khan, Kunz, Kleijnen & Antes, 2003.)

After identifying relevant literature to be included the material must be assessed. PEDRO critical appraisal tool will be used to assess the literature. Material should have a rating 6/10 or higher to be included. (Khan, Kunz, Kleijnen & Antes, 2003.)

After Quality assessment there will be the included literature remaining that will be used in this thesis. The remaining literature must be then summarized together. (Khan, Kunz, Kleijnen & Antes, 2003.)

Concluding the findings is the last part. Summary of the evidence helps to determine if the conclusion can be trusted or not. The risks of different biases such as publication bias should be thought of and strengths and weaknesses of the evidence. (Khan, Kunz, Kleijnen & Antes, 2003.)

The search for literature was conducted through database PubMed. The search was conducted by using a search term phrase (“cumulative trauma disorders” [mesh] OR tendinopathy[mesh] OR “Patellofemoral Pain Syndrome”[mesh] OR “jumper’s knee”[tiab] OR overuse[tiab] OR cumulative[tiab]) AND (“Patellofemoral Joint”[mesh] OR “knee joint”[mesh] OR knee[mesh] OR “Patellar Ligament”[mesh] OR knee[tiab]) AND basketball[mesh]. Filters applied to the Pubmed database where studies not older than 2011 and studies concerning male athletes. The search phrase and terms are illustrated in Table 5.

Table 5. Search terms

PUBMED		
TERMS	AND	AND
''Cumulative trauma disorders'' [mesh]	''Patellofemoral Joint'' [mesh]	Basketball[mesh]
Tendinopathy[mesh]	''Knee joint'' [mesh]	
"Patellofemoral Pain Syndrome" [mesh]	Knee[mesh]	
"Jumper's knee" [tiab]	"Patellar Ligament" [mesh]	
Overuse [tiab]	Knee [tiab]	
Cumulative [tiab]		

The studies selected must follow criteria to be included in the systematized literature review. Inclusion and exclusion criteria are shown in Table 6. The studies assessed and their scores can be seen in Table 7. The Prisma flow chart was used to illustrate the research process, seen in Table 8.

Table 6. Inclusion criteria

Inclusion	Exclusion
2011 or newer	Older than 2011
Male 17-35yo Basketball athlete	Population outside of said range.
Studies including risk factors/injury prevention/rehabilitation	Studies focusing on different topics
Patellar tendinopathy or patellofemoral pain	Other conditions such as traumas
Randomized control trials, systematic reviews	Other study methodologies
Full text accessible	Full text inaccessible

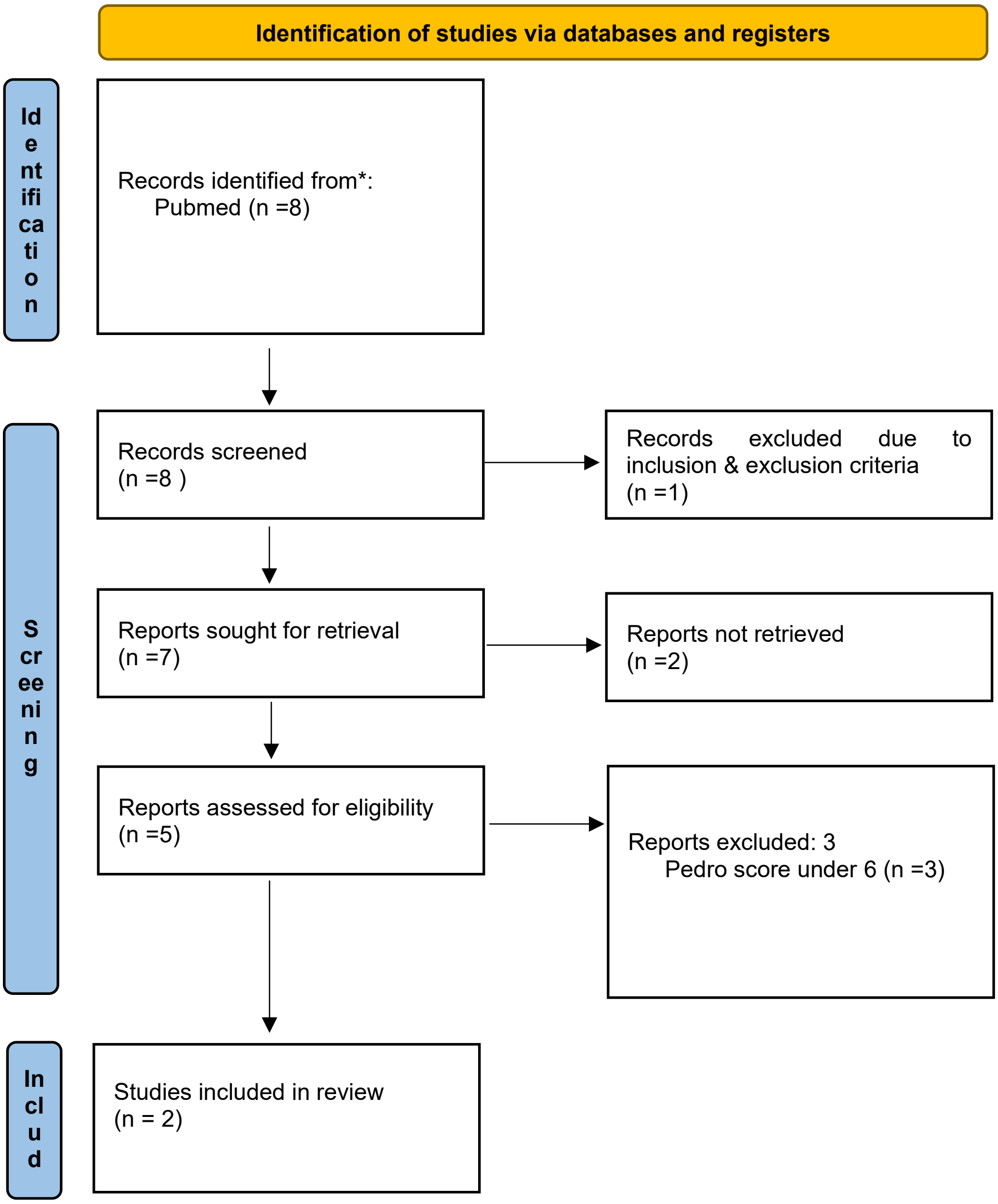
Pedro score 6 or higher	Pedro score 5 or lower

Table 7. Studies from the search and Pedro scores

1.	van Ark, M., Cook, J. L., Docking, S. I., Zwerver, J., Gaida, J. E., van den Akker-Scheek, I., & Rio, E. (2016). Do isometric and isotonic exercise programs reduce pain in athletes with patellar tendinopathy in-season? A randomised clinical trial. Journal of science and medicine in sport, 19(9), 702–706. https://doi.org/10.1016/j.jsams.2015.11.006	Pedro score 5/10
2.	Pearson, S. J., Stadler, S., Menz, H., Morrissey, D., Scott, I., Munteanu, S., & Malliaras, P. (2020). Immediate and Short-Term Effects of Short- and Long-Duration Isometric Contractions in Patellar Tendinopathy. Clinical journal of sport medicine: official journal of the Canadian Academy of Sport Medicine, 30(4), 335–340. https://doi.org/10.1097/JSM.0000000000000625	Pedro score - Unaccessible article
3.	Rio, E., van Ark, M., Docking, S., Moseley, G. L., Kidgell, D., Gaida, J. E., van den Akker-Scheek, I., Zwerver, J., & Cook, J. (2017). Isometric Contractions Are More Analgesic Than Isotonic Contractions for Patellar Tendon Pain: An In-Season Randomized Clinical Trial. Clinical journal of sport medicine: official journal of the Canadian Academy of Sport Medicine, 27(3), 253–259. https://doi.org/10.1097/JSM.0000000000000364	Pedro score 6/10
4.	van Ark, M., Rio, E., Cook, J., van den Akker-Scheek, I., Gaida, J. E., Zwerver, J., & Docking, S. (2018). Clinical Improvements Are Not Explained by Changes in Tendon Structure on Ultrasound Tissue Characterization After an Exercise Program for Patellar Tendinopathy. American journal of physical medicine & rehabilitation, 97(10), 708–714. https://doi.org/10.1097/PHM.0000000000000951	Pedro score -
5.	Gual, G., Fort-Vanmeerhaeghe, A., Romero-Rodríguez, D., & Tesch, P. A. (2016). Effects of In-Season Inertial Resistance Training With Eccentric Overload in a Sports Population at Risk for Patellar Tendinopathy. Journal of strength and conditioning research, 30(7), 1834–1842. https://doi.org/10.1519/JSC.0000000000001286	Pedro score 4/10

6.	Zhang, Z. J., Lee, W. C., & Fu, S. N. (2020). One Session of Extracorporeal Shockwave Therapy-Induced Modulation on Tendon Shear Modulus is Associated with Reduction in Pain. Journal of sports science & medicine, 19(2), 309–316.	Pedro score 5/10
7.	Zwerver, J., Hartgens, F., Verhagen, E., van der Worp, H., van den Akker-Scheek, I., & Diercks, R. L. (2011). No effect of extracorporeal shockwave therapy on patellar tendinopathy in jumping athletes during the competitive season: a randomized clinical trial. The American journal of sports medicine, 39(6), 1191–1199. https://doi.org/10.1177/0363546510395492	Pedro score 9/10
8.	Longo, U. G., Loppini, M., Berton, A., Marinozzi, A., Maffulli, N., & Denaro, V. (2012). The FIFA 11+ program is effective in preventing injuries in elite male basketball players: a cluster randomized controlled trial. The American journal of sports medicine, 40(5), 996–1005. https://doi.org/10.1177/0363546512438761	Pedro score 8/10

Table 8. The Prisma flow chart (Page et al., 2021)



9 RESULTS

The results of the studies are shown in Table 4. The studies are quite different in the sense that the second study focuses solely on prevention. Rio et all, 2017 is assessing if isometric and isotonic contractions reduce pain in season. The overuse knee injury (PT) pain rating can be reduced by isotonic and isometric contractions. Isometrics do offer a greater decrease in pain "(mean ± SD change = 1.8 ± 0.39) than it was for the isotonic group (0.9 ± 0.25)" As a form secondary prevention when pain is present both methods offer significant improvements in 4 weeks. No significant difference between the groups (P=0.99).

Longo et all, 2012 is focusing on primary prevention with a well-known prevention program FIFA 11+ implemented for basketball athletes. The study does show significant injury risk reduction. The study is focusing on strength, awareness, and neuromuscular control of static and dynamic movements. The method for decreasing overall injuries is to increase athletic capacity in athletes. The specific exercise program implemented can be seen in the table below. (Table 4.) The study showed significant reduction in overall injuries (0.95 vs 2.16; P = .0004).

Table 9. Studies included in the review & key points.

	Key points	Practical implication	Exercises
Rio et al., 2017	"Both protocols appear efficacious for in-season athletes to reduce pain, however, isometric contractions demonstrated significantly greater immediate analgesia throughout the 4-week trial. Greater analgesia may increase the ability to load or perform."	"Moreover, the contextual cues associated with "active" analgesia imply recovery, health, and capacity, whereas the contextual cues associated with "passive" analgesia, such as ice, imply tissue damage and inflammation. Such cues are potentially powerful modulators of subsequent behavioral choices (e.g., increased	Exercise protocol 5 × 45 s single leg isometric contractions of each leg on a leg extension machine. Isometric contractions were performed at 80% of maximal voluntary contraction with a knee joint angle of 60 OR

		participation in rehabilitation), as well as pain" Active analgesia offers also benefits to the musculoskeletal system (quadricep architecture and tendon properties)	4x8 repetitions of single leg isotonic contractions of each leg on a leg extension machine. Isotonic contractions consisted of a 3-s concentric phase immediately followed by a 4-s eccentric phase and were performed on 80% of 8 repetitions maximum.
Longo et all. 2012	"The FIFA 11 warm-up program is effective in reducing the rates of injuries in elite male basketball players."	"As suggested for soccer, programs to improve strength, awareness, and neuromuscular control of static and dynamic movements should be implemented as soon as children start playing organized basketball."	Running exercise 8min Strength, plyometrics and balance 15min. Running exercises, 1min, 40 seconds

10 CONCLUSION

Fifa 11+ Program is effective in reducing injury rates in elite male basketball athletes. Reductions in pain in-season, can be made through isometric or isotonic exercise without modification in training load. Isometric contractions offer more immediate analgesia.

11 EXERCISE TEMPLATE

Theory part of thesis brought ideas for injury risk reduction by assessing and treating extrinsic and intrinsic risk factors, developing athletic capacity, and optimizing recovery to make an athlete more resilient to injuries. Product of the thesis will be taking parts of the systematized literature review and the literature search to conduct a simple exercise-based guide to injury risk reduction. Guide will have a minimalistic approach due to the training load from playing basketball and the exercises will target the main intrinsic risk factors and movements for basketball. Guide could be used off-season if basketball is present during this time.

The Program is based on current literature for general population. Optimal programming or injury prevention/performance programs are individual to athletes. As a standalone exercise program, there is limited volume, thus it would be best to seek help from a professional to optimize training program for performance and injury risk reduction.

The exercises chosen, have a similar “level” system as the FIFA 11+ program to find an exercise optimal for the individual. However optimal use of the program is not intended as a warmup but rather as a separate weekly training regimen because strength part might need equipment. Control, plyometric and sprinting exercises can be used during basketball practice warmup. Exercises are chosen to involve each part of movement control/balance, plyometric, strength, flexibility, and sprinting part and are targeting the potential risk factors of overuse knee injuries.

Before performing exercises, a proper warmup should be carried out which could be for example working sport specific skills. Further information provided in the booklet and the specifics of the program such as reps/sets & video instructions will not be documented as the booklet will be author's content, shared with the basketball team. Exercises are shown in Table 10.

Table 10. Exercise program layout

Exercise program	Level 1	Level 2	Level 3
Single leg control	Ball rotation around leg, waist, head	Passing with partner	Testing partner (dribbling)
Plyometric	Counter movement jumps	Repeated broad jumps	Repeated one-foot jumps
Sprinting	Acceleration	Max velocity	Curved sprinting
Strength	Goblet squat	Barbell squat	Barbell split squat
Strength/flexibility	Sliding Hip bridge	Nordic Hamstring curl	Barbell Romanian deadlift
Strength	Calf raises	Single leg calf raises	Weighted calf raises

12 DISCUSSION

The aim of the thesis was to provide information about knee overuse injuries for readers and create an exercise-based booklet for a basketball team based on a systematized literature review. The studies which have passed the authors exclusion criteria for the literature review unfortunately have limited number of practical implications. The studies assessing knee overuse injuries for basketball players are mainly concerning specifically patellar tendinopathy. However, they are mainly assessing secondary prevention or rehabilitation of patellar tendinopathy. There was only one study with specific search terms about prevention of injuries in general and it was the Fifa 11+ program study implemented for basketball players. The other study that has passed the selection process (Rio et all, 2017) focused on decreasing pain. The study had limited participants which increased the risk of statistical error. However as both groups in had significant results, both methods could be used clinically for pain relief.

In the systematized search there was limited number of studies (8 studies). Different searches and databases could have been used to find more results. Author was also considering using volleyball players as addition due to them having somewhat similar prevalence of anterior knee pain and the sport including jumping. However, because volleyball and basketball are very much different because there is more unconventional movement and player contact in basketball, author decided to leave volleyball athletes out of the search. The evidence was quite limited to prevention of overuse knee injuries and basketball athletes.

Information for theory background was searched via multiple sources and most of the source's trace back to the same research and protocols. Author did try to be objective with results. Unconscious Bias could have occurred in the theory part as search for the relevant topics was not systematized. Due to lack of results, heterogeneous data can be seen. The studies are reflecting on different aspects, primary and secondary prevention. However, this is a positive finding for the product of the thesis as it offers more variability to the evidence behind the product. The search terms are documented in the thesis, and it would be interesting to see in few years if there are more results as basketball as a sport gets more popular, researchers collect more data and learn more about the pathology of tendinopathy and patellofemoral pain.

As mentioned before, the prevalence of patellar tendinopathy has been studied during recent years to evaluate if there is as much PT as previously thought. Results have shown that there is in fact less PT and more patellofemoral pain syndrome type of problems. No findings of studies relating prevention of patellar tendinopathy or patellofemoral pain syndrome in basketball athletes with authors resources. Due to the recent prevalence studies, in the future, there will probably be more studies concerning other anterior knee pain issues than patellar tendinopathy. In the future more practical implications can be made for basketball players. The small amount of Patellar tendinopathy prevalence creates a dilemma for the number of studies concerning Patellar tendinopathy.

For clinicians' differentiation and further studies are important because PT and PFPS have very different rehabilitation and prevention protocols. It seems to the author that if an athlete has "suboptimal/weak" patellofemoral joint they will have an increased risk of PFPS treatment will include more general strength training and load management. If an athlete has strong and well controlled patellofemoral joint, they will be able to put more forces through the patellar tendon which places a risk for PT. Intervention aims to maintain the structure and abilities of athlete, however load management is the main concern.

As discussed in section 5 Injury, the prevention concept itself is very hard to put into practice. Having a higher or lower risk of injury does not mean a person will or will not face injury. Thus, it is somewhat understandable that there are not that many studies about the concept. The complex topic of dynamical systems approach somewhat describes the difficulty of injury prevention. As what discussed in section 5.4, the human body is smart and regulates via nervous system the coordination of the skeletal muscles to produce movement different ways. Variance is healthy and may be protective. Risk factors get generally triggered by incident event to be causal to injuries. Injuries are not simple, even if data suggest decrease in the number of acute or overuse injuries. As what was mentioned in the previous chapter the absence of a different risk factor creates another risk factor. For example, when the patellofemoral joint is strong enough to overload the patellar tendon. The relationship between risk factors is always dynamic. What we do know for sure is that participation in sport is healthy, but it does include risks for injury. The number of injuries can decrease with prevention programs and strength training.

Author thinks that in this prevention era, we should also have the tools and readiness for the injury to happen and help athlete manage with their injury. In a perfect world, injuries do not exist but in the real world, injuries can be viewed as a time to recover from excessive fatigue, work on weaknesses or sport skills. During my thesis process, the uncertainty in primary prevention, unknowns in the overuse injuries and limitations in studies in basketball athletes limit the results for primary prevention. Secondary prevention would have been more relevant topic due to the previously mentioned factors. However, author feels that the exercise booklet made based on the thesis is going to be very helpful for enhancing basketball players resilience and performance especially in a recreational level.

Suggestion for further research project would be rehabilitation of the overuse knee injuries in basketball athletes. As what discussed in the thesis, the two types of overuse injuries are very different, and have a very different management strategy. Thus, it would be very important for clinicians and readers to understand how to differentiate the two and offer evidence-based rehabilitation for athletes in both conditions. Primary prevention of overuse injuries in authors opinion is mainly about proper load management, making athletes more resilient and to increase their structural capacity. Secondary prevention should be included, as every athlete will suffer pains and injuries throughout their career. Thus, managing with pain is important. Another suggestion for future would be to test the exercise program shown in Table 10. and assess if it decreases the number of injuries in Basketball athletes. However, statistics of injuries are hard to measure thus for example testing the performance of athletes could be measured as better performance indirectly indicates better resilience of the athletes

Even though the systematized literature review did not give as many practical implications and the results were limited, I feel like I reached my aim of providing readers with information about overuse knee injuries and prevention. In the thesis, readers can find many interesting evidence-based concepts and information about the problems affecting the knee will provide great knowledge for clinicians and coaches dealing with basketball or other jumping athletes. In my opinion, training and primary prevention should be viewed in the same perspective. There should not exist a specific prevention program or a specific performance program, but the training program should focus on both with the goal of making athletes durable and athletic.

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