Satakunnan ammattikorkeakoulu
Satakunta University of Applied Sciences

MIKKO JYLHÄ

Prevention of lower back overuse injuries in 12–15-year-old ice hockey players

Guide for neuromuscular warm-up

DEGREE PROGRAMME IN PHYSIOTHERAPY
2023

Author(s)
Jylhä, Mikko

Type of Publication
Bachelor's thesis

Date: 1
Month: October
Year: 2023

Number of pages
43

Language of publication:
English

Title of publication
Prevention of lower back overuse injuries in 12–15-year-old ice hockey players: Guide for neuromuscular warm-up

Degree programme in physiotherapy

Abstract

Sports activities for children and young people today are largely focused on guided team sports, and at the same time, the total amount of free time sports and activities has decreased. This increases the risk of overuse injuries, and about half of the adolescents who are playing sports suffer from them today. Most overuse injuries in adolescents occur in areas of bone growth, and they almost always heal completely as growth progresses by themselves or with conservative treatment. However, overuse injuries are often long-lasting and may still significantly hinder a young athlete. Too monotonous and repetitive training should be avoided to prevent injuries.

The purpose of the thesis is to create a PDF-form guidebook for 12-15 years old ice hockey players, their parents, and their coaches, to increase knowledge of lower back overuse injuries, risk factors, and prevention, with the help of neuromuscular warm-up training program. The most common overuse injuries of the lower back in adolescents that have been reviewed in this work are spondylosis, vertebral apophysis, and herniated disk.

For the warm-up training program, eight different exercises were selected to activate, strengthen, and stretch the core, gluteal, hip flexor, and shoulder girdle muscles. According to the studies, increasing the strength and mobility of these muscle groups and areas has been proven to reduce the risk of injury in lower back.

Key words : ice hockey, neuromuscular, exercise, low back, overuse injury, prevention

CONTENTS

1 INTRODUCTION

Lower back overuse injuries have become significantly more common in recent years, (Ahola et al. 2019) and this is one reason why the author wants to bring out the knowledge about the most common lower back overuse injuries, risk factors, and exercise methods how to prevent them in junior ice hockey.

Children and adolescents free time voluntary exercise has decreased in recent years. Nowadays they spend more time indoors playing video games than outside playing yard games. Children and adolescents are turned into more passive but at the same time they are trying to aim at the top on the sports, which means a lot of training hours in a week. Thus, the responsibility for versatile training has been transferred more and more to sports clubs. (Pihlman, 2020, p.23) Versatile training should therefore be implemented within the sport in such a way that the focus is on the development and well-being of the athlete (Pasanen, 2021, p.41).

According to research, neuromuscular training has been found to reduce the risk of sport injuries. Pasanen et al. studied already in 2008, the preventive effects of neuromuscular training for non-contact injuries and the risk of leg injuries in female floorball players. Study showed that neuromuscular training was effective in preventing acute non-contact injuries, and training was recommended in the weekly training of these athletes. (Pasanen, 2009)

Practicing body awareness and body control is an essential part of a young athlete's skill training. This will be useful in the future, for example in strength training, when control of the position of the back, hips or knees becomes easier. (Vilén, 2019, p.26) In addition, practicing body awareness and body control helps to prevent ankle, knee, and lower back injuries (Vilén, 2019, p.120).

Overuse injuries are usually the result of excessively monotonous and heavy training. In addition, example rapid changes in training, incomplete recovery, conditions, and poor equipment increase the risk of overuse injuries. (Pasanen, 2021, p.26) During the growth spurt, the training emphasis must be changed in such a way that the young athlete is not caused, for example, a stress fracture of the lower back. Also, periods of sensitivity should not be interpreted too precisely, but training should be constantly versatile. (Pasanen, 2021, p.70)

2 AIM AND OBJECTIVE

The objective of the thesis is to create a PDF guidebook for 12-15 years old ice hockey players, their parents, and their coaches, to increase knowledge of lower back overuse injuries, risk factors, and prevention, with the help of neuromuscular warm-up.

The thesis aims to develop the ice hockey coaches, players and their parent's knowledge about most common lower back overuse injuries among youth ice hockey player, and key factors how to prevent them.

The aim is also to get the coaches to understand the importance of the neuromuscular warm-up training and be able to include it more clearly in training.

3 ICE HOCKEY

The Sponsor Navigator 2022 study showed that, according to Finns, ice hockey is still the most interesting and popular sport. There were 68,823 registered players in Finland in the 2021-2022 season. There are a total of approximately 190,000 active players in Finland. The number of registered players compared to the previous season was 1067 more. The largest increase was in the number of female and girl players. (Suomen Jääkiekkoliitto ry, 2022)

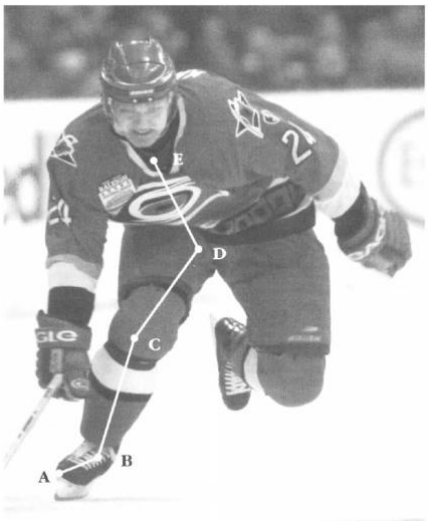
One of the focuses of Finnish ice hockey's strategy is to create conditions that enable success and growth. The Finnish Hockey Association has set a goal that 3–5 new ice rinks and 5–7 artificial ice rinks will be built in Finland per year. In addition to these, 5–7 of the existing halls undergoes basic improvements every year. According to the Lipas database, in June 2022 there were 240 ice rinks, 289 rinks and 84 artificial ices in Finland. (Suomen Jääkiekkoliitto ry, 2022) Junior ice hockey activities in Finland have developed, which can also be seen in the Junior World Cup success, as Finland has risen to the same level as Canada and the United States in the Junior World Cup. In the 2021–2022 season, 84 Finnish players already played in America with an NHL contract, and more and more Finns are moving to the NHL at an even younger age. (Urheilun kirjo, 2022)

3.1 Ice hockey sport analysis

Ice hockey is a game that is played under the guidance of a jury. Two teams compete in the match in scoring and the team that scores more goals is declared the winner. The actual playing time consists of three periods of 20 minutes of effective playing time. There is a 15-minute break between periods. The teams switch sides of the court before the start of each period. If the result is equal at the end of the actual 60-minute playing time, either an overtime or a shootout contest will be played. (Suomen Jääkiekkoliitto ry & IIHF, 2018)

Ice hockey is a fast and complex sport where players must constantly adapt their skills to respond to the dynamics of the game. The sport involves frequent starts and stops, forward power skating, and agility to move in multiple directions. In skating, the lower body plays an important role, especially the hip and knee flexors and extensors. However, the player is unable to use the power output of the lower limbs optimally, if there is not enough strength in the muscles of the middle body, lower back, and pelvis. Also, developing the upper body muscles is especially important when it comes to shooting, controlling the puck, and fighting situations. (Shamus, 2017)

Skating involves a much more complex set of movements than running. Since the ice has almost no traction, moving is not possible in the same way as when running, pushing straight ahead. This is why the player must push the skate sideways to the ice to perform a push-off and stride. (Hache, 2000, p.39-43) Most of the effective skating takes place in a position where the hip joint is bent. This leads to tightening of the muscles that flex the hip joint. When skating forwards and backwards in a curve, good mobility is required from the pelvis and hip joint. (Pihlman, 2020, p.199) To perform the optimal push-off, the blade must be faced approximately 45 degrees to the ice plane (Pearsall et al., 2000). During a stride, one leg performs a push-off movement, while the other leg moves forward in a raised position before sliding. Skating is a multi-joint movement, where mainly the bending of three joints, ankle (B), knee (C), hip (D), (Picture 1) forms most of the movement energy. (Hache, 2000, p.39-43)



Picture 1. The physics of hockey. (Hache, 2002)

Regarding speed and movement efficiency, the body needs a sufficient strength-mobility ratio and cooperation. One-sided sports training, however, loads the body unevenly. In ice hockey, the stick is mainly always used from the stronger side, so the leg with more load is in the front and the direction of movement is the same. This leads to the tightening of the gluteal muscles of the leg in front and load on the hip flexors of the leg behind. (Pihlman, 2020, p.199)

Hockey stick play often leads to muscle imbalances in the players' shoulder joints and shoulder girdle area. Having strong muscles in the middle of your body can help you skate faster and play with a stick more effectively. The chest and thoracic spine must also be well mobile, so that the power produced by the lower limbs is optimally transmitted. In addition, the upper limbs can then be used effectively for both skating and handling the hockey stick. (Pihlman, 2020, p.200-201)

3.2 Youth ice hockey in Finland

The Finnish Olympic Committee's Tähtiseura-program is part of the Finnish Ice Hockey Association quality system. There are currently a total of 186 junior ice hockey teams operating in Finland. (Suomen jääkiekkoliitto ry, 2022) On March 1, 2023, only 33 of these teams had been audited by the Tähtiseura quality system. (Suomen Olympiakomitea, 2023) On Leijonanpolku website, the Finnish Hockey League association wants to clarify essential information for players, coaches and parents, which things are essential at different age stages of a player and which things should be focused on as the player grows into an adult athlete. (Suomen Jääkiekkoliitto ry, n.d.-c)

3.2.1 10–14-year-old

At the age of 10-14-year-old, the emphasis is on growing as a player and learning the game. At this age, focusing on endurance training is essential, as the body is receptive to it. However, the child must also focus on other skills, such as specific skills of the sport, and speed training. Strength training in the early stages of puberty is challenging

because the beginning of puberty might vary in boys between four to five years. Mobility exercising is especially important because, during this growth stage, the child's bones, muscles, tendons, and ligaments grow and develop. In addition, children must also learn to tolerate the physical and mental pressures produced by the competition. (Suomen Jääkiekkoliitto ry, n.d.-a)

Skating and puck-handling skills are essential sports skills in hockey. A player needs strength, speed, endurance, and versatility to apply these skills in the game. The amount of exercise for 12-14-year-olds should be at least 20 hours a week. The hours used for exercise should consist of the following: 10 hours of guided training, ice hockey and other sports, 5 hours of school hockey and different ball games, and 5 hours of independent exercise. (Suomen Jääkiekkoliitto ry, n.d.-a)

3.2.2 15–19-year-old

At this age, the focus is on adopting an athletic lifestyle and evolving into a winning and self-directed player. In skating skills focus starts to be more on quick changes of direction, starts and stops. In addition, emphasis is placed on skating endurance, as well as dueling skills that require speed, power, and skill. Before puberty, you should focus on versatility. The main focus of physical elements is on developing basic fitness, muscle endurance, elasticity, and mobility. Development of skating skills such as quick starts, rhythm changes, and stops. After puberty, you can focus more on increasing muscle mass and practicing hard lactic acid training. The player must develop a good playing position that is balanced, strong in duels, and ready for constant reaction. The aim is year-round development. The amount of training is increased gradually, so that sport-specific training gradually increases, and the training of other sports decrease. (Suomen Jääkiekkoliitto ry, n.d.-b)

4 GROWTH AND DEVELOPMENT OF ADOLESCENTS

After birth, the human body undergoes constant maturation and development. Children's bodies are not yet as developed as those of adults, but their organ systems are still growing. Therefore, it must be remembered that children's training cannot be the same as that of adults. The development, size, functional capacity, and regulatory efficiency of organ systems, such as cardiac stroke volume, muscle mass, limb length, and hormonal activity, affect the exercise response and physical performance of a child. When planning and implementing exercise for children, three essential aspects should be considered: First is physical growth, the second is biological maturation, and the third is physiological development. (Hakkarainen, 2015, p.53)

Physical growth refers to an increase in body structures, such as height, weight, or muscle mass. Biological maturation refers to maturation towards adult maturity. This is more difficult to define. In practice, it means, for example, at what age the growth spurt begins, how fast height growth is and when height growth stops, or when sexual maturation occurs. Maturation occurs throughout growth, but variations between individuals can be large. Physiological development refers to the differentiation of the organ systems of body structures and their functional development. For example, an increase in the activity of aerobic enzymes or the differentiation of muscle cells to become faster. This development is influenced by many factors, such as childhood physical activity and environment, as well as intellectual, social, and emotional development. (Hakkarainen, 2015, p.54)

4.1 Physical development

Children and young people experience several growth spurts during adolescence, but especially at puberty, the body starts to undergo rapid changes (Figure 1). Puberty usually starts around the age of 12 for girls and a little later for boys, around the age of 14. It should be remembered, however, that biological age can vary from person to person by several years. (Vilén, 2019, p.8) Taking this into account is often a challenge in team sports, where teams are typically divided into groups according to a player's

year of birth. This means that the same team or group is likely to have several players with widely varying levels of maturity. (Ahola et al., 2019)

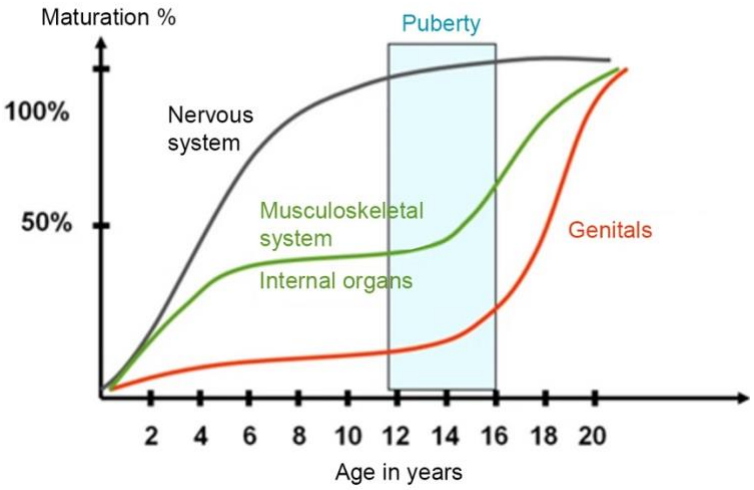


Figure 1. Physical development of adolescence. Modified from Hakkarainen 2020.

Based on current research, adolescents may be more sensitive to overuse injuries during growth spurts, but the research evidence is not entirely clear, so training during a growth spurt should not be feared (Vilén, 2019, p.11). By puberty, a child's nervous system and brain are almost fully developed. This is why it is important to emphasize exercises that increase motor skills and speed from an early age until adolescence. In adolescents, bones grow faster than muscles. Just before puberty, bone mass increases strongly along the longitudinal axis of the bone. Ossification usually occurs first in the lower and upper limbs and later in the body. Load, nutrition and hormone activity influence changes in bone mass and density. (Hakkarainen, 2015, p.69-71) Exercises that involve light impacts and jumps are effective in increasing bone density. However, monotonous training, high intensity jumping, and strength training should be avoided during the growth spurt phase, as they can cause pain and strain injuries for the young athlete. (Hakkarainen, 2015, p.69-71; Vilén, 2019, p.11) Exercises to develop balance with different stimuli should be favored, especially during the growth spurt, to develop control over the changing proportions of the body (Vilén, 2019, p.11).

The easiest way to monitor the start of a growth spurt and the level of maturity is the Peak Height Velocity (PHV) tool. PHV is calculated by determining the players gender, height, weight and sitting height. Sitting height is measured with the player

sitting on a chair, hips, and knees at a 90° angle, measuring the length from the seat of the chair to the top of the head. Putting this data into the calculator, the PHV age, in other words, the estimated age of peak height growth, and the so-called maturity offset, which is the current time point either before or after PHV, are calculated. By identifying the growth stage of the athlete, it is possible to develop the qualities required by the athlete at the right time. This does not mean that the athlete will not develop even if the PHV is not known, but it will help to better support growth-oriented development. (Vilén, 2019, p.9-11)

4.2 Sensitive periods

In the training of children and adolescents, sensitive periods refer to periods when the development of a particular feature is considered to be effective (Figure 2) and, partly, easier through natural growth (Hakkarainen, 2015, p.182).

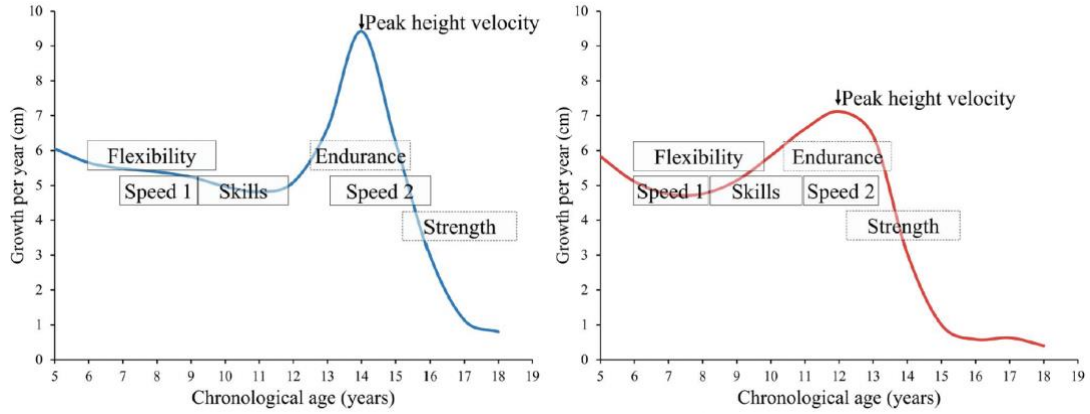


Figure 2. Sensitive periods to train general motor abilities in boys (left) and girls (right). Van Hooren & Croix, (2020).

Sami Kalaja challenges the children's and young people's sensitivity period training model, referring to the article published by Van Hooren & Croix, 2020, in his blog called VALMENNUSTAITO. Looks like there is no very reliable scientific evidence for exact periods of sensitivity. However, the seasonal sensitivity model should not be completely forgotten or ignored, because it also brings to the surface good things to consider. Kalaja also refers to the text written Harri Hakkarainen (2020) for Yle, where he uses the so-called Sliding scale term. (Kalaja, 2020) However, periods of sensitivity

should not be interpreted too precisely, but the adolescent training should be constantly versatile. (Kalaja, 2020; Parkkari & Toivo, 2021, p.69) These models do not mean that training should not focus on different characteristics in different seasons. For example, in the phase of rapid height growth, coordination training should be emphasized to reduce the risk of injury. (Kalaja, 2020)

4.2.1 Flexibility

Changes in bone tissue and body proportions caused by growth bring challenges to body control and mobility. In boys, mobility usually weakens in the early stages of the growth spurt, and therefore mobility training should be included in the training. (Vilén, 2019, p.12) Still during this age it is good to develop mobility by training it. At this age, however, mobility develops differently, in other words, in those joints that are exercised, mobility improves and in others it weakens. (Kalaja, 2015, p.258)

4.2.2 Endurance

As the heart, respiratory and circulatory systems of an adolescent develop during normal growth, so does maximum oxygen capacity. However, there is little improvement in relative oxygen capacity, although the endurance result improves by itself. In other words, the body just gets used to moving a larger mass at the same power. (Vilén, 2019, p.10) Endurance training should be favored in young people's training, as it has positive effects on the brain and thus also on learning skills (Kalaja, 2022, p.134)

4.2.3 Strength

In boys, strength levels develop fairly linearly until the age of 12-14. The increase in testosterone secretion starts about a year before the peak of the growth spurt. (Hakkarainen, 2015, p. 212-215) Increasing muscle mass before puberty is not very effective, as the growth hormones and testosterone associated with the growth spurt have a significant effect on increasing muscle cross-sectional area. (Hakkarainen,

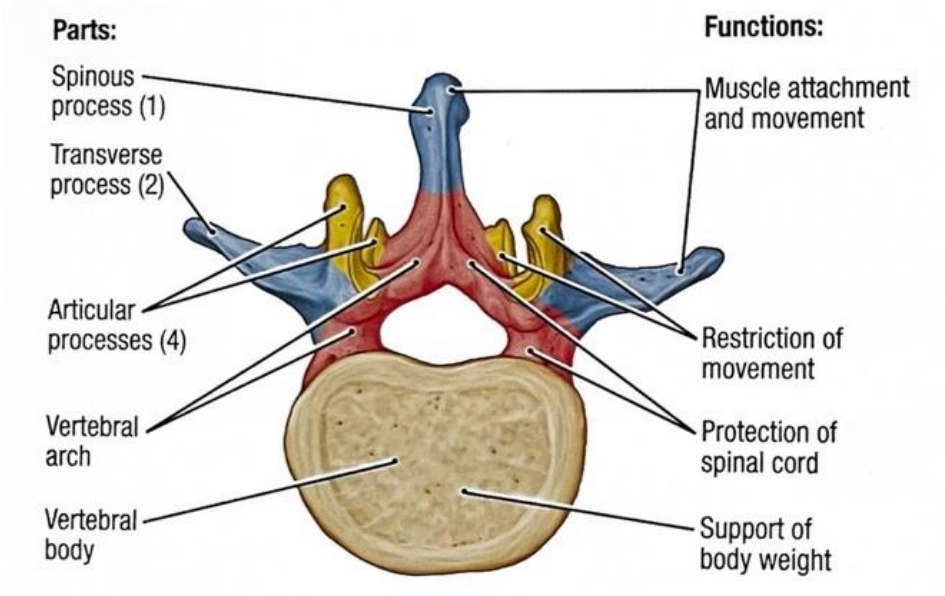
2015, p.69-71) Muscle strength and mass gains peak during and after the growth spurt when growth hormone and testosterone activity are activated. However, before the growth spurt starts, it is essential to do muscle strength training to develop mobility, body control, and balance. (Hakkarainen, 2015, p. 212-215; Vilén, 2021, p.10-12) In addition, strength training has been found to be effective in improving muscle strength, speed, motor skills, metabolic and arterial disease risk factors and preventing musculoskeletal injuries (Haapala, 2018, p.47).

5 LUMBAR SPINE

The vertebral column, also called the spine, is consist of 7 cervical vertebrae, 12 thoracic vertebrae, 5 lumbar vertebrae, sacrum, and coccyx. Viewed from the side, vertebral column shows four slight bends, called normal curves, resembling the letter S, although when viewed from the front, the normal spine is straight. (Tortora & Derrickson, 2017, p.187-188)

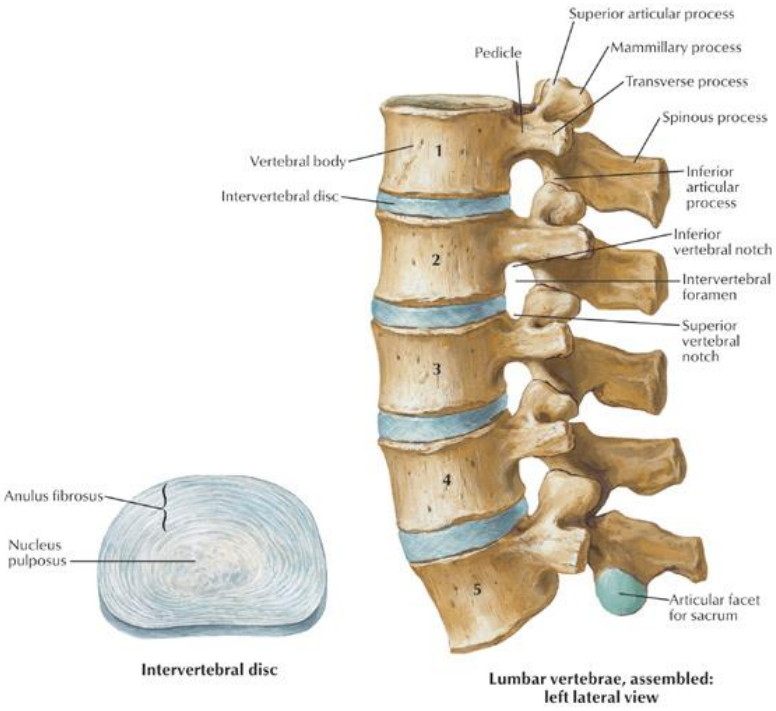
5.1 Lumbar spine anatomy

Vertebrae of the spine differ in shape depending on the area in which they are located. However, the lumbar spine vertebrae are mainly similar, so they all have the same basic features. The vertebra consists of three main elements, the body, vertebral arch, and processes (Picture 2). The body is the weight-bearing part of vertebrae. The vertebral arch is formed from pedicles and laminas. These structures form the triangular-shaped vertebral foramen, the spinal canal, where the spinal cord runs. There are three different types of processes, which are: spinous process, transverse processes, and articular processes. Processes enable attachment points for ligaments and muscles. The superior and inferior articular processes form zygapophyseal joints, also called as facet joints. These joints allow flexion and extension movement of the lumbar spine. (Tortora & Derrickson, 2017, p.188-194)



Picture 2. Lumbar Vertebrae. Parts and functions. Agur, A. M. R. (2021)

Between the two vertebral body endplates there is an intervertebral disc (Picture 3). The outer part of the disc is ringlike fibrocartilage called the annulus fibrosus. The inner part is called the nucleus pulposus, which is a highly elastic, soft, and pulpy substance. A thin plate of hyaline cartilage covers the superior and inferior surfaces of the disc. The intervertebral discs main function is to provide shock absorption. Discs also allows movement between the vertebrae and prevents the vertebrae from grinding against each other. Due to loading and compression during the day, the discs lose water from their cartilage and flatten and broaden. During the night, the load is less, which allows the discs to grow in height due to rehydration. This why we are taller in the mornings than in the evening time. (Sassack & Carrier, 2022; Tortora & Derrickson, 2017, p.188) Decompression of the discs and blood circulation can be increased with certain stretching exercises since oxygen and nutrients are provided to the annulus fibrosis and nucleus pulposus by blood vessels from the vertebrae bodies (Tortora & Derrickson, 2017, p.188).



Picture 3. Intervertebral disc and lumbar spine. Adapted from Physiopedia (2022).

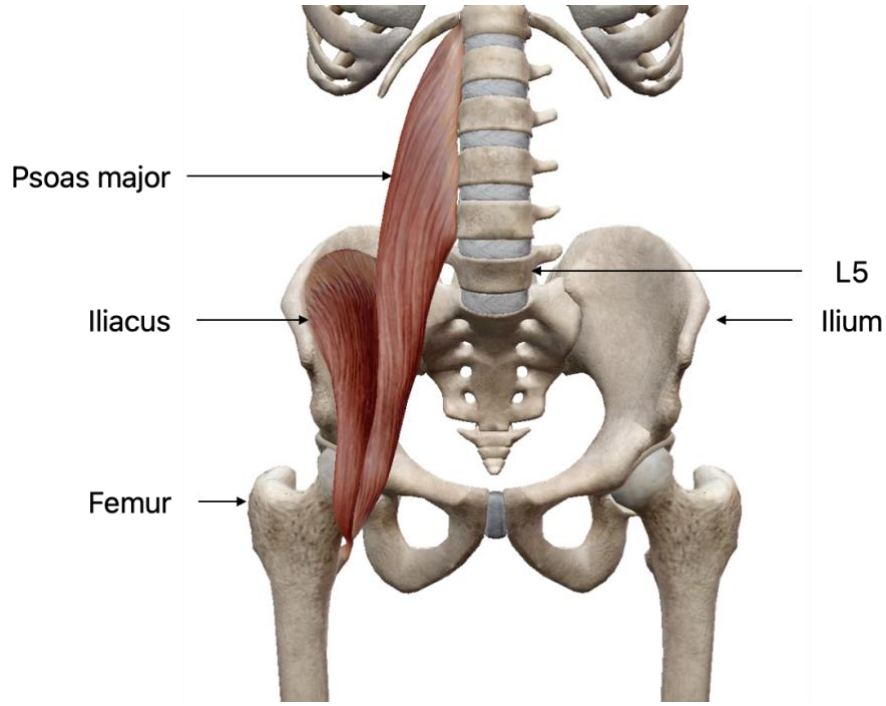
The lumbar vertebrae joints are supported by several ligaments. The longitudinal ligaments are located in front and behind the vertebral body. The anterior longitudinal ligament resists lumbar extension, translation, and rotation. The posterior longitudinal ligament resists lumbar flexion. (Sassack & Carrier, 2022) Between two laminae is very elastic structure called the ligamentum flavum. Between the two consecutive spinal processes runs deeply the interspinous ligament which limits flexion movement. On the tips of the spinous processes from the 7th cervical vertebrae until the 4th lumbar vertebrae, there runs a broad, thick, and cord-like structure, called the supraspinous ligament. Because it is positioned the most posteriorly, it has more effect in resisting flexion than all the other dorsal ligaments. (Physiopedia, 2022) Iliolumbar ligament is a strong band of connective tissue that origins from L5 transverse process and attach to iliac chest. This ligament has an important role to stabilize the movement in the lumbosacral and sacroiliac joint. (Jones & Tubbs, n.d.)

5.2 Lumbar spine function

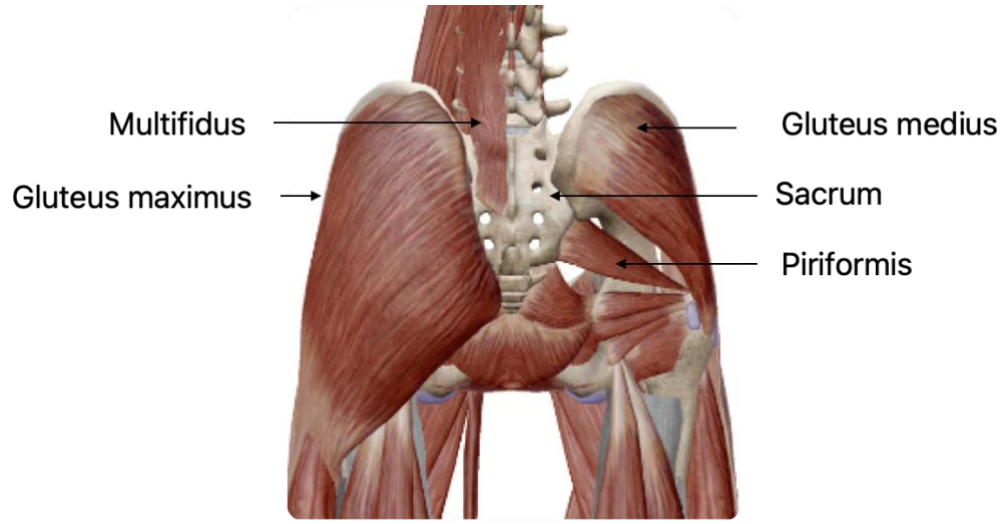
The lumbar spine has three main functions, assist the upper body, protect the spinal cord and spinal nerves, and allow diverse movements. The lumbar spine vertebrae are larger than thoracic and cervical vertebrae's, allowing them to absorb axial forces delivered through the body. (Sassack & Carrier, 2022) The vertebral column functions as a strong, flexible rod, allowing our bodies to bend forward, backward, sideways, and rotate (Tortora & Derrickson, 2017, p.187). Movements in cervical and lumbar region are greater than in the thoracic region. Lateral bending and extension movements are most free in the lumbar region. (Agur, 2021, p.5)

When assessing the mid-body and pelvic region, it is important to observe the position of the pelvis and spine in relation to the rest of the body. The main aspects to look at are the forward-backward tilt of the pelvis and the position of the lumbar spine. By tilting the pelvis forward (anterior tilt), it affects the alignment of the lower limbs and emphasizes the curvature of the lower back and the position of the lumbar spine. (Alanen & Pasanen, 2021, p.74) According to research, the tightness of the hip flexors and hamstrings may limit the movement of the pelvis, and thus put extra force on the vertebrae of the lower back. In addition to these, weak core and gluteal muscles make it difficult to maintain the normal natural lordosis position (Lawrence, 2016) .

The lumbar spine, pelvis and hip joints share closely related functions. The pelvis provides support between the body and the lower limbs. When there are issues in the pelvis area, it often results in pain in the lower back, pelvic, or groin. This is typically caused by excessive tension in the hip flexors (psoas major and iliacus) (Picture 4) or hamstring muscles, or a lack of strength in the gluteal muscles (gluteus maximus and gluteus medius) (Picture 5). Movements of the ilium in the sagittal plane are anterior and posterior rotation. When the lower limb is in contact with the ground, the task of the psoas major is to take care of the posterior rotation of the ilium. The Gluteus maximus prevents excessive posterior tilting of the sacrum, while the piriformis maintains functional symmetry by pulling the sacrum laterally. (Halén, 2021, p. 458-462)



Picture 4. Anterior view of lumbar spine and pelvic area. (Human Anatomy Atlas, 2023)



Picture 5. Posterior view of lumbar spine and pelvic area muscles. (Human Anatomy Atlas, 2023)

6 MOST COMMON OVERUSE INJURIES IN ADOLESCENTS

Sports injuries are divided into two different groups based on the way they occur: Acute accidents and Overuse injuries (Hämäläinen at al., 2015, p.187). Overuse injury refers to a symptom or finding related to exercise or sports that is not caused by trauma or do not have a single acute onset time (Ahola et al., 2019). Overuse injuries have become more common in children and adolescents due to decreased daily physical activities combined with increased intensity of sports (Launay, 2015). It is estimated that about half of all sports injuries among adolescents are overuse injuries. Most overuse injuries in adolescents occur in the bones because the tendons and ligaments are relatively stronger than the bone growth areas to which they attach. (Ahola et al., 2019) Lumbar back pain is the most common musculoskeletal problem both in sports and in everyday life (Halén, 2021, p.458).

Low back pain is a common problem among athletes. Studies have shown that the lifetime prevalence of low back pain in athletes is 63%, while the prevalence of low back pain during 12 months study was 44%. Psychosocial stress, fatigue, anxiety, and sleep difficulties are all factors that can contribute to back pain in athletes. Regular exercise can help reduce the risk of back pain, but vigorous exercise can increase the risk. The prevalence of low back pain did not vary significantly by age or gender. Neither the imaging results nor the movement tests were found to be clearly related to back pain. (Leppänen, 2021) In 2016, the Terveurheilija website compiled the prevalence of lower back pain in young athletes of various sports (Figure 3). The average age of the athletes was 22 years, and the measurement interval was 1 year. The highest prevalence was among ice hockey (94%). The next biggest sports where back pain occurred on the list were gymnastics (86%), football (64%), skiing (63%), floorball (62%), and weightlifting (59%). In comparison, the prevalence of low back pain in non-athletes was 22-65%. (Terveurheilija.fi, 2016)

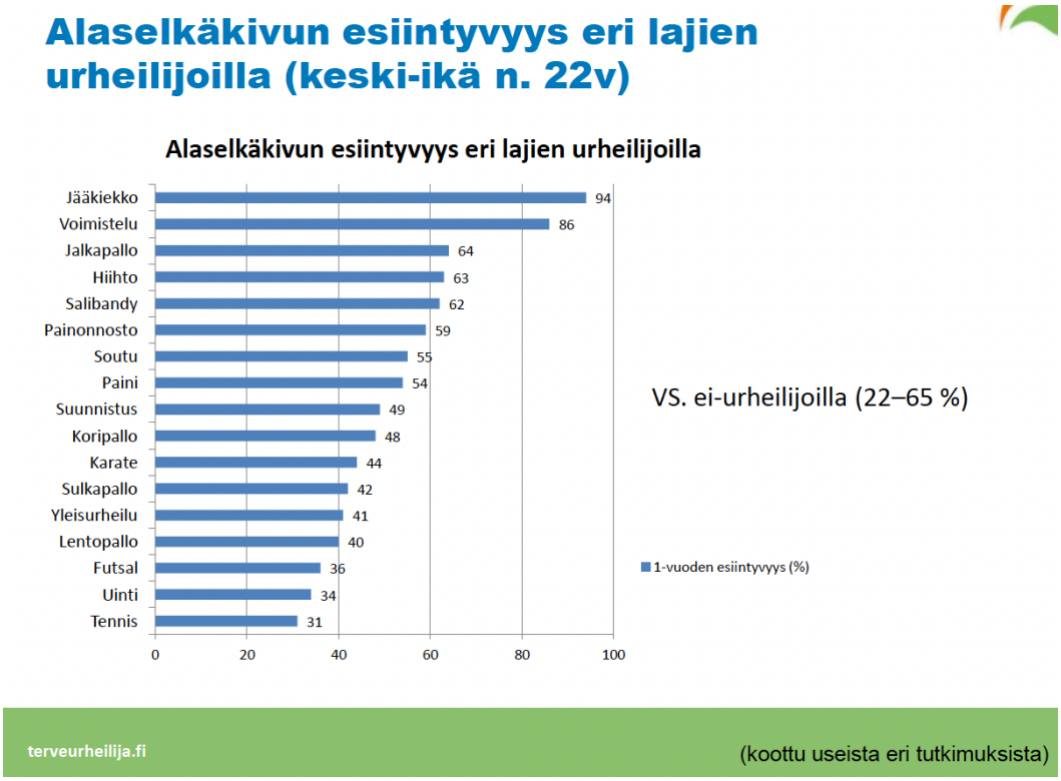


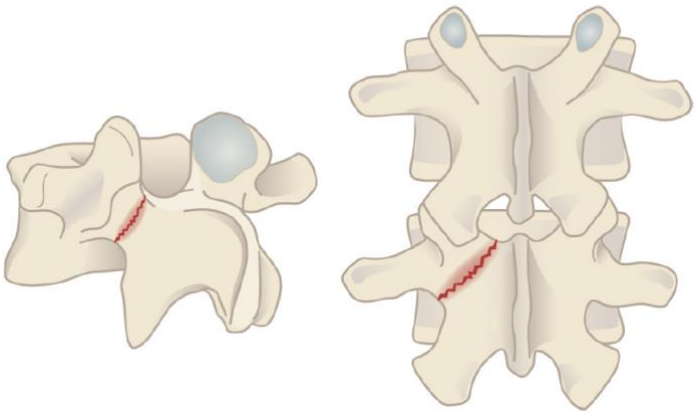
Figure 3. Prevalence of low back pain in different sports. (Terveurheilija, Nuoren urheilijan selkä, 2016)

6.1 Spondylosis and spondylolisthesis

The forces that load the bone, such as tension, compression, and impact loading, as well as their various combinations like bending and rotation, cause microdamage to the bone. This loading leads to targeted bone remodeling in the damaged area. Stress fractures occur when repetitive loading causes microfractures in the bone that the bone remodeling cannot repair sufficiently. (Myllyniemi, 2021, p.173)

Stress fractures of the vertebral arch, more specifically, spondylolysis, are common injuries in adolescent athletes (Walker et al. 2014, p.149; Wong et al, 2020, p.262). It is one of the most common causes of low back pain in adolescence, accounting for up to 47% of low back pain in young athletes (Virkki, 2021, p.5). Between the superior and inferior articular processes there is a small and thin portion of the vertebra, called pars interarticularis, which connects the upper and lower facet joints (Sassack & Carrier, 2022).

In spondylolysis, a crack or stress fracture develops in this part (Picture 6), which is the weakest point of the vertebrae (Walker et al. 2014, p.149). The spondylolysis can occur a unilateral or bilateral in pars interarticularis, most commonly in the fifth lumbar vertebrae (Mäntymäki & Neva, 2021, p.453).



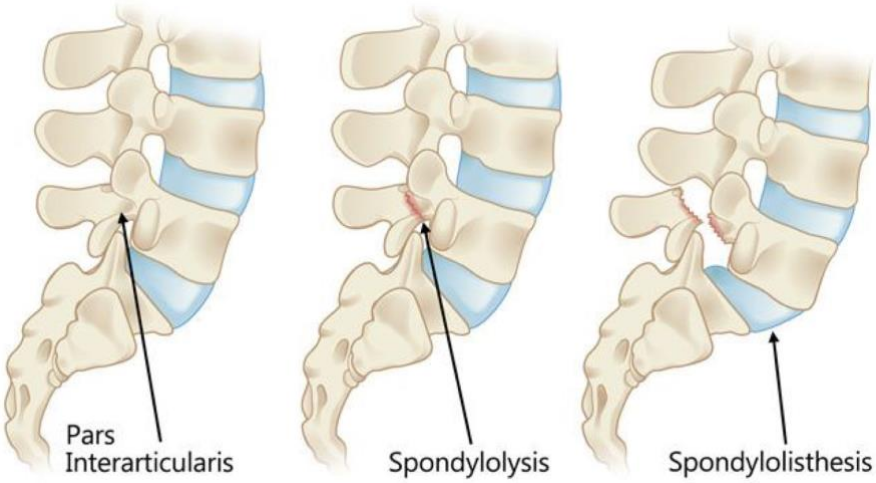
Picture 6. Anatomy of spondylolysis. (Virkki,2021)

Stress osteopathy is a precursor to spondylolysis. The term stress osteopathy refers to a condition caused by excessive strain on the back, where no clear fracture line is detected. In stress osteopathy, magnetic resonance imaging reveals swelling in the vertebral arch of the lower back. The observed swelling in the vertebral arch impairs blood circulation to the bone, thus posing a risk factor for stress fractures. (Mäntymäki & Neva, 2021, p.453) Stress osteopathy can be treated by reducing the intensity of exercise, particularly those that cause back pain. Activities that put significant strain on the lower back should be lightened for a period of 2-6 months, which may require a break from sports training as well. The aim of reducing the intensity of exercise is to decrease the load on the area affected by stress osteopathy and therefore prevent the development of a stress fracture. (Mäntymäki & Neva, 2021, p.458)

The treatment for pediatric spondylolysis is usually conservative (Virkki, 2021, p.22). In an acute phase, spondylolysis is treated using the same principles as stress osteopathy (Kattilakoski & Parkkari, 2021, p.454). When the load has been lightened in the acute phase and the pain is relieved, we can move on to exercises that either strengthen the injured tissue or stabilize the injured area. These include exercises that activates and strengthens the muscles of the middle body. (Kattilakoski & Parkkari, 2021, p.239) In some cases, the treatment can involve the use of a brace, however,

there are not enough studies that prove whether a brace adds value to the treatment or not (Virkki, 2021, p.22). A rigid thoracolumbar orthosis does not increase the likelihood of achieving bony union of pediatric spondylolysis when compared to an elastic, low-profile lumbar support (Virkki, 2021, p.55). The typical duration of treatment is approximately three months, but treatment time should always be individual. The treatment aims to relieve pain, support bone healing and the young athlete's return to their previous level of activity. (Virkki, 2021, p.23-29)

As spondylolysis progresses, it can lead to spondylolisthesis (Picture 7), which is the anterior displacement of the upper vertebra in relation to the lower one. Clinical findings include tenderness and tapping sensitivity at the site of the fracture. (Ahola et al., 2019; Heinonen & Kujala 2001.) About 80% of stress fractures are associated with spondylolisthesis, which is mostly mild and can usually be asymptomatic (Mäntymäki & Neva, 2021, p.453). It is recommended to maintain good muscle health and use pain relief if necessary. Movement should not be avoided, but light exercise should be favored. Surgical treatment of spondylolysis has not been shown to relieve back pain better or faster than physiotherapy. (Kattilakoski & Parkkari, 2021, p.454)

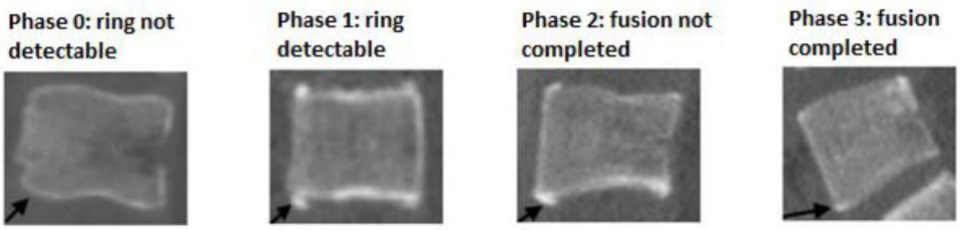


Picture 7. Spondylolysis and Spondylolisthesis. (OrthoInfo, AAOS, 2020)

6.2 Vertebral apophysis

The apophysis is the location in the bone where the tendon of the muscle attaches. Most overuse injuries in adolescents occur in the growth plates of bones because tendons and ligaments are relatively stronger than the bone growth areas to which they attach. Apophysitis refers to a painful condition in the ossification area caused by repeated tensile stress. Most commonly, the growing age is vulnerable to this problem between the ages of 10 and 18, mainly in their adolescent years before the fusion. (Heinonen & Kujala, 2001; Wong et al. 2020)

The cause of apophyseal ring injuries is uncertain, with some sources suggesting that they can result from acute trauma, degeneration, or stress. The apophyseal ring itself does not contribute to growth, but it is important as an attachment point for the longitudinal ligaments and the annulus fibrosus of the disk. The ring apophysis calcifies at around the age of 6 and ossifies at age of 13. Then it fuses with the vertebral body between the ages of 17 and 22. (Wong, 2020) Between the ages of 12-15 for girls and 13-16 for boys, the ring apophysis undergoes significant changes (Costa et al., 2021). Although it is rare, young athletes can experience a fracture of the vertebral apophysis (Wong, 2020). The injury is more common with boys, and most commonly involves the inferior apophysis of L4 vertebra (Patel & Kinsella, 2017, p.232-233). The computed tomography (CT) image (Picture 8) shows the different stages of maturation of the ring apophysis. During phase 0, the ring is in a cartilaginous stage and is not detectable on CT scans. In phase 1, the rings become ossified, making them visible on CT scans. Phase 2 marks the beginning of the rings fusing with the vertebral bodies. Finally, during phase 3, the rings are fully fused with the vertebral bodies. (Costa et al., 2021)



Picture 8. The four phases of maturation of the ring apophysis. (Costa et al., 2021)

Symptoms can usually be similar to an acute herniated disc. Typically, the pain is located in the lumbar region during exercise where the lumbar spine hyperflexes, usually during weightlifting. The pain is described as burning and it can also radiate to the leg. The pain can be aggravated by sitting, coughing, and sneezing. (Patel & Kinsella, 2017, p.232-233) Exercise and load must be reduced if the symptoms are severe. However, it is not necessary to stop exercising completely. Mobility and muscle strength exercises are generally recommended as a treatment to improve muscle control. Apophysitis can be long-lasting, as the symptoms can last from a few months to even a couple of years. (Ahola et al., 2019)

6.3 Herniated disk

A herniation disk also known as a slipped disk or a ruptured disk, occurs when the nucleus pushes out through a tear in the annulus, causing local inflammation in the surrounding tissues and mechanical pressure on the nerve roots (Walker et al. 2014, p.147). Disk herniation can result from acute or repetitive trauma. With adolescents whose spine is immature, disk herniation can be caused by compression force during forward flexion. Most commonly lumbar spine levels L4-5 and L5-S1 are affected. (Picture 9) However, herniations of the intervertebral disks are rare in adolescents. The most common symptoms are pain and stiffness in the back and lower limbs. However, the bulge does not necessarily always cause radiation to the lower limbs. The pain can worsen, for example, with coughing, sneezing, or sitting, and most have movement limitation in lumbosacral spine. In the clinical assessment, the most common finding with almost every patient is the positive result of the straight leg raise test. (Patel & Kinsella, 2017, p.232)

Picture 9. A large disc herniation in the L5/S1 space in the magnetic image. (Mäntymäki & Neva, 2021)

The treatment for the acute phase is rest and possibly pain and anti-inflammatory medication. In addition, cold and heat therapy can be beneficial. (Walker et al. 2014, p.147) Most young people respond well to conservative treatment, typically within 6–12 weeks (Patel & Kinsella, 2017, p.232). The treatment should focus on rest and avoiding lifting, in addition, normal daily activities should be carried out within the limits allowed by the pain, to maintain normal mobility and muscle balance (Walker et al. 2014, p.147). Light exercise and muscle exercises are recommended from the beginning, while bed rest is not recommended (Mäntymäki & Neva, 2021, p.455). By following the appropriate treatment, the prognosis is excellent for returning to sports fully for young athletes (Patel & Kinsella, 2017, p.232).

7 RISK FACTORS AND PREVENTION

In school-aged children, as sedentary behavior increases, spontaneous movement and play decrease. A large number of school-age child do not meet the general exercise recommendations anymore. According to the new national recommendations, all 7-18-year-olds must exercise at least 1-2 hours a day in a versatile and age-appropriate way. Sitting periods of more than two hours should be avoided, and screen time with entertainment media should be no more than two hours a day. (Pihlman, 2020, p.77)

Identifying and intervening in predisposing factors is key to preventing overuse injuries to the lumbar spine. When mapping risks and preventing injuries, attention must be paid to many different areas. These areas include the content of the training program, warm-up, mobility and strength training, training rhythm, proper training and protective equipment, training conditions, training platform, as well as travel schedules, nutrition, and rest. (Pasanen, 2021, p.62-65)

7.1 Risk factors

Sports injuries are a common occurrence in different sports, and their causes have been studied in detail. It is beneficial to utilize the existing research information to assess the risk of injuries to your team. Besides research data, the review should consider the events of earlier periods such as the frequency, types, and severity of injuries, amount, content, and rhythm of training, the number and pace of competitions and games, and training conditions and equipment while assessing the risks. (Pasanen, 2021, p.62-65)

Common factors that increase the risk of sports injuries are lack of body and movement control, insufficient energy intake, low aerobic performance, weak muscle strength, growth spurts, fatigue, excessive load, and injury history (Kattilakoski & Parkkari, 2021, p.239; Vilén, 2019, p.15). The number of overuse injuries increases during the growth spurt, when growth cartilage and joint surfaces are sensitive to damage. Overuse injuries are slightly more common in girls than in boys, regardless of the

sport. (Ahola et al., 2019) However, the connection between the growth spurt and the risk of injury is not clear based on the research data (Vilén, 2019, p.15).

Individual risk factors that especially predispose to overuse injuries include a previous overuse injury and insufficient night sleep and rest. In addition to these, factors predisposing to overuse injuries are the amount of training, the intensity of the training, early specialization in one sport, practicing one's sport all year round without rest periods, competition, and playing in team sports on an adult team. (Ahola et al., 2019)

Since every athlete and sport is different, it is impossible to say the exact number or threshold at which a stress fracture occurs. Although the actual evidence is still limited, one new measure proposed for young athletes is that the risk of total injury increases when the number of hours of training per week exceeds the athlete's age. (Ahola et al., 2019; Beck, 2021 p.5-6) However, also too little physical activity increases the risk of overuse injuries (Ahola et al., 2019). Too little training can weaken the body's readiness to train or perform at a high intensity, thus increasing the risk of injury (Vilén, 2019, p.15).

In certain sports such as hockey, gymnastics, and baseball, where repeated hyperextension and rotational movement put pressure on the vertebrae of the lumbar spine, young athletes are at a higher risk of developing spondylolysis. In addition, adolescents doing only one sport, are at a higher risk of developing spondylolysis, than those who are doing multiple sports. (Virkki 2021, p.13)

7.2 Neuromuscular training

"Without sensation, there is no movement" (Vilén, 2019, p.26). Practicing the proprioception is the most essential part of a young athlete's skill training. When youths will learn how to control their body, back, hips and knees, it will be rewarding when they start example strength training. Our body sends information to our brains all the time, and without this information, we are not able to move, because we would not know what kind of position our body and limbs are. (Vilén, 2019, p.26) Neuromuscular training plays an important role in sports injury prevention and post-

injury rehabilitation. The neuromuscular training involves diverse running techniques, agility, balance, jumping, and strength exercises. Neuromuscular training refers to training aimed at developing the performance of the neuromuscular system. Its goal is to improve the cooperation of the nervous system, central nervous system and sensory and motor systems, and muscles. Neuromuscular training develops muscle strength, rapid force production, timely activation of muscles, dynamic stability of joints, movement control and movement skills. In addition, the training includes training of balance, agility, and movement skills. (Pasanen, 2021, p.41)

The effects of neuromuscular warm-up programs in the prevention of sports injuries have been studied in several randomized controlled trials, and several systematic reviews and meta-analyses combining individual studies have been published on the subject. In studies, a neuromuscular training program has often replaced the usual warm-up, which still includes jogging and static stretching in many sports. It can be stated that the research evidence for the preventive effect of neuromuscular warm-up programs on sudden sports injuries is strong. (Pasanen, 2021, p.41) Stretching during the warm-up increases blood circulation, raises body temperature, lowers muscle tension, improves neuromuscular integration, and increases connective tissue flexibility (Kalaja, 2022, p.64).

In 2021 a study was conducted by the Tampere Sports Clinic and the UKK Institute to determine whether a warm-up training that activates the neuromuscular system can prevent lower limb overuse injuries in young soccer players aged 9-14. However, the study found that the neuromuscular warm-up training did not effectively prevent overuse injuries. Therefore, more research is needed to explore how exercise can be used to prevent overuse injuries in children and young people. (Hilska et al., 2021)

Proper warm-up before exercise can significantly impact the effectiveness of your workout. When you warm-up, your heart rate and breathing rate increase, which improves blood circulation throughout your body. As a result, your muscles, tendons, and joints receive more oxygen and nutrients, making them better prepared for more demanding physical activity. (Walker et al., 2014, p.21) The warm-up done before sports training can also be thought of as physical training, the purpose of which is to promote the movement, skill, and performance of your players (Vilén, 2019, p.19).

7.3 Strength training

Having good muscle strength is central to functional ability and body control, with the most important muscle groups being those in the middle body and lower limbs (Kalaja, 2022, p.70). Young people need meaningful and motivating strength training to establish a foundation for the future. In addition, sufficient strength supports the movement of the limbs and body in challenging situations and can help prevent overuse injuries. (Vilén, 2019, p.83-85)

Types of strength are endurance strength, maximum strength, and speed strength. Different strength types should be developed in the right order, so that starting strength training should be done with endurance strength training. When the performance techniques are in order, you can start gaining muscle strength with basic and maximum strength training. Last in the development cycle focuses on speed and strength, which are enhanced through fast, explosive, and speed strength training. Endurance strength refers to maintaining the strength level of muscles for a relatively long time or repeating certain strength levels multiple times with short recovery periods. Its goal is to enhance the muscle's ability to function in high lactic acid concentration conditions. Maximum force is the highest level of voluntary muscle contraction, typically lasting 0.5 to 3 seconds. Speed strength training is the ability of the neuromuscular system to produce the greatest possible force in a short time or the ability to move a submaximal load at the greatest possible speed. (Kalaja, 2022, p.70-76)

There is still a myth about strength training for children and young people, according to which strength training started at a young age would be harmful and even dangerous. This myth is based on studies conducted in the 1970s-1980s, which reported individual injuries mainly due to poor performance techniques. (Kalaja, 2022, p.76) Later, it has been found that strength training is safe and effective for improving muscle strength, bone density, motor skills, running speed, and ability to change direction, and reduces the risk of injury without any signs of decreased height or bone growth plate damage (Haapala, 2018; Kalaja, 2022, p.76).

7.4 Mobility training

Mobility is an important aspect when it comes to exercise and body control, whether you are into sports or simply living your daily routine. It is required for regular activities like walking, as it helps to extend the hip, thus reducing the risk of lower back pain. (Kalaja, 2022, p.57) Mobility refers to the mobility of the joints combined with the flexibility of the muscles and tissues surrounding the joints. Although mobility is partly an inherited physical characteristic, it can also be developed through training. The body's different structures have varying levels of resistance to stretching movements: muscle and muscle membrane 41%, ligament 47%, tendon 10%, and skin 2%. Therefore, stretching exercises can have the greatest effect on the stretching of the muscles. (Kalaja, 2022, p.58-59)

Mobility training is training where the aim is to promote joint range of motion. The most common form of mobility training is stretching, which is classified into different forms of stretching, such as passive, static, dynamic, or ballistic. (Vilén, 2020, p.97) The word static means to be still. In general, when people talk about stretching, they often mean static stretching specifically (Pihlman, 2020, p.83). Static stretching calms the body, and thus weakens performance and tunes the body in a direction not desired (Vilén, 2020, p.20).

In dynamic stretching or mobility training, the purpose is to move actively all the time along the entire range of motion of the joint, either from one position to another or actively doing one set of movements. So, you don't stay in any position for a long time, as in static stretching. In the warm-up, one set is enough, but in the actual training aimed at increasing mobility, the sets must be repeated 3–4 times. Dynamic exercises can be done daily, but it would be recommended to do them at least three times a week. (Pihlman, 2020, p.79) Active stretching, where the body is moved to large ranges of motion while challenging body control, brings benefits to mobility, balance, muscle strength, promoting performance. The stretches should be kept short, about 1-5 seconds long, and more repetitions should be done, about 10 per movement. In active stretching, it is good to think that at least the muscle groups and movement chains specific to the sport should be worked through. (Vilén, 2020, p.20-21)

Ballistic exercises refer to movement that is created primarily from kinetic energy. It would be good to add ballistic exercises to the exercise programs of young people, so that the body gets used to this type of movement. When doing exercises with young people, attention should be paid to the control of movements. During puberty, changes in height and growth can affect the body's movements. It's important to be mindful of the range of motion and number of repetitions when exercising as overdoing it can cause irritation and pain in the attachment points of the tendons and bones. (Pihlman, 2020, p.82)

Having good mobility can bring about several benefits, such as improved power output, balance, relaxation, speed, and endurance. It also reduces the risk of injury, increases economy of movements, speeds up the motor learning process, improves motor regulation, prevents muscle imbalances, and contributes to overall health, well-being, and quality of life. (Kalaja, 2022, p.57) Staying active and moving in a variety of ways is the best way to prevent movement restrictions and the resulting musculoskeletal problems (Pihlman, 2020, p.93).

7.5 Sleep and recovery

Recovery is the most important phase in terms of performance development and learning, and more than 90% of recovery takes place while we sleep. Lack of sleep has significant effects on the body. Vitality, performance, mood, and motivation decrease, the body's defense systems, and sugar and fat metabolism weaken. Sleep deprivation is also known to weaken balance, reaction ability and coordination. These characteristics affect body control, strength, speed, and rhythmicity of movement and thus predispose to poor movement control and, especially in contact sports, to an increased risk of injury. In addition, the risk of exposure to overuse injuries, sports injuries and accidents increases. (Tuomilehto, 2021, p.141-144)

Getting enough sleep is crucial for young athletes. Experts recommend getting at least eight hours of sleep every day. In addition, the quality and regularity of sleep are equally important for proper recovery. Not getting enough sleep compared to what

your body needs increases the risk of injuries. Studies have shown that increasing the amount of sleep can reduce the risk of injury by 40-60%. (Terveurheilija, n.d.)

7.6 Nutrition

Proper nutrition supports the prevention and treatment of sports injuries. In general, an athlete's goal is to develop, succeed, and stay healthy. High-quality and efficient training is necessary for development, but proper recovery is equally important. A versatile, healthy diet supports the athlete's performance and the overall well-being of the athlete. In addition, good nutrition maintains the athlete's resistance, prevents fatigue, and illnesses, and reduces the risk of injury. (Hietavala, 2021, p.135)

The primary role of vitamin D is to regulate calcium balance in the body, which, when deficient, can increase the likelihood of stress fractures in athletes (Ilander & Mursu, 2021, p.501). With girls, low body mass index, menstrual disorders, poor nutrition, and lack of vitamin D increase the risk of stress fractures (Ahola et al., 2019).

It has been found in many studies that a fluid deficit exceeding 2% of body mass can impair performance in activities of various durations and quality. Athletes may not always drink enough between exercises, which is why mild dehydration is common at the beginning of exercise. Young people are also vulnerable to dehydration. According to a study, most young elite athletes from various sports were dehydrated in the morning and did not achieve fluid balance at any point during the day. (Ilander et al. 2021, p.546)

7.7 Overuse injury treatment

The basic principles of the treatment of overuse injuries are early identification, finding out the cause of the injury, and reducing the load enough. Patient education regarding the load, and exercise that rehabilitates and prevents new injuries are key. (Kattilakoski & Parkkari, 2021, p.239) Especially in the case of overuse injuries, it is

important to recognize repetitive movements in the sport and the risk factors that may be associated with them (Kattilakoski & Parkkari, 2021, p.241-242).

The goal of rehabilitation is for the athlete to be in better condition at the end of the rehabilitation than when the injury occurred (Walker et al., 2014, p.49). In the treatment of overuse injuries, early intervention aims to prevent the prolongation of injuries and pain. Often, a previous injury, growth spurt, insufficient energy intake, low aerobic performance, weak muscle strength, lack of body and movement control, or technical error in movement performance may lead to an overuse injury. Addressing the issues mentioned above is especially emphasized in the treatment of overuse injuries. Depending on the quality of the injury, treatment generally does not mean complete rest, but training can often be continued with replacement exercises. For example, it is a good idea to change high impact running to cycling or swimming, where endurance fitness can still be practiced. However, it must be remembered that temporary reduction of the load is central in the treatment of overuse injuries. (Kattilakoski & Parkkari, 2021, p.239)

8 METHOD AND THESIS PROCESS

The planning of the thesis started in October 2022. I started by thinking about various interesting topics for work. The topic of lower back strain injuries among young athletes which has been a lot of talk about in different media, came up quite quickly. I started to get to know the subject in more detail by searching for information and reading articles and books.

In November 2022, I was in contact with a local company that had started to implement physical training for junior players in the local hockey team. As a result of the discussion, it became clear that some lower back overuse injuries have occurred in the past also in the team in question. Since many people's knowledge of the subject is almost non-existent, the idea was born to create a guide that can be used to increase

the knowledge of players, their parents and hockey coaches about the most common low back overuse injuries, risk factors and preventive training.

The search for a theoretical framework and familiarization with the topic began at the end of 2022, and in December 2022 I presented the thesis plan. The realized schedule (Figure 4) succeeded quite well according to the planned schedule. The writing and research work mainly took place between March and August 2023. In June 2023, we had a meeting with the customer to discuss the guide's content, and we reached a good understanding of what kind of guide they wanted. In September 2023, I presented the guide again, and we mainly focused on minor details that needed changes. The chosen exercises for the warm-up program were video recorded and saved in the client's private YouTube channel. During September 2023, the theoretical portion of the thesis was completed along with the accompanying guide.

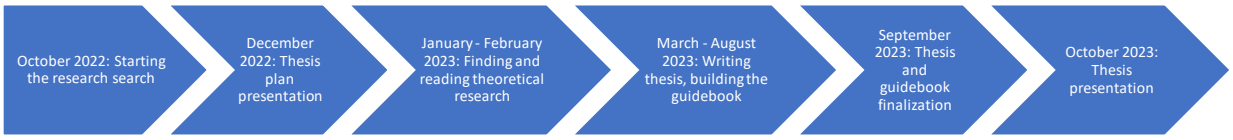


Figure 4. Brief schedule of the thesis.

Action-based research was chosen as the way to implement this thesis because author felt it served the client's wishes and my own learning in the best possible way.
The purpose of this action-based research was to find out, from the point of view of physiotherapy, the recommendations related to the prevention and treatment of overuse fractures of the lumbar spine according to the latest research information.

The theoretical framework search was done using studies from the Pubmed database from the years 2010–2023 with the search words "overuse injury" AND "prevention" AND "neuromuscular" AND "youth". A few new works by well-known researchers were used as book sources, which dealt with sports injury prevention and rehabilitation as their main topic. The author wanted to extract only the latest and reliable research data mainly using studies and books published during the 2020s as sources.

9 GUIDEBOOK

The design of the guide started from a perceived need. Knowledge of overuse injuries of the lower back and their prevention was insufficient. The author wanted to make the guide informative, so that the player, the player's parent, and the hockey coaches can easily understand the key factors. The guide briefly explains the anatomy of the lower back, common overuse injuries in adolescents, and the key points for their prevention and treatment.

The guide also includes a neuromuscular warm-up training program, which the players do always before hockey practice. For the program, we have selected eight different exercises that strengthen and stretch different parts of the body. We wanted to name the exercises so that it is easy for the players to remember them. All the exercises are recorded on video, where you can check their correct performance technique. These exercises are design to activate and strengthen the core, gluteal, hip flexor, and shoulder girdle muscles. All the exercises are done in dynamic rhythm, and part of the exercises are also stretching the hip flexor, gluteal, and adductor muscles, as well as increasing the thoracic spine rotation. According to the studies, increasing the strength and mobility of these muscle groups and areas has been proven to reduce the risk of injury.

The purpose is for the players to learn to understand the importance of a properly implemented exercise, which aims to develop the athlete and prevent injuries. In addition, the hockey coaches also need to understand these things and supervise that the exercises are done correctly. Without the coaches' supervision and intervention, there is always a risk that young athletes will not be able to concentrate on a properly performed exercise, and the quality of the movement will suffer.

10 DISCUSSION

It is worrying that sports injuries and overuse injuries among children and young people have increased in recent decades, as many studies have shown. (Pasanen, 2021) Most injuries occur in sports club activities, but this is also explained by the fact that children and young people engage in other free time sports has decreased, and they are more passive. Modern technology has brought its own challenges to the matter, as it offers many kinds of addictive pastime games and applications.

The purpose of this action-based research was to find out the recommendations related to the prevention and treatment of overuse fractures of the lumbar spine among young ice hockey players according to the latest research information. The purpose was also to find and list the most significant risk factors affecting injuries, and to tell in the guide what things coaches should pay attention to when mapping risks. The author wanted to use the physiotherapist perspective to plan the guidebook and warm-up training program to prevent lower back overuse injuries in adolescents based on evidence-based knowledge.

Ethical considerations were taken into consideration so that the thesis and the guidebook will use up-to-date and sufficiently high-quality sources, which ensures the reliability of the theory part. However, when implementing the warm-up training program, it should be noted that you cannot trust the self-directed training of young people, so the coaches must supervise the exercises to ensure that movements are done correctly and safely.

The sensitivity periods of children and young people in connection with training has been a somewhat controversial topic in recent years, and therefore the author wanted to highlight the main features related to it. Thinking about the sensitivity periods is not entirely a bad thing, but they should not be interpreted and implemented in the training of children and young people in too black-and-white terms. The most important thing is that the training of children and young people should be versatile, meaningful, developing, and challenging enough.

The ideal situation would be that the team could be divided into small groups for physical training, according to physiological age. In this case, in the planning and implementation of the content of the exercise, for example, adolescents in the growth spurt phase could be better taken into account. However, this is quite challenging, as few organizations have the required resources to implement this idea. Maintaining good muscle balance should be also considered in training. In ice hockey, it is easy to implement, for example, so that in the warm-up the players always use the stick from the weaker side, so to speak, from the wrong side.

The prevention of overuse injuries is still a rather understudied topic. In part, I believe this is because it might be extremely difficult to study due to the many changing factors. Each sport has its own special features, and in addition, every athlete, every person, is different. So far, studies cannot truly explain why some players within the same team are exposed to overuse injuries, but others are not. Although a neuromuscular training program has not yet been proven to completely prevent overuse injuries, several studies show that it significantly reduces non-contact sports injuries. However, research data and works based on clinical experience show that improving movement control, strength, stability, and mobility, has an impact on the prevention of overuse injuries. In addition, especially the tightness of the hip flexors, and hamstrings, together with the weakness of the strength of the gluteal muscles seem to have a connection to increase the load and pressure on the lumbar spine, which can lead to low back pain or a stress fracture in the lumbar spine.

Studies related to overuse injuries specific to ice hockey was also challenging to find, which is why the research information used in the thesis was also based on other ball and team sports such as soccer. Soccer is a much more popular sport in the world than ice hockey, and therefore a lot of research has been done on it to prevent sports injuries.

The guide was built based on the latest evidence-based research, but the effectiveness of the warm-up training program for the prevention of overuse injuries could not be verified during this thesis. The warm-up training program presented in the guide is planned to be implemented in a local ice hockey organization, for several teams of 12-15-year-old players during the 2023-2024 season. Thus, the organization has the opportunity to compare the prevalence of injuries in the future compared to previous

seasons. One useful and interesting topic for follow-up research would be to conduct a study that would monitor the effect of neuromuscular training on the incidence of overuse injuries in junior ice hockey.

This thesis as a whole was a really interesting learning process for the author. During this work, the author learned to better understand the functional anatomy of the lower back and pelvis. In addition, it was particularly interesting to learn to understand the sports-specific structures that are loaded in ice hockey, as well as the characteristics required by the player.

REFERENCES

Agur, A. M. R. (2021). Grant's atlas of anatomy (Fifteenth edition. International edition.). Wolters Kluwer.

Ahola, J-A., Vasankari, T, Nietosvaara, Y., Mattila, M. & Haara, M. (2019). Kasvuikäisten rasitus-vammat. Lääketieteellinen aikakausikirja Duodecim, 135(20):1953-60. https://www.duodecimlehti.fi/duo15199

American Academy of Orthopaedic Surgeons. (2021). Spondylolysis and Spondylolisthesis. OrthoInfo. Retrieved May 15, 2023, from https://orthoinfo.aaos.org/en/diseases--conditions/spondylolysis-and-spondylolisthesis

Costa, L., de Reuver, S., Kan, L., Seevinck, P., Kruyt, M. C., Schlosser, T. P. C., & Castelein, R. M. (2021). Ossification and Fusion of the Vertebral Ring Apophysis as an Important Part of Spinal Maturation. *Journal of clinical medicine*, *10*(15), 3217. https://doi.org/10.3390/jcm10153217

Haapala, E. A., & Ihalainen, J. K. (2018). Fysiologiset vasteet liikuntaan lapsilla ja nuorilla. LIIKUNTA JA TIEDE, 55 (4),45-49. https://erepo.uef.fi/handle/123456789/7033

Haché, A. (2002). The physics of hockey. JHU Press.

Hämäläinen, K., Danskanen, K., Hakkarainen, H., Lintunen, T., Jaakkola, T., Arajärvi, P., Lehtoviita, T., Forsblom, K., Pulkkinen, S., Pasanen, K., Kalaja, S., & Riski J. (2015). Lasten ja nuorten hyvä harjoittelu. VK-Kustannus.

Heinonen O. J., & Kujala U. M. (2001) Kasvuikäisen urheilijan ongelmat. Lääketieteellinen aikakausikirja Duodecim, 2001;117(6):647-652. https://www.duodecimlehti.fi/duo92159

Helander, K., & Vilén, S. (2015). Onnellinen urheilija: Lapsen kasvu urheilijaksi. Readme.fi.

Hilska M., Leppänen, M., Vasankari, T., Clarsen, B., Aaltonen, S., Bahr, R., Haapasalo, H., Parkkari, J., Kannus, P., Pasanen, K. (2021) Neuromuscular training

warm-up in the prevention of overuse lower extremity injuries in children's football: A cluster-randomized controlled trial. Transl Sports Med. 2021; 4: 849–858. https://doi.org/10.1002/tsm2.289

Ilander, O., Heikura, I., Hietavala, E., Laakso, M., Manner, L., & Mursu, J. (2021). Liikuntaravitsemus 3.0. VK-Kustannus Oy.

Jones L. & Tubbs, R.S. (n.d.) The Ligaments of the Lumbar Vertebrae. Wheeless' Textbook of Orthopaedics. Retrieved April 15, 2023, from https://www.wheelessonline.com/issls/lumbar-vertebrae-ligaments/

Kalaja, S. (2020, April 17). Valmennustaito.info, Taitotohtorin blogi. Retrieved May 22, 2023, from http://www.valmennustaito.info/taito/mitapa-jos-vihdoin-unohdettaisiin-herkkyyskausiajattelu-valmentautumisessa/

Kalaja, S., & Kalaja, T. (2022). Kehonhallinta: Liikuntataitojen oppiminen ja harjoittelu. VK-Kustannus Oy.

Launay F. (2015). Sports-related overuse injuries in children. Orthopaedics & traumatology, surgery & research: OTSR, 101(1 Suppl), S139–S147. https://doi.org/10.1016/j.otsr.2014.06.030

Lawrence KJ., Elser T., Stromberg R. (2016) Lumbar Spondylolysis In The Adolescent Athlete, Physical Therapy in Sports. https://doi.org/10.1016/j.ptsp.2016.04.003

Leppänen, M. (2021) Terveurheilija. Alaselkäkipu on yleinen vaiva eikä se rajoitu vain tiettyihin lajeihin. https://terveurheilija.fi/ahkanohaista/uusi-tutkimus-alaselkakipu-on-yleinen-vaiva-eika-se-rajoitu-vain-tiettyihin-lajeihin/

Lumbar Anatomy. (2022, January 12). Physiopedia. Retrieved April 10, 2023 from https://www.physio-pedia.com/index.php?title=Lumbar_Anatomy&oldid=291466.

Lumbar Vertebrae. (2022, January 24). Physiopedia. Retrieved April 9, 2023 from https://www.physio-pedia.com/index.php?title=Lumbar_Vertebrae&oldid=292432.

Pasanen, K. (2009). Floorball injuries: epidemiology and injury prevention by neuromuscular training. Tampere University Press. https://urn.fi/urn:isbn:978-951-44-7822-2

Pasanen, K., Haapasalo, H., Halén, P., Parkkari, J., & Aho, J. (2021). Urheiluvammojen ehkäisy, hoito ja kuntoutus (1. painos.). VK-Kustannus Oy.

Patel, D. R., & Kinsella, E. (2017). Evaluation and management of lower back pain in young athletes. Translational Pediatrics, 6(3), 225–235. doi:10.21037/tp.2017.06.01

Pearsall, D., Turcotte, R, & Murphy, S.D. (2000). Biomechanics of ice hockey.

Pihlman, M., Luomala, T., Mäkinen, J., & Palsi-Ikonen, A. (2020). Liikkuvuusharjoittelu: Hallittua voimaa ja liikkuvuutta (second edition). VK-Kustannus Oy.

Sassack, B. & Carrier, J.D. (2022) Anatomy, Back, Lumbar Spine. https://www.ncbi.nlm.nih.gov/books/NBK557616/

Shamus, E. (2017). Sports Injury Prevention & Rehabilitation (second edition). McGraw-Hill Medical.

Suomen Jääkiekkoliitto ry & IIHF. (4.9.2018). Jääkiekon virallinen sääntökirja 2018-2022. Retrieved April 20, 2023, from https://www.dropbox.com/s/ecl4f7rjfddklwb/SÄÄNTÖKIRJA%202018-2022.pdf?dl=0

Suomen Jääkiekkoliitto ry. (2022). Suomen jääkiekkoliiton vuosikertomus 2021-2022. http://www.finhockey.fi/index.php/info/toimintakertomus

Suomen Jääkiekkoliitto ry. (n.d.-a) Leijonanpolku 10-14 vuotiaat. Retrieved April 20, 2023, from https://www.finhockey.fi/index.php/pelaajalle/leijonanpolku/10-14-vuotiaat

Suomen Jääkiekkoliitto ry. (n.d.-b) Leijonanpolku 15-19 vuotiaat. Retrieved April 20, 2023, from http://www.finhockey.fi/index.php/pelaajalle/leijonanpolku/15-19-vuotiaat

Suomen Jääkiekkoliitto ry. (n.d.-c) Leijonanpolku. Retrieved April 20, 2023, from https://www.finhockey.fi/index.php/pelaajalle/leijonanpolku

Suomen Olympiakomitea ry. (2023) Tähtiseurat lajeittain. https://www.olympiakomitea.fi/uploads/sites/1/2023/03/f9cb23ed-tahtiseurat_lajeittain_tilanne_1.3.2023.pdf

Suomen Olympiakomitea ry. (n.d.) Jääkiekko. Retrieved April 20, 2023, from https://www.olympiakomitea.fi/huippu-urheilu/huippu-urheilutietoa/olympialajit/talvilajit/jaakiekko/

Terveurheilija. (2016) Nuoren urheilijan selkä. Retrieved September 4, 2023, from https://terveurheilija.fi/wp-content/uploads/2019/10/Pasanen_ym_Nuoren_urheiijan_selka.pdf

Terveurheilija. (n.d.) Uni ja vuorokausirytmi. Retrieved September 4, 2023, from https://terveurheilija.fi/harjoittelu/uni-ja-vuorokausirytmi/

Tortora, G. J. K. & Derrickson, B. H. (2017). Tortora's principles of anatomy & physiology (15th edition.). John Wiley & Sons.

Urheilun kirjo. 2022. Jääkiekko Suomessa. Retrieved April 22, 2023, from https://www.urheilunkirjo.com/suomalainen-jaakiekko.html

Van Hooren B., De Ste Croix M. (2020). Sensitive Periods to Train General Motor Abilities in Children and Adolescents: Do They Exist? A Critical Appraisal. Strength Cond J. 2020;42(6):7-14. DOI:10.1519/SSC.0000000000000545

Vilén, V., (2019) Nuoren Urheilijan Fysiikkavalmennusopas.

Virkki, E. (2021). Treatment of pediatric spondylolysis and spondylolisthesis. https://urn.fi/URN:ISBN:978-951-29-8591-3

Walker, B., Grönholm, M., Salminen, M., Wegelius, I., Larsson, B., Alanen, A., Suomalainen, V. (2014). Urheiluvammat: Ennaltaehkäisy, hoito, kuntoutus ja kinesioteippaus. VK-Kustannus.

Wong, J. S., Lalam, R., Cassar-Pullicino, V. N., Tyrrell, P. N. M., & Singh, J. (2020). Stress Injuries of the Spine in Sports. Seminars in musculoskeletal radiology, 24(3), 262–276. https://doi.org/10.1055/s-0040-1709484