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Physiotherapy in Management of Pes Planus

Independent Learning Material for Physiotherapy Students

DEGREE PROGRAMME IN PHYSIOTHERAPY
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ABSTRACT

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Pes Planus or pes planovalgus or flat foot is a common foot deformity, where there is a height loss in the medial longitudinal arch of the foot. This means the medial side of the foot is nearly or completely in contact with the floor. There are two types of flat feet: congenital and acquired, in which the latter is progressive. It is estimated that about 20% to 37% of the population has some degree of pes planus.

The aim of this thesis was to collect evidence-based knowledge about physiotherapy for patients/clients with pes planus. The objective of this thesis was to create an individual learning material for the physiotherapy students about physiotherapy methods for patients/clients with pes planus. The learning material provided the students information about flat feet and how effective physiotherapy is in treating flatfoot deformity.

Conservative treatment methods usually consist of making modifications in activity levels, if necessary losing weight, footwear modifications, immobilization, anti-inflammatory medications, massage and lastly physical therapy approach. If conservative methods fail to help, surgical intervention would be considered. Physiotherapist can approach in different ways to treat clients/patients with flat feet, these are by strengthening the foot muscles, stretching the triceps surae muscle, and using different taping techniques.

It was found from meta-analysis of randomized control studies that 8 weeks of strengthening intrinsic foot muscles increased medial longitudinal arch. However, this meta-analysis included studies with relatively small sample sizes, which affects the reliability of the study. Additionally, there has not been done a study to see the long-term effects of strengthening intrinsic muscles and performing short-foot exercises to treat flat feet.

Keywords: pes planus, pes planovalgus, flat foot, flat feet, flatfoot deformity, congenital, paediatric, physiotherapy, medial arch

CONTENTS

1 INTRODUCTION

Flat foot is a condition, which is used to describe foot with visually observed height loss in the medial longitudinal arch, and this can cause different lower extremity injuries, ranging from the knees and moving down to the toes. (Banwell et al., 2014; Kodithuwakku et al., 2019; Neal et al., 2014; Shibuya et al., 2010; Williams et al., 2001) “The reason for this could the altered foot kinetic or poor postural stability due to abnormal foot structure.” (Kodithuwakku et al., 2019)

There are different types of flat feet, these are flexible, rigid and acquired. These are caused by ligamentous laxity, lack of neuromuscular control, genetics as it typically runs in the family, fusion between two or more tarsal bones, posterior tendon dysfunction and/or many other factors. (Arain et al., 2022; Mortazavi et al., 2007; Raj et al., 2022)

The human foot can be divided into three types according to the (MLA) medial longitudinal arch and these are low-, normal- and high arched. Pes planus (low arched) MLA height is classified at height 1.86 ± 0.23 cm, pes rectus (normal arched) MLA height at 2.57 ± 0.14 cm and pes cavus (high arched) MLA height at 3.26 ± 0.16 cm. (Gwani et al., 2017; Kodithuwakku et al., 2019) It was found that foot length has an influence on the navicular drop in both men and women, whereas no significant effect was found of age or body mass index. “Per 10 mm increase in foot length, the navicular drop increased by 0.40 mm for males and 0.31 mm for females.” (Nielsen et al., 2009)

Conservative treatment methods usually consist of making modifications in activity levels, if necessary losing weight, footwear modifications, immobilization, anti-inflammatory medications, massage and lastly physical therapy approach.

If conservative methods fail to help, surgical intervention would be considered. (Bubra et al., 2015; Carr et al., 2016; Lee et al., 2005; Soni et al., 2020)

Physiotherapist can use different tests to assess what type of flat feet client/patient has. Examining the medial arch with and without weight-bearing, performing different tests such as jack's test, too many toes sign test, single-leg heel rise test and many more. (Bubra et al., 2015; Carr et al., 2016; Raj et al., 2022)

Physiotherapist can approach in different ways in treating clients/patients with flat feet, these could be by strengthening the foot intrinsic muscles, stretching the triceps surae muscle, and using different taping techniques. (Bubra et al., 2015; Huang et al., 2022; Tang et al., 2021)

With this thesis, author focuses on the conservative treatment methods on treating clients/patients with pes planus and not post-surgical rehabilitation methods/guidelines. Author wishes to find the etiology of pes planus and can intervention of physiotherapy help to treat patients/clients with flat feet.

2 AIM AND OBJECTIVES

The aim of this thesis is to collect evidence-based knowledge about physiotherapy for patients/clients with pes planus.

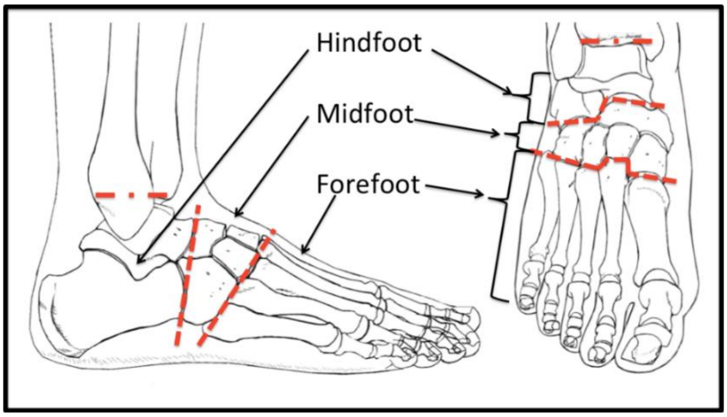
The objective of this thesis is to create an individual learning material for the physiotherapy students about physiotherapy methods for patients/clients with pes planus. The learning material will provide the students information about flat feet and how effective physiotherapy is in treating it.

The completed independent learning material will then be included in Musculoskeletal course for future physiotherapy students studying at Satakunta University of Applied Sciences (SAMK) on the learning platform Moodle. This allows for the students to study on their own pace and return to the study material at any time.

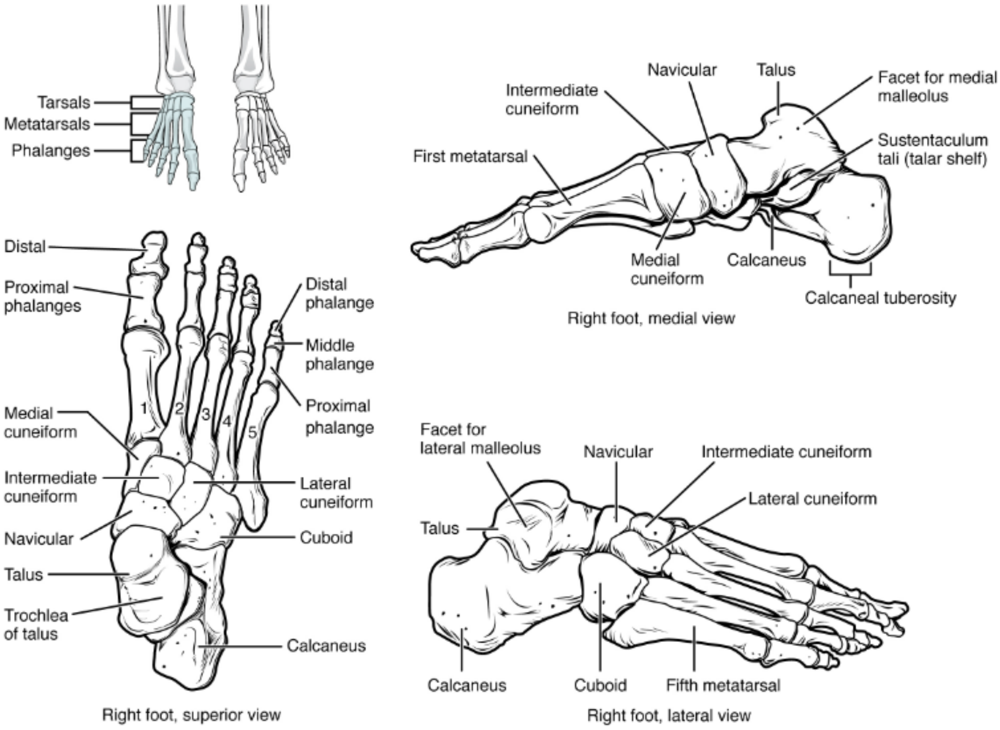
3 ANATOMY OF THE FOOT

In the human foot, there are total of 26 bones and 33 joints, which are controlled and stabilised by multiple muscles, tendons and ligaments (Picture 2.). (Manganaro et al., 2022)

The foot can be divided into three anatomic regions (Picture 1.): **the hindfoot** or **the rearfoot** (talus and calcaneus); **the midfoot** (navicular bone, cuboid bone, and three cuneiform bones); and **the forefoot** (metatarsals and phalanges). (Manganaro et al., 2022)



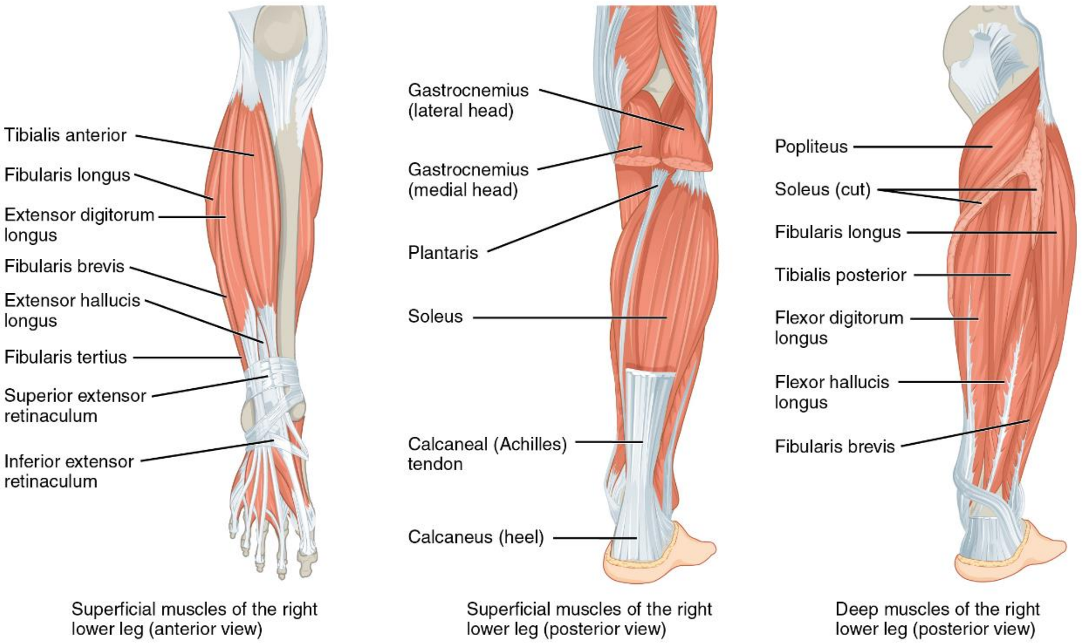
Picture 1. Three anatomic regions (Website of the Orthopaedia, 2023)



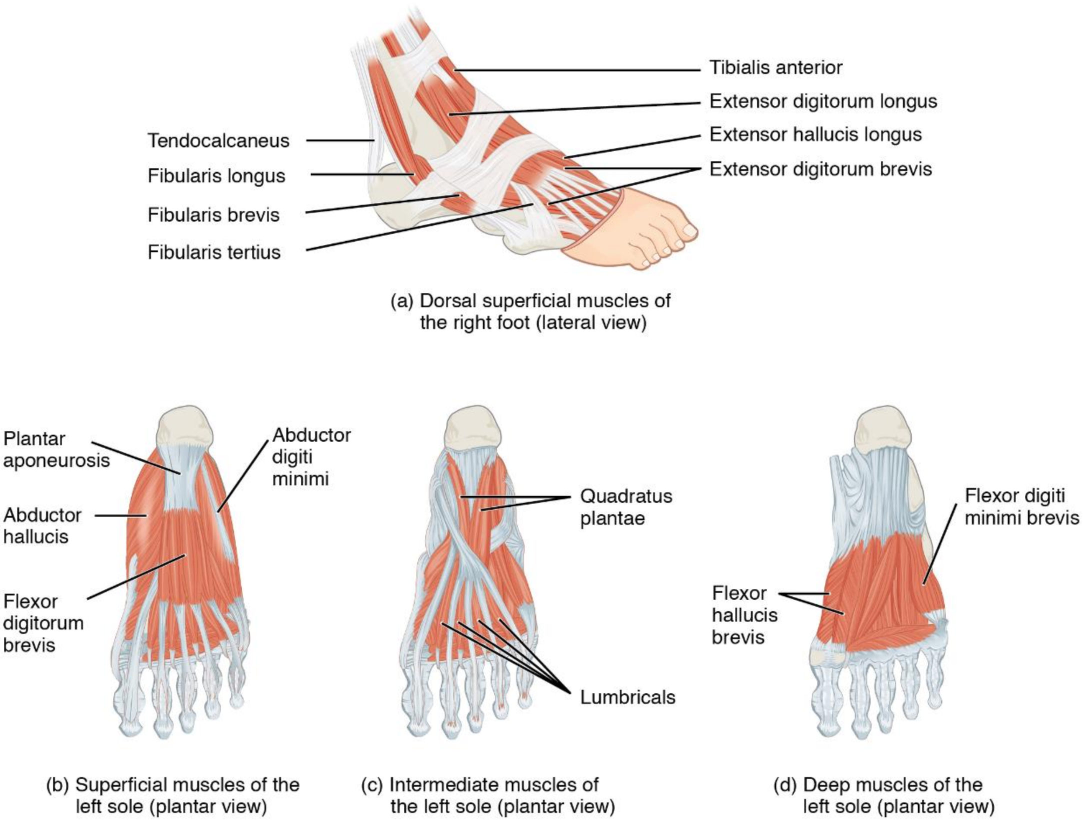
Picture 2. Bones of the foot. (Betts et al., 2013a.)

3.1 Muscles of the foot

The extensor hallucis longus, extensor digitorum longus and peroneus longus/brevis belong to the ankle evertors. The tibialis posterior, flexor digitorum longus, flexor hallucis longus and tibialis anterior are considered to be ankle invertors. (Picture 3.) The moment arm of the tendons and thus the amount of force translated by the tendons is dependent on the subtalar joint position. The tibialis posterior and the peroneus longus are the strongest invertor and evertors, respectively. (Krähenbühl et al., 2017)



Picture 3. Muscles of the lower leg. (Betts et al., 2013b.)



Picture 4. Muscles of the feet. (Betts et al., 2013b.)

The tibialis posterior muscle origin point is the proximal tibia, the fibula, and the interosseous membrane. Muscle's insertion is navicular tuberosity, but additionally has lesser insertions onto structures like tarsal and metatarsals. (Arain et al., 2022; Richie, 2007) It was found that this long slender muscle is strong in eccentric contractions, withstanding lengthening forces. Additionally, when there was weakening and thinning (attenuation) of the tendon by just a centimetre that already caused a loss of the tendon's function as a dynamic stabilizer of the medial longitudinal arch. (Richie, 2007)

> The gastrocnemius and soleus muscles through the Achilles tendon provide the most powerful dynamic arch deforming force on the foot. The Achilles tendon has a threefold greater arch-deforming effect than the arch-supporting effect of the posterior tibial tendon. The peroneus brevis is another important muscle that plays a role in the progressive adult flatfoot deformity. This muscle has been proposed to contribute to a valgus hindfoot deformity when the posterior tibial tendon becomes incompetent. The flexor digitorum longus has equivalent strength of the peroneus brevis, but significantly less strength than the tibialis posterior. In patients, who had weak or attenuated posterior tibial tendons showed hypertrophy of the flexor digitorum longus muscles. Thus, the flexor digitorum longus appears to compensate naturally when posterior tibial tendon function is compromised. (Richie, 2007)

In the study done by Wong 2007, found that abductor hallucis muscle acts as a dynamic elevator for the medial longitudinal arch. As the posterior tibial muscle has an important role in the dynamic arch, Wong suggests that if the intrinsic muscles, like the abductor hallucis, work together with the posterior tibial muscle, the loss of the abductor hallucis muscle's function may overload the posterior tibial muscle and lower the medial longitudinal arch. This finally can lead to degenerative changes like adult acquired pes planus. (Wong 2007)

Study done by Fiolkowski et al., 2003, where they analysed whether the intrinsic muscles of the foot have a role in supporting the medial longitudinal arch. Subjects were tested bilaterally for navicular drop and myoelectric activity of the intrinsic muscle before and after the subjects were injected with anaesthetic to the tibial nerve near to the medial malleolus. What they found was significant decrease in abductor hallucis muscle activity and increase in navicular drop test in static stance. "The values for navicular drop increased 3 mm after the nerve block, from a mean of 6 mm ± 2 mm to 9 mm ± 3mm." (Fiolkowski et al., 2003) However, authors presented their study's limitations; the small sample size as there were 10 subjects in total; they only analysed 1 muscle and no other intrinsic muscles. Additionally, they discussed that this approach did not show how individual plantar muscles contribute to the arch integrity, however this study provides evidence that there is a link between the intrinsic muscular function in supporting the medial arch during static stance.

In the study done by Headlee et al., 2008 they assessed whether the medial longitudinal arch height decreases when the foot's intrinsic muscles (Picture 4.) were fatigued. The height decrease was measured with navicular drop test both before and after exercising. Authors designed custom-fabricated pulley system, which was attached to the toes and subjects were asked to perform toe curls. It was found that through fatiguing the intrinsic muscles, the medial arch height decreased. "Subjects exhibited 10.0 ± 3.8 mm of navicular drop at baseline and 11.8 ± 3.8 mm after fatigue." Additionally, authors discussed about their limitations that their aim was to minimize the contraction of the extrinsic muscles, however they did not measure them with EMG. They stated that they were not completely sure that were the extrinsic muscles active or not.

In 2014 a study done by Angin et al., 2014 they examined and compared cross-sectional area (CSA) and thickness of the foot's extrinsic and intrinsic muscles, as well as thickness of the plantar fascia between pes rectus and pes planus groups with ultrasound. Total of 98 participants were recruited, where half of them were in pes rectus and other half in pes planus group. It was found in pes planus group that CSA and thickness of flexor hallucis brevis, abductor hallucis and peroneal muscles were smaller compared to pes rectus group. However, muscles such as flexor hallucis longus and flexor digitorum longus were significantly larger in the pes planus group. With plantar fascia, they found that metatarsal and middle parts were thinner in pes planus group. Authors did discuss their study limitations, for example this study did not provide explanation to the cause of flat feet, or that they only focused on the structures and they did not evaluate the tibialis posterior muscle due to its deeper location within the posterior leg compartment.

> "Greater CSA and thickness of the extrinsic muscles might reflect compensatory activity to maintain the shape of MLA, if the intrinsic foot muscle function has been compromised by altered foot structure. The action of extrinsic muscles at the rear as well as mid and forefoot might explain the failure of extrinsic and intrinsic structures to work in tandem. Mid and forefoot plantar fascia was thinner in pes planus, suggesting reduced load bearing." (Angin et al., 2014)

3.2 Ligaments of the foot

The spring and deltoid ligaments, they both play an important role in stabilising the foot and the ankle. (Arain et al., 2022) The spring ligament complex consists of the following: anterior tibionavicular ligament, which is also a component of the superficial deltoid ligament, posterior tibial tendon, the superomedial calcaneonavicular ligament and inferior calcaneonavicular ligament. (Richie 2021, p251)

In acquired pes planus, the spring ligament complex is commonly ruptured in this condition and the ligament complex's role is to support the head of the talus by resisting plantar and medial talar head subluxation that occurs more in severe stages of acquired pes planus. (Richie 2021, p251; Steginsky & Vora, 2017).

Richie 2007 presented in his article that there were studies done by others, where they found out that there is a close relationship between the spring ligament complex and the posterior tibial tendon. The posterior tibial tendon, which has a dynamic support to the medial arch, assists the static support of the spring ligament complex to control plantar and medial movement of the head of the talus.

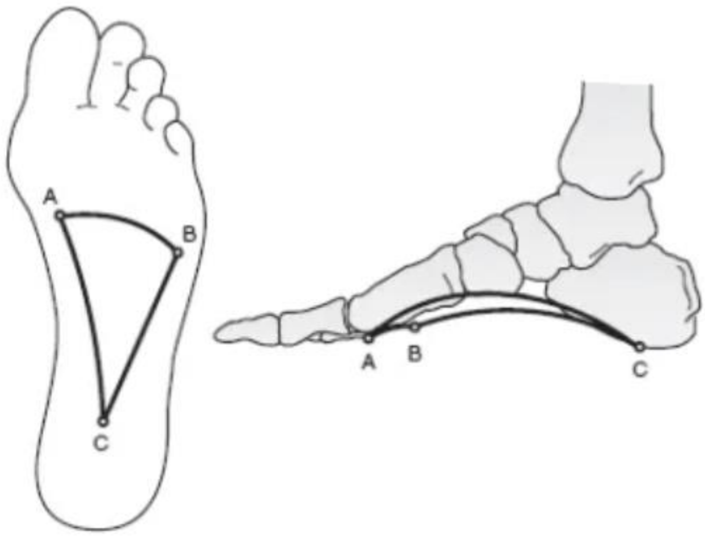
The deltoid ligament complex, also known as the medial collateral ligaments, is composed of superficial and deep portions. The superficial consists of talocalcaneal, superficial posterior tibiotalar, tibiospring and tibionavicular ligaments. The deep anterior tibiotalar and deep posterior tibiotalar ligaments make the deep portion of it. (Richie 2021, p251)

As the acquired pes planus progresses, the deltoid ligament complex becomes more and more affected in later stages. These medial collateral ligaments as a unit are essential in supporting the articulating surfaces of the ankle and as well as the spring ligament. The superficial deltoid portion’s role is to resist valgus movement in tibiotalar joint and deep deltoid portion stops axial rotation of the talus. (Arain et al., 2022; Brockett & Chapman, 2016)

Plantar aponeurosis also has a role in supporting the structures of the arch, both in static and dynamic way. It was shown that when cutting off the plantar fascia, it brought visible negative effects on the midfoot and forefoot stability. Additionally, when there was load put onto the foot, the plantar aponeurosis developed considerable amount of tension, while there was minimal amount of strain on the spring and long plantar ligaments. After cutting off the plantar aponeurosis, the spring and long plantar ligaments developed significant amount of strain. (Richie, 2007)

3.3 Arches of the foot

The human foot has three arches and these are (Picture 5.) the medial longitudinal arch, the lateral longitudinal arch, and lastly the anterior transverse arch. (Babu & Bordoni, 2022) The medial longitudinal arch is made up of calcaneus, talus, navicular, the three cuneiforms and first three metatarsals. The lateral longitudinal arch is made up of the calcaneus, cuboid, and last two metatarsals. Both play a crucial role in providing support during locomotion as the body’s weight distributed to both arches. The transverse arch is made up of the three cuneiforms and cuboid proximally and bases of the five metatarsals distally. (Gwani et al., 2017) “This arch helps to distribute body weight from side to side within the foot, thus allowing the foot to accommodate uneven terrain.” (Betts et al., 2013.) “Bones of the foot are arranged in a longitudinal and transverse manner, forming a dome relative to the ground, which gives rise to longitudinal and transverse arches on the plantar aspect of the foot" (Gwani et al., 2017)



Picture 5. Arches of the human foot. (A-B) *Anterior transverse arch*. (B-C) *Lateral longitudinal arch*. (A–C) *Medial longitudinal arch*. (Website of the Musculoskeletalkey, 2022)

Gwani et al., 2017 discussed in their article about how the medial and lateral longitudinal arches work together as an unit alongside with the transverse arch, and which were clinically explained by two other articles. However, the amount of data, which specifies this relationship, is very low. Gwani et al., 2017 pointed out that these two previously mentioned articles were limited only to the medial longitudinal arch, however in reality all these three arches contribute to support the biomechanical activities of the foot. "Moreover, it has been shown that motion of the lateral arch is similar to that of the medial arch; whereas the transverse arch is essential to the stability of both arches." (Gwani et al., 2017)

3.3.1 The medial longitudinal arch

The medial longitudinal arch is the highest one of the two longitudinal arches. (Babu & Bordoni, 2022) This arch is formed and supported by different structures such as spring ligament complex, deltoid ligament complex, posterior tibial tendon, plantar aponeurosis and foot’s intrinsic muscles. (Babu & Bordoni, 2022; Raj et al., 2022) “The medial longitudinal arch plays a critical role in shock absorption and propulsion of the foot while walking. The medial longitudinal arch of the foot allows for the proper function of the lower extremity during the gait cycle.” (Babu & Bordoni, 2022)

The medial longitudinal arch’s morphology, its shape and structure, is often used to classify the foot into three types (Picture 6.): pes rectus, pes planus and pes cavus. The first, pes rectus, is normally aligned foot, the medial longitudinal arch is within the normal range. Next, pes planus as previously discussed, is where the medial arch is nearly or completely in contact with the ground. Pes cavus, however is the opposite, where there is an abnormally high medial arch in the foot. Officially, the medial longitudinal arch is the main point of reference when diagnosing either the pes planus or pes cavus. Additionally, it is important to take into consideration of both lateral and transverse arches, as they may provide helpful information in pes planus and pes cavus. (Gwani et al., 2017)

Picture 6. Foot types: *pes cavus, pes rectus, pes planus* respectively. (Website of the FootIQ, 2023)

4 PES PLANUS

Pes Planus or pes planovalgus or flat foot is a common foot deformity, where there is a height loss in the medial longitudinal arch of the foot. This means the medial side of the foot is nearly or completely in contact with the floor. There are two types of flat feet: congenital and acquired. It is estimated that about 20% to 37% of the population has some degree of pes planus. (Raj et al., 2022)

Congenital flat foot is common in infants and toddlers. As the foot arch develops, there is a fat pad underneath the medial longitudinal arch, which resolves up to the age of 5 or 6. In children, flat feet can be divided into flexible or rigid pes planus. (Halabchi et al., 2013)

Clinically, a flexible pes planus has an arch that is present in open kinetic chain (non-weight bearing) and lost in closed kinetic chain (weight bearing). A rigid pes planus however, has loss of the longitudinal arch height in both open and closed kinetic chain. (Napolitano et al., 2000)

Acquired flat feet however can be caused by multiple factors. There may be dysfunction of the posterior tibial tendon, trauma to the midfoot or hindfoot, ligamentous laxity, pregnancy, which typically corrects itself post-partum, patients with arthropathies (joint diseases), diabetes and obesity. (Raj et al., 2022)

4.1 Congenital pes planus

Congenital is defined as existing at or dating from birth. Thus, all children are born with pes planus, as almost every child’s foot has initially a fat pad on the medial side, which then slowly decreases as the child grows up. The medial longitudinal arch, which is not present at birth, slowly develops during childhood, usually when the child reaches the age five or six. This process occurs throughout the growth and that is not affected by the presence or absence of external arch support. (Halabchi et al., 2013; Mortazavi et al., 2007) There are occasions, where the medial longitudinal arch takes longer to take shape, and the arch can develop in the first decade of the child's life, which normally does not cause any problems. (Mortazavi et al., 2007; Uden et al., 2017). The majority of children with pes planus achieve spontaneous partial correction in the arches. However, there is a small portion of children, who fail to develop medial longitudinal arch by adulthood. (Mortazavi et al., 2007)

Uden et al., 2017 stated in their systematic review that currently there is no consensus on how flat the foot should be, when observing the child's foot. Moreover, while the children's feet decrease in flatness with getting older, it is currently not known how flat the feet should be at each advancing year. Additionally, no consensus could be found on what age the foot postures should stop to change any further. Clinical opinion is that mature foot posture is reached from the ages of seven to ten years. (Uden et al., 2017) It is important to differentiate between the flexible and rigid pes planus, additionally classifying whether the condition is painful or painless. (Mortazavi et al., 2007)

4.1.1 Flexible pes planus

Flexible flat foot is considered to be an indication of laxity affecting all ligaments around the foot, immature neuromuscular control and increased fat tissue. The physiologic ligamentous laxity typically improves as the child gets older and the structures of the foot are increasingly ossified, providing greater rigidity. (Banwell et al., 2018; Dare & Dodwell, 2014; Ueki et al., 2019) In flexible flat feet, medial longitudinal arch collapses in various degrees during weight-bearing, however that medial arch is present in non-weight bearing. (Atik & Ozyurek 2014; Ueki et al., 2019).

Flexible flat feet rarely cause pain or disability in early childhood. Children usually are presented for evaluation due to their parents' concern on the appearance of the feet, the prevalence of flat feet in family history or parents' concern in what kind of impact flat feet will have on their child's life. (Halabchi et al., 2013; Uden et al., 2017) However, flat feet can sometimes be painful, for example after intense workout or long walks, and the pain is usually located in the feet and/or lower legs. (Halabchi et al., 2013)

Chang et al., 2010, Chen et al., 2009, Mauch et al., 2008, Mickle et al., 2006, Pfeiffer et al., 2006, Riddiford-Harland et al., 2011 and Villarroya et al., 2009 found that obesity is one of the factors contributing to flattening of the medial longitudinal arch. Chang et al., 2010, Chen et al., 2009, Pfeiffer et al., 2006 and Villarroya et al., 2009 found that prevalence of flat feet in boys was higher than compared to girls. In children, it is estimated the prevalence of flat feet have been suggested to range from 0.6–77.9%, with consistent of reduction in prevalence with increasing age. (Banwell et al., 2018; Pfeiffer et al., 2006)

However, Evans & Karimi 2015 examined in their study that do heavier children really have flatter feet. They explored the relationship between children's foot posture and body mass with the use of foot posture index (FPI-6) as opposed to the most studies, where footprints (printed, scanned, digitized) were used. In their study, three different FPI-6 scores levels were used to define the ranges of flatfeet, these were FPI-6 ≥ + 6; FPI-6 ≥ + 8; FPI-6 ≥ + 10. Pronated postures are given in a positive value, meaning the higher the value the more pronated or flatter the foot is. Total of 728 children participated in their study, flatfeet (FPI-6 ≥ + 6) were found in 290 children. 272 children out of 728 were overweight and only 74 of the overweight children had flatfeet (FPI-6 ≥ + 6). They found that the correlation between the FPI and BMI (body mass index) was statistically significant but also very weak ($r = -0.077$, $p < 0.05$). Authors discussed in their study that this study refuted the finding of flatter feet in heavier children. This was also repeated and confirmed by previous study done by Evans 2011, with fewer number of participants (140 children in total).

4.1.2 Rigid pes planus

Fixed or rigid pes planus is rare and it usually develops during childhood. It develops from the tarsal coalition, which is characterized as a painful unilateral or bilateral deformity, oftentimes associated with peroneal (*fibularis* another term for this muscle group) spasm. Additionally, it can develop from the congenital vertical talus, accessory navicular bone or other forms of congenital hindfoot pathology. (Cass & Camasta, 2010) When compared to flexible pes planus, where medial arch is present in non-weight bearing, with rigid pes planus the medial longitudinal arch is not seen even when the foot is not bearing any weight. (Cass & Camasta, 2010)

With tarsal coalition, the tarsal bones fail to separate, which leads either bony, cartilaginous or fibrous bridge between two or more of the tarsal bones. This fusion between the bones restricts normal subtalar and midfoot motion, which can lead to inflammation of the joints involved. Additionally, the peroneal muscle tendon that crosses over the subtalar joint can go into spasm and inflammation can occur. (Mortazavi et al., 2007) However, Cass & Camasta, 2010 stated in their article that many tarsal coalitions are asymptomatic and present no peroneal tendon spasm or pes planus deformity. In addition, patients may show peroneal muscle spasms from another cause than tarsal bone fusion.

Cass & Camasta, 2010 presented in their article several theories from other authors in relation to the cause of tarsal coalition. The most widely accepted is LeBouq's theory, which describes as a failure or differentiation of embryonic mesenchymal tissue, which is believed to be a heritable autosomal dominant defect or that there was an insult sustained in the first trimester of pregnancy. Another theory was presented by Pfitzner, who believed that coalitions occurred from ossification of the accessory bones into the neighbouring bones. However, when Harris found evidence in fetuses with tarsal bone fusions, it is suggested to disprove Pfitzner's theory. (Cass & Camasta 2010)

Tarsal coalition has been reported to be present from 0.04% to as high as 14.54% of cases, although authors support that the occurrence rates is less than 1% of the general population. This type of pes planus is bilateral about 50% to 80% of the time. There does not appear to be a sex predisposition of tarsal coalitions, which is consistent with LeBouq's autosomal dominant inheritance theory. The coalitions that make up 90% of the cases are calcaneonavicular and talocalcaneal coalitions. A talonavicular coalition is the third most common coalition, however with fewer cases. (Cass & Camasta, 2010)

4.2 Adult acquired pes planus

Adult acquired flat foot, also previously described as posterior tibial tendon dysfunction, is a condition where the medial longitudinal arch collapses with continued progressive deformity of the foot and ankle. As previously defined condition, the tissue that is mainly behind this pathology is the posterior tibial tendon. (Arain et al., 2022) MRI is considered a reliable method, when it comes to diagnostic imaging. It has been shown to have both high sensitivity and high specificity in diagnosing acquired pes planus. (Smyth et al., 2017)

Although, now the understanding of acquired pes planus has changed, where not only the posterior tibial tendon is involved, but also ankle's ligamentous structures play a role in the development of this condition. Many patients have pre-existing flat feet and the tendon's dysfunction typically occurs in obese, middle-aged women. Conditions such as diabetes, hypertension, traumas to the foot and ankle areas increase the risk of developing acquired flat feet. Another risk factors are relative hypovascularity of the posterior tibial tendon, arthritis, neuromuscular conditions and local steroid injections. (Arain et al., 2022; Bubra et al., 2015)

Ikpeze et al., 2019 found that in elderly patients the posterior tibial tendon issues are quite prevalent, which reaches about 10% of the geriatric population and has a higher prevalence in women. Furthermore, Ikpeze et al., 2019 speculates that elderly are more susceptible to adult acquired pes planus than general population due to degeneration of the muscle mass and decrease in bone density.

In acquired pes planus, Johnson and Strom created a three stage classification system in 1989, based on the condition of posterior tibial tendon. (Johnson & Strom, 1989) Myerson added the fourth, the last grade to their classification system in 1997. (Myerson, 1997) (See Table 1.)

In conclusion, stage I consists of posterior tibial tendon tenosynovitis, where tendon has normal function and tendon's length is usually normal. Pain, swelling and tenderness can be presented on the medial side of the ankle/foot. Patients are able to perform a single-leg heel rise test, may present mild weakness when performing the test. By stage II, the pain level is more moderate and localized at along the tendon. Swelling and tenderness are more notable. There is also more elongation of the posterior tibial tendon. Single-leg heel rise test shows either great weakness or the patient is unable to perform the test at all. Too many toes sign can be seen. Important note in the second stage is that whether the patient's deformity is passively correctable. The stage II has been furthermore classified into IIa and IIb stages. IIa stage is where the patient has hindfoot valgus with arch collapse with no midfoot abduction. IIb however presents the midfoot abduction. In stage III, the patient can report severe pain, there is additionally elongation and disruption of the posterior tibial tendon. Performing the single-leg rise test is painful and shows tendon's weakness. Too many toes sign is still present. (Abousayed et al., 2016; Smyth et al., 2017). "Lastly, stage IV includes deformity of the ankle with evidence of lateral talar tilt due to attenuation of the deltoid ligament." (Smyth et al., 2017)

Table 1. Acquired pes planus deformity staging by Johnson and Strom, later modified by Myerson. *Recreated from* (Richie, 2007)

	Stage I	Stage II	Stage III	Stage IV
Posterior tibial tendon	Tenosynovitis, degeneration, or both	Elongation and degener-ation	Elongation and degener-ation	Elongation and degener-ation
Deformity	Absent	Flexible, re-ducible pes planovalgus Deformity with hindfoot held in equines	Fixed, irreduc-ible pes planovalgus deformity	Fixed, irreduc-ible pes planovalgus deformity
Pain	Medial	Medial, lat-eral, or both	Medial, lat-eral, or both	Medial, lat-eral, or both
Single limb heel-rise	Mild weak-ness; hindfoot inverts normally	Marked weak-ness; no or weak inversion of hindfoot	Unable to perform test; no inversion of hindfoot	Unable to perform test; no inversion of hindfoot
Too many toes sign	Negative	Positive	Positive	Positive
Valgus de-formity and arthritis of ankle	No	No	No	Yes

5 COMPLICATIONS FROM PES PLANUS

Flat feet can be a possible cause of anterior knee and low back pain (Gross et al., 2011; Kosashvili et al., 2008), damaging the medial tibiofemoral cartilage (Gross et al., 2011), patellofemoral pain (Neal et al., 2014), foot pain (Mølgaard et al., 2010), medial tibial stress syndrome (Neal et al., 2014), developing plantar fasciitis (Babu & Bordoni, 2022; Luffy et al., 2018), hallux abducto-valgus (Nguyen et al., 2010), calluses, hammertoes and arthritis (Shibuya et al., 2010). Flat feet could be a contributing factor to sever's disease. (James et al., 2015) "Patients with tarsal coalition have insidious and occasionally acute onset of arch, ankle or midfoot pain. Patients are predisposed to frequent ankle sprains secondary to the limited subtalar motion." (Mortazavi et al., 2007)

Banwell et al., 2014 discussed about flexible pes planus in adults and in what way it can affect their health. They presented, from 3 different articles, in short that adults with flexible flat feet can experience pain in the lower limbs and hip area, also an increase in fatigue in the lower limbs. Additionally, the adults with flexible pes planus are more susceptible to Achilles tendinopathy, osteoarthritis and patellofemoral disorders.

Williams et al., 2001 did a study on runners with high-arched and low-arched feet, to observe what type of injuries they exhibited. Participants were asked to fill out questionnaire, where they had to report all running related lower extremity injuries. All of the mentioned injuries had been formerly diagnosed by the medical professional. Findings reported that flat feet runners had more medial side injuries, as the pronation of the foot places increased stress on the medial structures. Additionally, low-arched runners had more soft tissue injures and reported more knee injuries. General knee pain, patellar tendinitis and plantar fasciitis were the most frequent injuries. Second and third metatarsal stress fractures and syndromes were reported the by the low-arched runners, where high-arched runners had stress fractures at the fifth metatarsals.

5.1 Effects on vertical jump and athletic performances

There was a study done by Şahin et al., 2022, where they investigated how athletes with flat feet performed vertical jumps and how do flat feet affect the balance. Total of 50 male team sport athletes participated in the study (soccer 18, rugby 16, basketball 12 and volleyball 4). It was found that flat feet affected both postural control and height of the vertical jump negatively, the greater the degree of pes planus the more it affected negatively those two factors.

Although Hu 2016, did her master’s thesis on relationship between foot arch height and two-legged standing vertical jump height in male college-age students. Total of 66 healthy, male students participated in the study. Author found that there was no significant correlation between the foot arch height and the vertical jump height in both normal-arched and pes planus participants.

Additionally, a study done by Tudor et al., 2009 assessed whether flat feet have negative effects with different motor skills and athletic performances in children. Total of 218 children aged 11 to 15 participated in the study and they were categorized into 4 different groups according to the flatness of their feet. Children were tested on different movements for example: eccentric-concentric contraction; hopping on a platform; speed-coordination polygon test; balance tests etc, in total of 17 measures of athletic performances. As authors compared the results between children with flat feet and children with ‘normal’ feet, they found no significant correlation between the arch height and the 17 measures of athletic performances. In addition, it was found that they did not reveal any differences between those 4 groups in athletic performances, even after the authors compared only the 2 extreme groups, meaning children with pes planus and pes cavus feet.

5.2 Effects on static and dynamic balance

Takács et al., 2019 did a study on elementary school children and assessed their standing balance. They had to perform 60 second bipedal stance with eyes open and be as motionless as possible. What they found that there was no difference in standing balance between the pes rectus and pes planus group. However, there was a small difference in the postural control, where the pes planus group had a slightly poorer control. The authors did discuss about their limitations of the study, as they did not perform the test with closed eyes during the bipedal stance, additionally they did not perform the test with single-limb stance with open and closed eyes. Another study conducted by Harrison & Littlewood 2010 found that both balance and postural control were affected negatively in individuals, who had pes planus.

Cote et al., 2005 and Hyong & Kang, 2016 did a study, where they assessed balance in participants between pes rectus, pes cavus and pes planus groups. Cote et al., 2005 used single-limb stance and star excursion balance test (SEBT) tests, with SEBT using all 8 directions. However, Hyong & Kang, 2016 used only dynamic balance SEBT and 3 directions out of the 8 (anterior, posterolateral and posteromedial). SEBT was used due to its high reliability. From Hyong & Kang they found no significant differences between the three groups and they discussed what could be the reason for it. “This result was likely due to the compensation adaptation of the muscles surrounding the ankle joint to external factors that affect balance, such as the visual, auditory, and somatosensory systems, despite the foot shape differences.” (Hyong & Kang 2016) Cote et al., 2005 also found no significant difference in center of balance and postural sway in single-limb stance. In SEBT, there were slight differences among the groups and these were only in some directions.

6 PHYSIOTHERAPY IN PES PLANUS

Multiple authors like Dare & Dodwell, 2014, García-Rodríguez et al., 1999, Pfeiffer et al., 2006 and Tudor et al., 2009 argue that most asymptomatic flat feet do not need any treatment. Abdel-Fattah et al., 2006 and Esterman & Pilotto 2005 stated in their studies that flat feet does not cause any disabilities. However, Pita-Fernandez et al., 2017 found in their study that flat feet do have a negative effect on the quality of life and as well as on foot function. Additionally, Shibuya et al., 2010 presented from multiple authors that neglecting on treating flat feet could have negative consequences. The debate between treating asymptomatic flat feet or not continues. (Bresnahan, 2009; D'Amico, 2009; Evans, 2008; Harris, 2010)

6.1 Assessment of pes planus

Uden et al., 2017 stated in their article that currently there is no gold standard to assess flat feet and there is no single standardized way to determine it. The position of the foot and height of the inner arch can be analysed with footprint-based techniques such as Arch Index, Staheli Arch Index, Clarke's angle, Chippaux-Smirak Index etc. Other measurements are navicular height, arch height ratio, the Foot Posture Index 6 (FPI-6) and rearfoot angle. Banwell et al., 2018 did a systematic review on different foot posture measurements and found Statheli Arch Index, Chippaux-Smirak Index and Foot Posture Index 6 to be the preferred methods within the paediatric population due to their reliability. However, authors did discuss about each of the limitations, as these methods are static foot posture measurements and that clinicians should consider dynamic measurements to better understand paediatric foot structure.

6.1.1 Assessment tools and tests for physiotherapist

Hubscher's maneuver or Jack's test

The Hubscher's maneuver is an effective method to assess the flexibility and reducibility of flat foot deformity. While the patient is standing on their feet, the hallux is passively dorsiflexed by a clinician and additionally the leg is externally rotated. This will restore the medial longitudinal arch in flexible flat foot by the windlass loading of the plantar aponeurosis. However, this test won't restore the medial arch in patients with rigid flat feet. This test may also fail to restore the medial arch in flexible flatfoot patients, who have significantly tight calf muscles/Achilles tendon (equinus contracture). (Cass & Camasta, 2010) "Having the patient stand and then step forward with the involved extremity can negate the effects of equinus. With the foot plantarflexed on the leg, the gastrosoleal complex is relaxed, and a flexible deformity will reduce" (Cass & Camasta, 2010)

Tip toe standing test

Tip toe standing test can be used to assess whether the patient has flexible or rigid pes planus. This test is performed with patient standing on their feet, the clinician observes the feet from behind. Patient is asked to go onto their toes with both feet and clinician observes the position of the heel and medial arch. In flexible flat feet the heels turn inwards (varus position) and medial arch should reappear, however with rigid flat feet there is no heel inversion nor visibility of the medial longitudinal arch. (Mortazavi et al., 2007; Papaliodis et al., 2014)

Single-leg heel rise test

The single-leg heel rise test is used to evaluate static weight bearing muscle function. This test is used in adult acquired pes planus (posterior tibial tendon dysfunction). When there is weakness in the posterior tibialis muscle that can affect the performance of this test. Patient is asked to stand near to a wall with arms placed onto the wall for balance. Next the patient lifts the opposite foot off the ground and attempts to rise onto their toes of the affected foot. When the patient can't perform a heel rise or performs the test with hindfoot eversion (patient fails to invert the hindfoot), this may suggest that the posterior tibialis muscle is no longer acting as an invertor of the hindfoot or that the patient is demonstrating progressing acquired pes planus (posterior tibial tendon dysfunction). (Bubra et al., 2015; Durrant et al., 2015) “Patients with a fully functional tendon can complete 8–10 repetitions, but by Stage II, the vast majority of patients are unable to perform a single unsupported heel rise (or may only be able to complete a few).” (Bubra et al., 2015) Chimenti et al., 2014 compared single-limb heel rise performance between individuals with stage II adult-acquired flat feet and healthy individuals. They found that individuals with stage II adult-acquired flat feet displayed poorer heel-rise height than healthy individuals.

Too many toes sign test

Too many toes sign test is another way to assess whether the patient has flat feet or not. This test is performed with patient standing on their feet, the clinician observers the feet from behind. Normally with pes rectus, the clinician should be able to see the fifth and half of the fourth toe. However with flat feet, more toes are seen, which indicates abduction and external rotation of the foot. (Carr et al., 2016) “It is easy to use the number of toes seen from behind as an objective measure to document progression or resolution of flatfoot.” (Carr et al., 2016)

Navicular drop test

Navicular drop test is used to measure the height of the navicular bone and evaluates the function of the medial longitudinal arch. The test is performed with patient standing barefooted. Next, the lateral and medial aspect of talar dome (curved trochlear surface) of the foot are palpated. Thumb is placed over the sinus talus (cavity located between the talus and calcaneus bones), and the index finger is placed over the anterior medial aspect of the talar dome. The foot is next slowly moved until the talus is positioned in a central position and the depressions felt under the thumb and index finger are equal. Once the subtalar joint is in neutral position, clincian measures the distance between the floor and navicular bone in millimeters with a ruler. This will be repeated in non-weight bearing stance (sitting for example), where clinician measures again the height of the navicular bone. (Nielsen et al., 2009; Zuil-Escobar et al., 2018) Aboelnasr et al., 2019, investigated the intra-rater reliability, sensitivity, and specificity of the navicular drop test in children. Authors found that the intra-rater reliability of ICC = 0.98, the sensitivity was 88.1% and specificity was 99.5%.

Silfverskiöld test

Silfverskiöld test is used to examine the Achilles tendon and triceps surae complex. The test differentiates gastrocnemius tightness from an Achilles tendon contracture. Clinician takes a hold onto the patient's leg, with knee in flexion, then the foot is held in an inverted position and finally dorsiflexed. The degree of ankle's dorsiflexion is measured between the anterior border of the distal tibia and the lateral border of the foot. Clinician performs the tests again, however this time with knee in extension. (Carr et al., 2016) "Less than 10 degrees of dorsiflexion above plantigrade with both the knee flexed and extended implies that the entire Achilles tendon is tightened. Less than 10 degrees of dorsiflexion with the knee extended only implies isolated gastrocnemius tightness." (Carr et al., 2016) Molund et al., 2018 investigated the reliability of the Silfverskiöld test, and they found that the ICC values ranged from 0.230 to 0.791 in the inter- and intrarater reliability. Authors concluded Silfverskiöld test's reliability to be poor.

Foot Posture Index (FPI-6)

The foot posture index is a tool used to assess the degree in which the foot can be considered, and these foot postures are supinated, neutral or a pronated position. There are six criteria for the FPI-6 for the clinician to observe, and these observations are done with the patient standing in a relaxed, static standing position, arms by their side and looking straight ahead. Neutral foot posture is graded as zero, with supinated posture the values are given in a negative value, the more negative the value the more supinated the foot is. With pronated posture the values are given in a positive value, the higher the value the more flat the foot is. (Redmond, 2005)

6.2 Treatment intervention in tarsal coalitions

In tarsal coalitions, when the condition becomes painful, treatment may be required and this may include surgical intervention at the end. Initial treatment options are footwear modifications, which includes arch supports and orthoses, activity modifications, weightloss if necessary, immobilization and anti-inflammatory medications. After conservative treatment about 30% of the patients continue to stay asymptomatic. If conservative methods fail to help, surgical intervention would be considered. (Lee et al., 2005; Soni et al., 2020)

6.3 Treatment intervention in adult acquired pes planus

In asymptomatic adult acquired pes planus, the treatment consists of patient education, observing the condition of the flat feet, whether it becomes symptomatic or not and discussion of the prognosis. In the symptomatic adult acquired pes planus, the aim with conservative treatment is to prevent the progression of the deformity, however correction of the deformity should not be expected with this manner. The conservative treatment methods consists of making changes in patient’s activity levels, losing weight if necessary, immobilization, orthotics devices which include foot orthoses or ankle-foot orthoses and the aim with orthotics is to provice arch support and correct the flexible component of the deformity. Furthermore, footwear modifications can be implemented, use of anti-inflammatory medications and with physical therapy, stretching the Achilles tendon and strengthening the tibials posteior muscle is usually performed in stage I. (Bubra et al., 2015; Lee et al., 2005) “Surgical management should be considered if nonsurgical options fail to provide adequate relief from pain, if there is progression of deformity or instability, or if there is failure to return to acceptable function.” (Lee et al., 2005)

6.4 Treatment intervention in flexible pes planus

> The initial treatment of painful-but flexible flatfoot is non-operative. Conservative treatment modalities, such as rest, activity modification, icing, massage, and nonsteroidal anti-inflammatory medication, are the initial interventions for pain reduction. Treatment options for symptomatic patients include physical therapy, shoe wear modification, orthotics, and, occasionally, surgery. For patients with pain-free, flexible flat feet, there is no concrete evidence that any available intervention can alter the natural course of foot shape development. (Carr et al., 2016)

“Children often are noncompliant with such treatments as stretching and orthotic maintenance. The support of the parents is crucial to maintaining an effective treatment program continued at home.” (Napolitano., et al 2000) Using orthotics in children before the development of the true flat feet deformity is premature and does not fasten the medial arch development. It may even inhibit the normal development of the arch. (Nemeth, 2011) “Wearing closed shoes affects the development of the longitudinal arch more than sandals, which indirectly led to a higher detection rate of flatfoot in urban children than that in rural children.” (Xu et al., 2022) “Shoes should be considered protection for the feet when outdoors and they should be flexible and well-fitting. Indoors, children should be encouraged to be barefoot, in stocking feet or minimal slippers.” (Nemeth, 2011)

> In terms of physical activity, children who exercised less were more likely to have flat-foot. Low levels of physical activity could lead to delayed or uneven muscle strength, resulting in poor arch strength. The exercise was closely related to physical development, weight management, and a healthy lifestyle. However, children need to engage in appropriate physical activities. Adolescents who are not fully developed should avoid taking part in overloaded labor (such as burden-bearing) and sports (such as weight lifting). They could engage in high leg lifting, jumping activities (such as rope skipping, long jump, high jump, vertical take-off, etc.), and climbing activities (such as climbing ladders, using balance beams, rope climbing, pole climbing, etc.) to fully exercise the muscles and ligaments of the arch of the foot (Xu et al., 2022)

6.5 Intervention of taping and exercises

A meta-analysis done by Tang et al., 2021 where the authors investigated the effects of taping techniques on arch deformitites in adults with flat feet. Different taping techniques such as low-Dye, navicular sling, fan-arch support, kinesiotape, augmented low-Dye and Double X were observed. Authors found that all taping techniques included in their study significantly increased navicular height right away after taping. Another aspect what they observed was effect of taping on navicular height post exercised compared with immediately post tape and baseline. The results revealed that navicular height was significantly lower after running for 15 min and walking for 10 min than immediately post tape.

> “The findings revealed that augmented low-Dye was the most effective taping technique for controlling foot arch collapse immediately post tape compared with baseline. Moreover, modified low-dye was better than augmented low-Dye in maintaining immediate navicular height after walking for 10 min. However, the overall difference in foot arch deformation among the taping techniques after exercise was less than 11 mm in the current study.“ (Tang et al., 2021)

“Foot exercises to strengthen intrinsic foot muscles have been suggested to be helpful in the management of pes planus. It has been reported that these exercises can change plantar pressure distribution and thereby relieve the pain.” (Kodithuwakku et al., 2019) These exercises could be for example toe curls with the use of a towel and short-foot exercise. With the latter exercise, it is performed by pulling the metatarsal heads toward the heel, while the long toe flexors are relaxed. (Jung et al., 2011)

A meta-analysis of RCT’s was conducted by Huang et al., 2022, where the authors examined the effects of short-foot exercises (SFE) on foot alignment and muscle hypertrophy in pes planus individuals. Total of 6 studies were included in this meta-analysis. Navicular drop was assessed in five RCT’s and foot posture index (FPI-6) was assessed in three RCT’s. The intervention’s length of performing the exercises ranged from 4 weeks to 8 weeks, exercises included were: short-foot exercises, towel curls and one study included hip and knee strengthening exercises. “The meta-analysis indicated that the short-foot exercises significantly corrected foot alignment, with the tendency of a decreased navicular drop and a more neutral position compared with the control group.” The authors did discuss their study’s limitations which were: several study biases, which may have affected the evaluation of outcomes; 5 of the RCT studies had relatively small sample sizes; the RCT did not include participants aged less than 18 years old or above 50 years old and lastly the long-term effects of short-foot exercises are still uncertain.

Randomized controlled trial study done by Alam et al., 2018 analysed the effects of strengthening the tibialis posterior muscle and stretching of iliopsoas on navicular drop, dynamic balance and lower limb muscle activity in young adults with pes planus. Total of 28 participants were included in the study, where first half (SSG group) performed towel curl exercise and strengthening of tibialis posterior, plus stretching exercise and the control group (CEG group) only performed towel curl exercise. Exercise training lasted for 6 weeks by both groups, where stretching and strengthening exercises were performed 3 times a week and towel curls were performed daily in both groups. Tibialis posterior muscle was strengthened with resistance band, 3-4 sets and 10 repetitions per set, stretching of iliopsoas was in 30-second hold each time and three times in total. Towel curl exercise was performed 100 repetitions. Authors found that SSG group demonstrated a greater improvement in medial longitudinal arch height than the CEG group. Authors did discuss their study limitations: only a single method (Navicular drop test) was used to assess flat feet and that the study had a small sample size.

Allam et al., 2021 found that plyometric exercises and foot correction exercises in obese children with flat feet had positive effects on navicular height and balance. Study done by Goo et al., 2016 examined the effects of gluteus maximus and abductor hallucis strengthening exercises on navicular drop and found positive results with a significant improvement in navicular height.

7 THESIS PROCESS

Author had personal interest towards the flatfoot deformity. When there was first discussion about thesis in the 2nd year, the author's first thought was to write something about flat feet, but nothing was set in stone. What contributed to the idea was that in the current curriculum there was not enough material and/or information about flat feet. Therefore, the author had a discussion with the lecturers on writing the thesis about flat feet and contributing it to Musculoskeletal course in a form of individual study material. Musculoskeletal course lecturer supported this idea, as the study material could give a strong foundation and during the classes students could focus on the practical implementations.

Author used databases and search engines such as PubMed and ScienceDirect to write both the thesis and independent study material. Key search terms used included "pes planus", "flat foot", "rigid flat foot", "flexible flat foot, "adult acquired flat foot", "posterior tibial tendon dysfunction", "medial longitudinal arch", "physiotherapy". Inclusion criteria included articles written in English, published from 2013 to 2023 with exceptions was made for a few older articles and peer reviewed. Exclusion criteria included articles written in other languages, not peer reviewed.

7.1 Independent study material

Author has not made an independent study material before and unfortunately did not participate in a piloting process of another independent learning material by a third-year student of the international physiotherapy programme. Therefore, author did not know what this study material would look like, or how this H5P Moodle extension works. The H5P extension has variety of choices to build the individual study material, thus student who wishes to compile together the material package in the future, can use quite a creative approach. Author decided to use Moodle platform to compile together the study material due to its conveniency. As the students can easily access and learn from the study material online. In addition, they have the possibility to study in their own time and on their own pace, bringing flexibility to their schedules.

The study material contains information from this thesis, as well as the pictures and tables. All in all the content is the same between the thesis and the study material. Although, the study material in Moodle consists more pictures and videos, as its aim is to help the student with the learning process. For instance, pictures of ligaments located in the medial side of the ankle, illustrative pictures of certain physiotherapy tests, videos that show how to perform these certain tests to differentiate the type of flat foot the patient might have and videos of performing exercises correctly to strengthen the given muscles.

7.2 Piloting physiotherapy students

Author decided to choose second-year students of the international physiotherapy programme for piloting, as they were enrolled in the musculoskeletal physiotherapy course at that time. The timing of piloting was convenient as the students were about to start with ankle and foot region in their musculoskeletal physiotherapy course. Students had one month to go over the material and give feedback through Google Form.

Author had discussed with his thesis supervising teacher and with the musculoskeletal physiotherapy course lecturer about piloting process. Author asked both of the lecturers to go through the compiled study material before the piloting process. Both of the lecturers gave positive feedback of the study material and proposed that the author could start with the piloting. Author asked the musculoskeletal physiotherapy course lecturer about the possibility of joining her class via Hill platform and present the topic. The course lecturer proposed that author could either present in the beginning of the studies of ankle and foot region or at the end of it.

Total of 15 physiotherapy students volunteered for piloting. Students gained access to the study material on Moodle on 11th of April. The deadline for completing the study material and filling out a feedback questionnaire was set to 14th of May. After 14th of May, 10 responses were collected, meaning a drop-out number of 5. Google Forms questionnaire was used to collect the feedback anonymously. The feedback from the students were positive. They found the provided material easy to understand and easy to follow, in addition they found the study material well-structured and organized. Students found the added images and videos helpful, as well as the references added to each topic. Based on the feedback, the author did not make any big changes to the study material, only to a few grammar mistakes pointed out by the students.

8 DISCUSSION

The process of writing a thesis was new and quite a challenging experience for the author. Author first thoughts on physiotherapy intervention towards flat feet was quite superficial, although the more the author delved into the subject the more he understood the complexity of the flatfoot deformity. As it involves bones, ligaments, muscles, tendons, aponeurosis. Author desired to be detailed with his thesis, so that the future physiotherapy students could obtain a strong foundation.

Gathering articles and information started already during the thesis process in October 2022. Once the topic was accepted by the lecturers in November 2022, the author started to write the thesis. The goal was to write the thesis and the study material to the finishing stage before the start of clinical practice abroad. As author knew during that time the focus will mostly be in the practice placement. Once the thesis and the independent study material were written by the March 2023, the next objective was to pilot the second-year students of the international physiotherapy programme students. Discussion with the second-year students was done online through Hill platform on 28.03.23 and the timing was convenient both for the author and the group. As that day the physiotherapy students started to learn about the ankle & foot.

Compiling together a study material in H5P Moodle platform was a bit challenging in the beginning, as it has variety of choices to build the material with. Author wanted to make it simplistic and detailed, with a lot of pictures and videos to aid the students with learning process. For instance, to each test author added pictures and videos on how to assess and what to look for. The structure of the study material is similar to the thesis structure, starting with anatomy of the foot, pes planus and types of flat feet, complications from flat feet and lastly the assessment and physiotherapy aspect. In each section, the author added references at the end, so that the student has a possibility to read about it more. There were some issues on Moodle with giving the access for the students, which delayed the start of the piloting by two weeks.

Overall, the whole writing process was fluid and what contributed to the fluid writing process was that the author found the topic interesting. At first, the idea of writing thesis was daunting to the author. However, writing every day and noticing the small progress day by day motivated the author. Author did experience good and bad days, seldom there was lack of motivation. There were days, where author could write for hours and hours and in other days, where the progress was not that rapid. What helped the author to write the thesis was that there was goal set to write it to the finishing stage before clinical practice abroad. For the author, the most difficult section to write about was the treatment methods for pes planus. As there was not a clear structure and direction on how to write it in the beginning. Furthermore, it was difficult to stay in the borders of how physiotherapist can treat the patient/client and not to write off topic.

Author thinks that there is still much to investigate and learn about flatfoot deformity. Ideas for future plans could be investigating how do individual plantar (intrinsic) muscles contribute to the arch integrity, developing an exercise program to strengthen the targeted muscles to increase the medial longitudinal arch. Author has an interest whether through intrinsic muscle strengthening intervention the arch height increase is permanent or does it decrease in time. Additionally, seeing studies on strengthening exercise intervention that is longer than 4 to 8 weeks and the expected results from that intervention.

Author hopes that this thesis and the individual study material will help future physiotherapy students to understand the complexity of the flatfoot deformity and what can or cannot be done about it at this moment.

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