VENOUS INSUFFICIENCY AND FOOT DYSMORPHISM: EFFECTIVENESS OF VISCO-ELASTIC REHABILITATION SYSTEMS ON VENO-MUSCLE SYSTEM OF THE FOOT AND OF THE CALF.

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Chronic venous disease is very common and widespread. Chronic Venous Insufficiency (CVI) is a condition characterized by hypertension of the venous system of the lower limbs which manifests itself through a large range of symptoms. The main cause of (CVI) is hypertension of the venous system of lower limbs, which in most cases is due to reflux for the incontinence of the valvar system of veins. Other causes are related to obstruction of the venous outflow, or at a reduced venous emptying due to inefficiency of the system of the veno-muscular pumps of the calf and of the foot. The purpose of this study was to evaluate if the use of a non-invasive rehabilitative model, which is characterized by two different visco-elastic insoles, is effective both to reduce postural imbalances and to improve the efficiency of the veno-muscular pumps of the foot and of the calf using photoplethysmography in reflected light.

Fifty (50) patients suffering from flatfoot and ped cavus, were studied doing a stabilometric and baropodometric test to evaluate the angle of the foot and the podalic angle. Patients were evaluated by examining vascular examination and venous reography in basal condition, using corrective visco-elastic insoles for the correction of dysmorphisms that we were studying.

An improvement of the angle of the Right and Left axis ($p<0.05$) and the podalic angle ($p<0.001$), using the right insole both in the flatfoot and cavus foot, was shown by the podobarographic examination. A not important tendency to improvement was also shown by the use of non-specific insole in both pathologies. The vascular examination showed an improvement of 38% in venous emptying capacity of the foot/calf veno-muscular pump in cavus foot with the specific "B" insole ($p<0.002$). An important improvement of 24%, using the specific "A" insole ($p<0.05$), was documented in flatfoot.

The photoplethysmography examination documented a significant improvement of the venous emptying capacity of foot-calf veno-muscular system due to the use of specific insoles for the studied dysmorphism, with an improving tendency even with the use of non-specific insoles. The hemodynamic improvement is correlated with the improvement of the analyzed biomechanical parameters: contact time, lenght of the halfstep, podalic angle and angle of the foot. The partial normalization of biomechanical parameters allows a reorganization of relationships of forces between ground and foot, as well as the improvement of the function of the subtalar joint, causing a partial recovery of the complex physiological mechanism of activation of the veno-muscular pumps of the foot and of the calf.

Chronic venous disease is very common and widespread. Chronic Venous Insufficiency Chronic Venous Disease is very common and widespread. Chronic Venous Insufficiency (CVI) is defined as a condition which is characterized by hypertension of the venous system of the lower limbs which manifests itself through a wide range of symptoms including: edema, pain, cramps at night, dyschromia, venous ectasia up to skin ulcer (1). A new and complete classification has been recently introduced: CEAP classification which includes a clinical, etiological, anatomical and pathophysiological evaluation (2 -3). "The Edinburgh Vein Study" showed a prevalence of CVI of 9.4% in men and 6.6% in women (4). In the "Framingham Study" the annual incidence of varicose veins was 2.6% in women and 1.9% in men (5). The venous ulcer is the most dreadful complication of CVI. Its prevalence is estimated to be about 0.3%, although active or healed ulcers are estimated to be about 1% of

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the population (6). The socio-economical cost of the CVI is enormous resulting from a reduced ability in social and employment relations, with a significant deterioration in the quality of life. The CVI is a huge economic burden for health care costs (7-8). Some risk factors for CVI are: heredity, age, sex, obesity, pregnancy, hormonal therapy, prolonged sitting or standing. (5-9-10). The main cause of CVI is the hypertension of the venous system of lower limbs, which, in most cases, is due to reflux because of the incontinence of the valvar system of veins. Other causes are related to the obstruction of the venous outflow due to thrombosis or to compression (11-12-13). The CVI may be determined by a reduced venous discharge due to inefficiency of the system of veno-muscular pumps of the foot and the calf (14-15-16). A lot of conditions can determine a modified mechanism of the system of veno-muscular pumps, including some dysmorphisms of the foot, immobility, postural and walking disorders, use of inappropriate footwear. The flatfoot and the cavus foot are the most common dysmorphisms of the foot. The essential function of the venous system of the lower limbs is to ensure the return of venous blood from the periphery to the heart. The venous system, to be effective, is based not only on the normal functioning of the veins and venous valves, but on a complex mechanism of impulse-aspirating pumps, so called veno-muscular.

These pumps are formed by the vein, its valves and the elements of the muscles, tendons and joints, differentiated into primary and secondary. The valves play a central role by enabling the venous return to the heart, during the muscular contraction, thanks to a complex system of opening and closing, and preventing the centrifugal flow at the same time.

While walking, the efficiency of muscular-venous system allows the progression of the column of blood contained in the veins of the lower limbs towards the heart, allowing a reduction of the venous pressure of the lower limbs of about 20-30mmhg, in physiological conditions.

The recovery time is over 20-25 seconds, always in physiological conditions. Pathological conditions will lead to a reduction of venous pressure in the lower extremity, much lower than in physiological conditions, as well as a reduction in the filling time (21-22-23-24). Several recent studies confirmed the central role of the plantar veins, of the muscular contraction of the calf and of the mobility of the subtalar joint in determining the mechanisms of venous emptying (25-26-27).

The most peripheral impulse-aspirating system is the foot which performs a considerable hemopropulsive effect. From a functional point of view, "the venous plantar sole" is a mixed pump, muscular local and remote, concerning phenomena both of compression type of the venous plantar sole, and of functional-articular type for the action of the different joints of the foot- ankle subsystem. There are areas in the foot sole in which the fibres are prevalent and others in which the vascular content prevails.

The fibrous components prevail in the areas of the greatest plantar weight-bearing, on the contrary the vascular components prevail in the areas of minor weight-bearing. Therefore, it should be considered as a real impulse-aspirating system, which represents the first push of the venous blood of the lower limbs during walking. The plantar pump distributes blood, in its push phase, both to the deep and the superficial venous system, in spite of what normally happens in other districts.

During walking, this system activates through the support of the external border on the external plantar vein and through the bending of the big toe (hallux) on the internal plantar vein. During walking, openings and contraction of the intermetatarsus spaces and of the plantar aponeurotic fissures adapt themselves to the compression applied to the venous "mattress", closed between the skin and the mobile osteo-articular arch of the foot (28-29-30-31-32). The flatfoot and the cavus foot are the possible causes of the bad functioning of this system. In the first case, it's a whole of anatomical changes, characterized by the deviation of the heel in valgism with pronation and sliding forward, down and medially of the astragalus which drags away the scaphoid. It leads to a flattening of the longitudinal medial arch with possible reduction or absence of the plantar longitudinal foot. In the case of cavus foot you have a series of anatomical changes, characterized by a difference of level between forefoot and hindfoot, associated with torsion of the medial column on the external column one. We can also notice an exaggerated concavity of the plantar arch and consequent abnormal supination of the mediotarsal (33-34-35-36-37). The changes which characterize these dysmorphisms determine changes in the reactions of foot-ground forces (38-39-40).

The aim of this study is to evaluate, using photoplethysmography in reflected light (PPG/RLR), if a non-invasive rehabilitation model, characterized by two different visco-elastic insoles, is effective, besides reducing the postural imbalance, to improve the efficiency of the veno-muscular pumps of the foot and the calf, determining a benefit for the venous emptying during walking in patients suffering both from dysmorphisms of the foot, such as cavus and flatfoot, and from symptoms compatible with CVI.

MATERIALS AND METHODS

The study was carried out on patients examined in the Physiatrics Laboratory of the Department of Physical Medicine and Rehabilitation at Chieti University. Informed consent was obtained by all patients involved. 50 patients with dysmorphic foot were enrolled: 25 patients with flatfoot of grade III, 25 patients with cavus foot of I and II grade. Participants were all evaluated through case-history (Tab I).

An instrumental examination as the Doppler Ultrasonography (Logic 7 General Electric Medical System Wisconsin USA) was made to exclude the presence of venous insufficiency due to venous reflux or obstruction, according to standardized procedures (17). Patients suffering from severe osteo-articular or neurological disease such as to compromise posture and walking, were not considered eligible for the study. Patients suffering from diabetes were excluded from the study, too.

The Physiatric examination included an evaluation of ROM of subtalar joint without charging it and a biomedical study for all patients with Milletrix system (Diagnostic Support Italia, srl, Rome, Italy). The acquisition using digital pedobarography was of 5 sec. for a picture of the points of pressure and the middle one was used to observe the distribution of pressure on the ground of each person. Pressure centres of the two limbs and the projection of the centre of gravity in the polygon of support were obtained. The examination was repeated with different visco-elastic insoles to assess the corrective intervention realized. Stabilometric examination was done in the same position. Subjects were asked to fix a point on the wall far 3m from them, then, after having controlled the lack of noise or annoyance, data were recorded for 52 sec. The assessment was repeated blindfold.

The sway area, the area of the ellipse and the Romberg index were analyzed to rule out diseases of balance and standing control. (Diagnostic Support, srl, Rome, Italy).

The examination of walking was made on a platform of acquisition of 4 m, the patient was asked to do a walk for 30 sec. The average values were taken into account. The test was performed barefoot and with some soft plastic specific cases used to support the plantar orthosis. The barefoot data were taken as a basal reference after having shown that no patients, using soft plastic cases, produced any significant modifications of data.

We took into consideration the following two barefoot values: the angle of the podalic axis (PA), the angle formed by the axis of each foot, considering the vertical, was considered as an indicator of joint stiffness oversegmentary. The angular dynamic variations (ADV) can quantify the angular deviations made by the pressure centre of each foot, in the concerned area, compared to the midline of the foot itself; it is an indicator which shows a possible waste of energy.

Two different plantars orthosis were used: one specific for flatfoot (plantar A), a visco-elastic insole which had three controls: for the angle of pronation, for the time of pronation and for the system of balance of the podalic propulsion, passing from the phase of medium support to the phase of push.

The second specific plantar orthosis for the cavus foot (plantar B), a viscoelastic insole with the control of the angle of supination, of the inversion time and of a system of balance of the podalic propeller, passing from the phase of medium support to the phase of push.

For the vascular evaluation patients were subjected to a clinical-vascular examination for the evaluation of clinical symptoms related to CVI. We used a prefixed scale with a score from 1 to 3 in which 0 represented the absence of symptoms before and 3 the maximum intensity (Table 2).

For the evaluation of the emptying of the venous foot-calf section, photoplethysmography in reflected light or reography was used (System II, MicroLab Padova Italy) (PPG / RLR). This method uses a photosensor, set on the skin, which measures the filling of the venous skin plexus. The intensity of the reflected light provides us with information about the volume of blood in the skin and thus, indirectly, about the one present in the veins of the legs.

This examination provides with data on total venous reflux (degree of valval incontinence) measured as time of filling (refilling Time), it can also provide with information about the venous emptying and the effectiveness of the muscle-venous calf pump (degree of venous emptying during the muscular exercise).

The test provides with information on the venous regional functionality, not on specific anatomical distributions (18-19-20). The hemodynamic assessment was made after appropriate training of patients to determine the adjustment to the platform and the PPG / RLR. Patients were trained to cover the board with the PPG / RLR in telemetry, first barefoot. This route was used as a basal reference of the capacity of venous emptying (referring to value 100%) (Fig 1). The examination was repeated twice, using both the insole A and the insole B in each patient and calculating the value of change in percentage, compared with basal reference (Fig. 2).

Before making the tests, we asked our patients to make an adaptation period with the insoles of about 10 minutes. The test with the insoles was made using a soft plastic case. Patients who had venous emptying changes, using plastic cases without insoles, compared with the barefoot evaluation, were excluded from this study.

Statistics

We used the "t" test of Student for small samples to determine correlations of the variables of the groups. A value of $p < 0.05$ was chosen as the cut-off for statistical significance.

Results

The clinical evaluation did not show any ROM increase of the ankle before and after the test. Concerning the data from the walking assessment analysis of biomechanical type, an improvement of the angle of the axis (right and left) with the use of the appropriate insole "A"($p<0.05$) was shown in patients with flatfoot of grade III. An improvement concerning the podalic angle was observed, always using the appropriate "A" ($p<0.001$) insole (Graph. 1).

Graph. 1 :An improvement of 24% was noticed in patients suffering from flatfoot, thanks to the use of A($p<0,05$) insole. No significant changes were observed in the reographic evaluation of the venous blood emptying using a non-specific plantar.

In patients suffering from cavus foot of I and II grade, significant results were observed from pedobarographic examination of walking, with an improvement on the angle of the axis (right and left) using the appropriate insole "B" ($p<0.05$). Even in the case of cavus foot, a more obvious improvement($p<0.01$) concerning the podalic angle was noticed, always with the use of appropriate insole (Graph 2).

Graph 2: In patients with cavus foot(38%),obtained using the B insole ($p<0,01$). We have a non-significant improvement (13%), using a non-specific A insole. The stabilometric examination clarified the total absence, in both groups, of standing and balance pathology.

Table I. *Characteristics of the population reported means ± standatd deviation.*

	Flatfoot (n=25)	Cavus Foot (n=25)	Overall	Total
Age (years)	24.0 ± 4.0	23.4 ± 2.8	23.5 ± 4.5	
Height (cm)	165.1 ± 10.8	162.5 ± 15.5	163.8 ± 14.2	
Weight (Kg)	71.1 ± 18.2	74.0 ± 14.7	72..5 ± 16.8	
BMI (Kg/m^2)	19.1 ± 1.9	18.2 ± 2.1	18.6 ± 2.4	
BMI percentiles	95th	94th		
Gender distribution:				
Males	14 [56%]	15 [60%]	→	29 [58%]
Females	11 [44%]	10 [40%]	→	21 [42%]

Table II.

Prefixed scale	Pain	Edema	Skin changes
3	***************	********************	********
2	********************	******************	**********
1	*********	***********	****************************
0			***

The length of the step shows a significant improvement only during the use of the insole, specific to the pathology ($p<0.05$).

Again, the length of the step shows a significant improvement only during the use of the insole, specific to the pathology ($p<0.05$). We find a major improvement with the second B plantar orthesis.

The contact time is reduced in both study groups during the use of plantar orthesis. The improvements are greater in patients with flatfoot where the improvement is significant.

The examination with PPG/RLR showed an improvement of efficiency of the foot/calf veno-muscular pump, determined by an increase of 24% of emptying of the venous system, obtained using the special □ ($p<0.05$) insole, in the hemodynamic assessment, in patients suffering from cavus foot..

Any significant change was noticed using a "B" insole applied to non specific group, but there was a tendency to a slight improvement, less than 13% recorded in the other group (Figure 2). Not significant changes were shown by the data of the pedobarographic examination.

DISCUSSION

The basic function of the venous system of lower limbs is to ensure the return of venous blood from the periphery to the heart. In order to be efficient, the venous system is based not only on the normal functioning of the veins and venous valves, but on a complex system of impulse-aspiration pumps, so-called "eno-muscle". These are formed by the vein, the valves that it owns and by muscular, tendinous and joint elements, classified as primary and secondary. The valves play a key role allowing, during muscle contraction, the venous return to the heart, through a complex system of opening and closing, preventing the flow centrifugal at the same time.

During walking, the efficiency of the muscular-venous system allows the progression of the column of blood, contained in the veins of the lower limbs, to the

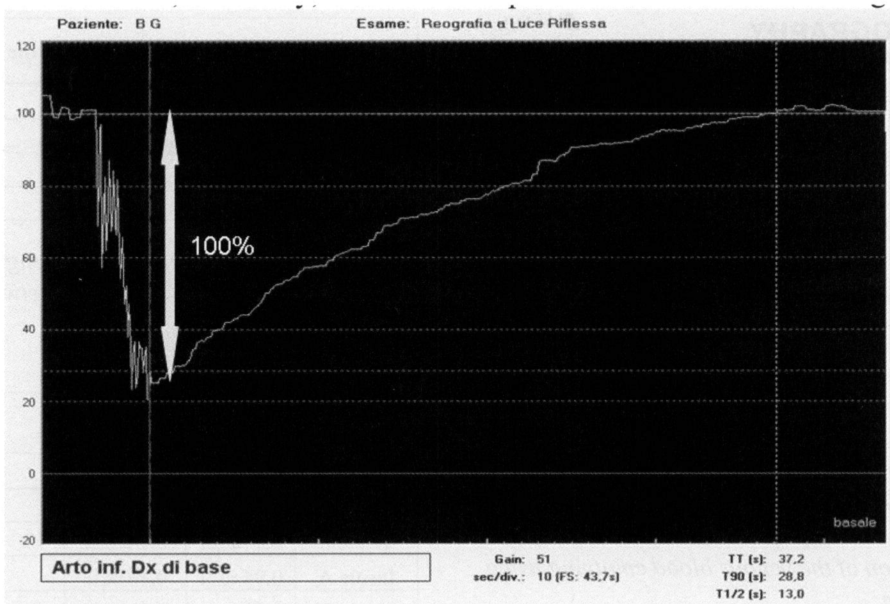


Fig 1. *Walking in basal conditions*

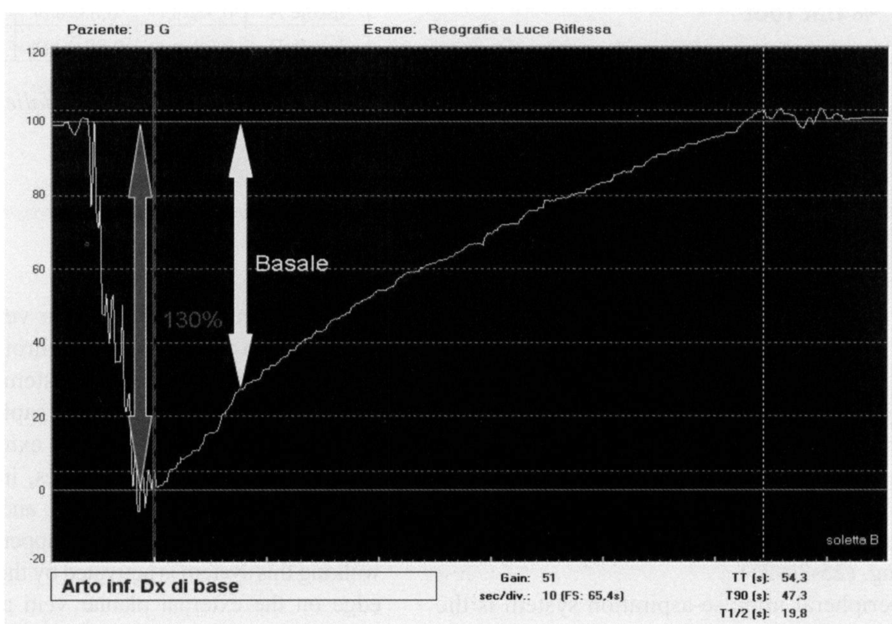
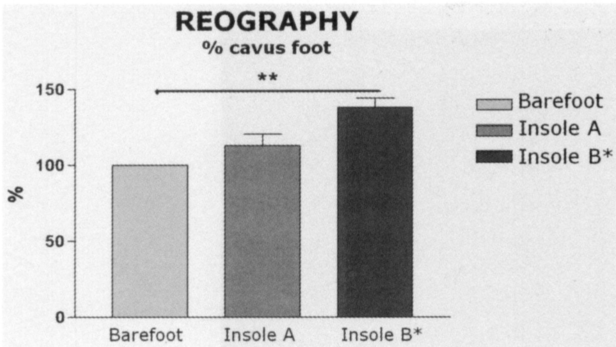
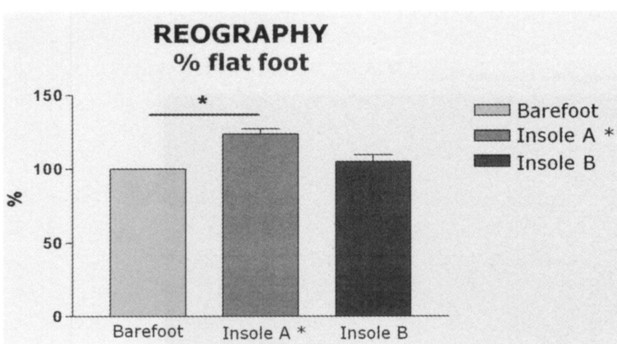


Fig 2. *Changing from basal with insole*

heart, and, in the physiological conditions, a reduction of venous pressure in the lower limbs to approximately 20-30mmhg.; however, more than 50% of the initial value. The recovery time is over 20-25 seconds, in physiological conditions. In pathological conditions, the fall of venous pressure in the legs is very small as the time of filling (21-22-23-24). Chronic venous insufficiency is determined, from a physiopathological point of view, by capillary and venous hypertension caused by a reduced venous return. This system results from the functional integrity, besides the morphologic one of a complex system that includes: veins, venous valves, muscles, joints. Several studies have recently confirmed the central role of the plantar veins of the calf muscle contraction and of the mobility



Graph. 1. *An improvement of 24% was noticed in patients suffering from flatfoot, thanks to the use of A(p<0,05) insole. No significant changes were observed in the reographic evaluation of the venous blood emptying using a non-specific insole.*



Graph 2: *In patients with cavus foot(38%),obtained using the B insole (p<0,01). We have a non-significant improvement (13%), using a non-specific A insole.*

Lenght of the halfstep (cm) in the cavus foot			
	T0	T1	%
Without	38,42±9,64	38,48±12,85	107,31
Insole A	38,42±9,64	42,62±14,24	65,36
Insole B	38,42±9,64	46,92±15,08	91,63

Table 5 *shows the values of the length of the halfstep during the analysis of walking between the different experimental situations.*

Contact Time (s)			
	T0	T1	%
Cavus foot			
Without	0,94±0,21	0,94±0,21	-8,51
Insole A	0,94±0,21	0,86±0,18	
Insole B	0,94±0,21	0,83±0,24	-6,74
Flatfoot			
Without	0,98±0,17	0,98±0,17	-15,31
Insole A	0,98±0,17	0,83±0,19	
Insole B	0,98±0,17	0,89±0,28±	

Table 6 *shows the monopodalic contact time during walking*

of the talocrural joint in determining the mechanisms of venous emptying. (25-26-27)

The most peripheral impulse-aspiration system is the foot that carries a considerable hemo propulsive effect. From a functional point of view "the plantar venous sole " is a combined pump: local, remote, muscular pump and compressive, joint pump. In the

foot sole, there are areas in which fibres prevail, and others in which the vascular content prevails. In the areas of greater plantar support, the fibrous part prevails, in contrast to those of lesser load where the vascular part predominates; therefore it must be considered a real impulse-aspiration system. It represents the first push of the venous blood of lower limbs in walking. It consists of a series of venous, muscular, tendinous, joint, aponeurotic and bone elements. The plantar veins push most of their contents into the deep system through the posterior tibial vein and into the superficial system, through the marginal internal vein and the internal saphena, and through the external, marginal vein and the external saphena.

The plantar pump distributes, in its push stage, blood both to the deep venous system, and to the superficial one, on contrary of what normally happens in other areas. While walking this system is activated by the support of the external edge on the external plantar vein and the bending of the hallux on the internal plantar vein. Openings and narrowing of the intermetatarsal spaces and of the aponeurotic plantar fissurae, adapt to the compression exerted on the venous "mattress", closed between the skin and the mobile osteo-articular foot arch (28-29-30-31-32). The flatfoot and the cavus foot are among the possible causes of the malfunction of this system. In the first case, a set of anatomical variation occurs; they are characterized by deviation of the heel in valgism with pronation and sliding forward, downwards and medially of the astralagus which drag along the scaphoid. A flattening of the medial longitudinal arch with possible reduction or absence of the longitudinal plantar arch. In the case of the cavus foot, on the contrary, you have a set of anatomical variations characterized by a difference of level between the forefoot and hindfoot, associated with the torsion of the astragalar foot on the calcanean one. An exaggerated concavity of the plantar arch can be noticed with consequent invertion and of the medium tarsal (33-34-35-36-37). Alterations that characterize these dysmorphic changes determine the reactions of ground-foot forces. (38-39-40).

CONCLUSION

Our data, based upon a a pedobarographic examination of walking, showed an improvement of the parameters taken into account by the study: the angle of the foot (right and left) and the podalic angle. A normalization of the considered parameters was highlighted both in patients with flatfeet and in patients with cavus foot. Greater benefit was documented when we used the "visco-elastic insole", specific for specific disease.

Thus, there were changes in terms of biomechanics of the foot-ground response, with a reorganization in the distribution of power loads: that allows you to restore the initial support on the external edge, allowing a better activation of the external plantar vein and, simultaneously, a more physiological flexion of the big toe (hallux) with activation of the internal plantar vein.

The increasing of the capacity of the venous emptying, documented with the PPG / RLR in patients with cavus foot ($p = 0,002$) and in those with flatfoot ($p<0.05$) is correlated to the correction of biomechanical parameters which produced an improvement of the joint motion and function in the two examined groups. That doesn't concern the capacity of the out of load ROM of the subtalar joint, which affects the veno-muscular systems of the foot and of the calf under an ameliorative point of view.

It is also correlated to redistribute the forces of the points of support which, in case of flatfoot, is able to avoid an overload on the medial edge of the foot, with a reduction of anomalous compression of the internal plantar vein, which can occur during the supporting phase for a long time.

A modest improvement was achieved with the use of a non-specific "viscoelastic insole" in patients with cavus foot. This improvement was more evident in patients with flatfoot. This phenomenon, in its wholeness, may be attributable, in both cases, to the increased proprioceptive information, which is known to be lower in the cavus foot and which characterizes in a similar manner the two "A" and "B" visco-elastic insoles.

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