POSTURAL DISTORTIONS. The Foot Connection

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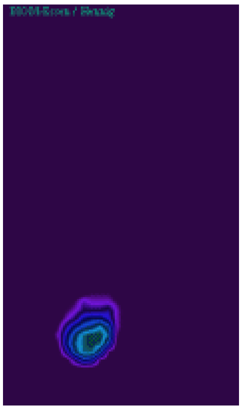
Abstract
Rothbart described a foot in which the 1st metatarsal is structurally elevated and inverted relative to the 2nd metatarsal. He terms this foot structure Primus Metatarsus supinatus (PM*s*). Rothbart suggests that PM*s* is the end result of a failed or incomplete unwinding of the talar head. Clinically, the 1st metatarsal and hallux are off the ground when the standing foot is placed in its anatomical neutral position. This distance between the 1st metatarsal and ground, referred to as the PM*s* value, is quantified using microwedges. PM*s* values between 10 mm and 30 mm define the Rothbart Foot structure (RF*s*).
RFs is biomechanically dysfunctional, demarcated by its prolonged mid-stance hyperpronation. Dynamic hyperpronation shifts the posture forward: (1) the innominates rotate anteriorly, (2) the pelvis unlevels, augmenting the scoliotic and kyphotic curves, (2) the shoulders protract, and (3) the head moves forward relative to the cervical spine. Rothbart terms this shift in posture BioImplosion which closely resembles the common compensatory pattern described by Zink and Lawson.
A medial bar (the medial column insole) has been developed which reverses BioImplosion.

Riassunto
Rothbart descrive un piede nel quale il 1° metatarso è strutturalmente elevato e invertito rispetto al 2° metatarso. Egli definisce questa forma podalica Primo Metatarso Supinato (P.M.s.).
Rothbart sostiene che il P.M.s. è il risultato finale di un insufficiente o incompleto rotolamento della testa dell'astragalo. Clinicamente il 1° metatarso e l'alluce sono lontano dal terreno quando in statica è posto nella sua anatomica posizione neutra. La distanza tra il 1° metatarso ed il terreno, riferito al valore del P.M.s., è quantificato usando microcunei.
Il valore del P.M.s. tra 10 e 25 mm caratterizza la Rothbart Foot Structure (R.F.*s.*).
R.F.s. è biomeccanicamente disfunzionale, delimitato dalla sua prolungata longitudinale iperpronazione. L'iperpronazione dinamica sposta la postura in avanti :(1) le innominate rotazioni anteriormente, (2) i dislivelli di bacino, che aumentano la scoliosi e le curve dei gibbi dorsali, (2) le spalle protratte e (3) e la testa posizionata in avanti nel tratto cervicale.
Rothbart definisce questa alterazione posturale una Bioimplosione che ricorda da vicino la comune forma compensatoria descritta da Zink and Johnson.
Una barra mediale (il sostegno della colonna mediale) è stata creata in grado di invertire (risolvere) la Bioimplosione.



Rothbart (1) described a foot in which the 1st metatarsal is *structurally elevated and inverted* relative to the second metatarsal. Referred to as Primus Metatarsus {Elevatus} Supinatus (PM*s*), this foot type is frequently identified by its deep 1st web space (**See Figure 1**).

Fig. 1

PM*s* is biomechanically dysfunctional, delineated by its prolonged phase of midstance hyperpronation. But what forces this foot to dynamically hyperpronate? And what impact does this dynamic hyperpronation have on posture?

Rothbart suggests that as the body's weight passes over the inner longitudinal arch, GRAVITY pulls the elevated 1st metatarsal inward, forward and downward (dynamic hyperpronation) until it reaches the ground. Dynamic {walking} hyperpronation, in turn, "initiates" a shift in standing posture: (1) the innominates move anteriorly, (2) the knees hyperextend, (3) the sacral base tilts, (4) the lumbosacral junction side bends {destabilizing the spine), (5) the shoulders protract, and (6) the maxilla moves anteriorly relative to the mandible (**See Figure 2**).

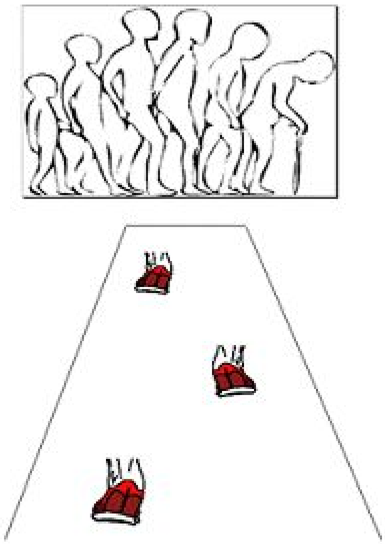


Fig. 2

Rothbart refers to this postural shift as BioImplosion (2) which he links to the development of chronic pain conditions, foot to jaw (**See Table 1**) (3-5).

Plantar Fasciitis
Oblique patellar tracking pattern (chondromalacia)
Sacral iliac joint inflammation
Low back pain
Thoracic outlet syndrome
Tension Headaches
Temporal mandibular joint dysfunction

Table 1. Chronic Pain Conditions Associated with BioImplosion

By effectively stabilizing posture, chronic pain conditions become more amendable to long-term resolution (not long-term management). Non-supportive type (medial column) insoles have been developed to meet this end.

This paper discusses (1) the normal ontogenesis of the foot and abnormal ontogenesis of the foot which could result in PMs, (2) a methodology for measuring PMs, (3) the bioimplosion patterns resulting from PMs, and (4) the treatment of PMs.

EMBRYOLOGY

Normal Embryonic and Foetal Development of the Foot

At week 3 post fertilization (pf) the lower limb bud appears as a slight swelling opposite the lower lumbars. At week 6 pf, the limb bud sits at right angles to the rump of the embryo, soles and posterior surfaces of the foot and lower limb facing cephalad (**See Figure 3**).

Fig. 3

By week 8 pf, the foot and lower limb have rotated 90 degrees around their longitudinal axis. The plantar and posterior margins of the foot and leg, respectively, now face one another (**See Figure 4**).

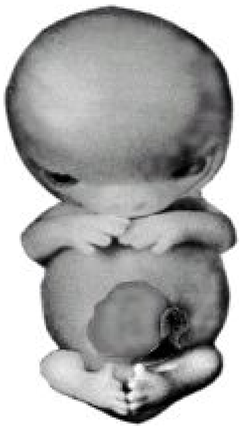


Fig. 4

By week 9 pf, the primordial ankle joint appears. Week 10 pf, the lower leg (not the foot) continues rotating around its longitudinal axis (left leg – clockwise, right
leg – counterclockwise). This places the entire foot in a structurally twisted (supinatus) position relative the leg. Week 11 pf, the calcaneus and body of the talus renew their longitudinal rotation. This slowly and progressively reduces the relative supinatus of the lateral column of the foot relative to the leg. Week 12 pf the head of the talus begins to rotate around its longitudinal axis relative to its body. This longitudinal rotation of the talar head, slowly and progressively reduces the relative supinatus of the medial column of the foot (navicular, internal cuneiform, 1st metatarsal, and hallux) relative to the leg. Within 1-2 years postpartum, the foot has sufficiently unwound to place the entire sole of the foot in a structurally plantargrade relationship relative to the leg.

Proposed Etiology of PMs

Measuring 1006 Egyptian Feet, Sewell (6) was the first to publish on the substantial variances in the twist of the talar head relative to its body (angle alpha) (**See Figure 5**, Plates 1A & 2A).

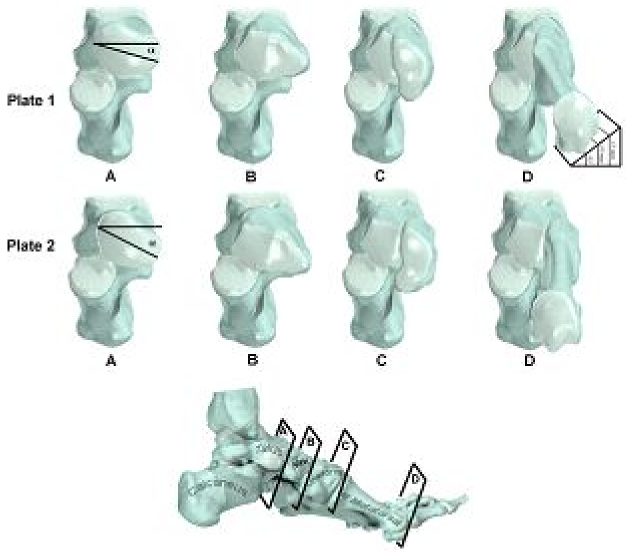


Fig. 5

Subsequently, Straus (7) reported angles ranging between 26 and 43 degrees, McPoil (8) between 24 and 51 degrees and Sarrafian (9) between 30 and 65 degrees. This torsion or twist within the talar head (termed **talar torsion**) shapes the entire medial column of the foot (10-12). Rothbart (13) suggests that low alpha angles (**See Figure 5**, Plate 1A) maintain the navicular (**See Figure 5**, Plate 1B), medial cuneiform (**See Figure 5**, Plate 1C), 1st metatarsal (**See Figure 5**, Plate 1D) and hallux in relative supinatus. In the adult foot, this supinatus of the 1st metatarsal and hallux is termed Primus Metatarsus *s*upinatus (PM*s*).

PM*s* appears to be an atavism (throwback) to the chimpanzee's foot in which the big toe functions as a prehensile appendage, a classic example of ontogeny recapitulating phylogeny (14-16).

PM*s* CLINICALLY

In the young pediatric foot, the bulging longitudinal fat pad and malleability of the tarsal bones makes it difficult to ascertain the presence of PM*s*. However, by age 4 the inner longitudinal arch (ILA) has ossified into its adult shape (17-20). This substantially facilitates the process of measuring the foot.

Figure 6 demonstrates the procedure for measuring Primus Metatarsus Supinatus (PM*s*).

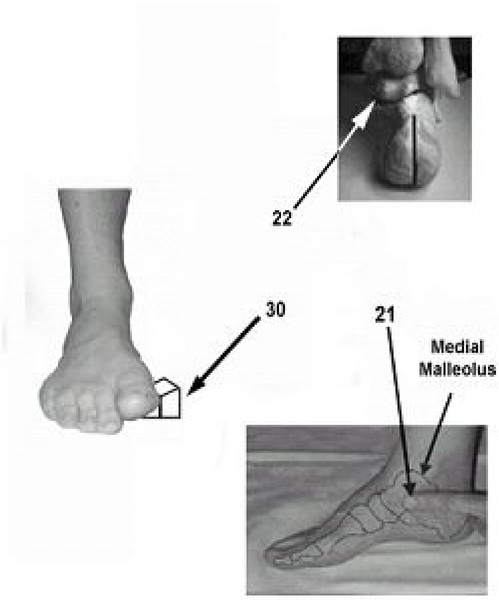


Fig. 6

PMs values between 10 and 30 mm define the Rothbart Foot Structure (RFs) (21). This measuring technique has proven to have high intra-relater reliability (22).

Tacoma Study

In a single blind clinical study (23), 317 chronic pain patients were categorized into 1 of 4 groups based on their arch type (stable, flexible, functional and dysfunctional). Visual gait analysis was conducted on each group. An objective scale was used in judging the degree of dynamic hyperpronation (absent =1/mild =2/moderate =3/severe =4). The scores were mathematically compiled and an average computed for each group (reported under the heading pronation). Concurrently, PMs readings were taken on each of the 317 individuals and mean values calculated for each group.
Results: A direct linear relationship was noted between PMs values and dynamic hyperpronation (**See Table 2**). A dynamic hyperpronation pattern of left > right (72%) was found to be more common than right > left (28%). An unanticipated outcome was the frequency of PMs values above 10 mm (307/317 patients). However, this was attributable to the skewed sample: only patients with a chronic history of intractable musculoskeletal pain.

Mean PMs Values	Pronation	Arch Phenotype	#Patients	Total% with Arch Type	Pronation Pattern	
					Lf>Rt	Rt>Lf
06 mm	Absent	Stable Arch: Same arch height, sitting or standing	010	03%	70% 007	30% 003
14 mm	Mild	Flexible Arch: Arch height higher sitting than walking	270	85%	72% 194	28% 076
24 mm	Moderate	Functional Flatfoot: Arch sitting. No arch walking	035	11%	75% 026	25% 009
38 mm	Severe	Disfunctional Flatfoot: No arch sitting. No arch walking	002	<01%	100% 002	0% 000
		TOTAL	317	100%	72%	28%

					229	088

Table 2. TACOMA STUDY - PMs Values vs. Pronation Patterns in Chronic Pain Patients

Other researchers have reported a similar statistical correlation between forefoot measurements and foot instability (24).
Assuming no concurrent occlusal or visual pathology, RFs produces bioimplosion patterns very similar to the common and uncommon compensatory patterns described by Zink. In the Tacoma study, 305 of the 317 patients were diagnosed as RFs. 220 (72%) of these RFs patients demonstrated a dynamic hyperpronation pattern of left > right (**See Figure 7**).

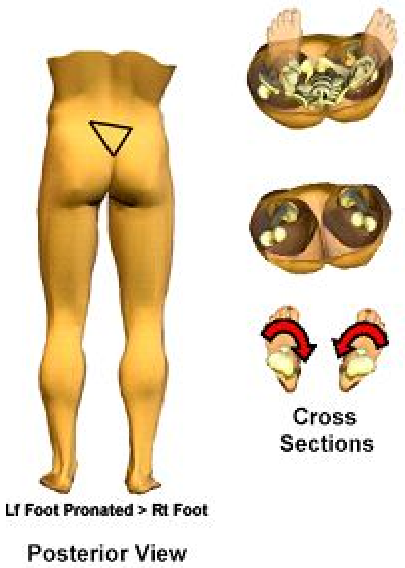


Fig. 7

This asymmetrical inward, forward and downward rotation of the feet relative to the ground pulls the innominates forward {anterior} and downward, left > right {using the ASIS as the reference point}, or forward and *upward,* left > right {using the PSIS as the reference point} (**See Figure 8**).

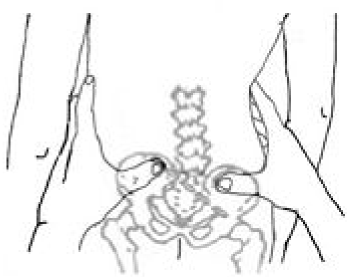


Fig. 8

The asymmetrical anterior rotation of the innominates hyperextend the knees {left > right}, shifts the buttocks posteriorly {left > right} (**See Figure 7** - middle, right illustration) and results in a high left femur head (25). The sacral base tilts right {high left iliac crest, low right iliac crest}. The lumbosacral

junction compensates by side bending left. This unleveling at the LS junction destabilizes the spine, augmenting the scoliotic, kyphotic and rotational curves. The shoulders protract, typically right > left. The head and maxilla displace forward relative to the cervical spine and lower jaw respectively (26-29). The left side of the face (eye to mouth) loses vertical height. In essence, RFs initiates and gravity "powers" this postural distortion (30).
Other researchers describe an almost identical postural distortion which they term the common compensatory pattern (31, 32). However, asymmetry in foot hyperpronation is not assessed. Leg length patterns are cited (left leg and right arm longer than right leg and left arm).
Of interest is a cadaver study in which 246 preserved lumbar spines are measured (using a computer graphics program) to gauge the frequency of the common compensatory pattern. Results: 76% of the lumbar specimens demonstrated facet angles consistent with CCP (33). This percentage correlates very closely to the Tacoma study.
A less common bioimploded pattern results from the less common hyperpronation pattern of right > left. The innominates rotate anteriorly {right > left}. The femoral heads displace posteriorly {right > left}; hyperextending the knees {right > left} and posteriorly shifting the buttocks {right > left}. The sacral base tilts left. The LS junction side bends right. Spinal curves, in all three body planes, are augmented. The shoulders protract, typically left > right. The right side of the face (eye to mouth) loses vertical height.
These two bioimploded patterns are mirror images of one another driven by their respective mirror image dynamic hyperpronation patterns. No discernable leg or arm length patterns were noted.
Inman defines normal pronation as that degree of pronation generated by the internal transverse plane oscillations of the hips (34) (**See Figure 9**).

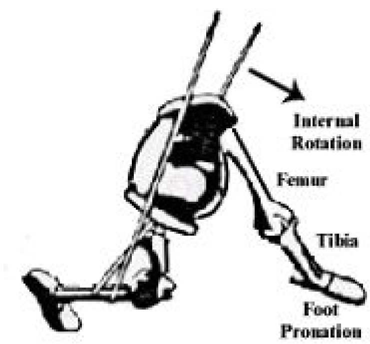


Fig. 9

Clinically this pronation pattern is invisible, e.g., the ankle remains visually stable (vertical) throughout the entire dynamic phase of gait. Conversely, Rothbart defines any visual ankle twist that occurs during the dynamic (walking) phase of gait (e.g., that generated by PMs values > 10 mm) as dynamic hyperpronation.

TREATMENT OF RFs (PMs values between 10 and 25 mm)

Heel Wedges and Arch Supports

Medial heel wedging visibly *decreases standing* hyperpronation. However, it concurrently increases PMs values (the distance between the 1st metatarsal and ground), which in turn, *increases dynamic* hyperpronation. Arch supports decrease rearfoot dynamic hyperpronation, but are ineffective as the 1st metatarsal head becomes weight bearing. Paradoxically, recent research utilizing 3d VRS Formetrics and Posturographic Rugs has demonstrated that orthotics incorporating heel/total forefoot varum wedging, arch supports and/or metatarsal pads (e.g. supportive type orthotics), while diminishing foot symptoms, tend to unlevel the pelvis and increase the kyphotic and scoliotic curves within the spine (35).

Medial Column Insoles

Medial column insoles do not support the foot. They do not wedge or cup the heel (**See Figure 10**).

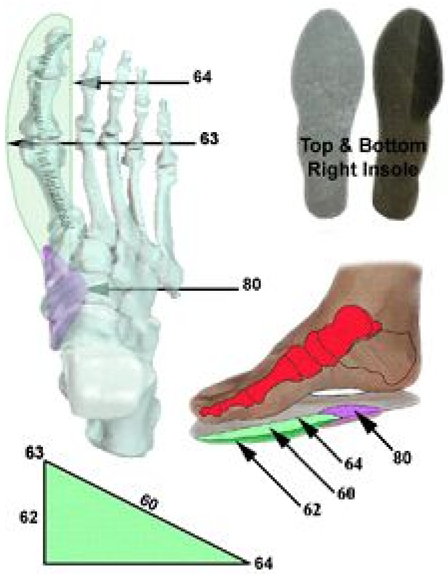


Fig. 10

These textured insoles appear to function as a tactile stimulant to the bottom of the foot (36), more specifically, to the bottom of the big toe and 1st metatarsal. In terms of postural mechanics, this most likely occurs via a "proprioceptive activated" feedback loop to the cerebellum (37 - 43). With each step, the foot appears to be reminded where it should be and automatically makes the adjustment. Dynamic hyperpronation is reduced. The body’s center of gravity shifts posteriorly. The knees move out of hyperextension. The pelvis becomes *visually* more vertical (tucked). The symmetry in the posterior contouring of the buttocks is restored. The shoulders retract. And the head tends to center over the spine (44).
Medial column insoles are manufactured at approximately 30% of the measured PMs value. For example, in a foot measuring 20 mm, the vertex or maximum point of tactile stimulation in the bar, (**See Fig. 10**) is dimensioned at 6mm. This percentage is empirically derived from the Tacoma study. It is observed that a 30% tactile stimulation underneath the 1st metatarsal and big

toe visually improves posture and reduces hyperpronation. It is also observed that a tactile stimulations > 30% tends to destabilize the pelvis. Fusco (35) reports similar findings in her evaluation of supportive type orthotics.
Using medial column insoles in ***non***-RFs places a disruptive upward load on the 1st metatarsal head. This can dramatically limit the range of dorsiflexion within the 1st metatarsal-phalangeal articulation and lead to a functional hallux limitus.

SUMMATION

Lower alpha angles result in Primus Metatarsus supinatus. Functionally, gravity pulls the elevated and inverted 1st metatarsal downward and inward, which in turn, "powers" bioimplosion.
Measuring supinatus at the level of the 1st metatarsal head facilitates a differential diagnosis. PMs values of 10 mm – 30 mm define the Rothbart Foot structure.
Medial column insoles effectively stabilize RFs and reverse bioimplosion. These insoles are dimensioned at approximately 30% of the measured supinatus.
As posture becomes more vertical, musculoskeletal dysfunctions become more amendable to treatment.

CALL FOR FURTHER RESEARCH

The linear correlation between RFs and dynamic hyperpronation is clinically compelling. Dynamic hyperpronation distorts posture, foot to jaw. Medial column insoles dramatically reverse BioImplosion, but their "modus of operandi" is still uncertain and needs to be clarified.

Captions for Figures 1-10

Figure 1. *Deep 1st Web Space*. The 1st metatarsal is shorter than the 2nd metatarsal creating the deep 1st web space. This relative shortness of the 1st metatarsal frequently occurs in the Rothbart Foot Structure.
Figure 2. *Postural Shift Associated with Hyperpronation.* BioImplosion (upper diagram) is a gravity induced postural shift powered by dynamic foot hyperpronation (lower diagram). As the foot rolls inward, downward and forward (hyperpronates), the entire postural axis shifts inward, downward and forward.
Figure 3. Embryo week 6.0 pf. Lateral View. Limb bud sits at right angles to rump of embryo. Soles of feet and posterior compartments of leg and thigh face cephalad.
Figure 4. Embryo week 8.0 pf. Frontal View. Lower leg and thigh has rotated 90 degrees around its longitudinal axis. Posterior leg and thigh compartments face one another, as do the heels and soles.
Figure 5. *Torsional Development of the Medial Column of the Foot.* [Sectional Views, Frontal Plane] Lower alpha angles are linked to Primus Metatarsus Supinatus. Supinatus of the talar head maintains the *entire* medial column of the foot remains in supinatus. Plate 1A illustrates Talar Supinatus, Plate 1B Navicular Supinatus, Plate 1C Cuneiform (Internal) Supinatus, and Plate 1D Metatarsal Supinatus and Microwedge. Higher alpha angles are linked to the plantargrade position of the 1st Metatarsal. The unwinding of the talar head, "directs" the unwinding of the entire medial column of the foot, navicular to hallux (See Plates 2A –D).
Figure 6. Protocol for *Measuring PMs (Right Foot)*. *Patient Standing, Vision Straight Forward*. Locate the medial talocalcaneal (subtalar) joint. This easily palpable joint is approximately one finger width below and in front of the medial malleolus (21). Keeping your finger on the medial subtalar joint, have your patient slowly rotate their hips, first counterclockwise and then clockwise. This will pronate (evert) and supinate (invert) the right foot respectively. Guide the foot through this range of motion until the upper and lower margins of the subtalar joint feel

congruous (parallel) to one another (22). This is the anatomical neutral position of the subtalar joint. If the subtalar joint is pronated or supinated, the joint space will feel collapsed (obliterated) or cavernous respectively. While maintaining this STJ *n*P, slide the microwedge (30) underneath the 1st metatarsal head until slight resistance is encountered from the bottom of the foot. Record the PMs value (vertical displacement between the 1st metatarsal head and ground). Repeat this protocol for the other foot.

Figure 7. *Common Standing Compensatory Pattern.* Posterior view demonstrates standing hyperpronation pattern of left foot > right foot (more apparent dynamically) and right tilt of the sacral base (high left hip). Middle diagram (right) illustrates the femur draw associated with the CCP (left femur head posterior relative to right femur head). This distorts the contour of buttocks. Upper right diagram demonstrates the out toeing of the right foot (compared to the left) and the counterclockwise rotation of the thoracic vertebrae [Adapted from Pope R S. 2003 The Common Compensatory Pattern. Its Origin and Relationship to the Postural Model. AAOJ 14 (4):19-40].

Figure 8. *Position of the Posterior Superior Iliac Spines in the Common Standing Compensatory Pattern.* The thumbs of the examiner are placed directly on the PSIS. Both innominates are rotated anteriorly, left > right. This results in the left PSIS being positioned more cephalad relative to the right PSIS.

Figure 9. *Transverse Plane Oscillations of the Pelvis*. (Downward, Transverse Plane View of the Lower Body) As the left leg is swung forward, the left innominate rotates inwardly on the transverse plane, and with it, the left femur and tibia. The internal rotation of the left tibia pronates the weight-bearing left foot. This mechanical link between the subtalar joint and pelvis defines normal pronation: *pronation generated by the internal transverse plane oscillations of the pelvis*. Pronation generated by the elevated 1st metatarsal is, by definition, abnormal (hyper) pronation.

Figure 10. *Medial Column Insoles*. Manufactured by a Subsidiary of GRD BioTech Inc. (top right photograph). The dimensions of the medial column within the proprioceptive insole is demonstrated (middle right drawing): 60 represents the slope, 63 the vertex (maximal tactile input) and 64 the nadir (minimal tactile input) of the medial column. Arch supports (80) are used in functional flatfeet where the structural integrity of the talonavicular joint is severely compromised.

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