Riina Varjokari

TRAINING YOUNG SKATERS FOR HEALTHIER CAREERS - PRIMARY PREVENTION EXERCISE PROGRAM OF KNEE OVERUSE INJURIES FOR 9-10-YEAR-OLD FEMALE SKATERS

Degree Programme in Physiotherapy
2019

samk
Satakunnan ammattikorkeakoulu
Satakunta University of Applied Sciences

TRAINING YOUNG SKATERS FOR HEALTHIER CAREERS - PRIMARY PREVENTION EXERCISE PROGRAM OF KNEE OVERUSE INJURIES FOR 9-10-YEAR-OLD FEMALE SKATERS

Varjokari, Riina
Satakunnan ammattikorkeakoulu, Satakunta University of Applied Sciences
Degree Programme in Physiotherapy
December 2019
Number of pages: 33
Appendices: 2

Keywords: knee overuse injury, primary prevention, exercise, figure skating

---

The purpose of this thesis was to collect theoretical knowledge regarding and knee overuse injuries among figure skating and create an exercise program for primary prevention to coaches use. This thesis was done in collaboration with Porin Taitoluistelu ry targeting 9-10-year-old female skaters. Exercises chosen for this program was selected based on the scientific literature and physical demands of the sport.

Research has shown that overuse injuries are sustained in figure skating especially among young single skaters. It was found that lower extremities and back are predominantly the most injured areas of the body. Findings in the literature showed that like in other jumping related sports, patellofemoral pain, Osgood-Schlatter disease and patellar tendinopathy are the most frequent overuse injuries in single skating.

Coaches have an important role in primary prevention, since it should be started from the early ages for the best result. Basic knowledge regarding risk factors and injury mechanisms should be understand by coaches regardless the sport. If attention was paid earlier, many overuse injuries could have been preventable.

Highlighting the key points for primary prevention, this thesis examines physical demands of the sport, anatomy of the knee, and growth development of 9-10-year-old females. With the scientific knowledge and proper tools coaches have the ability to decrease potential overuse injuries and promote the well-being of their athletes.

CONTENTS

1 INTRODUCTION

In the past few years the difficulty of figure skating has developed remarkable likewise physical requirements of the sport (Mero, Nummela, Kalaja, Häkkinen 2016, 334.). Therefore, it is necessary taking into consideration proper technique, smart training methods and prevention of injuries to maintain your body healthy.

Competitive sports are performed at different levels, at the top of the performance pyramid stands elite young athletes. Sporting federations around the world organizes youth competitions for athletes starting as low as under 13 years old depending on the sport. (Sabato, Walch, Cain 2016, 99.) The youngest skaters competing at the ISU events (Internation Skating Union) have only reached the age of 10 (ISU Communication 2242, 1.).

Finnish skating clubs are divided into seven different regions around Finland. There are approximately 80 operating clubs that offer skating lessons from beginners in skating school to internationally competitive skaters. In most cases practice groups are organized based on the skill level and the age of the skaters. In Finland, there are close to 8000 skaters competing at 16 different levels in figure skating. (Website of Finnish Figure Skating Association) Competitive career usually starts at regional level which means that the competitions are held close to their hometown. As the skater's skills develop the competition level may advance to national level. To be able to compete at national level skaters need to pass skill tests required to the level they are aiming to compete. (Website of Skating Finland, 2018)

In figure skating overuse injuries are more sustained among young figure skaters than acute injuries (Kowalczyk, Gemignani, Dahlberg, Micheli, Sugimoto 2019, 8.). When offering the right tools for the coaches to work with it evidently helps them identifying potential injuries and consciously take it into account when planning exercises.

This thesis is done in collaboration with Porin Taitoluistelu ry. There are currently over 100 skaters representing this club in international, national and regional level. It

is possible to take part in figure skating and skating school. In PoriTa 9 to 10-year-old figure skaters already exercises five to six times a week on-ice practice as well as off-ice practice, in addition competitions and camps. (Website of Porin Taitoluistelu ry.)

This thesis consists of written theory part and exercise guide. Theory part includes information regarding physical demands of the sport, anatomy of the knee joint, overuse injuries related to figure skating, primary prevention, and growth development based on literature. Exercises for the guide will be based on scientific sources and literature. Exercises are chosen according to the specific sport and the physical demands.

2 THE AIM AND OBJECTIVES OF THE THESIS

The aim of this thesis is to gather knowledge and evidence regarding overuse injuries of the knee related to figure skating and to produce an exercise guide for coaches in Porin Taitoluistelu Ry.

The objective of this exercise guide is to provide exercises supporting the primary prevention of the overuse injuries for young female figure skaters at ages 9 to 10. These exercises help coaches to diminish potential injuries and consequently build a more stable knee to increase performance capacity. In addition, knowledge regarding biopsychosocial growth development concerning to this age group will be presented in this thesis.

3 PHYSICAL DEMANDS OF FIGURE SKATING

Figure skating is a versatile sport, where physical qualities meet artistic performance interpret to music. Technical skills, skating skills and presentation related components are evaluated in figure skating. All technical elements such as jumps, and spins have a base value which can be elevated by complexity and with high quality. High quality

elements consist of pretentious physicality, difficulty of the element's variations and originality. (Mero et al. 2016, 334.)

Broadly the sport has been considered as a demanding and elite sports which should be started already at young age. Skaters who aim for competitive career start sport specific practicing regularly, commonly at the age of five. Besides sport specific training on ice, skaters also include other off-ice trainings such as ballet, endurance, strength, and flexibility. (Lipetz & Kruse 2000,1.) Early specialization in figure skating, increases the odds for excelling to the elite level. The stage of recommended sport specialization in figure skating is early adolescence (Myer, Jayanthi, DiFiori, Faigenbaum, Kiefer, Logerstedt, Micheli 2016, 66-68.). Single sport that involves intensive year-round training excluding other sports is considered as sports specialization (DiFiori, Benjamin, Brenner, Gregory, Jayanthi, Landry, Luke 2014, 2.). "The athlete must bring tremendous strength and endurance to her sport to create the effortless artistry that we have come to appreciate in this dynamic and growing sport." (Lipetz & Kruse 2000,1.)

On weekly basis young skaters from ages 7-9 practice already 5 to 8 times on ice and 3 to 5 times off ice. Sport skill training emphasizes fluent basic skating skills including diverse practising of footwork and deep edges, single and double jumps and basic spin positions with change of foot and flying entrance. Working on interpretation and expression of music becomes essential part of training since most of these young skaters start their competitive career at this point. Therefore, practicing personal competitive programs is necessary during competition season. (Mero et al. 2016, 339.)

Even though figure skating is thought of being a diverse sport, to learn the pretentious jumps and spins a skater needs considerable amount of repetitions which includes rotational movement mainly to one direction only (Website of Terveystalo, 2013). Practising rotational features and figure skating jumps on dry land plays major role in the off-ice program. Besides sport specific training, motor skills and coordinative skills are practiced in various ways. (Mero et al. 2016, 339.)

To be able to perform demanding figure skating elements with good quality, skaters need to be physically fast, strong and flexible (Mero et al. 2016, 334.). The competitive

performance in figure skating for skaters from the ages of 7 to 9 consist of only free program skating. Duration of the free program varies from 2 minutes to 3 minutes depending on the competitive level of the skater. (Single skating requirements 2019-2020, 11-14.)

3.1 Endurance features

When performing programs during competition season the significance of endurance increases. The performance in single skating designated as interval type due the variety of elements from explosive jumps to pretentious spirals together with alternation of speed and direction. (Mero et al. 2016, 334.) As an example, Springs A level free program consist of 8 elements including jumps, spins and step sequence lasting 2,5 minutes +/- 10 seconds (Single skating regulation 2019-2020, 12).

Endurance training can be divided into aerobic and anaerobic exercise. When exercising occurs at low and steady pace the needed energy for the performance is produced with oxygen aerobically. Exercise that occurs at high speed and intensity the aerobic energy production system is uncapable of producing the needed energy completely. This is the threshold for anaerobic exercising where among other things body's lactate concentration increases and breathing changes. (Mero, Uusitalo, Hiiloskorpi, Nummela, Häkkinen 2012, 138.)

During figure skating program the heart rate of the skater increases near maximum within the first minute and lasts there for the rest of the performance. While the program proceeds lactate accumulates to the muscles which might easily lead to failing in elements as the speed and performance precision decreases. Mostly the difficult elements are situated in the beginning of the program when the immediate energy sources (adenosine triphosphate=ATP and phosphocreatine=PC) are still available. Towards the end of the performance the significance of maximal oxygen intake and aerobic processes increases. The endurance requires for a figure skating program are good anaerobic capacity for tolerance of tiredness and economic movement and good anaerobic power endurance for explosive movements. (Mero et al. 2016, 335-336.) For this

reason, it is essential for figure skaters to have special endurance and well-developed muscular system (Kugayevskiy 2013, 1.).

3.2 Strength and power features

Highest level of force accomplished during muscular contraction is defined as maximal power (Cormien, McGuigan, Newton 2011, 18.). Generic movements such as running, jumping, throwing require neuromuscular systems ability to produce explosive power and coordination of different muscle groups. When aiming to maximize the velocity of the movement or force production it is crucial how much force individuals are able to produce as fast as one can. Uniting elements in competition program requires speed and skills including spins that demands quick transitioning in positions with acceleration of speed and steps occasionally requiring extremely fast footwork and changes of direction. Take-offs in jumps emphasizes explosive power and velocity where the skater needs combine explosiveness of the take-off to rapid closing of the limbs to cross-legged air position. Adequate muscular strength is needed for the jump landing as the skater faces approximately seven times their body weight of "collision" force when contacting the ice. (Mero et al. 2016, 335-337.).

To maintain postures for several seconds during performance, such as spirals and spins, skater needs muscle and strength endurance for upper body, lower body and core for holding postures tight and ensuring fast rotation. In fact, all types of muscle work are needed. As an example, concentric muscle work is performed when the skater is entering to sit spins from rather deep curve and knee angle. Muscles are working eccentrically when squatting to the sit spin position and for holding the position isometric muscle work is needed for the skater. (Mero et al. 2016, 336-337.) Motor control and muscular capacity is the product of core stability (lumbo-pelvic-hip complex) (Vescovi & VanHeest 2018, 7.). It is important for skaters to have stability and strength for core muscles to effectively perform required figure skating elements. Kinetic changes in spine and pelvis and their stabilization contributes to core muscles (Jesenský, Kokinda & Turek 2015, 23.). "Core plays an important role during the transfer of forces from the lower body which is in contact with ice to the upper body and vice versa." (Jesenský et al. 2015, 23.)

3.3 Balance and flexibility features

In daily life, all types of movements and motor tasks that involves moving body segments or the entire body need posture and balance control to be safely accomplished. Controlling the body's center of gravity is the foundation of balance. (Brachman, Kamieniarz, Michalska, Pawłowski, Słomka & Juras 2017, 45.)

As a sport, figure skating can be described as a constant control of balance for the ongoing risk to lose one's balance due slippery surface and thin blade. Skater's ability to control the center of mass play an important role for maintaining balance. (Aalto 2017, 5.) Normal training program should incorporate off-ice balance and ankle stability exercises according to studies specific to figure skaters (Saunders, Hanson, Koutakis, Chaudhari & Devor 2012, 2.).

Flexibility means the available range of motion in joint or group of joints and it can be described as static and dynamic. Stiffness and effortless movement are related to dynamic flexibility whereas static is associated with the range of motion in joints. (Magee 2014, 10.) There is a high requirement for range of motion in flexibility sports like dancing, gymnastics and figure skating. Like in ballet, flexibility in figure skating has great emphasis on turnouts in lower extremities as well as splits to the side and front. (Weber, Bedi, Tibor, Zaltz & Larson 2015, 1-2.) Pictures 1 and 2 demonstrates common flexibility movements performed in figure skating. For figure skaters, flexibility training starts already at early age from 7-9 years old using passive and dynamic exercise methods (Mero et al. 2016 337.). When it comes to performance, good flexibility is a fundamental ability for athletes. Proper technique in sports demands necessary flexibility enabling wide range of motion with minor resistance of tissue. (Mero et al. 2016, 313.) Sami Kalaja (Mero et al. 2016, 313) has collected significant evidence from literature regarding the benefits of flexibility training. To name few examples, flexibility training increases economical movement, decreases risk of injury as well as enhances soft tissue (muscles, tendons and ligaments) rehabilitation. It is also beneficial concerning the muscle imbalance prevention and increasing the aesthetics and elegance of movements.

Picture 1. Skater performing movement known as spread eagle spiral. Picture by author (c. Riina Varjokari)

Picture 2. Skater performing split spiral. Picture by author. (c. Riina Varjokari)

3.4 Biomechanics and techniques

It is difficult to separate techniques and biomechanics in figure skating (Aalto 2017, 5.). The implementation of mechanical principles to living organisms is called biomechanics and it has a great significance in the understanding of basic principles of human motion (Innocenti 2017, 491.). The biomechanical analysis is based on exploring phases of the movement. With three-dimensional video analysis in figure skating, researchers have solved i.e. jump height and length, airtime, rotational velocity and take-off angle. Phases of figure skating jumps are preparation, take-off, air position and landing. Fast force production and long lever arms are used with modern technique. The concept of impulse is also associated with the jump take-off. When the joint range of motion is increased the force production time rises as well as the impulse. In order to produce multiple revolution in air, the skater must jump high and be able to rotate fast in the air. The acceleration of the edge has great impact for achieving the rotation already in the take-off phase. When landing the jump, force production is eccentric. It is crucial for coaches to examine athletes' postures and alignments such as longitudinal axis according to center of gravity and positioning of extremities during movement. (Mero et al. 2016, 337.)

4 KNEE ANATOMY

The largest and most complex joint of the human body is the knee joint (tibiofemoral joint) (Tortora & Derrickson, 2014, 384-385.). It consists of several different structures and without it we couldn’t participate to multiple activities of daily living. It plays significant part in locomotion e.g. walking or running when being the shortener and lengthener of the lower in limb. (Palastanga & Soames 2012, 304) The main structures of the knee are bones, tendons, ligaments, muscles and cartilage. (Orthoinfo, 2014)

The knee joint is a modified hinge joint since it allows some movement in a second plane (Palastanga & Soames 2012, 19.). Typically hinge joint is a type of synovial joint that mainly allows motion in one plane. It is stabilized by connective tissue such as muscles and ligaments and it consists of two or more bones which are lubricated by

synovial fluid and surrounded by hyaline cartilage. (Gupton & Terreberry 2019) Primarily knee function limits to extension and flexion but some rotation is possible when the knee is flexed (Palastanga & Soames 2012, 248.).

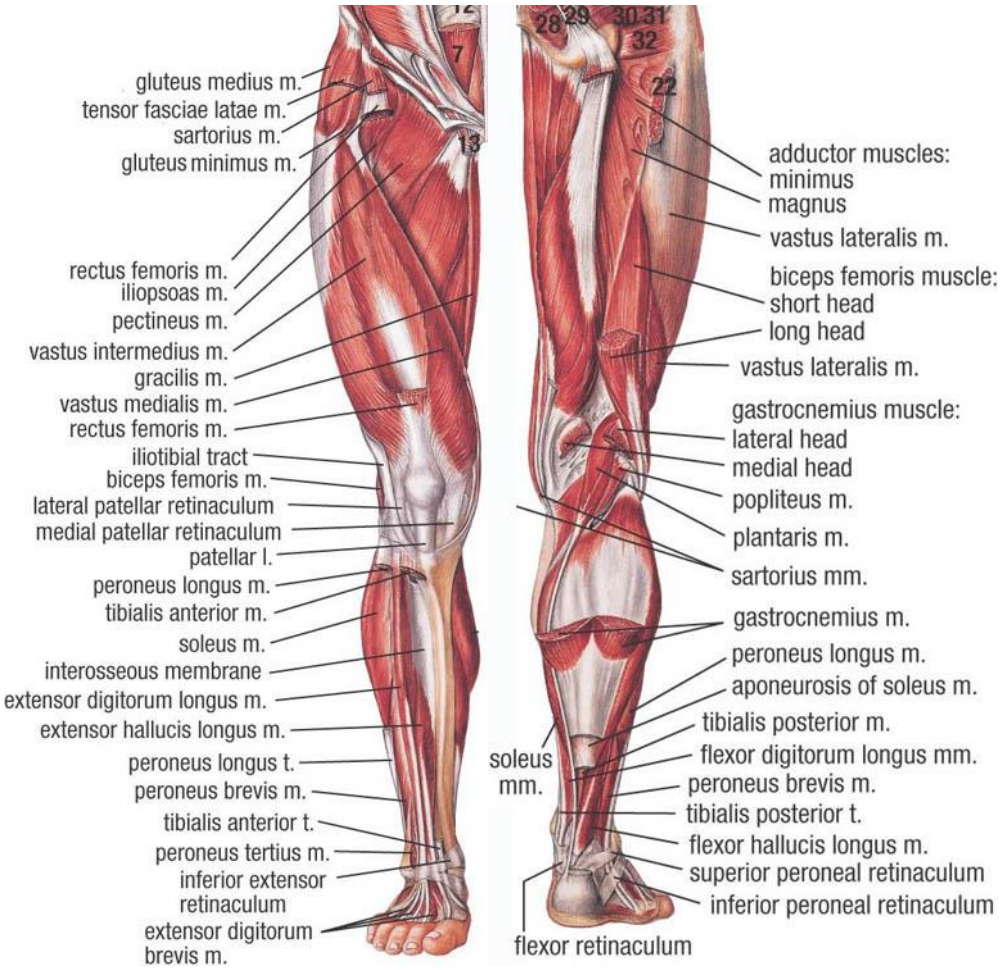
4.1 Bones

In the knee joint there are three bones involved: kneecap (patella), shinbone (tibia), and thighbone (femur). The head of the femur and tibia bone is covered with cartilage as well as the posterior side of the patella. Cartilage prevents the bones rubbing against each other and allows bones to glide smoothly when bending or extending then joint. (Orthoinfo, 2014)

4.2 Muscles and tendons

Muscles play an enormous part in moving joints. Movements happening in the knee joint are flexion, extension, slight medial rotation as well as lateral rotation of the leg in flexed position. The muscles on the anterior side of the joint moves the joint towards extension and muscles on the posterior side vice versa (Table 1). (Tortora & Derrickson, 2014, 384-385.) Flexion is accomplished primarily by muscles that originate various parts of the femur and anterior inferior iliac spine (Gupton & Terreberry 2019). The large muscle bulk composed of four parts (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius) on the anterior side of the thigh is called quadriceps femoris. Around patella all these four muscles join forming strong patellar tendon which inserts into the patella and tibial tuberosity. (Picture 3)

All of these muscles play their particular role in the extension. Muscles that accomplish the extension of the knee are biceps femoris, semitendinosus, semimembranosus, gastrocnemius, plantaris, gracilis, and popliteus (Table 1). They originate from different locations of the femur, ischias tuberosity and inferior pubic ramus. Insertion of these muscles are in tibia, fibula and calcaneus bones. (Gupton & Terreberry 2019)



Picture 3. Anterior view (on the left side) and posterior view (on the right side) of the lower limb muscles (Website of AnatomyUniverse)

Table 1. Muscles of knee and their function listed (Magee 2014, 787)

ACTION	MUSCLES ACTING
Knee flexion	m. Biceps femoris m. Semimembranosus m. Semitendinosus m. Gracilis m. Sartorius m. Popliteus m. Gastrocnemius m. Tensor fascia latae m. Plantaris
Knee extension	m. Rectus femoris

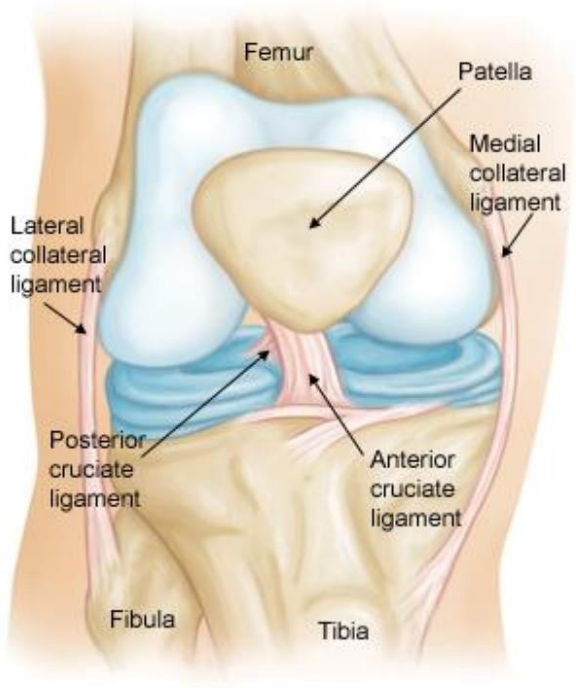
	m. Vastus medialis m. Vastus intermedius m. Vastus lateralis m. Tensor fascia latae
Knee medial rotation (flexed knee, non-weight-bearing)	m. Popliteus m. Semimembranosus m. Semitendinosus m. Sartorius m. Gracilis
Knee lateral rotation (flexed knee, non-weight-bearing)	m. Biceps femoris

4.3 Ligaments

Knee joint heavily depends on its ligaments. Ligaments function is to act as primary stabilizers of the tibiofemoral joint along with guiding the bone movements in proper way and relation between each other. There are various ligaments surrounding the knee but four of them are essential regarding knee stability (Picture 4). The medial collateral ligament is situated more posteriorly on medial aspect of the tibiofemoral joint. It consists of two parts, one strong and broad triangular strap which is the superficial layer and the thickening of the joint capsule that forms the deep layer. The superficial layer runs distal to the adductor tubercle and extends to the medial part of the tibia. The deep layer is sometimes called medial capsular ligament since it blends with the medial meniscus. The round shaped lateral collateral ligament lies under of the bicep femoris tendon. It is situated more posteriorly than anteriorly running from the lateral epicondyle of the femur to the head of fibula. In flexion this ligament loosens providing protections to the lateral side of the knee and when extended it tightens. (Magee 2014, 805-808.)

Primary knee rotary stabilizers are the strong cruciate ligaments that cross each other and are named concerning to their attachment to the tibia. Cruciate ligaments are

located inside the knee joint (Picture 4). The anterior cruciate ligament runs diagonally in front of the knee from the tibia to the femur and the posterior cruciate ligament in the back. Preventing the tibia anterior movement on to the femur the anterior crucial ligament gives rotational stability to the knee helping to control the normal rolling and gliding movement of the tibiofemoral joint. The knees strongest fan-shaped ligament, posterior crucial ligament, is a primary stabilizer against the posterior movement of the shinbone on the femur functioning as the knee's central axis of rotation. (Magee 2014, 805-808.)



Picture 4. Ligaments of the knee (Website of Orthoinfo)

5 KNEE OVERUSE INJURIES RELATED TO FIGURE SKATING

Comparing to acute injuries, in single skating most of the injuries are overuse injuries (Porter 2013, 318.). This section covers the theory and risk factors behind overuse injuries and their occurrence in figure skating.

5.1 What is a knee overuse injury?

Injuries occurring in sports can be divided into acute or overuse type. Overuse injuries are the result of gradually appearing and progressing tissue damage which causes pain during exercise. Commonly this type of injuries focuses to the body part or parts that becomes overstrained by the sport. Many overuse injuries are the consequence of doing too much repetitive and one-sided exercises too frequently. Also, rapid changes in exercising, training conditions e.g. hard floor or bad equipment (footwear) increases the risk. Wrong technique or structural abnormalities that causes too much loading for specific body part may also be the reason behind the injury. (Hämäläinen, et al. 2015, 187.) The risk of injury has been consistently proven to be increasing in multiple sports due higher training volume (DiFiori et al 2014, 1.). In females, knee movement control disturbance is more common. Difficulties of controlling the knee can appears as dynamic valgus (knee tilting inwards) when landing jumps, squatting or alteration of direction. Movement control disturbance in the pelvic area also impacts lower extremity biomechanics. (Mero et al. 2012, 207,222.) Table 2. demonstrates risk factors that exposes athletes for sport related injuries. Risk factors are split into internal and external factors. Athlete's personal features are related to internal factors (physical characteristics, age, gender) in opposite to external factor that are associated with specific sport, environment, and conditions. (Hämäläinen et al. 2015, 187-188.)

Table 2. Risk factors of sport related injuries. (Hämäläinen et al. 2015, 189.)

Internal factors	External factors
Physical characteristics	Nature of the sport
Age and gender	Training and competition content
Body composition and physique	Rules of the sport
General health	Level of competition
Anatomical abnormalities	Tactics, position and role
Previous injuries	Time used for practice and competing
Nutritional condition	Exercise programming
Recovery	Type of loading
ROM and condition of joints	Time and amount of loading
Muscle stretch ability	Loading density

Oxygen uptake	Loading intensity
Muscle power	**Conditional factors**
Speed	Base of exercising
Coordination	Outdoor/Indoors
Balance	Weather
Agility	Time of the day/year
Sport specific skills	One's action (coach, referee, teammates)
Mental factors	Nutrition
Personality and self-image	Sleep and recovery
Level of motivation	Life habits
Ability to focus and stress tolerance	Equipment (Game, protection)
Risk taking	Footwear

There is localized pain and discomfort involved in overuse injuries around the patella (kneecap). Other symptoms such as impaired functional ability, localized tissue swelling, and inflammation are a characterized in knee overuse injuries. Young females and growing individuals suffer from patella pain syndrome commonly known as patellofemoral pain syndrome more often than others. In all ages, anterior knee pain is prevalent. Sometimes there is no cause to be found for the pain. This happens often with growing individuals labelling the pain as idiopathic. (Peterson & Renström 2017, 446-459.)

5.2 Common knee overuse injuries among figure skaters

Focusing more and more on progressively to difficult elements (jumps, spins, footwork), figure skating continues to develop as a sport. Figure skaters are at risk for both acute and chronic overuse injuries for training year-round multiple hours a day to perfect these demanding moves. (Porter 2013, 320.) Multiple studies have shown that overuse injuries are most sustained in young skaters especially in single skating. Studies have also reported lower extremities and back being predominantly most injured areas of body. (Kowalczyk et al 2019, 1-8.) Like in other jumping related sports, patellofemoral pain syndrome and patellar tendinopathy arise in figure skaters (Porter

2013, 319.). In female figure skaters' patellofemoral pain, patellar tendinopathy and Osgood-Schlatter disease have the greatest percentage in the overuse injuries category at the knee area (Kowalczyk et al 2019, 1-8.).

General diagnosis referring to the pain around patellofemoral joint is called patellofemoral pain (PFPS). In overuse injuries the most common cause is PFPS. Anterior knee pain results from unusual stress and tissue overload across the patellofemoral joint caused by altered biomechanics in lower extremities. It is considered that PFPS is caused by several intrinsic and extrinsic factors interacting together such as limited flexibility in the lower extremities (quadriceps, hamstrings, hip flexors, IT band), deficiency in strength and neuromuscular control in the quadriceps and gluteal area along with errors in training volume progression, rest and inappropriate shoe wear. (Tecklin 2015, 524.)

Apophysitis is an overuse injury affecting apophysis which is a normal bulge or swelling of a bone. Apophysis serves as an attachment for muscle tendons. (Tecklin 2015, 502.) Familiar overuse injury in late childhood causing anterior knee pain is apophysitis known as Osgood-Schlatter disease. In Osgood-Schlatter disease pain and inflammation is emerging from the tibial tuberosity on the patellar tendon insertion. Physical activities like jumping and running often aggravates the pain often limiting participation in sports. (Vaishya, Azizi, Agarwal &Vijay 2016) Also pressure directly targeted to the apophysis e.g. kneeling or palpation causes pain and tenderness (Tecklin 2015, 524.). One-sided training is the most prevalent cause of apophysitis. Excessive strength training when growing should be avoided as the muscle strength develops faster than skeletal strength resulting as apophysitis. For this reason, strength training should be carried out only using light weights or own body weight as a load. (Peterson & Renström 2017, 569.) OSD commonly resolves without any specific treatment at the end of skeletal maturation (Vaishya et al. 2016).

Patellar tendon overuse injury is designated as patellar tendinopathy. Being common in all sporting activities especially where jumping is dominant, patellar tendinopathy relates to pain, diffuse, localized swelling and decreased functional ability. Loading of the patellar tendon for example in explosive jumping and running as well as high

demands on the extensor mechanism may result in chronic overloading of the tendon or partial tears in collagen fibres. (Tecklin 2015, 454.)

6 PRIMARY PREVENTION

Sports injuries have been effectively reduced by physical activity in general, but it also plays an important part concerning prevention (Lauersen, Bertelsen & Andersen 2013, 1-8.). Participating in youth sports is beneficial regarding the development of general fitness, peer socialisation and even self-esteem (DiFiori et al 2014, 1.). However, there is a risk of injury involved when engaging in sports at young age. Becoming internationally widespread, participation in sports is getting more and more popular among youth. Particularly in girls increased year-round training, early specialization and increased difficulty of the specific sports skill practiced is trending over the past decades. (Sabato et al 2016, 99.) In female dominated sports such as gymnastics and figure skating, children are engaging with sports at young age (Mero et al. 2012, 207.).

Primary prevention by its own means is to prevent possible diseases or impairments from occurring (Kisling & Das 2019, 2.). It is essential to be aware of the risk factors and injury mechanisms in order to understand the reason behind injuries. Athletes and coaches should understand how injuries develop and recognize the main risk factors existing within the sport. (Peterson & Renström 2017, 14.) Many injuries connected to sports could have been prevented if attention had been paid to the risk factors and cause of injuries when practicing and competing. (Hämäläinen et al. 2015, 187) Proper planning and execution of training are at key position in injury prevention. Poor condition can cause premature fatigue and decrease of coordination during performance leading to increased risk of acute and overuse injuries. (Mero et al. 2012, 223-224.) Diversely, individually and reasonably timed practicing, good motor control, and awareness of risky situations are essential factors in prevention of sport injuries. (Hämäläinen et al. 2015, 187.). Effective exercise programs based on research includes functional, diverse and alternating running, agility, balance, plyometric and strength training exercises. (Mero et al. 2012, 224.) Plyometric exercising has been proven to

be improving performance as well as effectively reducing lower extremity injuries. Studies have found that plyometric training is beneficial especially for females. (Chmielewski, Myer, Kauffman & Tillman 2006, 308,316.)

Coaches have an important role in the prevention of injuries especially when it comes to young athletes. Health promotion and basic principles of injury prevention should be known by every coach. Arising from the athlete's qualities, environment and from the sport itself, it is their responsibility to identify risks and intervene. Primarily biological age, base of fitness components and skills, as well as structural and functional anatomy should be considered when planning exercising. Diverse exercising is considered of being the corner stone for overall development of young athletes' physical components and motor skills. Intensity, volume, load and timing of exercising should be planned in a way, that the athlete has enough time for recovery between exercise sessions. Underlying life rhythm, decent diet and adequate sleep and rest time as the foundations for proper recovery. In addition, proper warm-up, cool down and flexibility training should be included to young athletes' routines. (Hämäläinen et al. 2015, 187.) Year-round improving agility, reactivity and postural control of joints, tendons and muscles should be incorporated as a part of warm-up. Load and volume of training should be gradually raised incorporating learning of new exercises and elements. Athletes are most receptive in the beginning of exercise session for more focus demanding tasks (Mero et al. 2012, 226-233.)

Meta-analysis done by Lauersen, Bertelsen & Andersen (2014) investigated the effectiveness of exercise programs regarding injury prevention. As a result, multiple exposure programs, proprioceptive training and strength training showed positive impact concerning injury prevention. Strength training, proprioceptive exercises and stretching were combined in multiple exposure programs. Stretching alone did not show any beneficial effect. However, the number of sports injuries and overuse injuries could be significantly reduced with multiple exposure exercises. Proprioceptive training aims to improve joint proprioception (sense of body position) and stability.

When coaching youngsters, it is important to invest in learning right performance techniques starting from basic movements. Controlling basic movement skills such as

running, squatting or jumping is fundamental for learning skills that are specific to the sport. Good movement control and rightful techniques prevent skaters from musculoskeletal impairments. Furthermore, it enables efficient, safe, and effortless movement. As an example, controlling the lower extremity alignment when squatting or landing jumps has a great significance in injury prevention. If there is deficiency controlling the movements, wrongful loading overcomes the tissue tolerance leading to possible injury. (Hämläinen et al. 2015, 187-192.)

7 BIOPSYCHOSOCIAL GROWTH DEVELOPMENT IN THE AGE 9-10 YEARS OLD IN FEMALE GENDER

Regarding child development, all humans go through similar developmental stages, but in their own individual pace. Physical, cognitive and socioemotional challenges needs be considered when coaching children. (Mero, Uusitalo, Hiilloskorpi, Nummela & Häkkinen 2012, 76.)

7.1 Physical growth

Physical growth simply refers to the increase in body structures and measure. Standing height, muscle mass and total weight increase are examples purely related to physical growth. Alteration in timing of physical growth individually depends on calendar age, environment, physical load and genetics. Lower extremity muscle mass increases more rapidly because of heavier loading that upper extremities. In female gender, muscle area reaches its natural adult cross-sectional size approximately at the age of 10. Biological maturation is more difficult to determine, essentially meaning body's maturation towards adulthood. Two factors are associated with maturation: timing and speed. Start of the genital maturation and age of the peak growth spurt relate to timing in maturation. The speed of height growth and final gender maturation associate with maturation speed. Nervous system matures considerably faster than skeletal system or genitals. (Hämäläinen et al. 2015 54-69.)

Skeletal development in childhood is mainly growth in extremities, proceeding to the upper body and trunk during puberty. These changes impacts learning new skills and techniques as the alteration in lever arms and center of gravity causing momentary difficulties. (Mero et al. 2012, 51.) In female gender growth spurt starts usually between ages 8,2-10,3 and it peaks around 11,3-12,2 years of age. Most significant factors that lie behind every young skaters' growth and maturation are genetics, hormones, nutrition and environmental stimulus. (Hämäläinen et al. 2015, 63.)

7.2 Mental and social growth

In the age of 9-10 some children may show prepubertal behaviour. Children in this age range are described as active, balanced, social, and showing interest towards many things. Especially with female gender, differentiation starts gradually happening. Critical and logical thinking starts to develop. Having their own opinions and awareness of their rights, it may appear as searching explanations for decisions made in sports. Even though thinking develops, for a child it is still partly concrete. It is hard to understand the contradiction between words and actions. Understanding feelings and considering others becomes possible in this age. For girls, recognition of feelings means also talking about them. Girls have already created a social network around them in this age but having a so-called best friend within the group matters. (Mero et al. 78-79.)

9-10-year-old girls already ponder deep questions about life. Having fears which they try to control with compulsory actions and thoughts, is not rare. It is fundamental to create a safe environment within the sport for children whom greatness of the world and life limitations begins to open. In coaching world, attention need to be paid to every athlete's development and career path individually in order to limit girl athletes' high demands for themselves. (Mero et al. 2012, 79-80.)

8 PORIN TAITOLUISTELU RY

The figure skating club Porin Taitoluistelu ry. has been operative since the year 2000. Currently the club employs executive director, two full-time coaches, three part-time coaches and skating school instructors. The club wish to provide joyful and pleasant physical activity to all participants regardless of the age, gender or level of skater. The number of skaters is constantly increasing. Currently there is approximately 100 skaters participating to the skating school and competitive skating. Besides skating school, the club operates five competitive groups that are organized mainly by the level but also according to age of the skater apart from few exceptions. Some young talents are practicing in higher groups than coeval skaters. In single skating, the club have representative skaters in international, national championship, national and regional levels. Competitions, summer camps and shows are essential part of the club operation. (Website of Porin Taitoluistelu ry.)

9 THERAPEUTIC EXERCISE PROGRAM FOR THE SKATERS

Exercises chosen to this program are intended for figure skating coaches to use as a tool for preventing potential knee overuse injuries. It was created based on scientific knowledge regarding injury prevention, observation and interview. Functional way of executing these exercises is to combine them with warm up when the skater is most receptive for learning new skills. The guide was divided in five parts; plyometrics, strength, balance, flexibility and guidance for coaching.

Primary prevention should begin at early age for best results. The most effective exercises in injury prevention are multi exposure exercises, basic and sport-specific movement control exercises, muscle strengthening, coordination, agility, plyometric and balance exercises. Functional flexibility exercises have also been found beneficial.

9.1 Plyometrics

Plyometric exercising, also titled as stretch-shortening drills, indicates to high-intensity and high-velocity resistance training. Plyometric exercises enhance neuromuscular reaction, muscle strength, power output and coordination. (Kisner & Colby 2012, 911-912.) Stretch-shortening cycle is defined as quick, resisted eccentric muscle work followed by immediate quick concentric muscle work of the same muscle. Due the SSC muscles are able to produce maximal force as fast as they can. Plyometric exercising improves athletic performance enhancing speed related to sports and pure strength. (Chmielewski et al. 2006, 308.) Plyometric training improves child's ability to produce power, increases movement velocity and enhances bone strength. Additionally, the knee injury risk has been found decreasing as a result of well-balanced exercise program. Plyometric training method for children can be safe and effective with proper age-related instructions and coaching. Training should begin with low intensity drills and over time gradually increase to higher intensity. Children could benefit from fewer repetitions and straight feedback when exposed to plyometric training for guaranteeing safe and correct movement patterns. (Faigenbaum & Chu 2017) Depending on the intensity of the plyometric exercise, repetitions vary between 5-20 repetitions and 2-5 sets. When doing low intensity exercises (repeated jumps), repetitions per training session may be hundreds. On the contrary, in vertical jumping and hurdle jumping exercises the amount of repetition should be considerably lower. (Hämäläinen et al. 2015, 229.) Recovery time between sets should be adequate since plyometric training specifically aims to improve neuromuscular performance. Ideal recovery time in neuromuscular exercising is between 2-3 minutes. (Leino 2014, 9.) Plyometric exercises chosen to this program are aimed to improve explosive muscle work, speed, coordination, and agility.

9.2 Strength, power and endurance

To successfully perform high-demanding movements, muscle strength and power stands out as critical elements. When performing movements that require large amount of repetition or holding position for a period, muscle endurance becomes essential. (Kilsner & Cosby 2012, 902-903.) When doing strengthening exercises, full joint

range of on motion should be performed for developing strength and promoting flexibility properly. For children and adolescents' loads should be selected in a way, that children are able to complete 1-2 sets of 10-15 repetitions correctly with some fatigue but without muscle failure. When 15 repetitions are easily performed, 5% to 10% load increase is suitable in general. There should be 1-3 minutes resting time between sets. (Dahab & McCambridge 2009, 224.) Motor skills (muscle control) should be emphasized for creating firm base for later strength training. Also, attention should be paid for pelvic girdle control and muscle endurance which is a weakness for today's children. (Hämäläinen et al. 2015, 224)

As stated earlier, adequate muscular strength and explosive power especially in lower extremities and pelvic area is required for figure skaters to be able to carry out demanding elements safely. Exercises chosen for this program are aimed to develop muscular strength in the pelvic girdle area and lower extremities. Strength training in children should be performed by using own body weight or light free weight as load.

9.3 Flexibility and Balance

With proper stretching skaters can ensure health promoting exercising which enhances their growth and development through different phases of their athletic career path. Good joint flexibility is very important for the athletic performance and functional ability in general. Maintaining flexibility demands permanent stretching. Needed flexibility in some sports require localize hypermobility to be able to perform certain movements. In judgement disciplines like figure skating, flexibility has a connection with judges scores due aesthetic impression. Stretching should be oriented to muscles groups that tend to tighten such as gluteal and hip muscles. (Hämäläinen et a. 2015, 256-258.) Many combinations of stretching durations and repetitions have been studied. The most used duration in static stretching varies between 30-60 seconds repeated several times. These durations and frequencies have been considered being the safest way for self-stretching program. Evidently, the duration should be based on athlete's tolerance and response during stretching. (Kisner & Colby, 2012, 87-91.) Concerning stretching, the element of control needs to be incorporated. From the start, it would be good for the children to learn avoiding positions that they can't control or come out

off on their efforts. The benefit with dynamic stretching is the improvement between muscle coordination, antagonist (muscle opposing the action of another) muscle strengthening. Moreover, muscle-tendon complex stretching enhances neural activity. (Hämäläinen 2015, 255,261.)

Skater is at constant risk of losing one's balance. For skaters, maintaining the center of mass is crucial for balance control. According to studies off-ice training should corporate ankle stability exercises that are specific to the sport. Evidence show, that balance control difficulties associated with lower extremities can be effectively prevented or treated with specific balance exercises (Kisner & Colby 2012, 282.).

Figure skating has high demands for flexibility and balance. Good flexibility is necessary for skaters to be able perform elements economically and with proper technique. There is a great emphasis on turnouts in lower extremities and splits to the side and front. Furthermore, flexibility training has been evidently proven to be decreasing the risk of injury. Dynamic and static exercises chosen to this program aim to improve flexibility specific to the sport in lower extremities, especially in the hips. Balance and proprioceptive exercises chosen to this program aim to improve dynamic balance control and postural control.

9.4 Guidance for coaching

Training condition should always be taken into consideration when working with athletes. After observing figure skaters off-ice routines it was clear that, off-ice training includes considerable amount of running, jumping, and squatting exercises. Inappropriate training conditions such as hard floor exposes the knee joint for heavier loading especially when landing jumps. I was pleased to see that coaches in PoriTa already had taken this into account by using gymnastics carpet during off-ice practice. Mirrors were also available for use in the off-ice space which would have been suitable when exercising squatting and jumping technique. With mirrors coaches and skaters can observe correct technique and alignments from all sides; front, back and side.

Coaches have a great impact on young athlete's well-being. The competence needs for coaches is strongly determined by the operational environment which consists of the athletes age, level, and gender as well as practice group, coach's role and the training structure. The coach itself is always one of the variables. As an example, when coaching children, the nature and objectives of operation differs compared to adolescences. Competent coaches absorb good knowledge about the sport. Meaning, that they have understanding regarding performance development and techniques, not forgetting health promotion. For athletes, coaching impacts on evolving as an athlete, sport skills, self-development, sense of belonging and growth as an individual. (Hämäläinen 2015, 22-25.) Pedagogical and didactical skills are indeed fundamental tools for teaching children necessary skills, values and attitudes needed in their sport and in life general. Pedagogy refers to general act of teaching. Didactics on the contrary means the theory of teaching eg. coaches work method. Pedagogically competent coach is able to find ways to promote athletes' physical condition, performance and technical skills individually. (Hämäläinen 2015, 125.)

Every coach should have basic knowledge concerning risk factors and injury mechanism within the sport to understand how injuries develop and how effectively prevent them from developing. The exercise program contains a section, which addresses key points for adequate injury prevention methods.

10 THESIS PROCESS

Table 3 presents the process of this thesis. This process started from the authors own interest towards the topic concerning figure skating. After meeting with PoriTa it was clear that there was a need for this type of exercise program. This thesis is a practical thesis including an exercise program concerning primary prevention. Practical thesis includes product which can be in for example in form of guide, program or a project (Airaksinen 2009). In the beginning, author started off by reading and collecting theory concerning the physical demands and common overuse injuries among the sport. A Study plan was produced and presented and afterwards accepted by the supervising teacher. When the theory part was finished, author started collecting exercises based

on the evidence and literature. The author also visited the skaters off-ice session to observe performed movement patterns and the coach's guidance. Pictures for the program was taken by the author and the subject appearing in the pictures is a peer student. Pictures was used by the peer student's permission.

Table 3. Timeline of the thesis process

Decision made for the topic	September 2018
Meeting with Porin Taitoluistelu ry	September 2018
Study plan accepted and signed thesis agreement	January 2019
Research of theoretical background and writing	January – November 2019
Creating the exercise guide and program	November 2019
Returning thesis to the supervising teacher and presenting the thesis	November 2019

11 DISCUSSION

The collaboration with Porin Taitoluistelu ry enabled the creation of this thesis. The aim of this thesis was to gather knowledge and evidence regarding overuse injuries of the knee related to figure skating and to produce an exercise program based on the evidence. This thesis process has been challenging journey which started from authors own interests in the topic from earlier experiences of her personal athletic career. Being familiar with the sport and working with children helped the author upkeeping the interest towards the topic.

Researching the scientific literature and creating the exercise package developed authors theoretical knowledge and gave vital information regarding the topic. Decision for the specific topic started from a broader approach which were narrowed down to specific subject. Even though writing the theory started in January 2019, most of the writing was done during the fall 2019. Challenges regarding the literature was the limited of research specifically concerning figure skating and overuse injuries of the knee

among children and adolescent in figure skating. Most of the studies concerning this were conducted for elite athletes or they were outdated.

For creating the exercise program, most common overuse injuries and physical demands of the sport needed to be carefully investigated to understand what elements the sport skill training emphasizes within the age range of the topic. Furthermore, gathering knowledge regarding the most effective primary prevention intervention was critical for the selection of exercises. There was plenty of information about primary prevention which gave the author difficulties of deciding what are the most relevant according young figure skaters. Choosing the exercises was challenging since the amount had to be kept fair so that it could be performed within the time limits of the session. Also, the physical level of the skaters needed to take into consideration when choosing the exercises so that they are challenging but not too difficult for the skaters. Exercises chosen for the program was based on the observing the skaters off-ice training and evidence found in the literature.

Although the topic of the thesis focused only one specific joint of the lower extremity, the joint is a very complex joint with a sea of information. It was challenging to decide what is the most relevant information needed for the anatomical view. Using tables helped to open the written text considerably, but overall the author felt like more figurative material could have been used.

Since the injury rates among sports especially in figure skating is expectedly increasing due the raise technical difficulty, further studies should focus more on investigating the prevalence of overuse injuries among children and methods for primary prevention specific to the sport.

REFERENCES

Aalto A. 2017. Taitoluistelun lajianalyysi ja valmennuksen ohjelmointi. Valmentaja-seminaarityö. Jyväskylän yliopisto

Airaksinen T. 2009. Toiminnallisen opinnäytetyön kirjoittaminen. Referred 17.11.2019 https://www.slideshare.net/

Brachman A., Kamieniarz A., Michalska J., Pawłowski M., Słomka K., Juras G. 2017. Balance Training Programs in Athletes – A Systematic Review. Journal of Human Kinetics 58, 45-64

Chmielewski T., Myer G., Kauffman D., Tillman S. 2006. Plyometric Exercise in the Rehabilitation of Athletes: Physiological Responses and Clinical Application. Journal of Orthopaedic & Sports Physical Therapy 36, 308-319 Referred 09.11.2019 doi: 10.2519/jospt.2006.2013

Communication no.2242. Referred 10.11.2019 https://www.isu.org/

Cormien P., McGuigan M., Newton R. 2011. Developing Maximal Neuromuscular Power. Sports Medicine 41, 17-38

Dahab K., McCambridge T. 2009. Strength Training in Children and Adolescents: Raising the Bar for Young Athletes? Sports Health 223-226. Referred 14.11.2019 doi:10.1177/1941738109334215

DiFiori P., Benjamin H., Brenner J., Gregory A., Neeru Jayanthi N., Landry G., Luke A. 2014. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. Sports Medicine 48, 287–288

Faigenbaum A., Chu D. 2017. Plyometric Training for Children and Adolescents. American College of Sports Medicine. Referred 13.11.2019 https://www.acsm.org/docs/default-source/files-for-resource-library/smb-plyometric-training-for-children-and-adolescents.pdf?sfvrsn=fcc67055_2

Gupton M. & Terreberry R. 2019. Anatomy, Hinge Joints.

Hämäläinen K., Danskanen K., Hakkarainen H., Lintunen T., Forsblom K., Pukkinen S., Jaakkola T., Pasanen K., Kalaja S., Arajärvi P., Lehtoviita T., Riski J. 2015. Lasten ja nuorten hyvä harjoittelu

Innocenti B. 2017. Biomechanics: a fundamental tool with a long history (and even longer future!). Muscles, Ligaments and Tendons Journal 7, 491-492

Jesenský M., Kokinda M., Turek M. 2015. Stabilization exercises as a means of fitness development in figure skaters. Scientific Review of Physical Culture 5, 23-28

Kisling L., Das J. 2019. Prevention Strategies. StatPearls Publishing, 1-7 Referred 7.11.2019 https://www.ncbi.nlm.nih.gov/books/NBK537222/

Kisner C., Colby L. 2012. Therapeutic Exercise – Foundation and Techniques.

Kotimaiset ikärajat - Yksinluistelu. Referred 28.10.2019. http://www.stll.fi/

Kowalczyk A., Geminiani E., Dahlberg B., Michelli L., Sugimoto D. 2019. Pediatric and Adolescent Figure Skating Injuries: A 15-Year Retrospective Review. Clinical Journal of Sports Medicine. Referred 12.11.2019 doi:10.1097/JSM.0000000000000743

Lauersen J., Bertelsen D., Andersen L. 2014. The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. British Journal of Sports Medicine. Referred 13.11.2019. doi: http://dx.doi.org/10.1136/bjsports-2013-092538

Leino O. 2014. Pro Gradu tutkielma. Plyometrisen harjoittelun vaikutukset hyppysuoritukseen ja harjoituksen aiheuttamiin fysiologisiin vasteisiin nuorilla ja ikääntyneillä naisilla. Jyväskylän yliopisto

Lipetz, J. & Kruse, R. 2000. Injuries and special concerns of female figure skaters. Clinics in Sports Medicine 19, 369-380

Magee D. 2014. Orthopedic Physical Assesment

Mero A., Uusitalo A., Hiilloskorpi H., Nummela A., Häkkinen K. 2012. Naisten ja tyttöjen urheiluvalmennus

Mero A., Nummela A., Kalaja S., Häkkinen K. 2016. Huippu-urheilu valmennus

Myer G., PhD, Jayanthi N., MD, DiFiori P., Faigenbaum A., Kiefer A., Logerstedt D., Micheli L. 2016. Sports Specialization, Part II: Alternative Solutions to Early Sport Specialization in Youth Athletes. Sports Health 8, 65-73 Referred 12.11.2019 doi: 10.1177/1941738115614811

Palastanga N. & Soames R. 2012. Anatomy and Human Movement: Structure and functions 6th Edition

Peterson L., Renström P. 2017. Sports Injuries: Prevention, Treatment and Rehabilitation, Fourth Edition

Porter E. 2013. Common injuries and medical problems in singles figure skaters. Current Sports Medicine Reports 12, 318–320 Referred 08.11.2019 doi: 10.1249/JSR.0b013e3182a4b94ere

Porter E., Young C., Niedfield M., Gottschlich L. 2007. Sport-Specific Injuries and Medical Problems of Figure Skaters. Wisconsin Medical Journal 6, 330-334. Referred 5.11.2019 http://www.wisconsinmedicalsociety.org/_WMS/publications/wmj/pdf/106/6/330.pdf

Sabato T., Walch T., Caine D. 2016. The elite young athlete: strategies to ensure physical and emotional health. Open Access Journal of Sports Medicine 7, 99-113 Referred 27.10.2019 doi: 10.2147/OAJSM.S96821

Saunders N., Hanson N., Koutakis P., Devor S. 2012. Figure Skater Level Moderates Balance Training. International Journal of Sports Medicine 34. Referred 11.11.2019 doi: 10.1055/s-0032-1327653

Tecklin J. 2015. Pediatric Physical Therapy

Tortora, G., Derrickson, B. 2014. Principles of anatomy & physiology 14th Edition

Vescovi J., VanHeest J. 2018. The Science of Figure Skating.

Vaishya R., Azizi A., Argawal A., Vijay V. 2016. Apophysitis of the Tibial Tuberosity (Osgood-Schlatter Disease): A Review. Referred 12.11.2019 doi: 10.7759/cureus.780

Varjokari R. Pictures of skater.

Vuorinen, V. 2013. Yleisimmät vammat: Taitoluistelu. Terveystalo. Referred 14.1.2019. https://www.terveystalo.com/fi/Palvelut/Urheilijat-ja-aktiiviliikkujat-Sport/Tietoa-urheiluterveydesta/Yleisimmat-vammat-Taitoluistelu

Weber A., Bedi A., Tibor L., Zaltz I., Larson C. 2015. Hyperflexible hip. Sports Health 7, 346-348 Referred 2.11.2019 doi:10.1177/1941738114532431

Website of Anatomy Universe. Referred 20.10.2019 http://www.anatomyuniverse.com/

Website of Finnish Figure Skating Association. Referred 15.10.2019 http://www.stll.fi/

Website of Orthoinfo. 2014. Common Knee Injuries. Referred 24.11.2018 https://orthoinfo.aaos.org/en/diseases--conditions/common-knee-injuries/

Website of Porin Taitoluistelu ry. Referred 10.11.2019 http://www.porita.net/

Website of Skating Finland. Referred 28.10.2019 https://skatingfinland.fi/

Yksinluistelun elementtivaatimukset 2019-2020. Referred 28.10.2019 http://www.stll.fi/