

**CHARACTERISTICS OF INTRINSIC
FOOT MUSCULATURE IN INDIVIDUALS
WITH ASYMPTOMATIC FLEXIBLE
FLATFOOT AND THE EFFECT OF
EXERCISE THERAPY**

A RANDOMIZED CONTROLLED TRIAL

Word count: 5,722

Raf Dejonghe, Yani Van Den Bossche and Miquel Van Den Driessche

Student number: 01600209, 01809602 and 01808706

Supervisor(s): Prof. Dr. Roel De Ridder and Dr. Valentien Spanhove

A dissertation submitted to Ghent University in partial fulfilment of the requirements for the degree of Master of Science in Rehabilitation Sciences and Physiotherapy

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Table of contents

List of figures and tables	6
List of abbreviations	7
Abstract	8
Abstract (Dutch)	9
1. Introduction	11
2. Methods	15
2.1 Design	15
2.2 Participants	15
2.3 Procedure	15
2.3.1 Foot Posture Index	16
2.3.2 Navicular drop test	17
2.3.3 Lower Quarter Y-Balance test	18
2.3.4 Strength measurements	19
2.3.5 Ultrasound evaluation of the IFM	20
2.3.6 Intervention	23
2.3.7 Data analysis	24
3. Results	25
3.1 Demographic characteristics	25
3.2 Flatfoot versus neutral foot at baseline	26
3.3 Flatfoot group: intervention versus no intervention	27
3.4 Flatfoot exercise group: pre- and post-intervention	28
4. Discussion	29
4.1 Results	29
4.1.1 Flatfoot versus neutral foot	29
4.1.2 Flatfoot exercise group: pre- and post-intervention	30
4.1.3 Flatfoot group: intervention versus no intervention	30
4.2 Limitations and strengths	31
4.3 Conclusion	32
References	33
Abstract (lekentaal)	37
Prove of submission at ethical committee	39
Appendix I	40
Populariserende samenvatting van het onderzoek	44
Maatschappelijke meerwaarde/impact van het onderzoek	46

List of figures and tables

Table I -----	16
Figure I -----	17
Figure II -----	18
Figure III -----	19
Figure IV -----	20
Figure V -----	21
Figure VI -----	21
Figure VII -----	21
Figure VIII -----	22
Figure IX -----	22
Figure X -----	23
Figure XI -----	23
Figure XII -----	24
Table II -----	25
Table III -----	26
Table IV -----	27
Appendix I -----	40

List of abbreviations

AbH: Abductor hallucis
AdH: Adductor hallucis
CSA: cross-sectional area
EFM: extrinsic foot muscles
FDB: Flexor digitorum brevis
FHB: Flexor hallucis brevis
FPI: Foot Posture Index
HHD: handheld dynamometry
IFM: intrinsic foot muscles
IP: interphalangeal
MLA: medial longitudinal arch
MRI: magnetic resonance imaging
MTP: metatarsophalangeal
ND: navicular drop
NDT: navicular drop test
QP: Quadratus plantae
SEBT: Star Excursion Balance Test
SFE: short foot exercises
SIAS: spina iliaca anterior superior
TCE: towel curl exercises
USI: ultrasound imaging
YBT-LQ: Lower Quarter Y-Balance test

Abstract

Background: Flatfoot is a foot deformity that is common in the adult population. Flatfoot deformity encompasses a variety of pathologic etiologies in various lower extremity overuse injuries. The foot core, including the intrinsic foot muscles (IFM), plays an important role in normal foot function and lower extremity function. Therefore, training the IFM to avoid excessive pronation may help prevent some of these injuries and pathologies. However, the effects of IFM training are not clear.

Study objectives: This study aims to investigate two study objectives. 1: Evaluate IFM function and strength in subjects with asymptomatic flatfoot and controls (neutral foot). 2: Evaluate the effect of IFM strengthening in subjects with asymptomatic flatfoot.

Study design: Randomized controlled trial

Methods: Participants were asked to come to the laboratory for initial testing. On the basis of the results of the first two tests: Foot Posture Index (FPI) and navicular drop test (NDT), they were assigned to the study group (asymptomatic flatfoot group) or the control group. After this allocation, the following tests were performed: 1. The Lower Quarter Y-Balance Test (YBT-LQ) to evaluate dynamic balance; 2. Handheld dynamometry (HHD) to measure the toe flexor strength; 3. Thickness and cross-sectional area (CSA) measurements of IFM by the use of ultrasound. Participants randomized to the intervention-study group performed two exercises, the short foot exercise (SFE) and extend toes, daily over a period of six weeks. After the intervention period of six weeks, all participants of the intervention-study group and the control-study group were asked to return for subsequent testing.

Results: At baseline, the control group had a significantly higher toe flexor strength (HHD) and M. Quadratus plantae (QP) thickness compared to the study group. For toe flexor strength (HHD) between baseline and week six in the intervention-study group, a significant difference was found. In the control-study group there was a significant difference for the thickness of the M. Flexor hallucis brevis (FHB) between baseline and week six. No significant differences were found for YBT-LQ, HHD, thickness and CSA of the IFM between intervention-study group and control-study group at week six.

Conclusion: This study provides some evidence for both study objectives. There is still a low level of evidence, so more research with larger study populations and longer time of intervention is needed in the future.

Key words: Flatfoot, intrinsic foot muscles, foot core training, short foot exercise and navicular drop

Abstract (Dutch)

Achtergrond: Een platvoet is een voetafwijking die veel voorkomt bij volwassenen. Een platvoetdeformiteit omvat een verscheidenheid aan pathologische etiologieën bij verschillende overbelastingsletsels van de onderste ledematen. De 'foot core', inclusief de intrinsieke voetspieren (IFM), speelt een belangrijke rol bij de normale voefunctie en de functie van de onderste ledematen. Daarom kan het opleiden van de IFM, om overmatige pronatie te vermijden, sommige van deze letsels en pathologieën helpen voorkomen. De effecten van het opleiden van de IFM zijn echter onduidelijk.

Doelstellingen: Deze studie beoogt twee studiedoelstellingen te onderzoeken. 1: Het evalueren van de IFM-functie en -kracht bij proefpersonen met asymptomatische platvoet en controles (neutrale voet). 2: Het evalueren van het effect van het versterken van de IFM bij proefpersonen met asymptomatische platvoet.

Onderzoeksdesign: Een gerandomiseerd onderzoek met controle groep.

Methode: Deelnemers werden gevraagd om naar het laboratorium te komen voor een eerste testmoment. Op basis van de resultaten van de eerste twee tests: Foot Posture Index (FPI) en navicular drop test (NDT), werden ze toegewezen aan de studiegroep (asymptomatische platvoetgroep) of de controlegroep. Na deze toewijzing werden de volgende tests uitgevoerd: 1. Lower Quarter Y-Balance Test (YBT-LQ) om het dynamisch evenwicht te evalueren; 2. Handknijpkrachtmeting (HHD) om de kracht van de teenbuigers te meten; 3. Dikte en dwarsdoorsnede (CSA) metingen van de IFM door middel van echografie. Deelnemers gerandomiseerd in de interventie-studiegroep voerden dagelijks, gedurende een periode van zes weken, twee oefeningen uit: de 'short foot exercise' (SFE) en het strekken van de tenen. Na de interventieperiode van zes weken werden alle deelnemers van de interventie-studiegroep en de controle-studiegroep gevraagd om terug te komen voor het tweede testmoment.

Resultaten: Tijdens het eerste testmoment had de controlegroep significant meer kracht in de teenbuigers (HHD) en een significant dikker M. Quadratus plantae (QP) in vergelijking met de platvoetgroep. Voor de kracht van de teenbuigers (HHD) van de interventie-studiegroep werd een significant verschil gevonden tussen de kracht tijdens het eerste testmoment en de kracht op week zes. Voor de dikte van M. Flexor hallucis brevis van de controle-studiegroep was er een significant verschil tussen de dikte tijdens het eerste testmoment en de dikte op week zes. Verder werden er op week zes geen significante verschillen gevonden tussen de interventie-studiegroep en controle-studiegroep voor YBT-LQ, HHD, dikte en CSA van de IFM.

Conclusie: Deze studie levert enig bewijs op voor beide studiedoelstellingen, maar het bewijsniveau is nog steeds laag. Dus in de toekomst is er meer onderzoek nodig met grotere studiepopulaties en een langere interventietijd.

Trefwoorden: Platvoet, intrinsieke voetspieren, foot core training, short foot exercise en naviculaire drop

1. Introduction

The foot is an important component of the body that performs critical functions (shock absorption, weight support etc.) when standing, walking, running or jumping. These activities of daily living require balance ability and control, which are provided by a stable foot that helps to keep the center of mass within the limits of the base of support. A lack or deficit of balance ability can lead to musculoskeletal disorders, such as ankle sprains and knee injuries, as well as falls. [1, 2, 3]

Flatfoot is a foot deformity that is common in the adult population. Pita-Fernandez et al. (2017) [4] have shown that the prevalence of flatfoot is 26,62%. In the study of Pita-Fernandez et al. (2017), the diagnosis of flatfoot was based on the footprint taken with a pedograph. Other studies such as Okamura et al. (2019) [5] use the navicular drop test (NDT) and Foot Posture Index (FPI-6) to assess foot posture. Flatfoot is characterized by partial or complete loss (collapse) of the medial longitudinal arch (MLA), eversion of the hindfoot and abduction of the loaded forefoot. [6] In addition, flatfoot deformity encompasses a variety of pathologic etiologies in various lower extremity overuse injuries, such as knee or hip pain [7, 8], achilles tendonitis [9, 10], plantar fasciitis [11, 12] and medial tibial stress syndrome. [13, 14] A past study found that 77% of adults with flatfoot have lower extremity or back pain. [15]

The conservative treatment for flatfoot deformity is exercises and/or foot orthoses. Foot orthoses are prescribed for a variety of foot conditions. Previous research has shown that 50% of adults with flatfoot were treated using foot orthoses to elevate the MLA and correct deformities. [15] However, there is limited evidence of the effect of foot orthoses for flatfoot in adults. [16] In addition, Desmyttere et al. (2018) [17] indicated in a systematic review and meta-analysis that the effect of foot orthoses on flatfoot were limited, and their impact on foot kinematics was debatable. Hoang et al. (2021) [18] investigated the impact of foot orthoses and exercises on pain and navicular drop (ND) for adult flatfoot. They conclude that the effects of foot orthoses and exercises caused a reduction in pain. Exercises and foot orthoses combined were found to be able to reduce pain more effectively than foot orthoses alone. However, the ND in adult flatfoot did not change. Similar results were found by Yurt et al. (2018) [19]. Yurt et al. (2018) compared different foot orthoses and concluded that computer-aided design/computer-aided manufacturing are both more effective than having sham insoles in reducing pain.

The foot core system consists of three subsystems to categorize the foot structures. These are called the active, passive and neural subsystems. [20] The core of the foot and normal foot function are obtained by the passive subsystem (stability of the foot arch). This subsystem consists of the ligaments, bones and joint capsules of the foot which form the structure of the foot and the various arches. [20] There are four arches of the foot that arise from this passive subsystem where the anatomical structures and bones have an important influence. These arches are subdivided in the medial and lateral longitudinal arches and the anterior and posterior transverse metatarsal arches. [20] The neural subsystem (somatosensory afferent system) and active subsystem (muscular activity) help to sense and interact the feet with the environment. [20] The muscles and tendons that insert on the foot form the active subsystem. These muscles are categorized in two different groups. The first group are the local stabilizers that both originate and insert on the foot, which are also named intrinsic foot muscles (IFM). [20] On the other hand, there are global movers that originate on the leg and insert on the foot and are referred to as extrinsic foot muscles (EFM). [21] The neural subsystem contains the sensory receptors of the tendons, muscles, joint capsules, ligaments and plantar fascia, which were named in the passive and active systems. [20] Research has shown that the anatomical positions of these IFM provide sensory response via the stretch posture induced by changes in foot posture. [20] The main IFM are abductor hallucis (AbH), flexor digitorum brevis (FDB) and quadratus plantae (QP). Their main function is to provide foot stability and flexibility for shock absorption. [22]

The IFM play a role in static and dynamic functions. An example of a static function is static postural balance. Dynamic functions on the other hand contribute to better balance and propulsion, which is critical for walking. [23] This has led to the fact that training the foot core has a significant positive effect on balance. [24, 25, 26] They coordinate mainly in the frontal plane and under increased load from the postural task. IFM [27, 28, 29], plantar fascia [25, 3] and posterior tibialis [30, 31] play an important role in preventing the decrease in MLA height. Okamura et al. [5] have shown that the IFM in people with flatfeet are able to support the MLA sufficiently to alter foot kinematics during gait. Exercises to strengthen these muscles, such as short foot exercises (SFE), can be effective in correcting foot alignment [24, 32] and in preventing or treating overuse injuries to lower extremities associated with flatfoot alignment. [5, 33] SFE involves contracting the IFM to pull the first metatarsophalangeal joint toward the calcaneus and raise the MLA without flexing the toes. [20, 34] The results of IFM training associates improvement on several functional outcome parameters (such as IFM strength and grip, pain, balance, dynamic function, foot posture, ND, MLA, activation and performance) in numerous studies. [24, 25, 26, 35 - 43]

To measure the strength of the IFM, magnetic resonance imaging (MRI) or ultrasound imaging (USI) can be used to quantify muscle cross-sectional area (CSA) and muscle thickness. [44, 45, 46] However, these modalities require expensive equipment and are not applicable in practice. Other measurement methods with interesting levels of validity and reliability are available and more affordable in practice. We can measure toe flexor strength with handheld dynamometry (HHD) [47] and the paper grip test [48].

When we look at the toe flexor strength, we know that the strength is generated by the combined activities of the plantar IFM and EFM. Some of these IFM (e.g., flexor hallucis brevis (FHB) and FDB) are specialized for toe flexion, while others (e.g., AbH and adductor hallucis (AdH)) act primarily for toe abduction/adduction. [49] This toe flexor strength plays an important role in postural control during standing and walking, and is positively associated with the performance of sports-related activities in adolescents and young adults. Therefore, an intervention of a training program aiming to enhance toe muscular strength would enhance physical performance. [49]

Some studies have been conducted to clarify the association between foot core training and ND, arch height and MLA. The ND and arch height contribute to the dynamic function of the foot and feature the MLA. The IFM exercises resulted in a significant decrease of the ND. [24, 38, 41, 42] Recruitment of the IFM and activation of the weakened IFM influence the MLA. The arch of the foot will not lower due to the greater tension of the foot muscles, which assists the prevention of running-related injuries. [24] This lowering of the arch would also result in more movement of the forefoot while walking, which negatively affects dynamic balance. [50]

Dynamic balance can be assessed by several methods, such as the Lower Quarter Y-Balance Test (YBT-LQ) and the modified Star Excursion Balance Test (SEBT). Pisal et al. (2020) [35] assessed dynamic balance using the YBT-LQ because it is a simple yet reliable test. This study investigated the effectiveness of SFE and towel curl exercises (TCE) to improve balance and foot posture in individuals with flexible flatfeet. Overall, interventions that targeted foot core training resulted in statistically significant post-intervention strength gains. [26, 36, 39, 41] Jung et al. (2011) [30] found that there was significantly greater activation of the AbH in subjects who performed SFE compared to TCE. However, Pisal et al. (2020) [35] concluded that SFE and TCE were equally effective in improving dynamic balance. Some studies have pointed out that the lack of research and evidence has increased uncertainty about the benefits of IFM exercises. [23, 51, 52, 53]

Therefore, a study was conducted to investigate the following questions depending on the information we already have and the knowledge gap we want to fill. "What is the difference between subjects with normal feet and subjects with flat feet at the beginning of this study?" and "What is the effect of intrinsic foot muscle training on patients with flat feet?". In order to find answers to these questions, we have set the following 2 study objectives.

- 1: Evaluate IFM function & strength in controls and subjects with asymptomatic flatfoot.
- 2: Evaluate the effect of IFM strengthening in subjects with asymptomatic flatfoot.

2. Methods

2.1 Design

This investigation is part of an experimental study. Participants were asked to come to the laboratory for initial testing, and on the basis of the results of the first two tests: FPI and NDT, they were assigned to the study group (asymptomatic flatfoot group) or the control group (cf. table I). After this allocation, the following tests were performed: 1. YBT-LQ to evaluate dynamic balance; 2. HHD to measure the toe flexor strength; 3. Thickness and CSA measurements of IFM by the use of ultrasound.

After the intervention period of six weeks, all participants of the intervention-study group and the control-study group were asked to return for subsequent testing. The independent variables were time (pre vs post) and group (intervention-study, control-study and control). The dependent variables were the results of the FPI, NDT, YBT-LQ, HHD and USI.

2.2 Participants

Thirty-six healthy participants volunteered for this study. After the initial testing, the participants were assigned to one of three groups (intervention-study, control-study or control), with five participants per study group and 26 participants for the control group. The inclusion and exclusion criteria are presented in table I. The study procedures were approved by the ethical committee of the University of Ghent, and all participants read and signed an informed-consent form before participation. The actual tests (pre and post) were conducted from October to December 2022.

2.3 Procedure

During the initial visit, a series of questions were asked to complete the baseline questionnaire (cf. appendix I). After the completion of this questionnaire, the FPI and NDT were evaluated for both feet.

Table I (inclusion and exclusion criteria)

INCLUSION	EXCLUSION
Age: 18-65	Age: <18 or >65
No complaints in the lower extremities (foot, ankle, knee and hip)	Pain, complaints or known injury of the lower extremities
Recreationally active: max 6h/week	
	Systemic pathology
	Pregnancy
BMI < 30 kg/m ²	BMI ≥ 30 kg/m ²
CONTROL GROUP	
Neutral foot position - 0 < FPI < 6 - ND < 10 mm	Abnormal foot position (supination/pronation)
STUDY GROUP	
Flexible feet FPI ≥ 6 ND ≥ 10 mm	Neutral or supinated foot position
	Recent participation in a physical rehabilitation program (< 3 months)
	Recent orthotics (< 3 months)

FPI: Foot Posture Index, ND: navicular drop

2.3.1 Foot Posture Index

The FPI consists of six validated, criterion-based observations of the rearfoot and forefoot of a subject standing in a relaxed position. [54, 55] The rearfoot is assessed via: 1. palpation of the head of the talus, 2. observation of the curves above and below the lateral malleoli and 3. the extent of the inversion/eversion of the calcaneus. The observations of the forefoot consist of: 1. assessing the bulge in the region of the talonavicular joint, 2. the congruence of the MLA and 3. the extent of abduction/adduction of the forefoot on the rearfoot.

To assess the participant and refer to a certain foot type the FPI reference sheet was used. [54, 55] Every participant was tested by at least two researchers. These were tested independent from each other and discussed afterwards. The aspects described above were scored between '2' and '-2', depending on the position of the foot. The total score was used to refer the participant to a foot type. When the score was higher than '+5', the foot was described as a pronated foot (flatfoot). With a score between '0' and '+5', the participant was described with a normal foot, and with a score less than '0', the participant was described with a supinated foot.

2.3.2 Navicular drop test

The NDT is used to evaluate the MLA. [57] It identifies the difference (in millimetres) between navicular tuberosity height in the subtalar joint in sitting and standing position.

The prominent part of the navicular tuberosity is marked. The distance from the supporting surface (floor) is measured from a sitting position (A). Next, the patient was asked to stand up and the amount of sagittal plane excursion of the navicular tuberosity is measured (B). The difference in height between these two measurements was calculated. If this difference was equal to or bigger than 10 millimeters, the participant was described as a static flat foot. As with the FPI above, every participant was tested by at least two researchers. These were tested independent from each other and discussed afterwards.

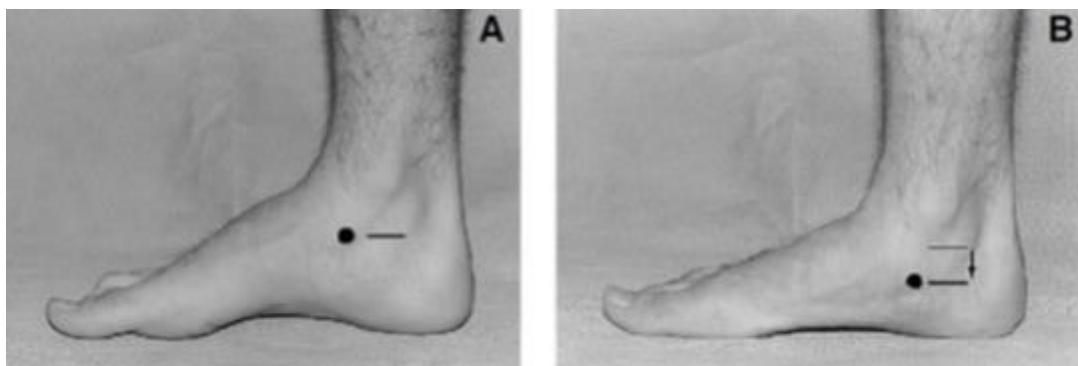


Figure I (measurement of navicular drop; Menz HB. 1998 [56])

A standardization of the posture was required: knees above feet, lower legs perpendicular and feet hip-width apart.

After the measurement of the FPI and the NDT, we indicated the foot that would be tested in the following measurements (only one foot was tested). If the ND was bigger than or equal to ten and

the FPI was bigger than five, the participant was included described as flatfoot and the flatfoot would be further tested. If the participant did not meet this inclusion criteria (control group), then the less pronated foot (most normal foot) would be further tested.

2.3.3 Lower Quarter Y-balance Test

Participants were then asked to perform the YBT-LQ. The YBT-LQ is derived from the SEBT and uses 3 reach directions: anterior, posteromedial and posterolateral. [58] Specifically, the support foot is put on the central point of the star with most distal aspect of the foot at the starting line. Hands are placed on the hips. First, six attempts per direction, then three consecutive measurements in the same direction. Per direction, there is a pause of thirty seconds.

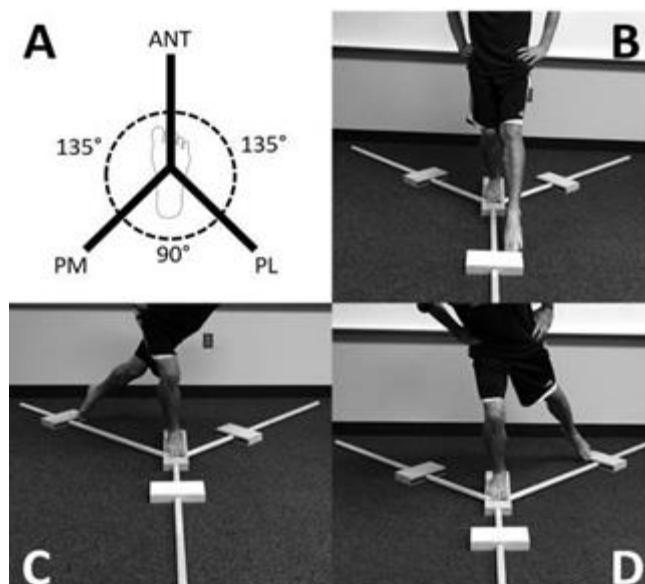


Figure II (YBT-LQ: A: setup, B: anterior reach, C: posterolateral reach and D: posteromedial reach; Powden CJ et al. 2019 [59])

Wrong executions are: 1. loss of unipodal stand (touches the ground with reaching foot or falls off the platform); 2. lose contact with the reaching indicator (gives a kick against the indicator to push forward); 3. uses the reaching indicator as a support (puts the foot on the indicator); 4. the support foot loses contact with the platform (heel detaches).

The greatest successful reach for each direction for each rater was used for analysis of the reach distance in each direction. The greatest reach distance from each direction was summed to yield a composite reach distance for analysis of overall performance on the test.

Afterwards, the leg length was measured, as described below, to calculate the normalized value. With the subject supine, the subject lifted the hips off the table and returned them to starting position. Then, the examiner passively straightened the legs to equalize the pelvis. The subject his/her limb length was then measured (with a tape measure) in centimeters from the spina iliaca anterior superior (SIAS) to the most distal portion of the medial malleolus. The normalized value was calculated as reach distance divided by limb length then multiplied by 100.

2.3.4 Strength measurements

Based on recommendation in Soysa et al. (2012) [60], toe flexor strength measurement with HHD was performed.



Figure III (strength measurement: setup)

The foot of the participant was put in plantar flexion to perform metatarsophalangeal (MTP) flexion of the hallux, with as little as possible influence of the calves/EFM. The participant sits on a crutch, which is placed backwards, resulting in plantar flexion of the foot. The more plantar flexion of the foot, the less influence of the EFM on the result of this test. [60] The foot is placed on the wooden block with the metatarsal heads at the edge of that block (toes are not on the block). The dynamometer is placed under the interphalangeal (IP) joint of the hallux. This makes MTP flexion possible, while the IP flexion is limited. Remark: the HHD was always placed on the low (L) threshold. This test was first practiced a few times before we proceeded to the measurements. For the execution of the test, the researcher counted down from three to one, after which the participant tried to flex the MTP1 joint for five seconds. The participant was also encouraged by another

researcher. This test was executed three times and the average of these results were taken into account.

2.3.5 Ultrasound evaluation of the IFM

Ultrasound images were collected with a Colormaster 128 EXT-IZ device (Telemed UAB, Vilnius, Lithuania) with a 5-10 MHz linear transducer. Settings were variable and set to optimize image quality. All ultrasound measurements were conducted by our co-promotor Valentien Spanhove. Participants lay supine in a comfortable position on a treatment table. The following IFM were tested: M. AbH, M. FDB, M. FHB and M. QP. For the AbH, the probe was placed along (CSA) or perpendicular to (thickness) a line perpendicular to the long axis of the foot near the anterior aspect of the medial malleolus (figure IV and V). [61] For the FDB, the probe was placed perpendicular to (CSA) or along (thickness) a line from the medial tubercle of the calcaneus to the third toe (figure VI). [61] For the FHB thickness, the probe was placed longitudinally along the shaft of the first metatarsal (figure VII). [61] For the QP thickness, the probe was aligned longitudinally along the muscle fibres, lying deep to the FDB. The probe was then rotated 90° to measure the CSA of the QP. [62] The ultrasound images were stored and transferred to another computer for analysis. Per muscle and parameter (CSA and thickness), three measurements were made of which the average was taken. These parameters were measured from the foot we selected earlier. It should be noted that only the thickness was measured of the M. FHB. The ImageJ software programme (National Institute for Health, Bethesda, MD, USA) was used to measure CSA and thickness, as depicted below.

1. M. Abductor hallucis



Figure IV (M. AbH CSA)

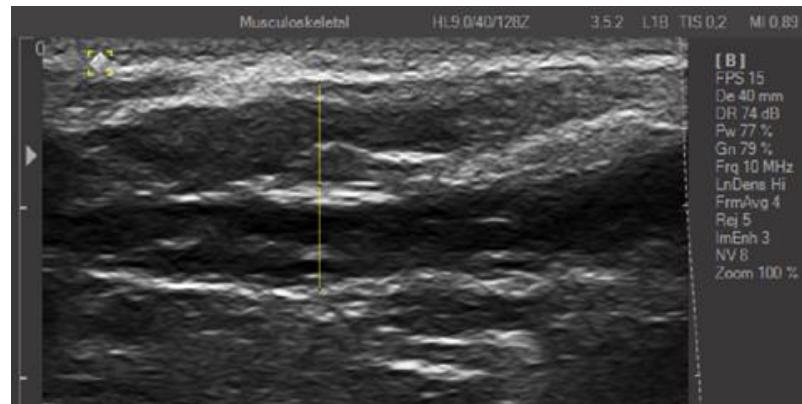


Figure V (M. AbH thickness)

2. M. Flexor digitorum brevis

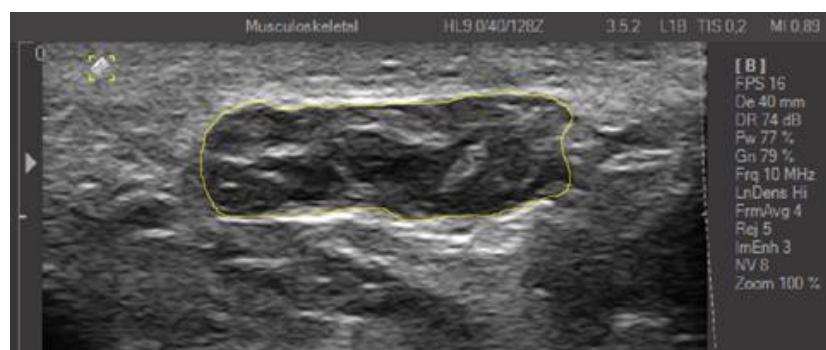


Figure VI (M. FDB CSA)

3. M. Flexor hallucis brevis

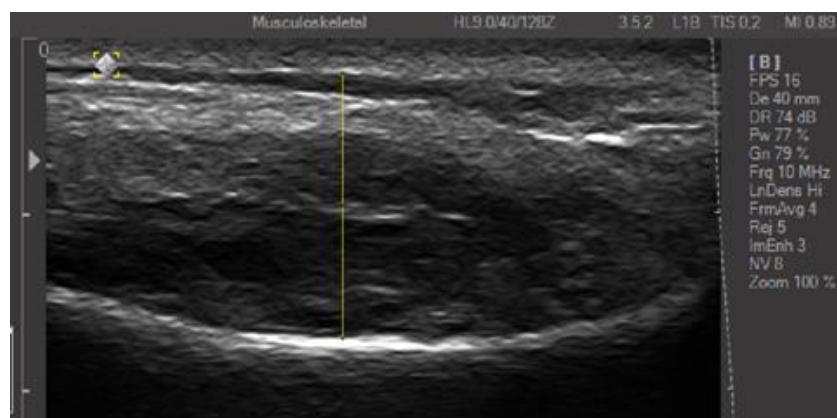


Figure VII (M. FHB thickness)

4. M. Quadratus plantae



Figure VIII (M. QP CSA)

5. M. Flexor digitorum brevis and M. Quadratus plantae

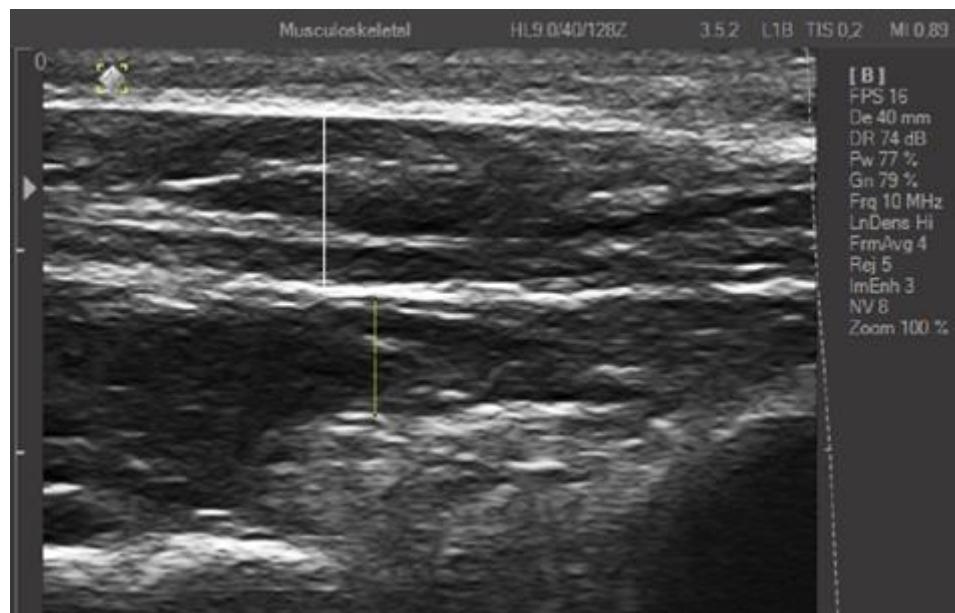


Figure IX (M. FDB thickness: white line and M. QP thickness: yellow line)

2.3.6 Intervention

Participants randomized to the intervention-study group performed the following two exercises daily over a period of six weeks. Weekly emails were sent as a reminder, in which they were also asked to indicate which days the exercises were actually carried out.

1. Short foot exercise

During this exercise, the foot is ‘shortened’ by using the intrinsic muscles (on the bottom side of the foot) to pull the first joint (MTP) of the big toe toward the heel, while the MLA of the foot is increased. It is important that the EFM are not activated and that the toes are not bent.



Figure X (short foot exercise; Lee E et al. 2019 [63])

With a relaxed foot (left picture below), we can observe the resting length of the foot. In the contracted position (right picture below), there is a change in foot length (dotted line) due to the contraction. This exercise is performed daily in three sets of fifteen repetitions. The contraction is held for five seconds each time. There is a two minute break between the three sets.

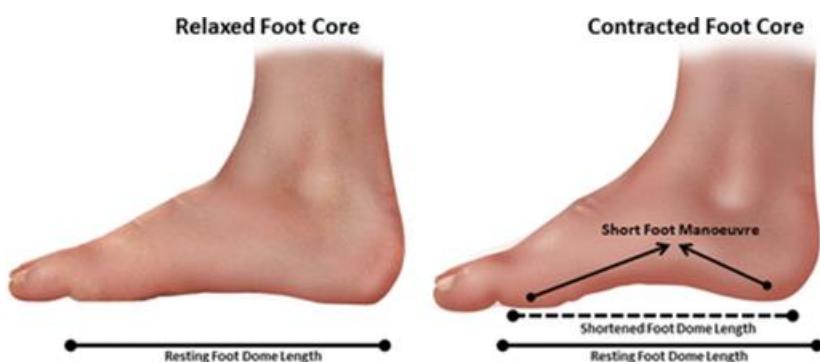


Figure XI (short foot manoeuvre; McKeon PO et al. 2015 [20])

2. Extend toes

During this exercise, the idea is to extend the big toe and the other toes separately. Here too, it is important that the toes do not bend. When the big toe is extended, the other toes maintain contact with the ground and vice versa. This exercise is performed daily in three sets of fifteen repetitions. There is a thirty second break between the three sets.



Figure XII (toe extension exercises; Robinson D et al. 2020 [64])

In the first two weeks, participants performed these prescribed exercises in a sitting position, feet supported on the floor. The exercises were progressed during the intervention period to increase the difficulty of the exercises as participants become more familiar with them. In the third and fourth weeks, they performed it in a standing position, feet hip-width apart. In the fifth week on one leg, and in the sixth week on one leg and at the same time make a rotational movement with the trunk.

All participants of the intervention-study group and control-study group were then asked to return to the laboratory six weeks after their initial testing session to be retested on all dependent measures. Testing procedures during the follow-up testing were identical to the initial testing, but the FPI and NDT were now only evaluated for the foot that we selected earlier.

2.3.7 Data analysis

The data analysis was executed in “SPSS Statistics 28”.

3. Results

3.1 Demographic characteristics

Regarding demographic characteristics, no significant differences were found for age, height, weight and hours of sport per week between the flatfoot group and the control group at the baseline of this study. The FPI scores of both feet (right $p=0,005$; left $p=0,021$) were significantly different between the flatfoot group and the control group, with the higher scores for the flatfoot group. The ND of both feet ($p<0,001$) was also significantly different between these two groups, with the higher scores for the flatfoot group. These demographic characteristics of the study subjects are shown in table II.

Table II (demographic characteristics of the study subjects)

	Flatfoot	Control
Age (y)	$22,3 \pm 1,70$	$24,12 \pm 4,03$
Height (cm)	$174,8 \pm 10,69$	$176,46 \pm 7,53$
Weight (kg)	$66,54 \pm 11,29$	$70,58 \pm 8,55$
Sport (hours per week)	$4,25 \pm 2,92$	$4,19 \pm 2,40$
FPI right foot	$7,90 \pm 2,42^*$	$4,73 \pm 3,01^*$
FPI left foot	$7,10 \pm 3,32^*$	$4,42 \pm 2,85^*$
ND right foot (mm)	$9,10 \pm 1,85^*$	$4,19 \pm 1,33^*$
ND left foot (mm)	$8,67 \pm 1,66^*$	$4,42 \pm 1,47^*$

Mean \pm standard deviation; *significant differences between flatfoot group and control group ($p<0,05$); FPI:

Foot Posture Index, ND: navicular drop;

3.2 Flatfoot versus neutral foot at baseline

No significant differences were found for dynamic balance (YBT-LQ) between both groups at baseline (pre-intervention). The control group had a significantly higher ($p=0,048$) toe flexor strength (HHD) compared to the flatfoot group. For thickness and CSA of the IFM, there was only a significant difference ($p=0,020$) of the QP thickness between both groups, with the higher value for the control group. All these values are shown in table III.

Table III (dynamic balance (YBT-LQ), toe flexor strength (HHD) and thickness/cross-sectional area (CSA) of the IFM (intrinsic foot muscles) of the flatfoot group and control group at baseline (pre-intervention))

	Flatfoot	Control
YBT-LQ (cm)	$19,04 \pm 6,02$	$19,53 \pm 3,83$
HHD (N)	$9,60 \pm 3,04^*$	$18,65 \pm 3,66^*$
AbH thickness	$1,21 \pm 0,32$	$1,45 \pm 0,75$
FDB thickness	$1,04 \pm 0,34$	$0,98 \pm 0,24$
QP thickness	$0,62 \pm 0,09^*$	$0,84 \pm 0,26^*$
FHB thickness	$1,57 \pm 0,31$	$1,59 \pm 0,28$
AbH CSA	$2,31 \pm 0,54$	$2,41 \pm 0,61$
FDB CSA	$2,35 \pm 1,07$	$2,15 \pm 0,42$
QP CSA	$1,10 \pm 0,42$	$1,28 \pm 0,58$

Mean \pm SD; *significant differences between flatfoot group and control group ($p<0,05$); YBT-LQ: Lower Quadrant Y-Balance test, HHD: handheld dynamometry, AbH: Abductor hallucis, FDB: Flexor digitorum brevis, QP: Quadratus plantae, FHB: flexor hallucis brevis, CSA: cross-sectional area;

3.3 Flatfoot group: intervention versus no intervention

No significant differences were found for dynamic balance (YBT-LQ), toe flexor strength (HHD) and thickness and CSA of the IFM between flatfoot exercise group and flatfoot control group at week six. These values are also shown in table IV.

Table IV (dynamic balance (YBT-LQ), toe flexor strength (HHD) and thickness/cross-sectional area (CSA) of the IFM (intrinsic foot muscles) of the flatfoot exercise group and flatfoot control group at baseline (pre-intervention) and week six (post-intervention))

Flatfoot	Flatfoot exercise		Flatfoot control	
	Baseline	Week 6	Baseline	Week 6
YBT-LQ (cm)	284,25 ± 19,14	286,11 ± 21,75	296,89 ± 18,69	290,53 ± 35,95
HHD (N)	8,8 ± 5,80*	30,37 ± 15,81*	14,21 ± 12,47	29,91 ± 17,53
AbH thickness (cm)	1,10 ± 0,16	1,37 ± 0,38	1,32 ± 0,42	1,18 ± 0,11
FDB thickness (cm)	1,09 ± 0,44	1,10 ± 0,21	0,98 ± 0,18	1,09 ± 0,11
QP thickness (cm)	0,59 ± 0,04	0,66 ± 0,18	0,65 ± 0,15	0,87 ± 0,13
FHB thickness (cm)	1,70 ± 0,25	1,62 ± 0,26	1,44 ± 0,33**	1,79 ± 0,17**
AbH CSA (cm)	2,07 ± 0,36	2,62 ± 0,64	2,54 ± 0,63	2,08 ± 0,54
FDB CSA (cm)	2,66 ± 1,47	2,37 ± 0,66	2,03 ± 0,41	2,44 ± 0,99
QP CSA (cm)	1,03 ± 0,35	1,09 ± 0,44	1,17 ± 0,52	1,13 ± 0,50

Mean ± SD; *significant differences between pre- and post-intervention flatfoot exercise group ($p<0,05$);

**significant differences between pre- and post-intervention flatfoot control group ($p<0,05$); YBT-LQ: Lower Quadrant Y-Balance test, HHD: handheld dynamometry, AbH: Abductor hallucis, FDB: Flexor digitorum brevis, QP: Quadratus plantae, FHB: Flexor hallucis brevis, CSA: cross-sectional area;

3.4 Flatfoot exercise group: pre- and post-intervention

No significant differences were found for dynamic balance (YBT-LQ) and thickness and CSA of the IFM between baseline and week six (post-intervention) in the flatfoot exercise group. For toe flexor strength (HHD) between baseline and week six in the flatfoot exercise group, a significant difference ($p=0,043$) was found.

No significant differences were found for dynamic balance (YBT-LQ) and toe flexor strength (HHD) between baseline and week six in the flatfoot control group. For thickness and CSA of the IFM, there was one significant difference ($p=0,014$) for the thickness of the FHB between baseline and week six in the flatfoot control group. All these values are shown in table IV.

4. Discussion

There is still further need for research on SFE and their outcome on participants with flatfeet in large study populations and over a longer intervention period.

Although there might be small evidence that an intervention program of six weeks with SFE has a positive influence on the IFM.

4.1. Results

4.1.1 Flatfoot versus neutral foot

Age, length, weight, FPI and ND were compared at baseline between the flatfoot group and control group. From this, we could deduce that these groups had the same characteristics. There was a significant difference between the ND and FPI between these two groups which makes sense because these variables determined the inclusion criteria. The results of the dynamic balance test (YBT-LQ), toe flexor strength (HHD) and thickness/CSA measurements of the IFM by the use of ultrasound were compared between flatfoot group and control group at baseline and were compared between flatfoot exercise group and flatfoot control group pre- and post-intervention. Between the flatfoot group and control group there was no significant difference in the result of the YBT-LQ while there was a significant difference of toe flexor strength (HHD) at baseline of this study. This might mean that participants with flatfeet had less strength and/or control of the IFM in this study. The participants who have no flatfeet (control group) had a significantly thicker QP compared to the flatfoot group. According to contemporary literature, there is a correlation between the largest IFM (AbH, FDB and QP) and the deformity of the longitudinal arch. [65] This might be the reason why the QP is thicker in the control group. All other variables of the thickness/CSA measurements of the IFM were equally distributed which shows that participants with or without flatfoot (according to this study) score about the same. This result can be caused because the comparison was made between participants with flatfeet and persons who were between a neutral foot and a flatfoot. These groups do not differentiate much from each other in general which can be reflected in these results.

4.1.2 Flatfoot exercise group: pre- and post-intervention

The results of the flatfoot exercise group were compared between the baseline and after six weeks of intervention. There was only one significant difference between these results. The HHD increased significantly after the intervention which might be caused because of the intervention program. This program made it possible for the participant to contract the IFM separately from the EFM. There was no significant difference in thickness and CSA between pre- and post-intervention. This was in contrast to what was found in previous research. This research showed that there was an increase in volume in all IFM after an intervention program of eight weeks. [66] There is no significant difference in results of the YBT-LQ between pre- and post-intervention in the flatfoot exercise group. Although, there is in previous research evidence that an intervention program of five weeks with SFE has a significant effect on the results of the YBT-LQ. [42] This is in contradiction to the results of this study which might be caused by the effectiveness of the intervention which still needs further research.

4.1.3 Flatfoot group: intervention versus no intervention

The results compared between the testing at baseline and after six weeks of the flatfoot exercise group versus flatfoot control group, showed the following information. There was a general improvement in the results of the testing in both groups which can arise because these tests were performed for the second time caused by the learning effect and the unreliability of the HHD-test. There is a significant improvement in the results of HHD between the pre- and post-test in the flatfoot exercise group which shows there can be a positive influence of the intervention on IFM strength. But in the control group, we also saw (a non-significant) improvement in the HHD-test. This ensures that the argument that the intervention can be a positive influence is weak. In literature, there is evidence that the inter- and intratester reliability is high in HHD while it is still unclear whether the intrinsic muscle strength can be tested isolated with this method. [60] In general, there were not a lot of changes between the pre- and post-test which can be caused by the short time of intervention, small study population and/or no accurate testing. Despite the short intervention time, there are studies where an intervention program of six weeks is effective for ND, FPI and maximum plantar force. [67] Intervention programs of five weeks and eight weeks showed significant results on thickness and CSA of the IFM and on YBT-LQ which shows that time was not the biggest limitation in this study. [42, 66] There is also a significant increase in the results of the thickness of FHB between the pre- and post-test in the flatfoot control group which confirms the inaccurate measurements. After the period of six weeks, the post-intervention test showed no significant differences between the flatfoot exercise group and flatfoot control group. This can be

caused by the limitations described below or might be caused by the effectiveness of the intervention program.

4.2. Limitations and strengths

First, the research was assessed by three master students who had no prior experience in the evaluation of the foot core. Furthermore, the tests were not always measured by the same student which might have an influence due to the intertester reliability. On the other hand, the co-promotor was always present during the measurements and double-checked the data from the inclusion tests to assign a participant to the correct group. In addition, only the co-promotor executed the ultrasound, which can be a strength. However, there is still little evidence regarding the inter- and intratester reliability of IFM ultrasound. Because of this, our co-promotor is currently working on a study investigating the inter- and intratester reliability of the ultrasound of the IFM.

Second, only ten of the 36 participants who were included in the study met the criteria for the group of flatfeet identified by the inclusion criteria. The inclusion criteria were too strict, resulting in many participants being excluded from the flatfoot group. A ND, greater than or equal to ten, was used to include participants as a flatfoot. In current ongoing research, whether or not a person has a flatfoot is indicated by a ND of six or higher. These strict criteria resulted in many participants in the control group who just fell short of the flatfoot criteria. This means that many of the participants in the control group do not have the ideal neutral feet, but are somewhere between neutral feet and flatfeet. On the other hand, this means that all participants of the study group clearly have a flatfoot. Third, there is a small number of participants because of the strict inclusion criteria. Therefore, it is challenging to extrapolate the findings to the full population. The average age of the participant (23,61 years), also undermines the validity of the generalization to the total population.

Fourth, the flatfoot exercise group followed an exercise program for six weeks which is only a short amount of time to notice significant improvement on the tests. If the time of intervention was longer than six weeks, maybe the progression would be much clearer.

Last, the HHD testing reliability is low because there was a lot of variability in the results between the different attempts executed by the same participants and the same student. Furthermore, there is not yet an ideal test to measure the strength of IFM. [60] The setup that was performed is not yet well known in the literature. Therefore, the reliability of this test is unknown. Further research to measure the strength of the IFM is therefore needed.

4.3. Conclusion

The first study objective of this study was to evaluate the differences of IFM function & strength between subjects with asymptomatic flatfoot and controls. The second study objective was to evaluate the effect of IFM strengthening in subjects with asymptomatic flatfoot. This study provides some evidence of these two study objectives. There is still a low level of evidence, so more research with larger study populations and longer time of intervention is needed in the future.

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Abstract (lektaal)

Achtergrond: Een platvoet is een voetafwijking die veel voorkomt bij volwassenen. Een platvoetafwijking omvat een verscheidenheid aan abnormaliteiten bij verschillende overbelastingsletsels van de onderste ledematen. De kleine spieren onderaan in de voet spelen een belangrijke rol bij de normale voetfunctie en de functie van de onderste ledematen. Daarom kan het opleiden van die kleine voetspieren, om het overmatig naar binnenvallen van de voet te vermijden, sommige van deze letsels en aandoeningen helpen voorkomen. De effecten van het opleiden van de kleine voetspieren zijn echter onduidelijk.

Doelstellingen: Deze studie beoogt twee studiedoelstellingen te onderzoeken. 1: Het evalueren van de functie en kracht van de kleine voetspieren bij proefpersonen met asymptomatische platvoet en controles (neutrale voet). 2: Het evalueren van het effect van het versterken van de kleine voetspieren bij proefpersonen met asymptomatische platvoet.

Onderzoeksdesign: Een willekeurig ingedeeld onderzoek met een controle groep.

Methode: Deelnemers werden gevraagd om naar het laboratorium te komen voor een eerste testmoment. Op basis van de resultaten van de eerste twee tests die de stand van de voeten nagingen, werden ze toegewezen aan de platvoetgroep of aan de controlegroep (neutrale voet). Na deze toewijzing werden de volgende tests uitgevoerd: 1. Een test om het dynamisch evenwicht te evalueren; 2. Een test om de kracht van de teenbuigers te meten; 3. Dikte en dwarsdoorsnede metingen van de kleine voetspieren door middel van echografie. De deelnemers in de platvoetgroep werden willekeurig opgesplitst in twee groepen: een groep die oefeningen uitvoerde voor zes weken en een groep die niets deed. De deelnemers in de platvoet-oefengroep voerden dagelijks, gedurende een periode van zes weken, twee spierversterkende oefeningen voor de kleine voetspieren uit. Na de oefenperiode van zes weken werden alle deelnemers van de platvoet-oefengroep en de platvoet-controlegroep gevraagd om terug te komen voor het tweede testmoment.

Resultaten: In het begin had de controlegroep beduidend meer kracht in de teenbuigers en een beduidend dikker voetspiertje in vergelijking met de platvoetgroep. Voor de kracht van de teenbuigers van de platvoet-oefengroep werd een beduidend verschil gevonden tussen de kracht in het begin en de kracht op week zes. Voor de dikte van een voetspiertje van de platvoet-controlegroep was er ook een beduidend verschil tussen de dikte in het begin en de dikte op week zes. Verder werden er op week zes geen beduidende verschillen gevonden tussen

de platvoet-oefengroep en de platvoet-controlegroep voor het dynamisch evenwicht, de kracht van de teenbuigers en de dikte en dwarsdoorsnede van de kleine voetspieren.

Conclusie: Deze studie levert enig bewijs op voor beide studiedoelstellingen, maar het bewijsniveau is nog steeds laag. Dus in de toekomst is er meer onderzoek nodig met meer proefpersonen en een langere oefenperiode.

Trefwoorden: Voetstand, platvoet, kleine voetspieren en spierversterkende oefeningen

Prove of submission at ethical committee

Afzender : Commissie voor medische ethiek

Prof. Dr. Roel De Ridder
Vakgroep Revalidatiewetenschappen
Afhier

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Aanvrager Valentien Spanhove	datum 16/09/2022	pagina 1/6
Onze referentie: ONZ-2022-0307	EudraCT-nr:	Belg. Regnr: B6702022000425

Betreft:

**Karakteristieken van intrinsieke voetmusculatuur bij personen met asymptomaticke flexibele platvoet en het effect van oefentherapie.
Characteristics of intrinsic foot muscles in persons with asymptomatic flexible flatfoot and the effect of exercise therapy**

Positief advies conform de wet van 7 mei 2004 betreffende experimenten op de menselijke persoon

Beste collega

De Commissie Medische Ethisch (CME) verbonden aan de Universiteit Gent (Ugent) en het Universitair Ziekenhuis Gent (UZ Gent) heeft het bovenvermelde dossier onderzocht en besproken op haar vergadering van 24/08/2022.

Na raadpleging van de bijkomende informatie en/of aangepaste documenten met betrekking tot dit dossier, is de CME van oordeel dat de voorgestelde studie, zoals beschreven in het protocol, wetenschappelijk relevant en ethisch verantwoord is.

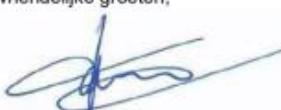
EC geeft daarom op 15/09/2022 een gunstig advies over deze studie.

Ingrediende documenten: zie bijlage 1

Ledenlijst: zie Bijlage 2

Aandachtspunten: zie Bijlage 3a

Met vriendelijke groeten,



Prof. dr. Philippe Deron
Voorzitter
Commissie voor Medische Ethisch U(Z) Gent



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Appendix I

DEMOGRAFISCHE BASISGEGEVENS

Code deelnemer	<hr/> <hr/>
Leeftijd	_____ jaar (geboortedatum: _____)
Lengte	_____ cm
Gewicht	_____ kg
Dominante zijde <i>(met welke voet trapt u tegen een bal)</i>	Links - Rechts
Emailadres	<hr/>

MEDISCHE VOORGESCHIEDENIS

- Heeft u momenteel klachten ter hoogte van uw onderste ledematen?

▪ Heup

- Nee
- Ja
 - Welke? _____
 - Wanneer? _____
 - Behandeling? _____

▪ Knie

- Nee
- Ja
 - Welke? _____
 - Wanneer? _____
 - Behandeling? _____

▪ Enkel/voet

- Nee
- Ja
 - Welke? _____

- Wanneer? _____
- Behandeling? _____

- Heeft u vroeger reeds klachten gehad ter hoogte van uw onderste ledematen (heup, knie en enkel/voet)?

▪ Heup

- Nee
- Ja
 - Welke? _____
 - Wanneer? _____
 - Behandeling? _____

▪ Knie

- Nee
- Ja
 - Welke? _____
 - Wanneer? _____
 - Behandeling? _____

▪ Enkel/voet

- Nee
- Ja
 - Welke? _____
 - Wanneer? _____
 - Behandeling? _____

- Heeft u momenteel andere fysieke klachten (vb. rug, schouders,...)?

- Nee
- Ja
 - Welke? _____
 - Wanneer? _____
 - Behandeling? _____

- Heeft u vroeger reeds andere fysieke klachten gehad (vb. rug, schouders...) gehad?

- Nee
- Ja
 - Welke? _____
 - Wanneer? _____
 - Behandeling? _____

- Heeft u reeds chirurgie ondergaan?

- Nee
- Ja

- Aan de onderste ledematen? _____
 - Soort chirurgie? _____
 - Andere localisatie? _____
- **Heeft u momenteel andere medische problemen?**
- Nee
 - Ja
 - Suikerziekte? _____
 - Reumatische aandoening? _____
 - Evenwichtsstoornissen? _____
 - Andere? _____
- **Draagt u momenteel steunzolen?**
- Nee
 - Ja
 - Hoelang al? _____
 - Links 0 Rechts 0 Beide 0
 - Waarvoor moet u die zolen dragen? _____
- **Is er bij u ooit een beenlengteverschil vastgesteld?**
- Nee
 - Ja
 - Wanneer? _____
 - Is er een ophoging van uw schoen? _____
- **Maakt u gebruik van een brace/tape voor het sporten?**
- Nee
 - Ja
 - Wanneer? Training? Wedstrijd? _____
 - Brace of Tape? _____
 - Waarom draagt u deze? _____

EXTRA GEGEVENS

Werk situatie	<input type="checkbox"/> Voltijsd betaald werk <input type="checkbox"/> Deeltijsd betaald werk (____%) <input type="checkbox"/> Ziekteverlof <input type="checkbox"/> Arbeidsongeschikt <input type="checkbox"/> Moederschapsverlof <input type="checkbox"/> Met verlof zonder wedde / loopbaanonderbreking
----------------------	--

	<input type="checkbox"/> Werkloos of werkzoekende <input type="checkbox"/> OCMW-bestangsminimum <input type="checkbox"/> Ik volg volledig dagonderwijs of stage <input type="checkbox"/> Ik ben op pensioen <input type="checkbox"/> Huisvrouw / huisman <input type="checkbox"/> Vrijwilligerswerk <input type="checkbox"/> Anders, namelijk _____
Sport	Welke sport? _____ Aantal uren per week? _____ uren/week Sport in competitie? <input type="checkbox"/> Nee, geen competitie <input type="checkbox"/> Ja, competitie
Medicatie gebruik (voorbije 72h)	<input type="checkbox"/> Nee <input type="checkbox"/> Ja, namelijk: <input type="checkbox"/> Analgetica <input type="checkbox"/> Anticonceptie <input type="checkbox"/> Andere: _____

Populariserende samenvatting van het onderzoek

Inleiding

Wij hebben onderzoek verricht naar de kleine spieren onderaan in de voet. Deze kleine voetspieren zorgen er onder andere voor dat de stabiliteit van de voet bewaard blijft tijdens alledaagse activiteiten, zoals wandelen, lopen en springen. Ze hebben een belangrijke invloed op de stand van de voeten en zo dus ook op de stabiliteit van een persoon. Het eerste doel van ons onderzoek was om de verschillende karakteristieken van deze spieren in kaart te brengen bij personen met een neutrale voetstand en personen met platvoeten. De karakteristieken dat we onderzochten zijn de kracht van de voetspieren, het dynamisch evenwicht en de dikte en dwarsdoorsnede van deze voetspieren. Het tweede doel van ons onderzoek was om het effect van twee spierversterkende oefeningen voor de kleine voetspieren na te gaan bij personen met platvoeten. Met dit onderzoek hopen we aan te tonen dat deze twee oefeningen een positief effect hebben op bovengenoemde karakteristieken, en aldus geïntegreerd zouden kunnen worden in revalidatieprogramma's en/of letselpreventieprogramma's.

Methode

Om te beginnen evalueerden we de stand van de voeten bij alle deelnemers aan de hand van twee testen. Op basis van deze resultaten konden we de deelnemers onderverdelen in twee groepen: een platvoetgroep en een controlegroep (neutrale voet). Hierna voerden de deelnemers nog enkele testen uit: een krachttest voor de kleine voetspieren, een test voor het dynamisch evenwicht, en een dikte en dwarsdoorsnede meting van de kleine voetspieren aan de hand van echografie. Voor het eerste doel van ons onderzoek werden de resultaten van de platvoetgroep (aan het begin van de studie) vergeleken met deze van de controlegroep. Voor het tweede doel van ons onderzoek werd de platvoetgroep verdeeld in twee interventiegroepen. De ene groep voerde zes weken aan een stuk, eenmaal per dag, twee spierversterkende oefeningen voor de kleine voetspieren uit. De andere groep voerde geen oefeningen uit gedurende deze periode. Na deze periode van zes weken keerden beide platvoet groepen terug om de testen die initieel uitgevoerd werden, te herhalen. De resultaten van deze tweede testing werden dan tussen beide platvoet groepen vergeleken (interventie versus geen interventie), en er werd voor deze platvoet groepen ook een vergelijking gemaakt tussen de resultaten van de eerste testing en de resultaten van de tweede testing (voor en na interventie).

Resultaten

Bij vergelijking van de resultaten tussen de platvoetgroep en controlegroep kunnen we het volgende afleiden. Uit de krachttest blijkt dat de teenbuigers van de controlegroep significant sterker zijn dan die van de platvoetgroep. We zien ook dat de M. Quadratus plantae (kleine voetspier) significant dikker is bij de controlegroep in vergelijking met de platvoetgroep. Bij vergelijking van de resultaten tussen de platvoet groepen voor en na interventie kunnen we het volgende afleiden. Uit de krachttest blijkt dat de teenbuigers significant versterkt zijn na de interventie bij de platvoetgroep die de spierversterkende oefeningen uitvoerde. Verder is er nog een significant verschil te zien voor de dikte van M. Flexor hallucis brevis (kleine voetspier) tussen de resultaten van de testen voor en na interventie bij de platvoetgroep die geen spierversterkende oefeningen uitvoerde.

Maatschappelijke meerwaarde/impact van het onderzoek

Er zijn niet veel noemenswaardige significante resultaten uit het onderzoek gekomen, uitgezonderd de significante krachttoename van de teenbuigers van de platvoetgroep die de interventie onderging. Aangezien deze kleine voetspieren instaan voor de stabiliteit van de voet kan het nuttig zijn om in te zetten op oefeningen om deze spieren te versterken. Daarom kan deze interventie geïntegreerd worden in blessurepreventie programma's bij zowel patiënten met platvoeten als patiënten met neutrale voeten. Dit zal dan ook resulteren in een daling van de gezondheidskosten, wat dan ook een positieve impact zal hebben op de maatschappij. Echter, het argument dat deze interventie een positieve invloed heeft is zwak. De reden hiervoor is dat er in de literatuur nog onduidelijkheid (en dus weinig betrouwbaarheid) heerst over de manier waarop de kracht van de kleine voetspieren getest kan worden. Verder zagen we ook een (niet-significante) verbetering in de krachttoename van de teenbuigers en een significante stijging in de dikte van een voetspiertje in de platvoetgroep die geen interventie onderging. We kunnen dus concluderen dat er meer onderzoek nodig is, maar dat wij met deze pilootstudie een eerste aanzet hebben gegeven voor verder onderzoek.

