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Dynamic-passive correction of hallux valgus and associated static foot deformities

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Abstract

Purpose: The paper presents, the effects of hallux valgus correction and coexisting static deformities of the foot (transversely-plano and plano-valgus foot) obtained with a new dynamic-passive method of treatment.

Methods: The study involved 50 patients; 26 with full big toe correction after the passive correction grip (group I) and 24 with big toe correction requiring additional passive abduction (group II). The patients regularly performed exercises using the designed device according to the planned schedule. The progress of the correction was assessed by a medical examination and additional tests.

Results: The cross-sectional area [cm2] of the abductor hallucis muscle in three-time points among I and II groups of patients with the Hallux Valgus was measured based on MRI images. The STIR examination showed among other the abductor hallucis muscle edema after exercises with the DPc device were carried out. It evidences that exercises with the new device activate the muscle. Alignment of the big toes of both feet in groups I and II were obtained with a statistically significant result ($p<0.05$). The percentage progression of correction for HV and I/II IM was calculated.

Conclusions: Based on the new correction approach the alignment of the big toe phalanges and the remaining toes was obtained. The passive setup of the tendons with their distal inserts at the level of the big toe phalanges to the correct path of their course with the withdrawal of articular subluxations was obtained. Simultaneously, the big toe's passive correction was dynamically consolidated through a specially selected set of exercises.

Keywords

hallux valgus, dynamic-passive correction, foot deformities, foot rehabilitation, orthopedics

1. Introduction

The most common musculoskeletal defects are static deformities of the feet, with the hallux valgus (HV) leading the way. Due to its common occurrence, it is included in the group of civilization diseases [24].

Despite many scientific studies, the pathomechanism of static deformities, i.e. plano-valgus and transversely flat foot, is not fully explained [13]. A lot of researchers describe that the formation of hallux valgus may be the result of the occurrence of the transversely plano-foot and plano-valgus foot [13, 35]. On the other hand, some researchers claim that deformity changes begin with hallux valgus and tend to further deformities such as the plano-valgus foot and transversally flat foot.. Hallux Valgus (HV) very rarely occurs without changing the shape of the arches [10, 21].

Hallux valgus in the human population occurs with a frequency of 23% of adults aged 18 to 65 years [16, 18]. In about 85% of cases, the deformity is bilateral [15]. Hallux valgus is statistically more common in women. In young female people, the deformity is 2-3 times more common than in men, and in the 3-5th decade of life this ratio increases to 15:1 [13]. In the 65+ age bracket, 35% of the population is affected [11]. A risk factor for HV is, in addition to age and gender, weakening of ligaments and other collagen structures during pregnancy [13, 20]. Estrogen deficiency and the onset of osteoporosis during menopause also affect the condition of the musculoskeletal system of the feet [12]. In the elderly, the predominance of catabolic processes over anabolic ones results in senile collagen atrophy (senile osteoporosis) and leads to loss of flexibility of tissues responsible for joint mobility [2].

In addition to biological risk factors, the efficiency of the musculoskeletal system is also influenced by environmental factors, such as improper lifestyle or bad eating habits, which can lead to obesity, increasing the static and dynamic loads on the foot (overload of ligaments and structure of the muscles) [18, 31, 38]. Non-physiological footwear, i.e. high-heeled shoes, or too tight and with a narrowed point, is another significant cause of foot pathology [6]. Wearing such shoes can lead to chronic malnutrition of intrinsic muscles of the foot (mainly interosseous muscles) [1, 3, 29].

The optimal load distribution for the individual foot points is as follows: 50% of the load on the heel, 33.5% on the anteromedial point, and 16.5% on the anterolateral point. The disturbance of these proportions causes destabilization of the dynamic-passive system of the foot [22, 26, 38]. It is observed in posture defects with excessive pressure on the forefoot or hindfoot, or on the medial or lateral edge of the foot. Disturbance of proportions in the load on any of the foot support points may also occur in dynamic conditions with systematic action spread over time. In athletes, dancers, and people wearing non-physiological footwear, excessive load is transferred from the hindfoot to the unadapted forefoot. Ultimately, the so-called transversely flat foot also called the sensitive foot, often with painful calluses under the head of the II and III metatarsal bones is created [27]. In some cases, the distribution of the pressure is proportional, but excessive stress on anatomical structures, such as in obesity, results in chronic ligamentous-muscular failure [4, 38].

The definition of hallux valgus states that it is "a deformity consisting in the varus position of the I metatarsal bone with the head of this bone protruding towards the medial side and deviation of the big toe towards the lateral side" this indicates that this is not just a problem with the lateral position of the big toe, as given in most of the definitions, but also the problem of widening I/II IM (I/II intermetatarsal angle) with varus position of the first metatarsal bone [13, 37]. Varisational, often hypermobile, and even rotational positioning of the I metatarsal bone and the lateral deviation of the big toe are a consequence of the collapse of the transverse arch of the foot resulting in the expansion of all intermetatarsal spaces (including mainly the I/II IM) [5, 8]. Flattening or even inversion of the transverse arch of the foot is closely integrated with the collapse of the longitudinal arch of the foot passively-dynamically stabilized. This is due to the support of both arches at three points (the support points of the transverse arch are at the same time the front supports of the medial and lateral longitudinal arch) [14, 23]. However, this does not exclude the situation that the hallux valgus is much less common with normal transverse and longitudinal arches (mechanical type deformation). This situation is most often the result of wearing tight, pointed, too-short shoes, often with worsening of the problem due to the production of sliding forces acting on the forefoot in shoes with, for example, high heels [30, 32].

In the mechanical type of hallux valgus, it is possible to exert a retrograde impact of the proximal phalanx on the head of the first metatarsal bone, displacing it medially and dorsally, varisating it. Most authors expose this rare pathomechanism in the development of hallux valgus, obscuring the most common pathomechanism, in which first the failure of the extrinsic muscles of the foot (including mainly the tendon stirrup muscles), and then intrinsic muscles of the foot resulting in the collapse of the foot arches under the influence of gravity [7]. The final effect is the positioning of the distal tendons of the muscles having their attachments on the phalanges of the big toe along the chord, making the big toe deform.

Currently, at the initial stages of foot deformities, patients are recommended non-invasive treatment using various types of orthoses or shoe inserts [19, 28, 33]. It has been assessed that in many cases the therapeutic effect after applying, e.g., abduction splints and interdigital inserts, is not entirely satisfactory [28, 36]. It comes down only to the cosmetic effect, slightly affecting the reduction of the pain level perception. They do not affect the correction of the longitudinal and transverse arches of the feet, the collapse of which is the most common cause of foot static deformities [8, 37]. These devices have the only passive stretching function of the contracted tissue and do not affect in many cases dynamic (muscular) correction of the deformities. Some elastic correctors dynamically abduct the big toes, but the action of which pathologically strengthens the hallux adductor muscle of both feet, increasing the degree of hallux valgus.

Another solution aimed at inhibiting the progression of static deformities of the feet is applying insoles elevating foot arches. In the early stages of static foot deformities development, metatarsal inserts fulfill their function because the foot is flexible and there is a "gravitational fall" of the I, IV, and V metatarsal bones. For advanced forms of the defect, footwear adapted to the deformities is recommended [6, 34].

Effective treatment must seek to remove the causes of deformities. In most clinical cases, the starting point of the deformities which is the hallux valgus (the last link of the cause-effect chain) is the collapse of the transverse and/or longitudinal arches of the foot (the first link of the cause-effect chain). In such cases, the corrective effect of the valgus big toe without the prior re-formation of the flattened and inefficient transverse and longitudinal arches of the foot will not lead to the final correction [8]. It will be only a seeming, temporary, cosmetic effect, affecting the patient's psyche more than it reduces foot deformities.

Medical rehabilitation specialists and physical therapists offer a whole range of exercises to strengthen the dynamic arch of the toes and shape the transverse and longitudinal arches of the foot depending on the type of foot deformities. This approach is effective in the prophylaxis and in the early stages of the development of the deformity when the foot is still flexible. The implementation of exercises on the fixed structural deformed architecture of the foot, without prior passive correction, is medical malpractice and will not achieve a healing effect. A rule to remember is that restoring the muscle balance through exercises must always be preceded by passive correction with the restoration of the correct shape and axis of the body parts.

The paper presents a new method of correction of static foot deformities, in which the presented dynamic exercise system is correlated with passive correction based on the newly designed device. Stretching and strengthening exercises take place on a properly shaped foot.

2. Objectives

The research aimed to check whether the proposed correction method using a device specially designed for this purpose will lead to the alignment of the big toe. In particular, the focus was on:

- reducing the value of the hallux valgus angle (HV) by the active strengthening of the abductor hallucis muscle, with simultaneous passive stretching of the adductor halucis muscle of the big toe,
- reduction of the varus of the first metatarsal bone, i.e. the angle between the first and second metatarsal bones (I/II IM), for which two external muscles of the foot are mainly responsible, i.e. m. tibial anterior and m. fibularis longus, forming the so-called stirrup tendon, which narrows the forefoot and lifts the transverse arch of the foot.

3. Materials and methods

3.1 Study design

Recruited patients were assessed by medical examination and additional examinations (X-ray and STIR) before the correction procedure. Then, they performed the recommended set of corrective exercises and were again examined at two time points, i.e. after three and six months. The individual steps using the specific methods and tools shown in the diagram are described below. The research was carried out under the scheme (Figure 1).

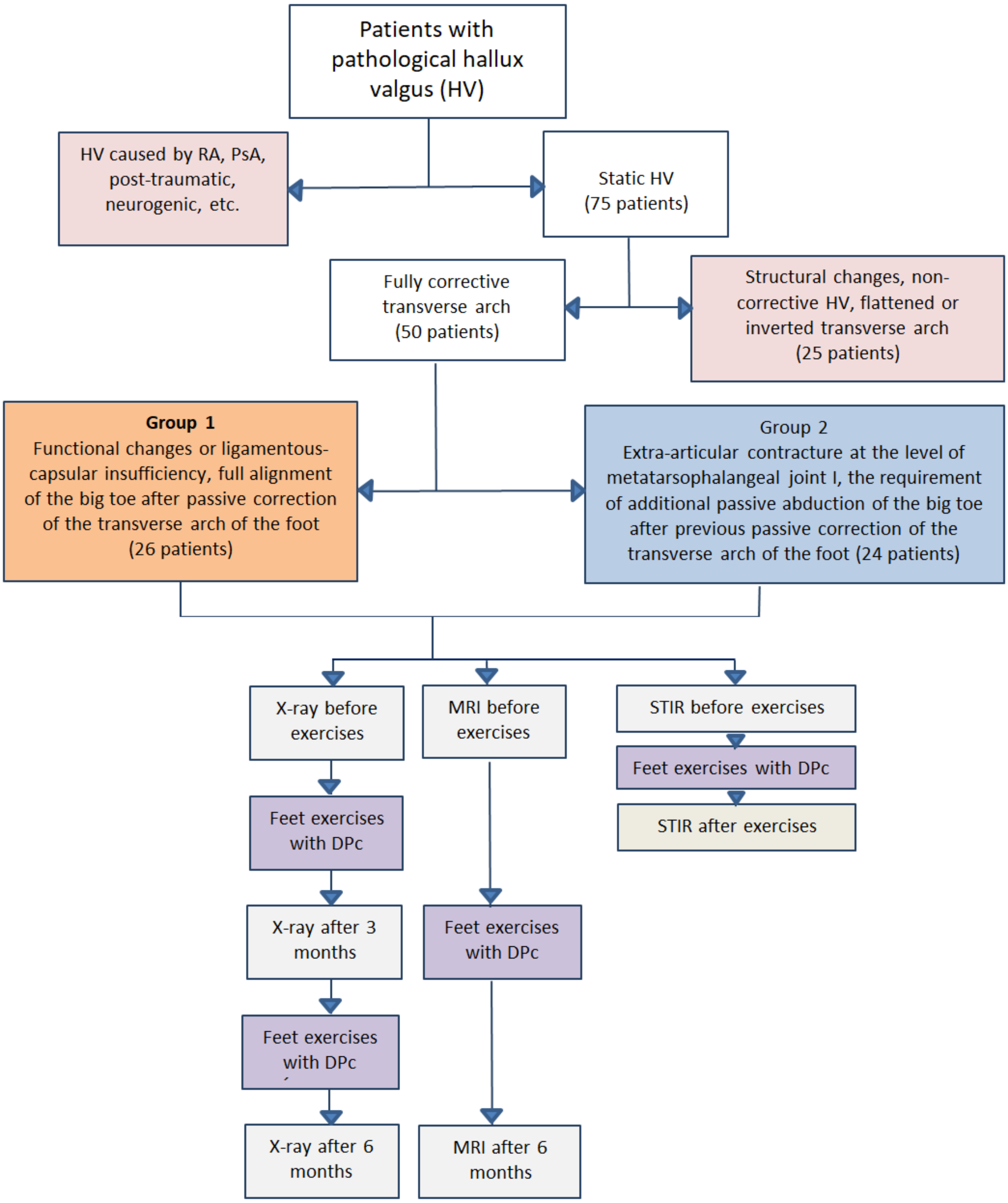

Figure 1. Diagram of the examination steps of the hallux valgus correction

The research was conducted with the consent of the bioethics committee no. 222/KBL/OIL/2016.

3.2 Participants

75 patients participated in the study. The diagnosis of hallux valgus was based on a physical examination. The cases of juvenile hallux valgus and other non-static etiology (e.g. traumatic, rheumatoid arthritis (RA), psoriatic arthritis (PsA), neurogenic) were rejected. Physical examination assessed the alignment of the toes as well as the transverse and longitudinal arches in the non-weight-bearing and equally weight-bearing foot. The passive correction grip [8] was used to assess the foot susceptibility to correction (the ability to self-align the big toe as a consequence of reconstructing the transverse arch of the foot was assessed) (Figure 2). A test was also performed to assess the dynamic correctness of the arches of the feet while standing on one lower limb. To avoid ambiguity in the assessment of patients, medical examinations were performed by one doctor. After a medical examination and preliminary selection of patients from a group of 75 patients, cases typical for the bilateral hallux valgus (>15° HV - equivalent to a pathological condition [6]) were selected, confirmed by the measurement of the HV angle in the radiological examination in the AP projection of the non-weight-bearing foot.

Figure 2. Passive correction grip. A - non-weight-bearing foot with visible pathological valgus of the big toe, B and C passive correction based on the principle of three parallel

forces (mobile bones I, IV, and V are pushed towards the plantar side with a contra applied under physiologically immobile bones II and III), B - lateral side projection, C - anterior-posterior projection.

From 75 patients, 50 cases were identified with the full passive ability of big toe correction by correction grip and dynamic susceptibility to correction of the longitudinal arch of the foot assessed by the test of standing on one leg. In 26 of 50 patients (aged 36-45 years), the spontaneous alignment of the big toe was achieved as a consequence of the correction of the transverse arch of the foot (cases of muscle failure and excessive ligamentous capsular laxity) (group I). In 24 of 50 patients (aged 38-64 years), beside the correction of the transverse arch of the foot an additional external abduction by corrective force was required by the examiner to fully align the big toe, which consisted of forcing the abduction to align the big toe (group II).

3.3 The device for dynamic-passive correction of the hallux valgus

The device for dynamic-passive-passive correction (DPc) is used for strengthening and stretching the muscles which are responsible for the proper shape and function of the foot (Figure 3). The DPc device is consisting of a rigid guide bar, inelastic finger straps located in the distal part of the guide element, and an elastic element in the proximal part being a ball or rotary ellipsoid with a through-hole located axially (Figure 4B). The distal part of the DPc device is responsible for passive correction and the proximal one for the dynamic correction of hallux valgus but they both work together and thus complement each other.

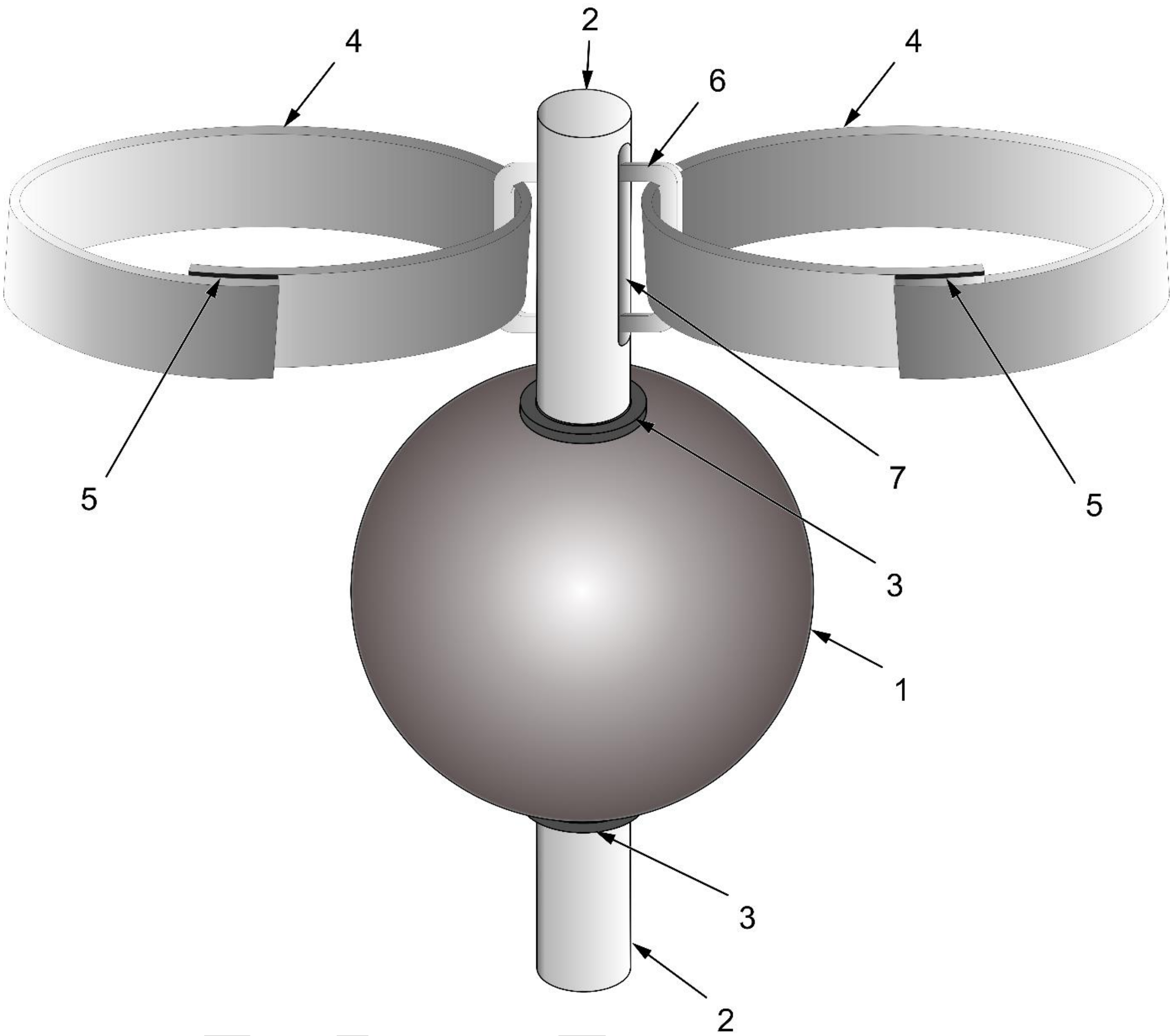

Figure 3. The individual elements visible in the drawings are marked as follows: 1- elastic element, 2 - rigid guide element, 3 - sliding block, 4 - inflexible straps forming loops, 5 - elements enabling the adjustment of the loop diameter, 6 - strap holder on the rod, 7 - passage channel on the guide.

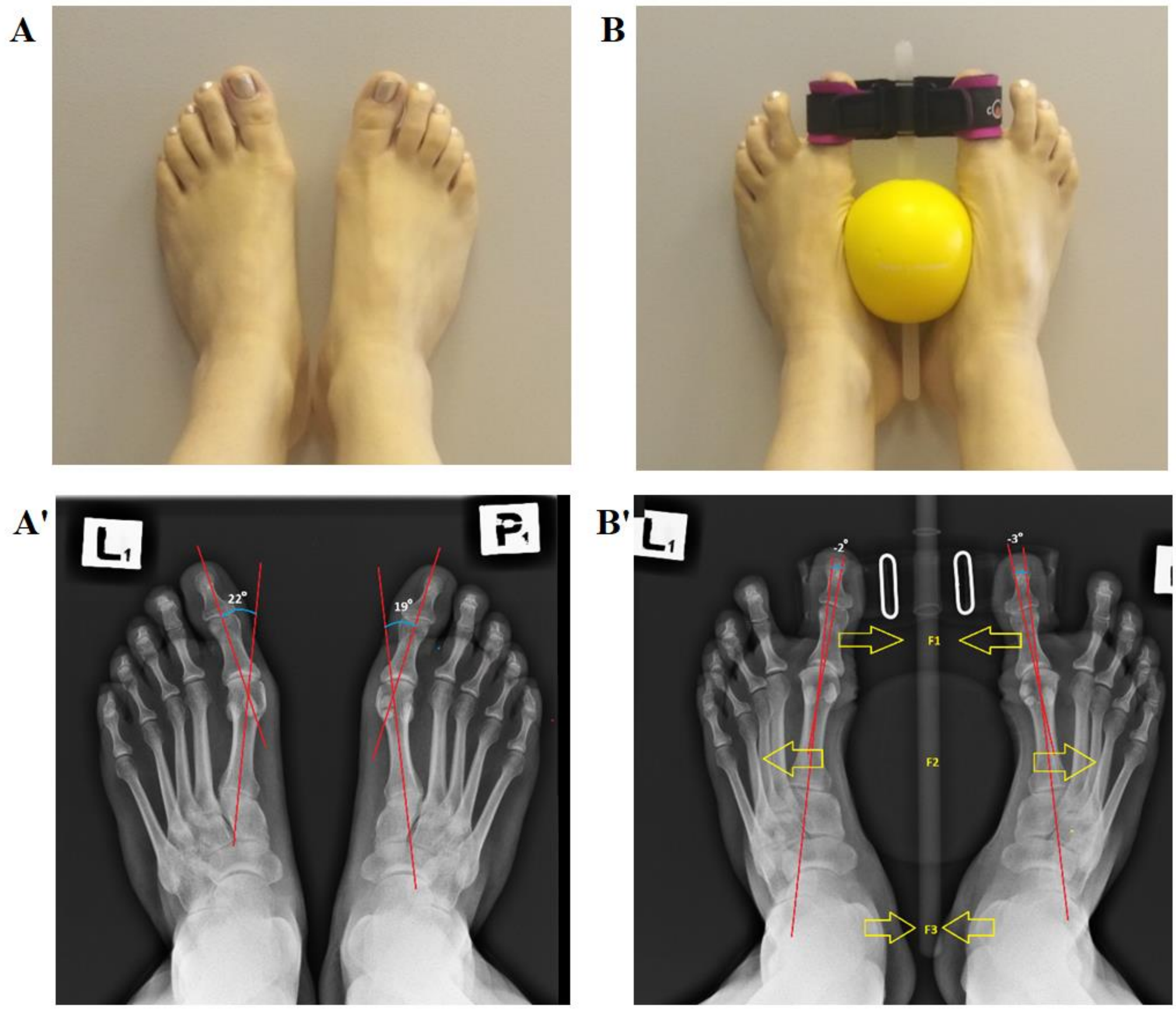

Figure 4: The design of the DPc device and the manner of its action. Feet without (A) and with (B) DPc device. Radiologic images in the AP projection of non-weight-bearing feet without (A') and with (B') DPc device. F1, F2, F3 - three corrective parallel forces.

The distal part of the device, i.e. the loop-shaped straps attached to the rigid guide bar, put onto the big toes, creates a passive stretching force on contracted extra-articular soft tissues (passive correction). It happens when slowly setting the hallux valgus in abduction concerning the second toe (II) with simultaneous "wrapping", and "surrounding" by the medial elevations of both feet on the elastic element until the inner surfaces of the heels come into contact.

As a result of the mutual proximity of both heels, with the simultaneous squeezing of the elastic element, a dynamic resistance force is generated resulting in the gradually strengthening abductor hallux muscles of both feet (dynamic correction).

Both passive and dynamic correction run simultaneously and the degree of their deepening depends on the severity of the defect and the individual predispositions of the exercising person (biofeedback based on own pain receptors and proprioception).
The size of the loop and the size of the elastic element are selected so that it is possible to change the exercise planes.
The correction using the DPc device is based on the common correction principle based on the action of three parallel forces (Figure 4 B and B'). Two parallel forces adduct to the medial plane of the big toes and heels. At the same time, a third parallel force is applied in the opposite direction, making a counterforce at the level of the I metatarsophalangeal joints.

3.4 Imaging tests

3.4.1 X-ray

To evaluate the correction progress, radiological examinations were performed in the Anterior-Posterior projection of non-weight-bearing feet at the following time points: before the beginning of corrective exercises, 3 months, and 6 months later. The X-ray image was taken in a sitting position with the central beam incident on the dorsal of the foot at an angle of 10-15 degrees.
The following angle measurements were carried out: hallux valgus (HV) angle; I intermetatarsal (I/II IM) angle. Hallux Valgus Differential Angle (HVDA) and InterMetatarsal Differential Angle (IMDA) were calculated by measuring the HV and I/II IM angle respectively in non-weight-bearing conditions, before and after the rehabilitation process.
The examination was performed with the apparatus General Medical Merate Opera 9LT X-ray scanner MTOES/TRN430.

3.4.2 MRI

The proper setting of anatomical structures with the alignment of the muscle tracts and the repositioning of the subluxation of the metatarsophalangeal joint I with the repositioning of the sesamoid bones were examed. A DPc apparatus stabilized on a specially designed splint was used for the test. The feet in the DPc device were positioned in the coronary plane. The correction was assessed with the heels together and the big toes maximally abducted.
To demonstrate the activity of individual muscles, short tau inversion recovery (STIR) was performed immediately before and after a series of exercises with the DPc apparatus in the plantar, sagittal, and intermediate planes. The use of the method was based on the knowledge

that intense muscle exercises are accompanied by the appearance of hyperemia and swelling. The high sensitivity of this method made it possible to detect edema foci in the area of the foot and shank. What was obtained was, in a way, "an image of glowing muscles".

To assess the strengthening of the abductor hallucis muscle in the correction process, an MRI was performed in the supine position of the patient before the beginning of corrective exercises, 3 months and 6 months later. A 16-channel coil dedicated to the foot and shin was used, which provides a homogeneous field, high resolution, and image quality. The cross-sectional area [cm2] of the abductor hallucis muscle was measured. The test was performed on a System MR Prodiva 1.5T Philips Healthcare apparatus.

3.5 Corrective exercises for hallux valgus

Patients performed the recommended corrective exercises according to the scheme (detailed description of exercises in supplement 1):

Exercise 1: Dynamic-passive correction, stretching big toes [an exercise in the plantar plane].

Exercise 2: Dynamic-passive correction with active alternating flexion and extension of the big toes [an exercise in the sagittal plane].

Exercise 3: Dynamic big toe correction [an exercise in the plantar plane]

Exercise 4: Dynamic correction of feet arches [an exercise in the sagittal plane]

Exercise 5: The feet arches and hallux valgus correction [an exercise in the intermediate plane]

Exercises were performed in series (Exercises 1-5) three times a day for six months (more details in supplementary material).

3.6 Statistical methods

Test results were compiled and analyzed using the R statistical package. To determine the scope of the pathological condition Correction Deficit Value (relation between the measured angle (in a pathological condition) and the corresponding normal range) was applied (according to the methodology presented in [8]). A comparison between the deficit correction measurements as well as the cross-sectional area of the abductor hallucis muscle at three points of time were carried out using a single-factor repeated-measures analysis of variance (the obtained value of $p <$ apha indicates statistical significance).

4. Results

75 patients participated in the study. 25 were rejected due to the failure of the conditions for inclusion in further stages of research. There were 26 in group I and 24 in group II, aged 35 and 43 years on average respectively (Table 1).

Table 1. Characteristics of patients

groups	Mean Age (SD)	Mean weight [kg]	Mean height [cm]	BMI	race
I	35 (2.8)	65 (3.1)	166 (6.2)	23.6	Caucasian
II	43 (3.2)	72 (4.2)	168 (4.9)	25.5	Caucasian

4.1 The assessment of the cross-sectional area of the abductor hallucis muscle

The progress of hallux valgus rehabilitation carried out with the use of the DPc apparatus was assessed, among others, based on magnetic resonance imaging, which confirmed a gradual increase in the thickness of the hallux abductor muscle (Table 2) (Figure 5).

Table 2. The average result of the cross-sectional area [cm2] of the abductor hallucis muscle in three-time points among I and II groups of patients with the Hallux Valgus. Measurement-based on MRI images

Bilateral HV groups	Before training [cm2] Mean (SD)	After 3 months of training [cm2] Mean (SD)	After 6 months of training [cm2] Mean (SD)	p-value
Group I n=52	2.13 ± 0.37	2.67 ± 0.49	2.85 ± 0.59	<0.017
Group II n=48	2.21 ± 0.45	2.47 ± 0.52	2.54 ± 0.65	<0.039

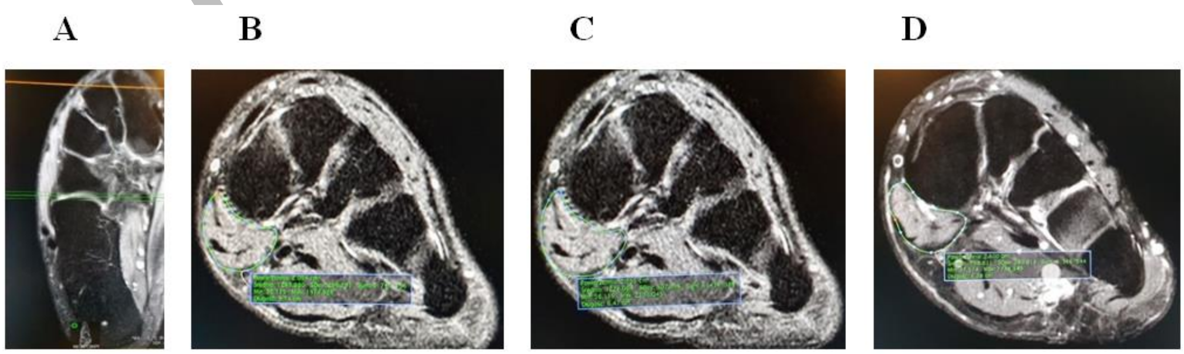

Figure 5. An exemplary result of the hallux abductor cross-sectional area in a patient from group 2. A - cross-section level at its widest point. Cross-section outline: B - before the exercises; C - after 3 months of exercise; D - after 6 months of exercise.

Fick's principle says that the increase in the cross-sectional area of a muscle is proportional to the increase in its strength [25]. On this basis, it can be concluded that as rehabilitation progresses, the strength of the hallux abductor muscle of both feet increases, and its advantage over the adductor hallucis muscle, which can explain a gradual devalgisation of the big toes observed in patients after rehabilitation.

4.2 The muscles activity detected by the STIR method.

Magnetic resonance imaging using the STIR method allowed visualizing the "tired", and "swollen" muscles that are active during exercise.

The correct shape of the foot arch is correlated with a correctly aligned toe, because the correct pulling forces of extrinsic muscles of the foot, including the m. flexor and m. extensor hallucis longus, do not produce pathological, valgus torques (position of the tendons of the above-mentioned muscles in the chord). The external muscles also create the conditions for the correct pulling forces of the intrinsic muscles of the foot [7]. In extreme conditions, with a collapsed transverse arch of the foot, the abductor hallucis muscle becomes start working as an adductor hallucis muscles thus deepens the deformity. By the STIR was confirmed the activity of muscles responsible for restoring the proper shape of the longitudinal and transverse arch of the foot, mainly extrinsic muscles of the foot (i.e. tibial anterior and fibularis longus, tibial posterior and fibularis brevis, medial head of the triceps muscle) and intinsic muscles (i.e. hallux abductor, flexor hallux brevis and extensor hallux brevis muscles) (Figure 6).

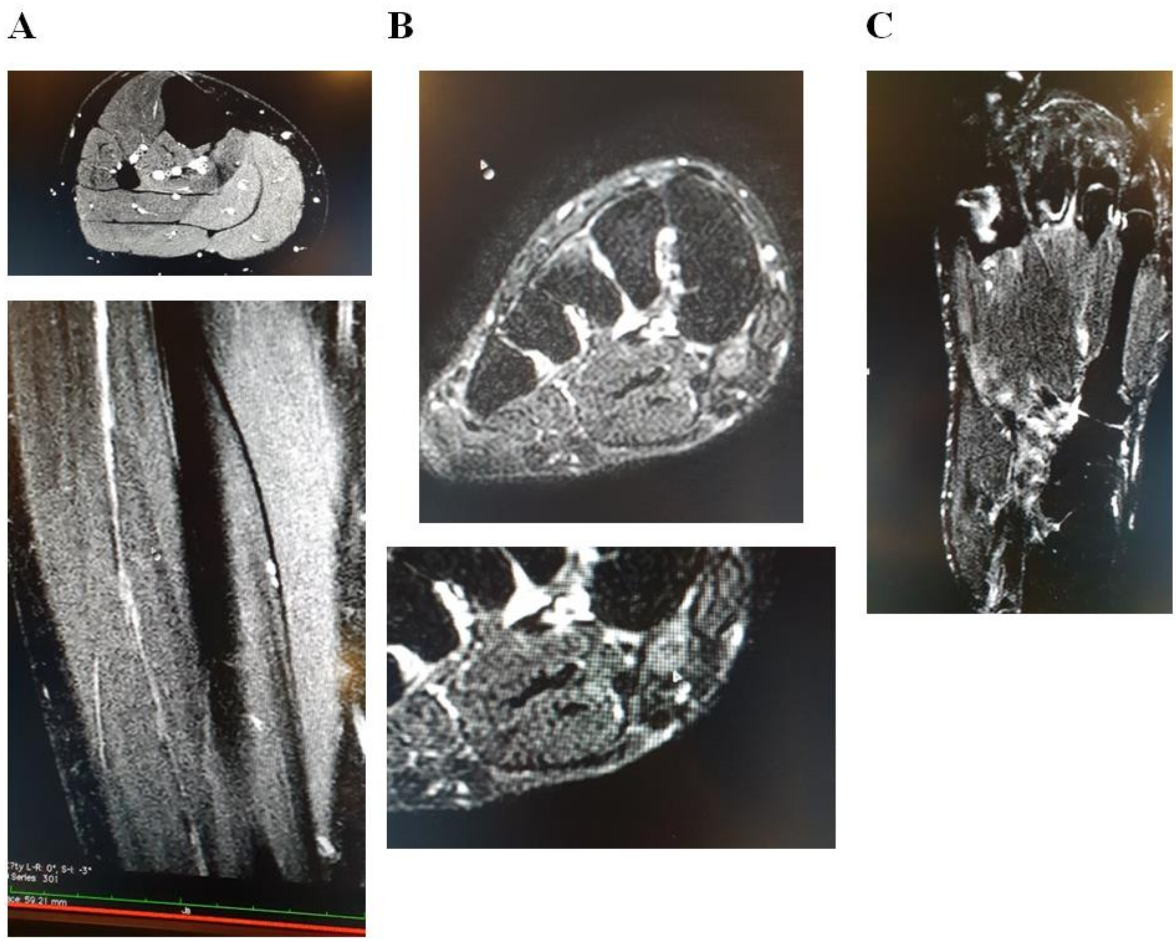

Figure 6. Sample scans from the STIR examination showing tissue edema after exercises with the DPc device. A - cross-sectional and longitudinal cross-section swelling of the soleus muscle, B - cross-section with a visible swollen and hyperemic flexor hallucis brevis, C - abductor hallucis muscle swelling.

4.3 Assessment of HV and I/II IM angles by X-ray examination.

Radiological examinations allowed the monitoring of the progress of the correction of hallux valgus in both feet. The values of Hallux Valgus (HV) and Intermetatarsal I (I/II IM) angles before rehabilitation after 3 and 6 months were compared (Figure 7).

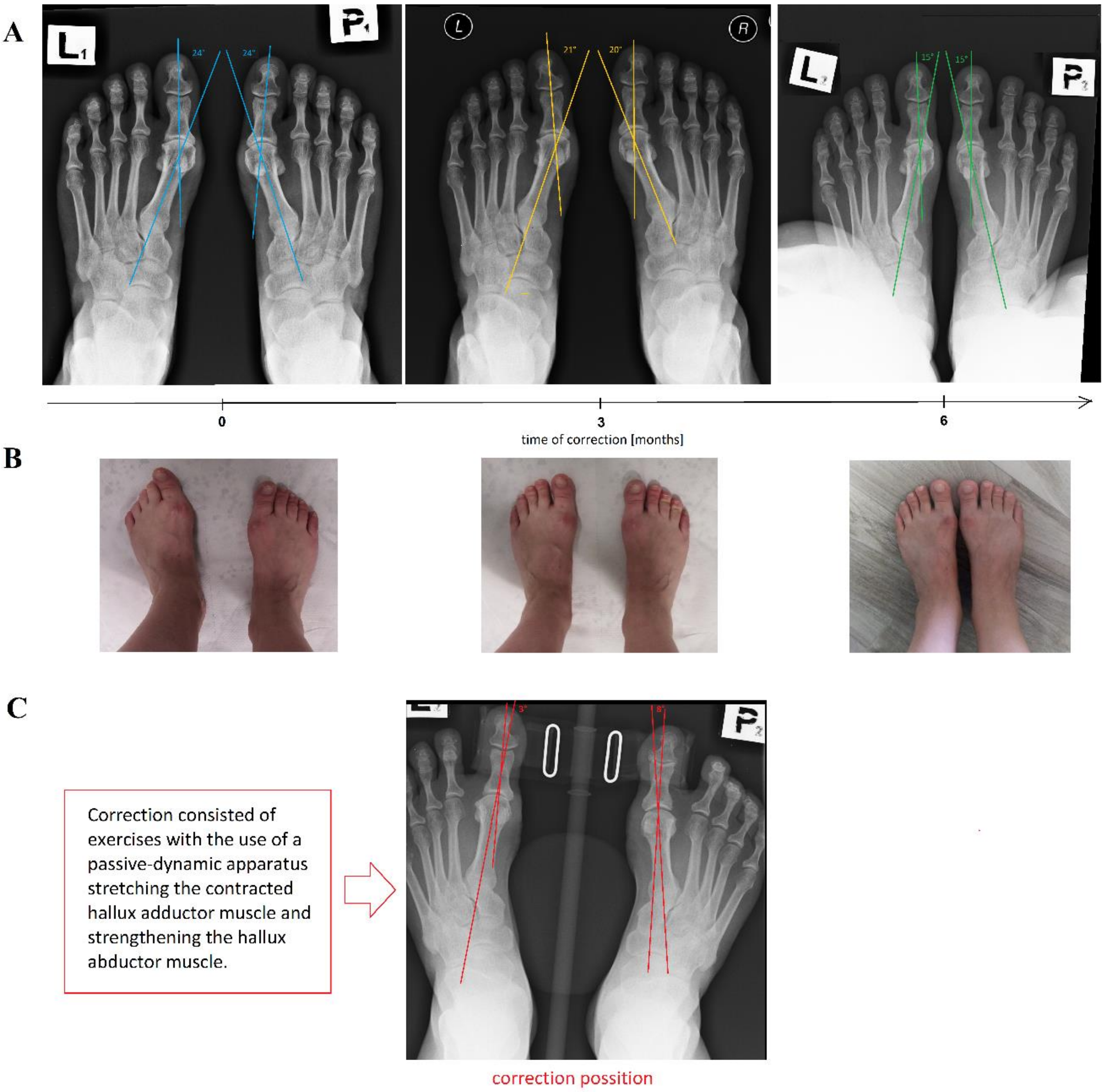

Figure 7. Example of DPc correction effects. A radiological image with designated HV and I/II IM angles in a patient from group II; B - photos of the feet from the dorsal side before and after rehabilitation; C- radiograph of the feet in the DPc device showing a reduction in valgus big toes (reduction of HV angles) and varus of the first rays (reduction of I/II IM).

There was a significant improvement ($p < 0.05$) in hallux valgus correction (reduction of varus I radii and HV angles of both feet) after 3 months. After six months, the effect of the correction deepened so that the patients from group I achieved a mean angular range within the normal range.

In the case of the HV angle, the correction deficit gradually decreased with the duration of rehabilitation from 30% to 0% in group I and from nearly 61% to 6% in the second group (Table 3). Similarly, the decrease in correction deficit was observed by measuring the I/II IM angle. From 52% it decreased to 0% after 6 months in group I, and in the second group from about 79% to nearly 29% (Table 3).

Table 3. Hallux valgus mean HV angles [degrees], correction deficits among patients in groups I and II before, after three and six months with the use DPc rehabilitation method

The differential angles for HV (HVDA) and I/II IM (I/II IMDA) and the correction progression in groups I and II were also calculated. Satisfactory results have been obtained. The correction progress visible in HVDA and I/II IMDA in group I was 100%, which means that after 6 months of rehabilitation, the correct angular ranges of HV and I/II IM were achieved. In group II, the correction progress was 90% concerning the HV angle and about 63% for I/II IM (Table 4). In this group, full correction progress within the normal ranges was not achieved, but the result was significant and promising for the next stages of rehabilitation.

Table 4. Hallux Valgus Differential Angle (HVDA) and InterMetatarsal I Differential Angle (I/II IMDA) [degrees] and Progress correction [%] after the rehabilitation process among patients in groups I and II.

The passive function of the DPc device results in the big toe abduction by the action of the F1 force (produced by the inelastic loops). Simultaneously take place the lateral pushing of the shaft of the first metatarsal bone with the force F2. The action of F1 and F2 forces causes the subluxation of the first metatarsophalangeal joint is set, obtaining the proper alignment (Figure 4 B and B’).

During the setting of the proximal phalanx the big toe moves medially away from the foot axis (passing through the 2nd toe), while the head of the first metatarsal bone is positioned laterally. This results in a reduction of varus of the first metatarsal bone and the value of the I/II IM angle, and a moving closer of the first to the fifth metatarsal bone, which is manifested in the deepening of the transverse arch of the foot in the anterior and posterior parts. Pushing the heads of the first metatarsal bones of both feet towards the plantar side results in a deepening of the longitudinal arch in the front part. At the same time, as a result of the force F3 (Figure 4B’), the Achilles tendon increases the shift to the medial side of Henke's axis deepening the supination of both heels.

5. Discussion

The most common static foot deformity in adults is the hallux valgus (HV) [9]. Passive correction of this deformity is not difficult [15]. Many orthoses on the market enable passive alignment of the big toe [17, 25]. However, these types of approaches are ineffective as they only work while orthosis is on the foot (when the abduction force is applied). After the device is removed, the hallux valgus returns. The problem of correction of hallux valgus arises from the inability to perform any abduction and adduction active movement of the big toe at the level of the metatarsophalangeal I joint. The consequence of this is the inability to implement resistance exercises, eg strengthening the muscles and devalgisationing the big toe. Devices available on the market, such as "*Toe Gizmo*" or "*Hallufit*", with a flexible connection of loops placed on the big toes, dynamize the hallux adductor muscles of both feet through resistance exercises. Gradual bilateral strengthening of the hallux adductor muscles has the opposite effect from the intended one and even deepens the deformity despite the visual abduction of the big toes during exercises.

DPc rehabilitation method is devoid of these disadvantages. During the exercises simultaneously, the contracted muscles (hallux adductor) are stretched and weakened muscles (hallux abductor) are strengthened, leading to the effective correction of the hallux valgus. Strengthening the hallux abductor muscles of both feet by the DPc method is performed by bringing the big toe inserts closer by resisting the deepening of the medial longitudinal arches of both feet (in the plantar plane). The method allows you to restore the correct foot architecture with the alignment of the big toes and other toes. Of key importance in the dynamic correction of HV (shaping the transverse arch of the foot) is a pair of muscles such as fibularis longus and anterior tibial forming a tendon stirrup (Testut 1904), the inserts of which lie next to each other on the plantar side of the first metatarsal bone. Simultaneous contraction of both muscles brings the base of the V metatarsal bone and the cuboid bone closer to the base of the I metatarsal bone, deepening the transverse arch of the foot in the posterior part [7].

A pair of these muscles, which are antagonists in movement context, and synergists in shaping the transverse arch, are the key to understanding the most common static deformity, which is the hallux valgus. Due to the proper function of these two muscles, the tendons of the muscles having distal attachments on the phalanges of the big toe regain their correct course, they descend from the chordal course, aligning the big toe.

The research discussed aboveshows that the causes of the hallux valgus deformity should be mainly found at the level of extrinsic muscles of the foot function localized at the lower leg and part of the thigh. The basis of the correction of static deformities e.g. hallux valgus, transverse flat foot, and plano-valgus foot, is to balance the action of the muscles that create the so-called tendon stirrup, mainly responsible for the correct shape of the transverse arches of the foot (measured by I/II IM angle). Proper foot architecture ensures optimal muscle tonus with the alignment of the big toe (measured by HV angle) and other toes. The proposed method of dynamic-passive correction of hallux valgus aims to achieve this goal.

6. Limitations

Exercises using the dynamic-passive method, although effective, are quite demanding in terms of the correct performance of exercises related to the correct positioning of the apparatus or the selection of the optimal size of the loops. Moving the elastic element higher or lower on the rod cause a slightly different effect on the dynamic work of the muscle on which it acts. This causes difficulties in objectively assessing the effects of rehabilitation in a group of patients. Similarly with the size of the loops. Too large loops result in a lower tensile force of m. adductor hallucis and poor stimulation of the m. abductor hallucis. On the other hand, if the loop is too small, it can lead to subluxation of the big toe. Therefore, it is important to perform the exercises, especially in the initial stage, under the supervision of an experienced physiotherapist, who will help to set the elastic element in the right position on the rod and determine the size of the loops.

7. Conclusions

The dynamic-passive correction strengthens the weak and stretches the contracted feet muscles. It has a dynamizing and relaxing function by balancing the tonus between muscles, synergists, and antagonists of the feet, restoring the physiological balance of the pulling force of muscles. Simultaneously, passively stretches extra-articular and articular contractures. This corrective approach makes it possible to:

• correction of the displaced I metatarsophalangeal joint with big toe alignment,

• balancing the muscles responsible for the correct shape of the transverse and longitudinal arches of the foot such as:

- extrinsic muscles of the foot (tendon stirrup and complementary muscles of the tendon stirrup)
- intrinsic muscles of the foot
- medial heads of the triceps muscle of the calf,

• pain reduction (painful calluses, bunion),

• preventing or reducing the rate of foot degenerative processes.The presented method of correction can be used in prevention (prevents the development of static feet deformities) and treatment (inhibits the deepening of the above-mentioned feet deformities and restores the physiological architecture of the feet conditioning).

The method can be effective in the phase of muscle-ligament insufficiency and the phase of contracture. In advanced conditions with the development of structural changes, surgical treatment is recommended.

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