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(54) **Dynamic device for the control of discharge to ground of the body weight**

(57) The invention consists in the positioning of springs or elastic return means with the aim of balancing the plantar support, under the foot sole in the following points: the heel, between the second and third metatarsus, the fifth metatarsus and the point that is specular to the latter on the opposite side. This disposition allows to carry the return force from the ground during the deambulation or walking through a trajectory of the discharge points having a helicoid form, through the center of the tibiotalar joint, i.e. the center of the ankle. Such a possibility is achieved because the position of the springs in the above points describes a figure of eight whose center coincides with the center of the plantar arch, i.e. the point wherefrom the ground reaction force propagates towards the ankle and therefore the rest of the system.

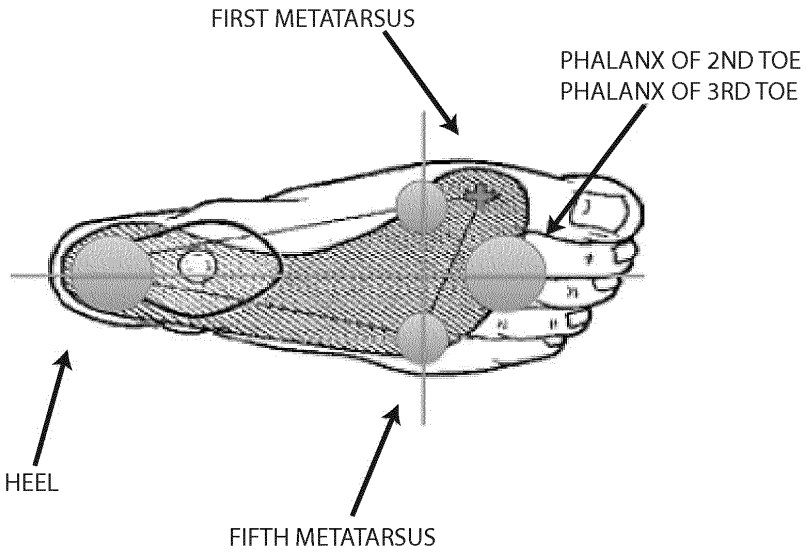

Fig.2

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Description

[0001] The present invention concerns a new typology of shoe sole including an innovative geometry of the structures of loading and discharge to ground.

[0002] More in detail, the present invention concerns a device that is to be used as support of the foot in such a way to discharge the loads onto precise points of the same foot and allows to centre physiologically the wave returning from the ground in such a way to enable a correct functioning of the foot and a physiologically correct walking.

State of the art

[0003] Great many typologies of shoes try to solve the problem of absorbing the effect of the impact of the foot to ground. For this purpose, rubber soles have been realised and patented, which have a cushion effect, as well as insoles with air chambers having fixed or variable pressure.

[0004] Other typologies of shoes try to solve the problem of restoring in a correct way the potential elastic energy accumulated in the shoe, mostly in the sport field, to favor the athletic action. This type of shoes generally includes a spring or a series of springs in fixed positions and with fixed elastic constants.

[0005] A third type of problem, which some typologies of shoes or plantar try to solve, is that of the correct postural adaptation and the best dynamics of the walking or running.

[0006] Almost all the patents concerning this matter face the highlighted problems individually.

[0007] The patents US 2002/0088142, US 2003/033731, US 2011/0107618 are here cited as an example.

[0008] Moreover, almost all the patented devices share the same type of limits and problems:

- limiting the weight and volume of the device utilised for the installation of the shoe sole;
- suitable intensity of the reaction/return force of the elastic potential energy accumulated by the spring or the shoe in general;
- limited available geometry for the travel of the spring or bearings, with ensuing significant limitation of the control on the device;
- necessity to guarantee continuity in the response of the sole or the shoe to received stresses and to the forces provided during the step;
- necessity to guarantee the maximum comfort and the maximum wearability of the shoe;
- necessity to guarantee the functioning of the device along time and limit its structural and functional deterioration;
- utilisation flexibility in relation to the different activity typologies for which the same shoe can be utilised;
- complex anatomy and physiology of the foot and its role on the posture of the individual.

[0009] More limited is the number of patents and inventions seeking to intervene on and simultaneously control the three process above highlighted:

- absorption of the shock;
- return of the accumulated energy;
- postural and plantar support control;

[0010] With reference to the last point, it is appropriate to stress that the foot is fundamental for the dynamic and postural functions. The plant arch is remarkably relevant and has an indispensable damping role in order to enable the walk in a physiological way. The alteration of the plantar arch from the biomechanical and sensorial point of view modifies the foot hold to ground, modifying the static and dynamic trim.

[0011] The plantar arch is a complex architecture associating osteoarticular, ligamental and muscular elements of the foot. With reference to figure 1 (a), it can be defined as an arches system, held on the ground on three points that are disposed at the vertices of a ABC triangle. A corresponds to the head of the 1st metatarsus, B to the head of the 5th metatarsus, and C to the back tuberosity of the heel. Each support point is common to two contiguous arches. Between A and B the front arch is drawn, between B and C the external arch and between A and C the internal arch. The latter is the longest and highest and is the most important for the maintaining of the static and dynamic posture.

[0012] With reference to fig 1 (b), the weight of the body transmitted to the lower limb applies on the back tarsus at the level of the astragalic pulley, from here the forces distribute in three directions, towards the support points of the arch. In the standing position, the heels support the main stress because the half of the body weight is transferred to them.

[0013] The loads on the three points ABC are subdivided in the measure of 2/6 on A, 1/6 on B and 3/6 on C.

[0014] The present remark is of particular importance to the end of the disposition, under the plantar arch, of the stability control devices, the constraining reaction and the absorption of the shock to ground.

[0015] The walk is characterised by a continuous adaptation of width and speed of the body segments, which adapt to the surroundings. The walk can be seen as the continuous search for equilibrium in order to maintain the gravity centre within the ground support polygon formed by feet. The deambulation of man is a movement comprised between the two calcaneal holds of the same foot and is constituted by a stance phase and a swing phase.

[0016] At the functional level therefore the step is subdivided in two phases and the stance and swing phases play a very specific role.

[0017] By analysing the deambulation cycle, one will well understand how this produces a resulting movement which translates under the form of a helix which, starting

from the foot constraining reaction to ground, favours and produces the advance of the subject ahead (horizontal plane).

[0018] In a correct physiology situation, the foot behaves as a helix in such a way that the projection to ground of the body mass centre remains mainly centred, i.e. it passes along its own axis, which corresponds roughly to the podalic axis, i.e. the one passing centrally to the backfoot and at the centre between second and third toe.

[0019] Backfoot and forefoot dispose on planes that intersect in a variable way. In the ideal condition, the backfoot is disposed vertically and the forefoot horizontally (on a surface of horizontal hold). With the foot under load, distortion between backfoot and forefoot mitigates in the relaxing (the foot becomes a platform that can be modeled) and intensifies in the stiffening (the foot becomes a lever).

[0020] Hence, the winding of the helix with the ensuing intensification of the apparent arch-like disposition corresponds to its stiffening. The unfolding of the helix, with ensuing attenuation of the apparent arch, is the loosening.

[0021] The importance of the concept of a good podalic hold, and therefore the trend of the podalic helix, above described, is not an end in itself; indeed, the torsion of the above-mentioned helix is connected to the external rotation of the above-breach segments (leg and thighbone).

[0022] Another important element to be considered to the end of the realisation of an insole supporting the physiology and biomechanics, contributing to a correct deambulation, is the fact that the modern biomechanics has individuated the transverse plane as a priority spatial element in the statics and dynamics of the man.

[0023] Indeed, the antigravity mechanism starts by the rotation on the transverse plane, the antigravity mechanism allowing migration of the mass centre upwards.

[0024] The articulations wherein the movement is done on the transverse plane are, with closed kinetic chain, the coxofemoral and the sub-talar ones.

[0025] In particular, the coxofemoral articulation and the talus-navicular articulations are structured analogically and are disposed in a corresponding way.

[0026] The essential movements in the antigravity mechanics of the hip are the extension and the concurrent external rotation. In the transfer from bending to extension, therefore, the thighbone rotates towards outside reflecting in the mechanism of podalic loosening-stiffening.

[0027] This is an anatomo-functional condition that favours our anti-gravity property.

[0028] The loading/discharging spiral transfers from the transverse plane to the front plane, thanks to the talocalcaneal thurst, at the podalic level, in presence of a congruous friction coefficient (without the latter indeed the podalic winding comes out to be difficult). Based on the latter sentence, it is intuitive that an excessively soft ground or soles come out to be unsuitable, because they disperse excessively the compression impulse deriving from the calcaneal shock during the step, indispensable for the execution and the transmission of the torsional forces at the rachidian level and therefore at the pelvis level.

[0029] The synthesis of the foregoing leads to synthesise the following concept, i.e. the foot is not simply an arches system, rather it is a very complex sensory-motor helicoid system (Paparella Treccia, 1978). Therefore, it is possible to suppose that the muscle-articular health of the human body is conditioned, in an important way, by a correct plantar hold and a suitable redistribution of the constraining reaction forces between the foot and the ground.

[0030] The prior art documents US 2005/022424, US 2863231, US2013/031804 and US5438768 do not individuate which are the best foot areas wherein a dynamic control of the discharge to ground is to be placed, the described areas being very broad and often connected with each other seamlessly. In particular, the position of the elastic means in the described areas is made as a function of the elasticity or damping effects by the sole to which the elastic means are applied, and not as a function of the possibility to balance a plantar hold orienting the force returning from the ground towards the tibial-talar articulation (centre of the ankle). A detailed comparison of the invention with these documents is provided in the following.

[0031] It is object of the present invention to provide a dynamic device for the control of the discharge to ground of the body weight, which overcomes the drawbacks and solves the problems of the prior art.

[0032] It is subject matter of the present invention a dynamic device for the support of the foot, the foot presenting a heel, a phalanx of the second toe and a phalanx of the third toe, and a fifth metatarsus as well as a longitudinal axis passing through the heel and between the phalanxes of the second and third toe, the device comprising a plurality of discharge elastic means for the discharge of the weight that are fixed in such a way to correspond to zones falling within a plurality of foot areas, the device being characterised by the fact that said foot areas are solely:

- the area of the heel;
- the area between the phalanxes of the second and third toe;
- the area of the fifth metatarsus;
- the area specular the fifth metatarsus with respect to said longitudinal axis.

[0033] Preferably according to the invention, said discharge elastic means comprise one or more springs.

[0034] Preferably according to the invention, the elastic means in correspondence of the heel comprise two springs, whilst the elastic means in correspondence of the other three foot areas comprise each an only one

spring.

[0035] Preferably according to the invention, the elastic means in correspondence of the heel and the area between the phalanxes of the second and third toe comprise each one or two springs, whilst the elastic means in correspondence of the two other areas of the foot comprise each and only one spring.

[0036] Preferably according to the invention, said elastic means are made by memory-foam material.

[0037] The invention will be now described by way of illustration must not by way of limitation, with particular reference the drawings of the enclosed figures, wherein:

- figure 1 shows in (a) the three hold points defining the arches system of the foot, and in (b) the distribution of the loads on the foot;
- figure 2 shows the dynamic points of control of the discharge to ground, according to the invention;
- figure 3 shows the geometrical figures formed by the points of figure 2;
- figure 4 shows the geometrical figures of figure 3 applied to the representation of the foot in figure 2;
- figure 5 shows a representation of a curve individuating the application points of the force resulting on the sole;
- figure 6 shows a simulation with the resulting force applied on the point of figure 5.

Detail description of the invention embodiments

[0038] The above presented physiologic analysis clarifies some known physiological concepts, but does not lead per se to individuating which are the best areas of the foot wherein a dynamic control of discharge to ground is to be put.

[0039] The inventors have therefore exploited the physiologic knowledge and effected simulations and laboratory tests in order to reach a determination of these areas.

[0040] The result is a sole with at least four springs inserted in its anatomy, preferably five or six springs, for example realised with memory-foam material, with calibrated force and with spring function realised in such a way to control the distribution of the weight in the three-dimensions of the space (including the transversal one).

[0041] These springs are to be applied in correspondence of four points, which differ from the above-mentioned ABC points, which are derived from physiology papers.

[0042] Indeed, the inventors have found that more importance is to be given to the phalanxes of the second and third toe as front hold, transferring to the fifth metatarsus the stabiliser function in the static hold.

[0043] In addition, it has been necessary to consider also a point specular to the fifth metatarsus, in order to be able to utilise the abstract concept of helix by which the ground returns the force on the foot. This helix concerns mainly the plantar arch, the tibial-talar articulation and the coxo-femoral articulation, in the correct deambulation and therefore it must be respected in a deambulation with a sole.

[0044] More in detail, making reference to figure 2, such springs shall be placed in correspondence of:

1- centre of the heel;
2- the area between the phalanxes of the second and third toe;
3- 5th metatarsus;
4- on the side of the first metatarsus but in the specular position with respect to the 5th metatarsus.

[0045] When one speaks of positioning of the springs (or, more in general, of elastic means), it is to be understood that such elastic means receive the load from a zone of the foot comprised in the four areas above listed. It is not necessary that the elastic means occupy these areas wholly.

[0046] The springs to be put in correspondence of the points of areas 1, 2 shall have a dimension which is larger with respect of that of the other two, because the maximum load rests on the heel; this spring in the zone between the phalanxes of the second and third toe will have to be therefore able to balance the reaction force of the spring placed under the heel. The lateral springs will have the function of stabilising the position of the foot and contributing to the control of the action and the reaction forces on the transversal plane.

[0047] The fact that point 4 is specular to the fifth metatarsus, serves to create three geometrical figures allowing to respect the dynamics of the above-mentioned helix.

[0048] The springs in the present invention do not have the object to improve the response of the soles for athletic aims, but to re-orient the sole underside the foot in relation to the ground. To this end, the above-mentioned areas are the only possible areas, and further springs, placed for example in the central part of the foot sole, would nullify wholly or partly the technical effect achieved by the present invention.

[0049] With reference to figures 3 and 4, first two isosceles triangles are individuated, a front one and a back one.

[0050] In the back triangle, which is larger, it is possible to intercept:

- a sagittal (front-back) plane, indicated with the yellow colour, which prosecutes in the front triangle. Such plane is dedicated to the control of the movements of vertical and transversal tilting on the sagittal plane;
- two oblique planes, indicated by the red colour, which have the function of controlling also the vertical tiltings of the foot on the sagittal plane, but since they are placed more laterally they have the main object of controlling the movements of the foot on the torsional plane, i.e. on the transverse plane. The presence of these axes, moreover, together with the sag-

ittal axis, allows to improve the stability of the plantar hold and the subdivision of the loads. Moreover, the synergy between these three axes increases the performance of the thrust starting from the foot sole during the deambulation.

[0051] The front triangle, in blue colour, is characterised by a base in common with the larger triangle, being a continuation of the latter, and has two oblique planes, smaller than those of the back triangle but having a similar function. Indeed, they provide for the control of the loads on the transversal plane in the zone of the forefoot were they are placed.

[0052] With reference to fig 5, the second geometrical figure is intercepted by connecting the four points by a continuous curved line, defining an "8" whose centre coincides with the centre of the foot (plantar arch) i.e. with the tibio-talar articulation (centre of the ankle).

[0053] The object of the positioning of the springs according to the invention is that of re-directing the return wave from the ground to the centre of the ankle. Each spring will have a different elastic force. The intensity of the force and the proportions between the springs vary depending on the subject to be treated.

[0054] In a first embodiment, a spring is placed in each of the four points above individuated.

[0055] In a further embodiment, at the level of the heel two springs instead of one are applied, because in such a way one controls better the force on the torsional axis. The same thing is made for the spring at the level of the second and third metatarsus, which can even be double.

[0056] A structuring of the sole in such a way, i.e. with springs suitable to direct the reaction force from the ground to the shoe and to redistribute it in the hold points of the plantar arch that the literature identifies as such, executes the function of being able to balance as much as possible situation wherein, for different reasons, the plantar holds changed, creating situations for which the muscles and articulations (both of the foot and the remaining soma, see above) work incorrectly and/or with excessive working loads.

[0057] Finally, making reference again to the helicoid form of the action and reaction force which generates when the forces are discharged to ground, the position of the springs as above illustrated describes a 8 whose cross point corresponds to the centre of the plantar arch, i.e., to the tibial-talar articulation, as shown in figure 5.

[0058] It is here recalled that the helix-shaped wave of the constraint force foot sole - ground passes through the tibial-talar articulation. This means that, therefore, the final resultant of the force absorbed by the springs that are present on the sole is such to generate a return wave through the centre of the foot and from there through the other articulations, as described previously by means of the physiology and biomechanics concepts.

[0059] Figure 6 shows the result of a simulation wherein at the centre of the plantar arch a resulting force is produced thanks to the action of the springs. If one shifts the application points of the above springs, the resultant varies a lot and it is no more applied at the centre of the plantar arch.

[0060] With the term "spring" it is here to be understood and the elastic means for the discharge of weight.

[0061] The position of the springs in the described points does not serve to claim elasticity or dumping effects by the sole to which they are applied (as in the case of the above mentioned documents of prior art), but the possibility of balancing a plantar hold orienting the return force from the ground towards the tibial-talar articulation (centre of the ankle).

[0062] The position here suggested, indeed, allows to optimise the distribution of the reaction forces (cf. Figure 5) coming from the elements that are present in the points: heel area, head of the fifth metatarsus, area specular to the fifth metatarsus with respect to the longitudinal axis and between the phalanxes of the second and third toe. In such a way, indeed, the sole is suspended on a quadrangular polygon which, generating a resulting force at the centre of the sole, determines its arching and ensures that the orienting of the resulting forces vector be upwards and pass close to the centre of the tibial-talar articulation (ankle) (cf. Figures 5 and 6).

[0063] Moreover, the presence of an elastic element between the phalanxes of the second and third toe favour the extension of the plantar arch through the proprioceptive and exteroceptive property of the foot sole. The latter, moreover, are stimulated continuously depending on the creation of the above described suspended system and the continuous stimulation under the foot sole, amongst other things, may allow the releasing of endogenous substances that are useful to the bony metabolism.

[0064] The totality of the effects tied to the proprioception and the possibility to orient the force towards the sole centre (and therefore near the centre of the ankle) allows to reach the goal of obtaining a tool useful to balance the plantar hold, i.e. the object of the invention.

[0065] The position of the elastic elements is similar but not equal to the other patent documents and in particular to the above-mentioned US2005/022424, US2863231, US2013/031804 and US5438768. Indeed, the elastic element positioned between the phalanxes of the second and third toe and not at the level of the metatarsuses (cf. Figures 2 and 4) is decisive to reach the three above-mentioned goals:

1. Foot positioned on a suspended system which as such is able to provide the continuous stresses to the foot sole;
2. Facilitation of the exteroceptive and proprioceptive system thanks to the possibility of favouring the extension of the plantar arch;
3. Favouring of a geometrical resultant of the solicitations received by all the springs, the resultant passing near the centre of the ankle.

[0066] The position of the front point, as already stated,

is different from that claimed by the mentioned patents.

[0067] Indeed, in the patent document US2005/022424, the rubber systems relevant to the heel zone and the metatarsal heads are placed externally to the shoe, i.e. not under the foot sole, so that the concept underlying such a patents is only connected to obtaining elasticity and dumping. Therefore, a concept absolutely different to that of the present invention which provides for the use of the plantar proprioception and orienting of the ground return force, which contribute to a balancing of the plantar hold.

[0068] In the patent document US2863231, the position of the element between the second and third metatarsus is at the level of the bodies of the metatarsal bones (therefore much more back of both the metatarsal heads and the zone wherein the present invention places the reference point, i.e. between the phalanxes of the second and third toe).

[0069] The patent document US2013/031804 has the sole structure that is completely different from that according to the invention. Indeed its bearing structure is an image of the anatomy of the plantar apo-neurosis fascia starting from the heel and arriving at the digital pulp of each toe.

[0070] Finally, the patent document US5438768 is of absolutely different conception with respect to what is proposed by the present invention, indeed the positioning points of the elastic elements are at the level of all the metatarsal heads of the five toes. This does not allow to create a suspended system like the one realised by the invention, and thwarts the position of the front reference point which by the way is solely at the level of the phalanx of the second toe. In this regard, one recalls that the podalic axis passes centrally to the backfoot and at the centre between the second and third toe.

[0071] Finally, in order to achieve the goals of realising a suspended system utilising the plantar proprioception to stimulate continuously the foot sole, a geometrical figure that provides as a final resultant a force passing near the centre of the ankle and therefore allows, at the end, to balance the plantar hold, the elastic elements shall be placed solely in correspondence of the areas:

- heel;
- fifth metatarsus;
- point specular to the fifth metatarsus, i.e. in the zone back to the head of the first metatarsus, i.e. in the end zone of the body the first metatarsus;
- in the zone between the phalanxes of the second and third toe.

[0072] Indeed, in such a way one realises the geometrical distances between the various points which allows what has been illustrated above, and most of all these positions are not to be seen as points wherein the elastic means are to be placed for the discharging or damping of the loads, but as points wherein the elastic elements, by exploiting together the exteroception and proprioception system of the foot and the ensuing positioning geometry, are able to re-orient the foot sole towards a more physiological position.

[0073] In the foregoing, preferred embodiment and variations of the present invention have been described, but it is to be understood that those skilled in the art will make modifications and changes without falling outside the relevant scope of protection, as defined by the enclosed claims.

Claims

1. Dynamic device for the support of the foot, the foot presenting a heel, a phalanx of the second toe and a phalanx of the third toe, and a fifth metatarsus as well as a longitudinal axis passing through the heel and between the phalanxes of the second and third toe, the device comprising a plurality of discharge elastic means for the discharge of the weight that are fixed in such a way to correspond to zones falling within a plurality of foot areas, the device being **characterised by** the fact that said foot areas are solely:

   - the area of the heel;
   - the area between the phalanxes of the second and third toe;
   - the area of the fifth metatarsus;
   - the area specular the fifth metatarsus with respect to said longitudinal axis.

2. Device according to claim 1, **characterised in that** said discharge elastic means comprise one or more springs.

3. Device according to claim 2, **characterised in that** the elastic means in correspondence of the heel comprise two springs, whilst the elastic means in correspondence of the other three foot areas comprise each an only one spring.

4. Device according to claim 2, **characterised in that** the elastic means in correspondence of the heel and the area between the phalanxes of the second and third toe comprise each one or two springs, whilst the elastic means in correspondence of the two other areas of the foot comprise each and only one spring.

5. Device according to any claim 1 to 4, **characterised in that** said elastic means are made by memory-foam material.

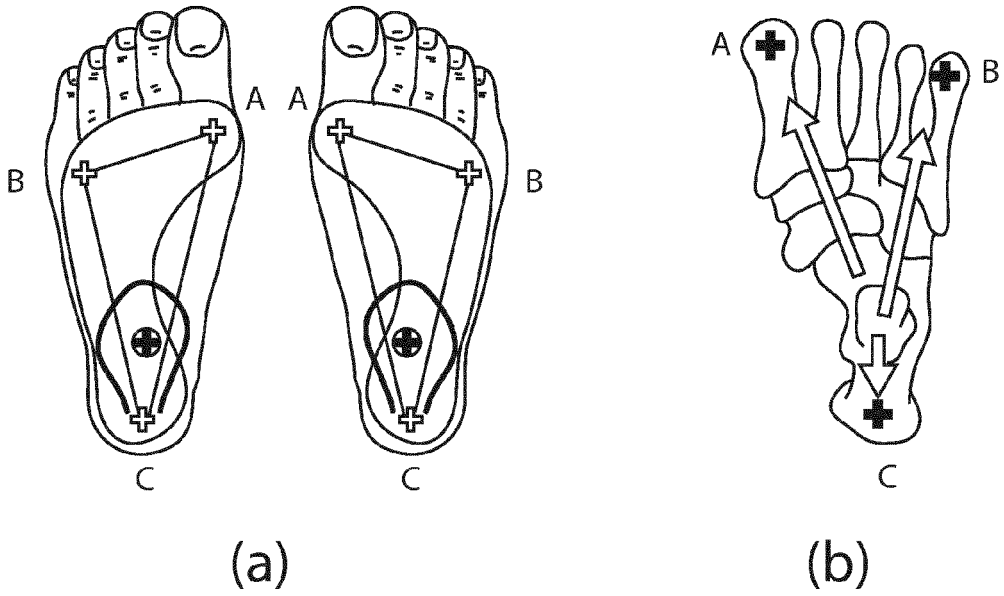

A
B
C
A
B
C
A
B
C
(a)
(b)

Fig.1

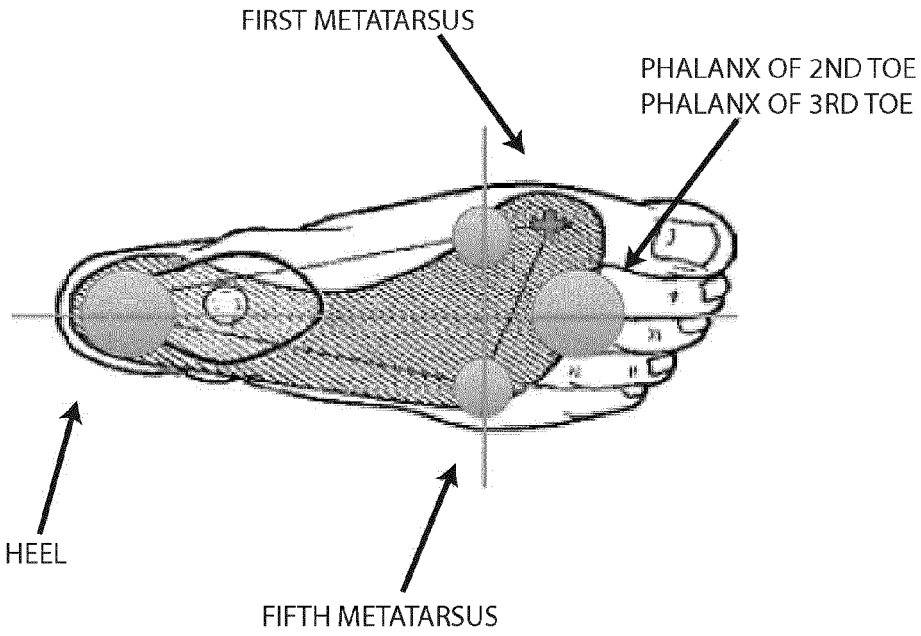

FIRST METATARSUS
PHALANX OF 2ND TOE
PHALANX OF 3RD TOE
HEEL
FIFTH METATARSUS

Fig.2

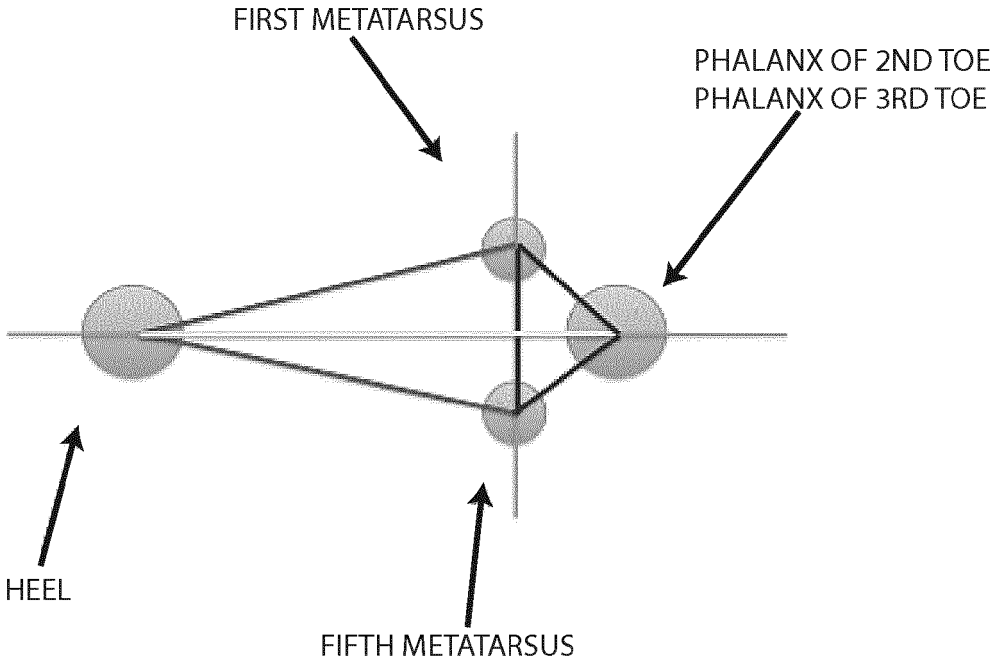
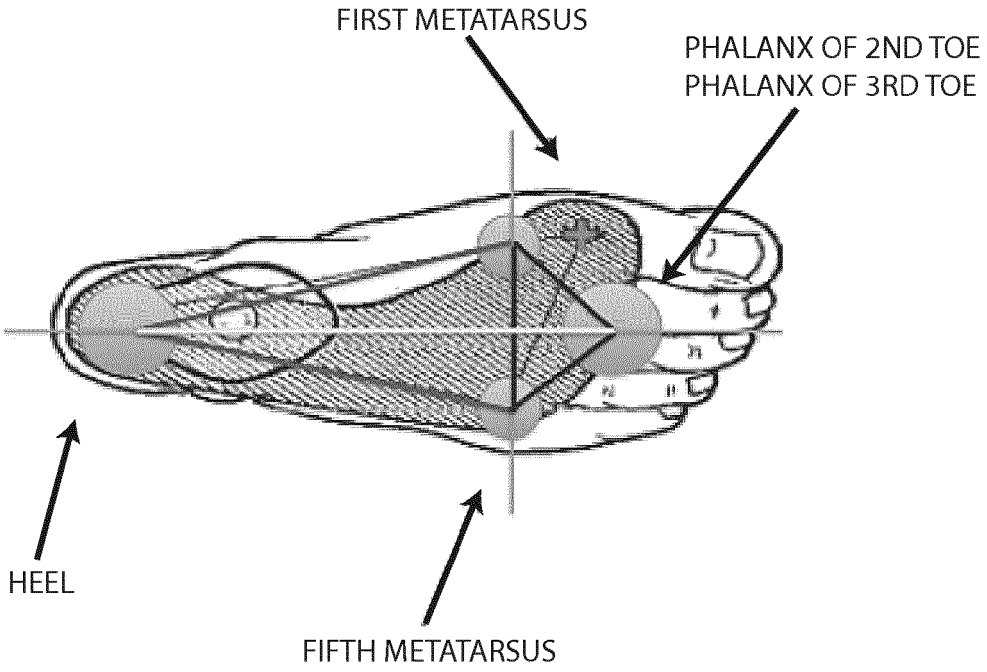

FIRST METATARSUS
PHALANX OF 2ND TOE
PHALANX OF 3RD TOE
HEEL
FIFTH METATARSUS

Fig. 3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HEEL
FIFTH METATARSUS

Fig. 4

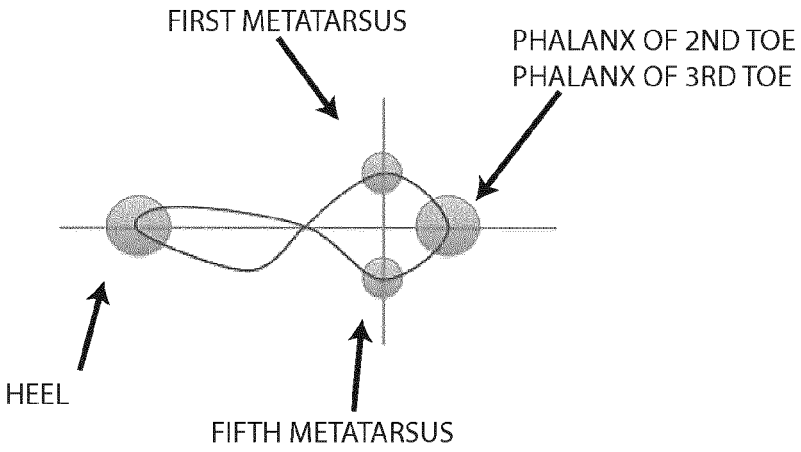
FIRST METATARSUS
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Fig. 5

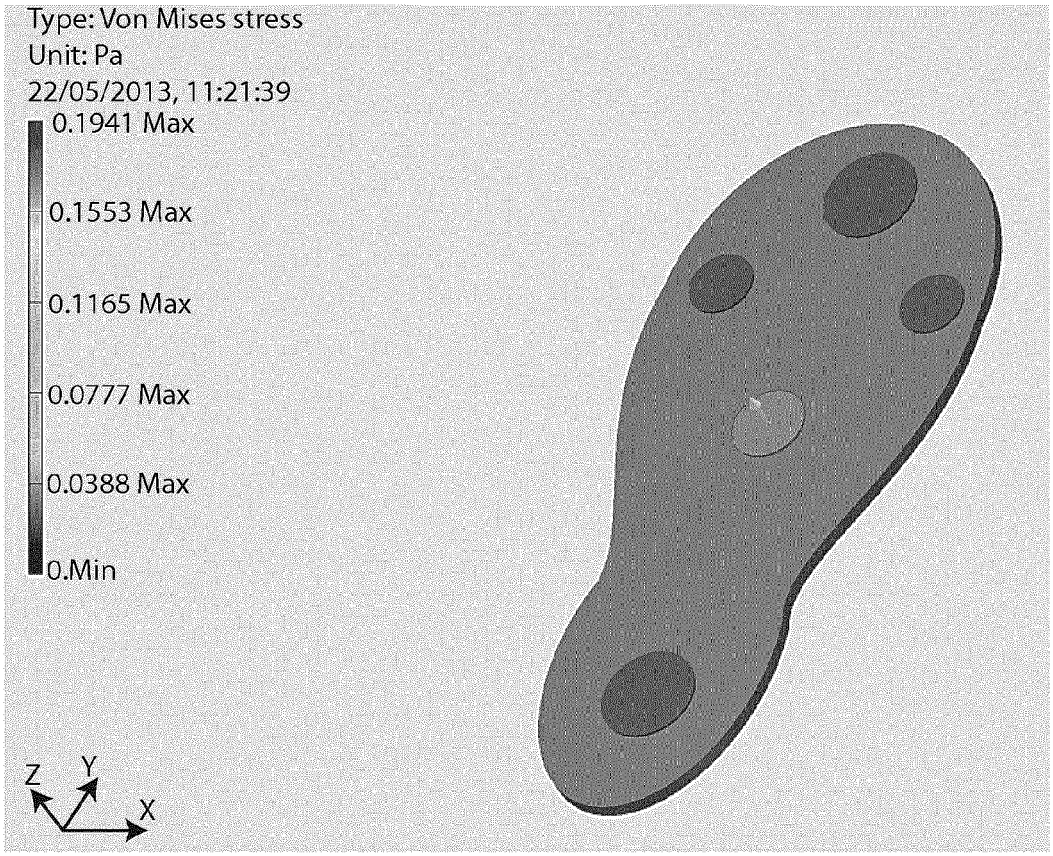
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Fig. 6

Europäisches Patentamt
European Patent Office
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EUROPEAN SEARCH REPORT

Application Number
EP 14 42 5063

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2005/022424 A1 (HELD) 3 February 2005 (2005-02-03) * the whole document *	1-5	INV. A43B13/18 A43B7/14
X	US 2 863 231 A (JONES) 9 December 1958 (1958-12-09) * column 3, line 66 - column 6, line 49; figures 1-13 *	1-5	
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