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Thesis:

“Pain in the lower spine after

supination trauma in the case of a rupture of the

Ligamentum Talofibular anterius”

Dissertation topic approved by Dr. Shahin Pourgol, MBA, DC, DO, PhD

Author's comment:

I certify with my honor that the content of my doctoral thesis has been prepared to the best of my knowledge and conscience.

Mumbai, 1. June , 2022

Introduction:

During my professional career as a physiotherapist and osteopath in high-performance Sport, I was often confronted with the clinical picture of supination trauma. Very often, after a period of time (post trauma) from weeks up to a maximum of half a year, there was a continuous pain in the lower back. This prompted me to examine the subject intensively and to look at it in more detail. A holistic therapy concept consisting of different treatment techniques of physiotherapy, osteopathy, sports science and psychology form an optimal therapy approach in my opinion. It is important to adapt the therapy plan to the course of the inflammatory phases and to not to start too early with exercises in the open kinematic system. Retrieve the patient at the point of care. A patient is an individual, which is subjected not only to physiological but also to psychological processes. Each of our patients has an individual pain threshold, is subject to different life situations and is exposed to different environmental factors. Optimal rehabilitation and recovery can only take place in harmony with both physical and psychological health, as well as mental health. If the therapist applies too early or too intense stimuli at the wrong moment, or scale, it can lead to a massive stress situation for the patient. This has the consequence that the healing process is disturbed or delayed.

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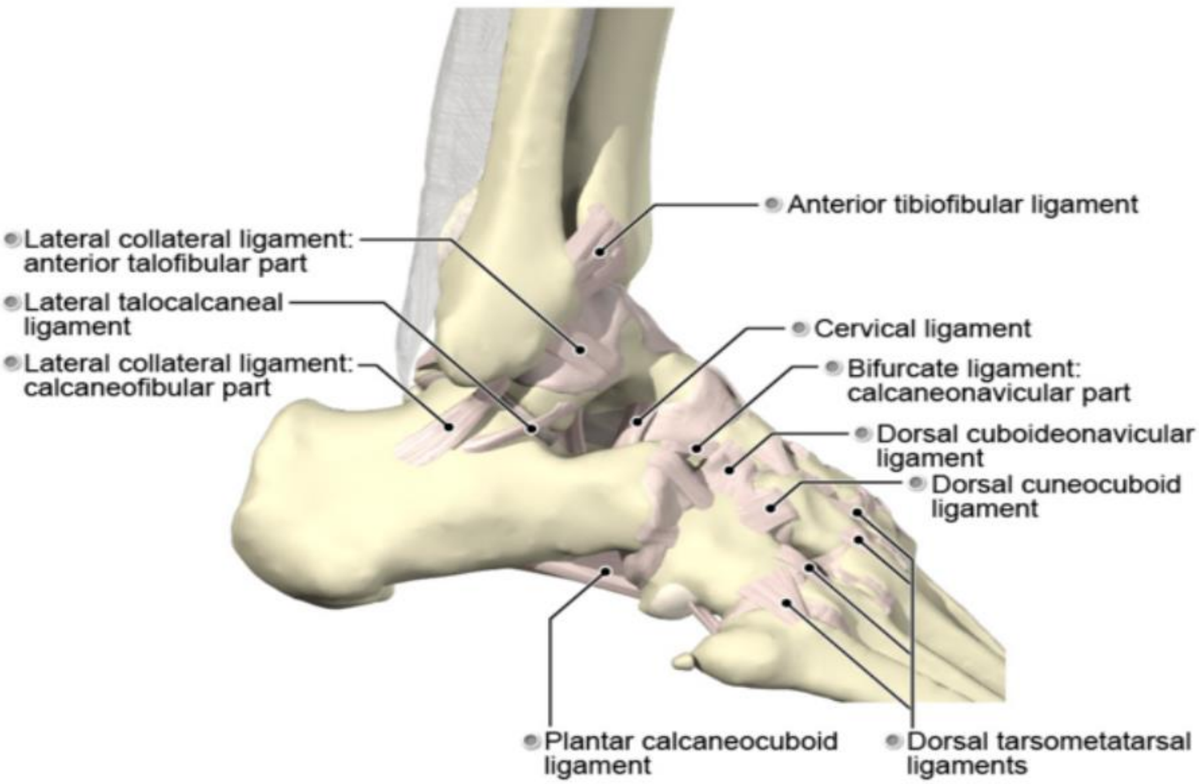
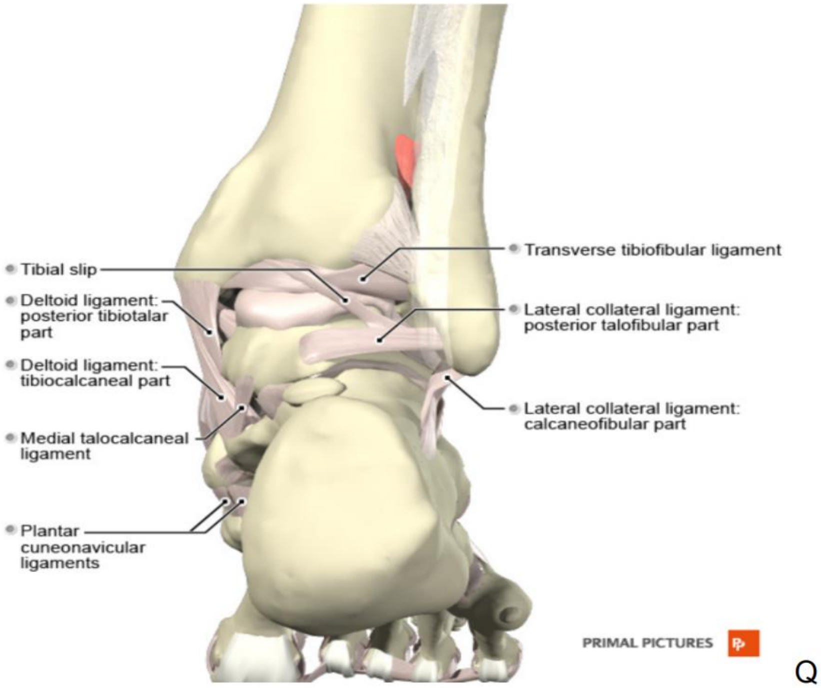
The foot

1) <u>Basics of anatomy</u>





Source: Physiopedia

The foot has the function of taking the loads when walking and standing. Contact with the support surface is established and controlled via various tactile sensory organs (receptors) in the sole of the foot (proprioception). Since the foot is to be as a supporting organ, the individual elements are correspondingly strong, e.g.: Calcaneus, Talus.

Since the flexibility of the foot is optimized by the interaction of ligaments, muscles and bones, this results in optimal adaptability to the support surface. Small disturbances of this structure lead to changes in the physiological support system.

1. Upper ankle joint - art. talocruralis
2. Lower ankle joint - art. talocalcaneonavicularis (anterior chamber)
   - art. subtalaris (posterior chamber)
3. Chopart joint - art. talocalcaneonavicularis et calcaneocuboidea (art. tarsi transversa)
4. Lisfranc joint - art. tarsometatarsal
5. Joints between: - os naviculare, os cuboideum and ossa Cuneiformia

6. art. intermetatarseal

7. art. metatarsophalangeal

8. art. interphalangeal

1.1 Upper ankle joint - Art. talocruralis

The ankle joint is the anatomical connection between the lower leg and the foot. The three corresponding bones are tibia, fibula and talus. The tibia and fibula bones form the so-called malleolar fork. The syndesmosis tibiofibularis connects both lower leg bones and holds them together. The lower articular surface of the tibia slides in the groove of the trochlea tali. The convex part of the upper ankle joint is formed by the trochlea. The upper part of the talus is convex in the sagittal plane and includes a groove in the middle that serves as a guide groove for the tibia. The groove is oriented somewhat ventral-laterally. In contrast, the head of the talus is oriented somewhat ventral-medial. Medial and lateral to the trochlea we find the two articular surfaces for the malleoli lateral and medial. As a result, the talus is grasped from three sides. The trochlea tapers, it is wider ventrally by about 5mm than dorsally.

The lateral malleolus is larger than the medial one. The result is that the axis of the of the upper ankle joint runs obliquely dorsal-lateral and distal.

Special feature: No musculature inserts at the talus.

1.2 Joint capsule:

It inserts at the edge of the cartilage-bone boundary. The capsule is slack at the ventral joint space and thus allows a wide range of movement. The capsule of the malleoli is strengthened by lateral collateral ligaments. In the ventrally applied area, the tendons of the extensor muscles protect it from knee locking. In the dorsal area the capsule is also strengthened by ligaments.

1.3 Ligaments of the upper ankle joint:

The collateral ligaments of the upper ankle joint extend like a fan from both malleoli to the tarsal bones. By that arrangement these results a primary guidance and stability factor. The laterally arranged ligament system consists of three ligaments:

1. lig. fibulotalar anterius

   - this runs from the ventral tip of the lateral malleolus close horizontally to the talus.

2. fibulocalcaneal ligament

   - this runs from the tip of the fibula obliquely dorsally to the lower outer surface of the calcaneus

3. fibulotalar posterior ligament

   - this runs from the inner side of the lateral malleolus horizontally towards the medially to the talus

The medial ligament system consists of a deep and a superficial layer.

(deltoid ligament)

Deep layer (has 2 ligamentous trains)

1. Lig. tibiotalar anterius - runs obliquely ventral-distal to the column tali.
2. Lig. tibiotalar posterius - runs obliquely dorsally distal to the talus.

Superficial layer (2 ligament trains)

1. pars tibionavicularis
2. pars tibiocalcanearis

Stability function of the ligamentous apparatus

1. Stabilization in plantar flexion by the following structures

a) Lig. fibulotalar anterius
b)Lig. tibiotalar anterius and pars tibionavicularis of the Lig. deltoidium
c) Ventral capsule wall

2. Stabilization in varus and valgus through
- fibulocalcaneal ligament and pars tibio-calcaneal of deltoid ligament

3. Stabilization in dorsal extension
- Lig. fibulotalar posterior and pars tibiotalar posterius of the Lig. Deltoidium

2. Biomechanics

The upper ankle joint is a "hinge joint" in terms of its shape. The movements of the upper ankle joint are plantar flexion and dorsal dorsiflexion. These run in an oblique axis, this means in the initiative of plantar flexion, the talus is almost too loose and consequently allows wobbling movements. In dorsal extension, the talus is tightly anchored in the malleolar fork and thus locks the joint. In the same function the malleolus fork is pressed apart by approx. 2

mm. due to the nature of the talus and its oblique axis, no pure hinge movements take place. Rather, they are combined with small rotational movements of the talus.

This results in the following combination movements:

Plantar flexion + internal rotation + adduction + supination = inversion

Dorsal extension + external rotation + abduction + pronation = eversion

This applies to movements in the open kinematic system.

The articulating bones are the talus, the os naviculare and the os calcaneus. The lower ankle joint consists of two joints, which are separated from each other by the structure of the joint capsules and enumerated below:

1. art. subtalaris (posterior chamber)

In the anatomical and biomechanical view, the calcaneus has in its posterior part a convex joint surface, which is oriented in sagittal plane and is too flat in the medio-lateral direction. The talus articulates with an articular surface concave in the sagittal plane. The joint is characterized by a rather lax capsule and reinforcing ligaments.

2. Talocalcaneonavicular articular surface (anterior chamber)

The calcaneus has two concave articular surfaces in its anterior chamber. The os naviculare is concave in its proximal orientation and therefore presents an optimal congruence to the convex caput tali an optimal congruence. In addition, the glenoid cavity is enlarged by a ligament that extends between the os naviculare and the calcaneus. This is called the calcaneonavicular ligament. The capsule of the anterior chamber is mainly reinforced by ligaments such as the lig. bifurcatum.

Advanced biomechanics

The two chambers of the lower ankle associate as a functional unit. The axis runs from the tuber calcanei ventral-dorsal through the neck of the tarsus. In the area of the tarsi, the line of motion is intersected by the axis of the ankle joint. Around this axis the movements of the inversion and eversion take place. In the biomechanical view of the convex and concave rule, no movement takes place in the lower ankle joint, since between the Talus and Calcaneus there are two opposite joint configurations. Analogous translations and rotations take place.

3. Art. tarsi transversa (Chopart's joint)

The transverse tarsal joint art. talonaviculare and art. calcaneocuboideum form together a functional unit, but have separate joint cavities. The combining is established by strong ligamentous pulls.

<u>Two important ligaments:</u>

1. Calcaneonavicular plantar ligament

Strong ligament up to 5 mm thick, which is cartilaginous on the upper side and forms the articular socket together with the os naviculare for the head of the talus.

2. Bifurcate ligament
- Lig. calcaneonavicular
- Lig. calcaneocuboideum

Connection between calcaneus, os naviculare and os cuboideum. The said ligament is also referred to as the ligament of Chopart's joint and ensures the functional unity. The ligaments are tightened in pronation, which cause a force transmission to the metatarsalgia. These are now the movement possibilities of the Pro- and Supination, which are made possible by a twisting.

4. art. tarsometatarsal (Lisfranc's joint)

The lisfranc joint line is formed by the three ossa cuneiformia, the os cuboideum and the bases of the five metatarsalgia. The axis is partially curved (Os metatarsale II displaced proximally). Due to their low mobility, these joints are defined as amphiarthroses. However, they are entirety involved in pro- and supination.

5. art. intermetatarseal

These are the joints between the bases of the metatarsal bones. They are also called amphiarthrosis.

6. art. metatarsophalangeal (MTP) - (toe joints).

The toes, like the fingers, have a proximal, middle, and distal phalanx except for the big toe, which has only a proximal and distal phalanx. The distal ends of the Matatarsalgia are convex and cylindrical. They articulate with the concave and oval shaped bases of the proximal phalanges. The metatarsophalangeal joint has a special feature that is biomechanically significant. The convex head of the os metatarsal I splits plantar into two concave articular surfaces, which are intended for the two sesamoid bones. The sesamoid bones allow a better Movement for the plantar foot muscles. (M. flexor hallucis brevis u.a.).

The two sesamoid bones slide distally during dorsal extension of the big toe and proximally during plantar flexion. The bursa subcutaneous capitis ossis metatarsalis I can cause discomfort when pressure is applied (hallux valgus). The metatarsophalangeal joints mainly perform flexion and extension movements whereas dorsal extension is greater (rolling behaviour).

In the metatarsophalangeal joint of the big toe, an abduction and adduction movements are possible. It is also the most important joint for the roll-off phase (toe off).

7. art. Interphalangeal DIP and PIP

The convex heads of the proximal and middle phalanges articulate with the concave (wedge-shaped) bases of the middle and distal phalanges. The great toe has only one interphalangeal joint.

Biomechanics of the rolling motion

Bony phase

The initial contact phase occurs with the calcaneal tuberosity in a supinated and dorsal dorsiflexed position. The further rolling movement runs over the lateral edge of the foot to the lateral edge of the foot to then initiate the push-off phase via the ball of the foot and finally over the big toe. The foot is then in a plantar flexed and pronated position.

Arthrokinematics:

The loading phase leads to a valgization of the calcaneus and consequently to a plantar-medial movement of the talus head. The naviculare must perform a counter movement in a dorso-lateral direction. Due to the convexity of the cuneiform I, the cuneiform moves to the plantar side and the metatarsal I to the dorsal side.

Osteokinematics:

The entire medial edge of the foot moves plantar. When the foot is unloaded the whole movements are reversed. From these simple biomechanics the treatment steps for a flat or hollow foot, e.g. build-up of the medial longitudinal arch in flat feet: the navicular bone must be mobilized to the plantar.

3. Pathologies:

<u>3.1. Bony pathologies</u>

- Arthroses
- Compression OSG ventral
- Osteochondrosis dissecans (talus)
- M. Köler I (Os naviculare)
- Heel spur
- Sesamoiditis
- Fatigue fractures (MT II or MT III) - Inversion trauma
- Eversion trauma
- Instabilities (mechanical)

3.2 Soft tissue pathologies

- Flatfoot syndrome
- Ligamentous stress on flatfoot ligament
- Plantar fasciitis
- Achillodynia
- Achilles tendon rupture
- Inversion trauma
- Eversion trauma
- Instabilities (functional)

3.3. Other pathologies

- Morton's neuroma
- Cuboid syndrome
- Hallux rigidus

4. Consequences for statics:

4.1 Functional systems

1. Postural system
2. Locomotion
3. Telekinesis (purposeful walking / running)
4. Idiokinetic system
5. Limbic system = motivation

to 1) Postural system, or also postural control defines the ability of the posture under the influence of gravitation, or the ability to maintain under the influence of gravity. This happens in the static sense as well as in movement.

to 2) Locomotion is an active change of location of living beings which move by their own effort. As well as the

interaction of open and closed kinematic chains.

to 3) Telekinesis is defined as a totality of static postural responses in the case of arbitrary movement.

To 4) Idiokinetic system

In addition to the integrative role of the spinal cord, the adult is dominated by the supraspinal control.

Truncus cerebri (brain stem) > Holding and supporting motor functions

Cerebellum (cerebellum) > Coordination of movements

Basal ganglia and thalamus > Movement program

Motor cortex > implementation of the movement design

Cortico- and Rubro-spinal pathways > Facilitation of excitatory and inhibitory transmissions from 1b fibers to gamma motor neurons

to 5) Limbic system

(with Amygdala, Hippocampus, Hypothalamus, Gyrus Cinguli) filters influences and enriches them with feelings. This happens before they are stored in the respective emotions such as fear and distress, the hypothalamus (via the amygdala) activates a hormonal cascade. If the hormones adrenaline and cortisol are permanently released, this can lead to a blackout.

Tasks include:

>Regulation at the vegetative level (digestion, reproduction, absorption of food).

>Coordination of (emotions, drive, memory, learning)

5. The acute and subacute causes of an adaptive postural pattern

First, a distinction is made between direct and indirect traumas.

5.1 Direct: Traumatic effects on the musculoskeletal system.

5.2 Indirect: Influences due to sport-specific stresses, which are based on stereotypical movement patterns in the sense of ascending or descending cause chains of consequences can be manifested. In this context it can overloading or even incorrect loading of the structures of the musculoskeletal system. Another important structure are the so-called nociceptors. A synonym for nociceptors is the word "damage detector", whose information is transmitted directly to the subcortex. In the subcortex no pain perception takes place, however, via rubrospinal pathways and the extrapyramidal system indicate an adaptive postural pattern. Nociceptors, however, are not only damage detectors but also pain detectors. They report their information to the cortex system and by means of corticospinal pathways and the pyramidal system, adaptive postural patterns are installed.

Due to direct or indirect trauma, information from the nociceptors leads to a compensatory posture. The most important priority of the central nervous system is to keep movement below the so-called pain threshold. This intelligent mechanism has ensured the survival of humans in the course of evolution. Referring to adaptive posture types, we have to consider different laws and biomechanical influences.

6. The Stability of the Habitus

6.1. Types of Bones:

- Long bone

- Short bone

- Plana bone

- Pneumatic bone

- Sesamoid bone

- Irregular bone

6.1.1. Ossa longa:

- long bones
- Ex. the humerus

- has corpus and ends

- in the shaft medullary cavity (Cavitas medullaris) with red and yellow bone marrow

- long bones

- Extension mainly in one direction

6.1.2 Ossa brevia:

- short bones
- Ex. carpal bone

- Outer substantia compacta

- Inside Substantia spongiosa

6.1.3 Ossa plana:

- flat bones
- Ex.: Scapula

- From two compact lamellae in between spongy bone material

- Growth in two directions

6.1.4. Ossa pneumatica:

- air-containing bone
- cavities are lined with mucosa

- Ex. upper jaw

6.1.5 Ossa sesamoidea:

- Sesamoid bones
- mainly in hand and foot
- may be incorporated in tendons
- Ex: patella

6.1.6. ossa Irregularia:

- all other bones
- Ex: vertebral body

7. Body fascia:

- it is a continuous connective tissue sheath
- it separates the subcutis from the musculature
- fascia consists of firm collagen fibers
- the fascia are presented by name in regional reference e.g. fascia lata

Decisive for the state of health of the connective tissue and the structures are mobility and state of tension.

Fascia are very sensitive and scar very quickly.

I would like to take a closer look at the subject of fascia properties, as they have an essential effect on ascending as well as descending cause and chains. Typaldos describes fascia as a living tissue that constantly needs oxygen and nutrients and fluids to dispose of waste products. If this happens the fascia has a high resistance against external forces. A primary role in this is played by the structure of the so-called proprioceptors (defined as damage sensors). Certain fibers have a certain tension which start to vibrate at a certain change in tension. Due to this ability it is guaranteed that constant proprioceptive information is transmitted. It is assumed that fascia have another task within the framework of muscle function. It is assumed that structures are involved in the coordination and motor movements of muscle contraction. The properties of fascia and their function, as well as their mechanism should be regarded as holistic. Purely figuratively speaking, one could imagine a road map. This means the uninterrupted gapless connection and a flowing transition between the fascial structures.

Continuity is the keyword in relation to fascia. This continuity is found in all areas of the body. Fascia separate and permeate bones, muscles, nerves as well as organs and have permanent properties of viscosity and temporary elasticity. This also explains the fact that after supination trauma of the foot the restrictive fascia of the calf can cause a continuous pain in the back or even into a higher lying region of the body and induce a subsequent posture.

If one considers the influences of the connective tissue in the therapy, then one should take classification as follows.

7.1 Classification:

- Connective tissue
- Cartilage tissue
- Bone tissue

From embryology we know that the so-called mesenchymal cells are the stem cells of the connective tissue and the supporting tissue. An important fact is that mesenchymal cells are undifferentiated stem cells of the mesoderm, which in turn can be synthesized by training stimuli. This means mesenchymal cells are able to form fibroblasts, lipoblasts, chondroblasts and osteoblasts. as well as osteoplasts. From the spinal cord they are to synthesize nerve cells from the spinal cord. I would now like to refer to the biomechanical regulation of the bio- and pathomechanics of the foot with accompanying pain in the lumbar region of the pelvis. I put at the beginning of my work the thesis " pain in the lower spine after supination trauma with a Rupture of the Ligamentum Talofibulare anterius". As already mentioned we have a myofascial influence on the pelvic and leg biomechanics.

8. But what exactly is a supination trauma:

An uncontrolled step into the " void" and it happened mostly in combination of a plantar flexion and supination of the foot (in plantar flexion there is an unlocking takes place and the talus is mobile). When the foot hits the ground, it flips outward. There is an immediate stabbing pain on the lateral side of the foot. If one defines a supination trauma, then one speaks of an overstretching, or even of a tear or even an avulsion of one or more ligaments of the lateral ankle joint. In the simplest case, there is merely an overstretching of the capsular ligamentous apparatus. Let us assume a severe supination trauma with a rupture of the anterior talofibular ligament (this is the ligament that tears most frequently). There is a massive swelling below the lateral malleolus. Usually, a linear blue line also forms on the lateral edge of the affected foot. The typical 5 signs of inflammation are positive (Redness, swelling, hyperthermia, pain, and functional limitation). This is accompanied by massive instability of the affected foot. This can become chronic if not followed by a secondary preventive therapy program. A therapeutic and sports protocol and training is indispensable and massively accelerates the healing process. The mentioned protocol should be carried out with strict attention to the phases of inflammation and healing. I will now list these in the following paragraph.

9. Phases of inflammation

Primarily, medicine distinguishes 4 phases of inflammation:

1) Exudative phase: day 0-3.
   The pain and accompanying swelling should be reduced, partial immobilization of the foot (often done with an Aircast splint).
2) Proliferative phase: day 4-10
   New tissue is slowly formed (builds up like a spider web)
   spider web-like structure, is called slow and steady)
3) Consolidation phase day 11-21
   Tissues structure and specify.
4) Orientation phase day 22 - several months
   The complete functional reconstruction of the affected joint and its structures takes place.

In the following, I will discuss the wound healing phases in detail

<u>9.1 Exudative phase:</u>

This phase lasts on average 0-3 days but may well last longer, this depends on the inflammatory signs mentioned. The top priority should be to repair the structures and to remove the inferior tissue. It is indispensable to follow the so-called R.I.C.E rule.

Rest > should be completed in order to prevent further injuries and to avoid not to provoke secondary injuries.

Ice > the affected patient can apply this in the home environment. It is the application should not be carried out for more than 4 minutes at a time. If the application of ice lasts longer than 4 minutes, a paradoxical vascular reaction occurs. It is recommended to repeat the application 5-10 times a day.

Compression > optimal in this case would be compression bandages, but also Tapes, such as lymphatic tapes or stabilization tapes. The mentioned tapes serve the lymphatic drainage as well as the immobilization and stabilization of the foot.

Elevation > To ensure optimal drainage of lymphatic fluids, the affected leg should be positioned above the heart line. As an optimal accompanying therapy, ultrasound and electrotherapy should be considered.

9.2 Proliferation phase:

From the first phase to the second, it is a fluid process. In that phase the pain at rest and at night decreases visibly. The continuous pain is followed by an intermittent pain, which can be triggered by mechanical pressure. New cells are formed, which in the course of the proliferation phase gain stability and functional strength as well as resistance. It is of immense importance to load the foot only moderately during this phase. Newly formed cells now receive information about how they should be and what kind of load they will have to handle in the future. Referring to the rehabilitation and training specific units the aerobic training methods should be used. These ensure matrix formation, vasodilatation and nutrient supply of the affected tissue. The method of choice should be proprioceptive training to activate and train stabilizing muscle groups. Hardly any weight but a high number of repetitions is an optimal training stimulus.

9.3 Consolidation phase & orientation phase:

Here, too, there is a smooth transition. You can now start with gentle Strength training, but it should be done step by step. In the course of the phases, the training and strength intensities should be increased. However, it is important to keep the patient where he is, which means to pay attention to any pain and adaptation patterns. A secondary preventive rehabilitation is the primary goal to avoid reoccurrence of instabilities and injuries. The bottom line here is that the stronger the trained muscles and around the affected joint, the less likely it is that the injury will recur. It is indispensable to train the patient for daily or even sport-specific situations. In the course of the second to the last phase, the focus must also be on the patient's gait pattern, as this will change during the healing process by means of adaptive posture patterns.

10. How the pathomechanics behave in the case of supination trauma:

It is important to look at it in a holistic context, due to our weak points. Every time the musculoskeletal system changes biomechanically there is a weak point (e.g. transition from the cervical spine to the thoracic spine to the lumbar spine to the sacrum). With a of the left foot, the os cuboideum is in external rotation and the os naviculare remains in internal rotation. The fibula manifests due to a ventro-caudal traction by the biceps femoris muscle and the ilium rotates posteriorly and into an inflair position of the left side. In a precise biomechanical view, this now means as a continuing consequence of a dorsally rotated ilium, the left acetabulum is moved cranially and minimally laterally. This inevitably leads to a pelvic obliquity and a sideways lateral inclination of the lumbar spine to the contralateral, i.e. the right side. As a result, the left leg becomes functionally shorter and enters an external rotation. Biomechanically, the sacrospinal and sacrotuberal ligaments are stretched, and further on a dysfunction of the symphysis manifests itself.

11. Summary:

Supination trauma can lead to lower back pain over time. Due to ascending cause, consequence chains (myofascial structures), muscular imbalances occur in the entire musculoskeletal system. The after treatment of the trauma must absolutely take place in the context of the healing phases. Further on a rehabilitation under consideration of the specific training parameters must be taken into account. Sport-specific and everyday life-specific movement patterns must be trained and reactivated.

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