Biomechanical foot function: a podiatric perspective: part 2

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Introduction

In the first paper (Prior 1999), varying concepts relating to the structure of the foot and the subsequent function were described. The aim of this paper is to review normal function and describe how varying abnormalities can effect this function. A more advanced method of analysis will be described along with some of the options available for treatment

Normal/abnormal function

The primary aims of locomotor function are to:

- facilitate forward progression (propulsion)
- provide shock absorption
- conserve energy by minimizing motion of the centre of gravity
- provide stability.

In order for this to be achieved, the various segments of the lower and upper limbs, in conjunction with the soft tissues, need to function in harmony. Imbalances to these systems will alter their ability to function, and thus effect locomotion.

Normal function was described in Part 1 (Prior 1999) but is worth summarizing and expanding. The walking cycle is split into two sections, swing and stance (the weightbearing portion). Whilst certain conditions (e.g. arthritis, neuromuscular etc.) may cause alteration in the swing pattern, the majority of inter subject

variability occurs during the stance phase.

Perry (1992) describes how the body progresses forward by pivoting over a stable foot allowing transfer of weight during the support phase of gait. This rocker system has three components (Fig. 1) each with specific sub components:

- The heel rocker
  (a) initial contact
  (b) loading response
- The ankle rocker
  (a) midstance
- The metatarsal rocker
  (a) terminal stance
  (b) pre-swing.

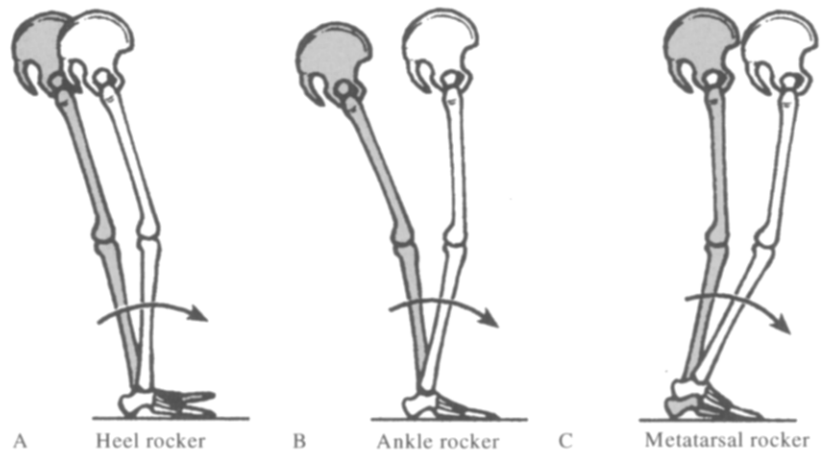


Fig. 1 The heel (A), ankle (B) and forefoot (C) rockers which allow weight during the support phase of gait (Perry 1992).

The heel rocker positions the heel for stance (initial contact) whilst assisting shock absorption, providing weightbearing stability and preserving progression (loading response). A degree of genu valgum occurs during this section to reduce lateral displacement (caused by weight acceptance on the limb).

The ankle rocker allows progression of the body over a stationary foot whilst maintaining limb and trunk stability. The pelvic drop of the non-weightbearing limb is prevented by the hip adductors of the weightbearing limb.

The forefoot rocker enables progression of the body beyond the supporting foot (terminal stance) and positions the limb for swing (pre-swing). It is during this phase that the knee and hip become extended, providing mechanical advantage to the hip flexors to initiate swing and continued forward progression

Whilst Root et al. (1977) described 5 sections of the stance phase of gait, these sections relate to those described by Perry (1992).

Figure 2 summarizes the position of the foot and leg during the stance phase of gait. Efficient function of these systems facilitates stable progression and allows phasic muscle activity. Dysfunction, be it structural, neurological (e.g. adverse mechanical tension) or muscular (e.g. muscle imbalance), may result in injury.

Abnormal function

In Part 1 (Prior 1999), the varying concepts utilized in the assessment of the foot and leg were described. These essentially relate to the cardinal body planes allowing the examiner to build a picture of function in three planes. This can then be applied to the dynamic situation and related to pathology. The bony anatomy of the foot is illustrated in Fig. 3.

The aspects of assessment are:

- Frontal plane (inversion/eversion of the foot) (Root et al 1977)
  — knee joint (varum/valgum)
  — tibia (varum/valgum)
  — subtalar joint (STJ) (varum/valgum)
  — midtarsal joint (varum/valgum)
- Transverse plane (abduction/adduction of the foot)
  — leg rotation (internal/external)
  — angle of gait
  — STJ axis position (Kirby 1987, 1989)
  — low and high gear axis (Bojsen-Moller 1979)
  — metatarsal position (e.g. adductus)
- Sagittal plane (dorsiflexion/plantarflexion)
  — 1st Metatarsophalangeal joint (MTPJ) motion (Dananberg 1986)
  — 1st ray position (Root et al. 1977)
  — windlass mechanism (Hicks 1954)
  — forefoot position (e.g. equinus)
  — ankle joint motion (Root et al. 1977, Dananberg 1986, Perry 1992)
  — leg length (e.g. length discrepancy).

Abnormal function may occur as a result of one or any number of combinations of these factors. An understanding of how these factors may manifest will then help the practitioner to diagnose and manage patients with dysfunction.

Table 1

Root et al. (1977)	Perry (1992)
Heel strike	Initial contact
Foot flat	Loading response
Midstance	Midstance
Heel lift	Terminal stance
Toe off	Pre-swing

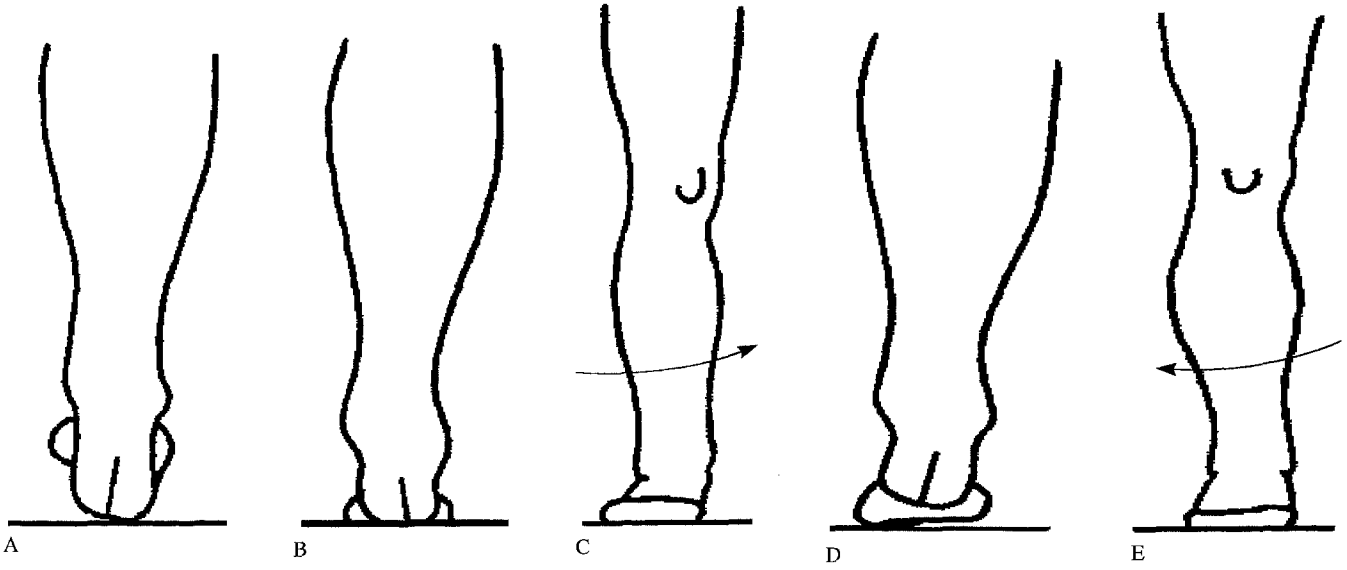
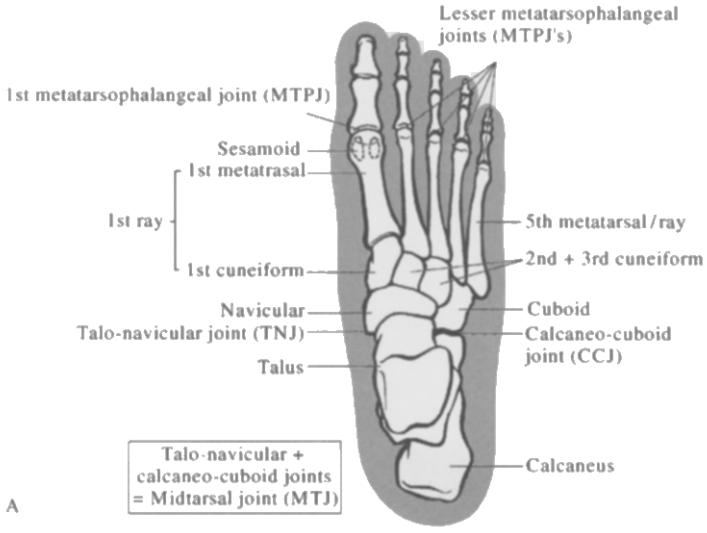


Fig. 2 At heel strike (A), the heel is slightly inverted (McPoil & Cornwall 1994, Pierrynowski & Smith 1996). As the foot receives weight (loading response/foot flat), ground reaction forces cause pronation at the subtalar joint. This causes the foot to pronate, observed as heel eversion (B), and internal rotation of the leg (C). As the heel lifts, the 1st MTPJ is dorsiflexed initiating the windlass mechanism. This causes plantarflexion of the 1st ray which is stabilized against the ground by peroneus longus. The net result is raising of the medial longitudinal arch, close packing of the calcaneocuboid joint, supination of the foot, observed as heel inversion (D), and external rotation of the leg (E).



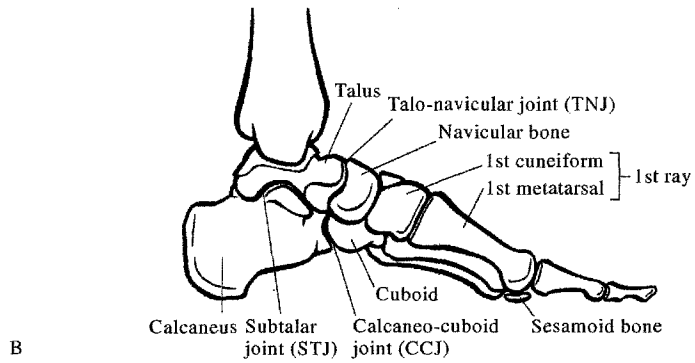


Fig. 3 A diagram of the foot in a dorsoplantar (A) and lateral view to describe the anatomical landmarks.

The pronated foot (Fig. 4)

Pronation of the foot is normal although excessive motion may lead to pathology. Generally, the majority of individuals land with the heel slightly inverted, therefore load the posterolateral aspect of the heel at heel strike (Fig. 2A). However, on loading (foot flat), excessive pronation (observed as eversion of the heel and/or excessive lowering of the medial longitudinal arch) is observed. This will cause an internal rotation of the leg and a rotation at the hip and pelvis resulting in undue stresses on the associate structures.

The supinated foot (Fig. 5)

Whilst supination of the foot is necessary towards the end of the stance phase of gait, some individuals have a relatively supinated foot throughout gait. As previously mentioned, a degree of pronation is normal during walking, thus reduced motion, as in the case of the supinated foot can cause

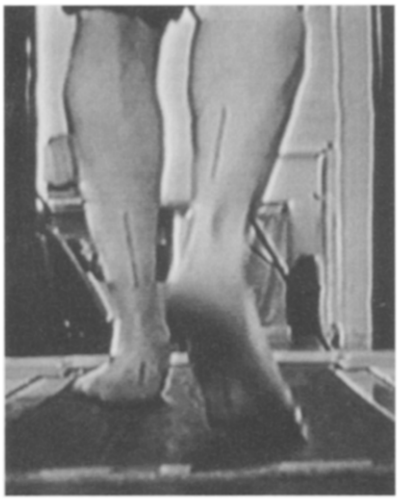


Fig. 4 The pronated foot. Note severe eversion of the heel on loading. This will place severe stress on the joints and soft tissues, particularly distally.

Possible causes include:
- Forefoot varus
- Rearfoot varus (subtalar or tibial varus/valgus)
- Functional Hallux Limitus
- Medially deviated STJ axis
- Muscle inflexibility (calf and hamstring)
- Genu varum or valgum
- Internal leg position
- Leg length discrepancy (usually the longer leg)
- A muscle imbalance disorder resulting in pelvic rotation.

Some associated disorders include:
- 1st MTPJ pain
- Plantar fasciitis
- Sinus tarsi syndrome
- Tibialis posterior dysfunction
- Medial tibial stress syndrome
- Anterior knee pain
- Lower back pain.

symptoms. Generally, these are the result of reduced shock absorbency as the foot utilises less motion and thus, is less able to absorb impact forces.

Muscle inflexibility (Figs 6 & 7)

Muscle inflexibility is one of the most common causes of abnormal foot and leg function. In particular, inflexibility of the calf muscle (gastrocnemius primarily) and hamstring muscle groups (either due to increased knee flexion or internal rotation of the leg) will place a pronatory force on the foot. Furthermore, the inflexibility may cause any combination of the following:

- forefoot or whole foot strike
- increased STJ pronation
- midtarsal collapse
- early heel lift
- genu recurvatum.

Figure 8 details the authors preferred method of assessing and treating calf muscle inflexibility.

Leg length discrepancy (Fig. 9)

The relevance of leg length discrepancies to injury has been debated in the literature (Friberg 1983). Some authors suggest that, as the clinical evaluation is prone to error, differences of less that 2cm should be ignored as this may represent the range of measurement error (Helliwell 1985). However, artificially induced discrepancies of as little as 5mm have been shown to effect muscle function in the spine (Vink & Kamphuisen 1989). It has been the author's experience that discrepancies as small as this contribute to painful conditions of the legs, pelvis and spine.

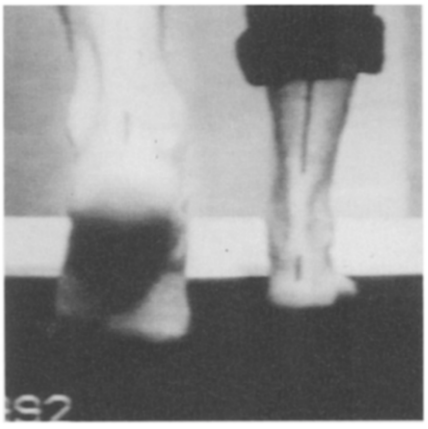


Fig. 5 The supinated foot. In this case, there is reduced eversion evident, with the heel remaining inverted in relation to the ground.

Possible causes include:
- A forefoot valgus or rigid plantarflexed 1st ray
- Insufficient motion available to compensate for a rearfoot varus
- Laterally deviated STJ axis
- An external leg position
- Limb length discrepancy (generally the shorter limb)
- A muscle imbalance disorder resulting in pelvic rotation.

Some associated disorders include:
- Sesamoiditis
- Retracted toes
- Achilles tendonitis
- Lateral ankle sprains
- Stress fractures
- Iliotibial band syndrome.

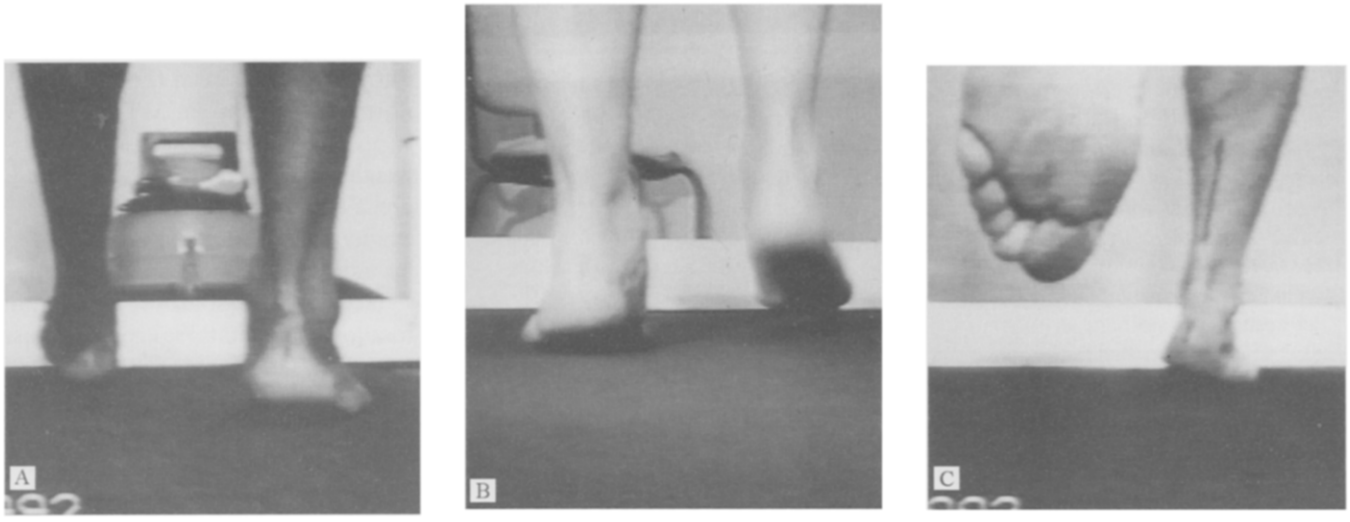


Fig. 6 Muscle inflexibility. Whilst the most common observation seen as a result of inflexibility of the calf or hamstring muscle groups is pronation, a forefoot strike, dorsiflexion of the foot at the cuboid articulations (A) and/or an early heel lift (B) are also common. On running, a forefoot (C) or whole foot strike are common.

The authors' preferred method of evaluation requires the patient to be standing. The feet are placed in their neutral calcaneal stance position (Fig. 10) and the anterior superior iliac spines, posterior superior iliac spines and femoral trochanters are palpated. For a true leg length discrepancy to exist, all three will be higher on the same side. Blocks are then placed beneath the shorter leg until equilibrium is achieved. Furthermore, the patients are asked for their subjective feeling regarding equilibrium. This invariably correlates to the degree of balance. However, should the patient feel level at a lower height, then this may represent a degree of adaptation or a rotational problem at the pelvis. The relative levels are also assessed with the patient standing in their relaxed calcaneal stance position (Fig. 10) to evaluate for any functional rotations.

This method of evaluation provides valuable information relating to leg length, pelvic rotations and possible muscle imbalances. Functional problems may be due to increased motion within one foot (distal to proximal) or a muscle imbalance at the pelvis (proximal to distal).

Generally, the foot on the longer limb will pronate more to shorten the leg, whilst the foot on the shorter side will supinate to lengthen the leg. In some instance this does not occur and simply reflects that foot

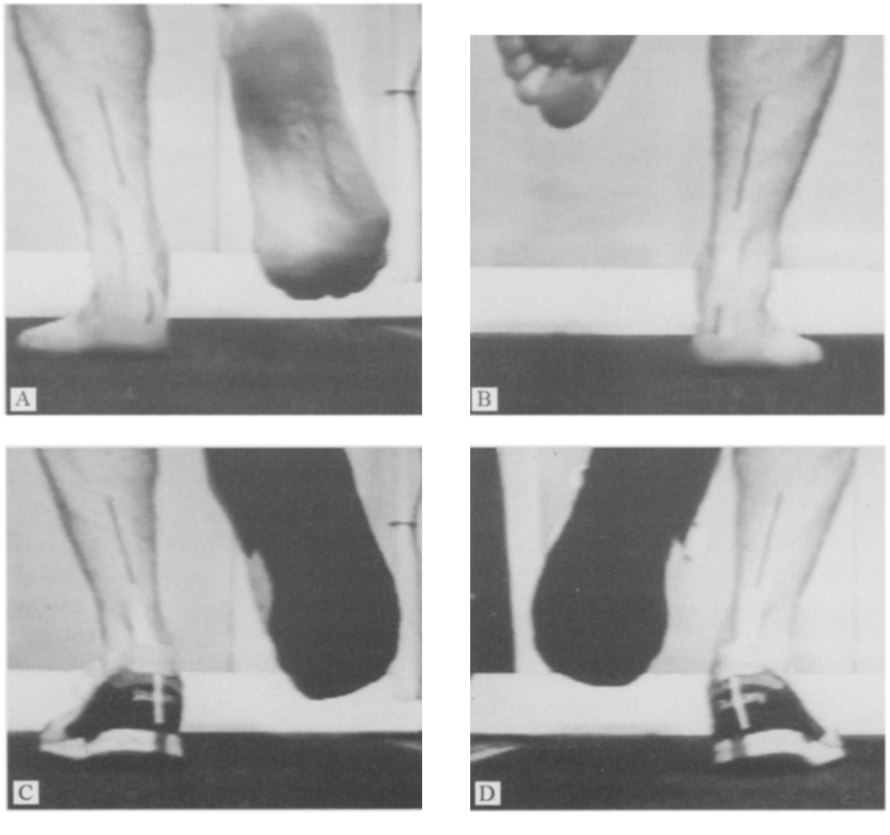


Fig. 7 See Box 1.

Box 1 Case history 1

A male patient presented complaining of excessive shoe wear, particularly on one side. There was no history of injury. Examination revealed considerable general muscle inflexibility. On video analysis, a forefoot strike was observed bilaterally with increased left sided pronation (Figs. 7A & B). However, when the shoes were worn, there was considerably greater right sided deformity (Figs. 7C & D). In this case, there was less motion at the right STJ, thus less ability to compensate. However, when shoes are worn, the pronatory force is transferred to the shoe which subsequently deforms. Orthoses are not indicated and the patient was referred to physiotherapy for an intensive flexibility programme.

function is not compensating for the discrepancy.

Leg length discrepancies can result in disorders from the foot to the spine.

Functional Hallux Limitus (Fig. 11)

Functional Hallux Limitus (Dananberg 1986, 1993a, 1993b) is the term used to describe limitation in dorsiflexion of the 1st MTPJ during walking, even though a normal degree of 1st MTPJ motion is present when assessed in a non-weightbearing situation. A reduced great toe extension test when evaluated in static stance may give an indication that this is occurring.

1st MTPJ dorsiflexion is essential to allow the metatarsal rocker phase to occur. This occurs with toe off through the high gear axis and initiates the windlass mechanism and the resultant chain of events for toe off. 1st MTPJ dorsiflexion is accompanied by ankle joint plantarflexion. A failure of this to

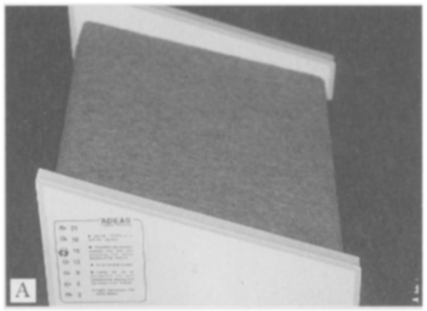


Fig. 8 CoCalf muscle flexibility assessment and management. The effect of calf muscle (primarily gastrocnemius) inflexibility can be assessed by having the patient stand on a 15° slope (A) with the feet touching the outer side of the wood (or slightly intoeing) to help control the foot position. If adequate flexibility (dorsiflexion of the ankle joint) is available they will be able to stand upright. If inflexibility is present, the patient will not be able to stand upright on the slope (B) and will have to lean forward to maintain balance. The slope can then be lowered in increments until the angle on which the patient can stand upright is found (C). This angle can then be used to stretch the calf muscles. The patient stands on the slope (preferably morning and evening) until a slight pull is felt in the calf muscle (not pain). At this point the patient should stop stretching however short the period. By repeating the stretch once in the morning and evening, the patient will gradually be able to stand on the slope for longer periods. Once the stretch can be held comfortably for 4 min, the angle should be increased slightly, and the process begins again. The author has found this to be the most effective and user friendly method of improving calf flexibility. The Ankle Dorsiflexion Evaluation and Stretching (ADEAS) pictured in this example has been designed to allow this to be performed easily. It is available from Pilgrim Technologies, Boston, Lincolnshire, UK. An alternative is to use a bread board (or equivalent) resting on a telephone directory.

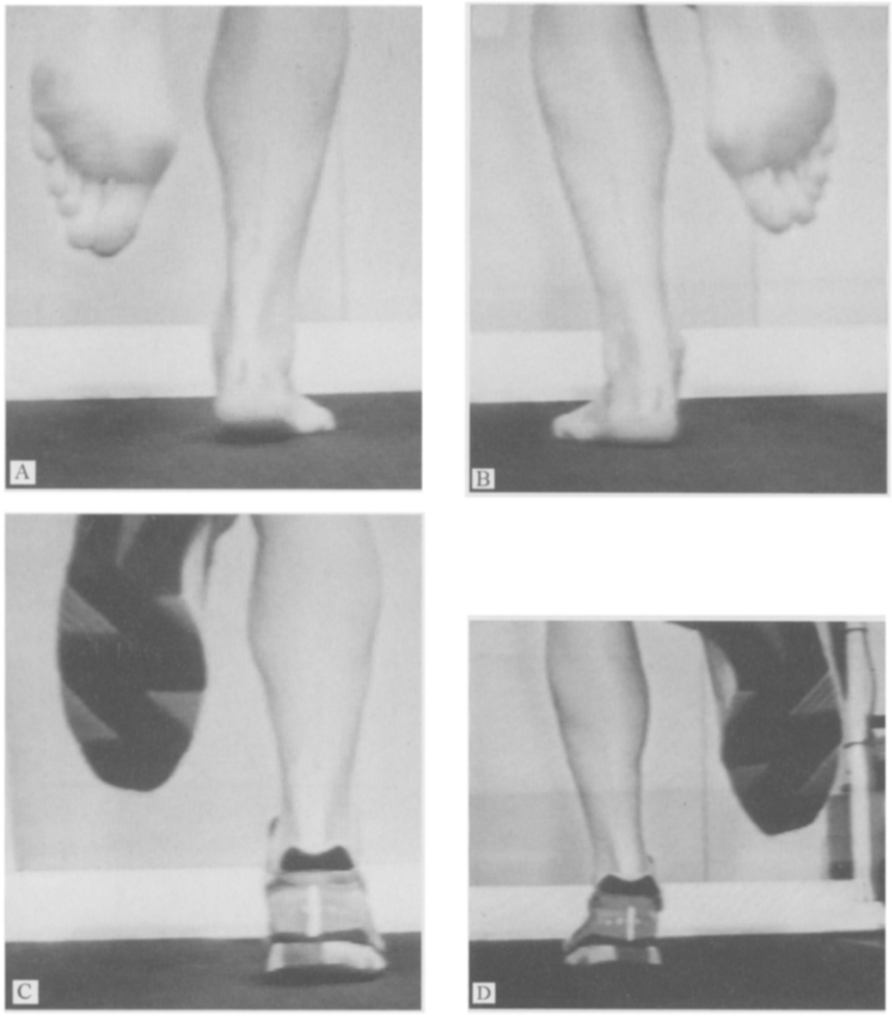


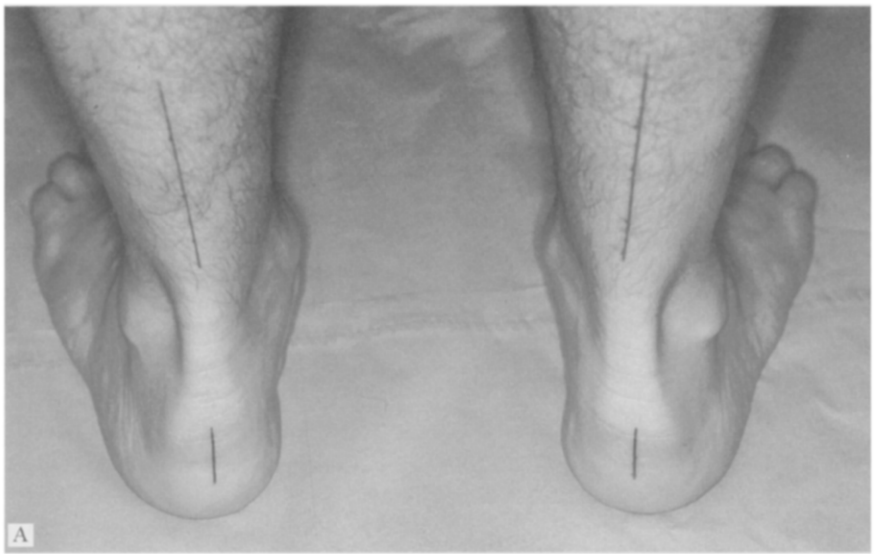
Fig. 9 Leg length discrepancy. A leg length discrepancy will typically result in a relatively supinated foot on the short limb (A) and pronated foot on the long limb (B). Barefoot, the heel contact phase may be reduced or absent (A) on the shorter side. This is less evident shod (C) due to the heel of the shoe but the relative position of the heels may still be evident (C & D).

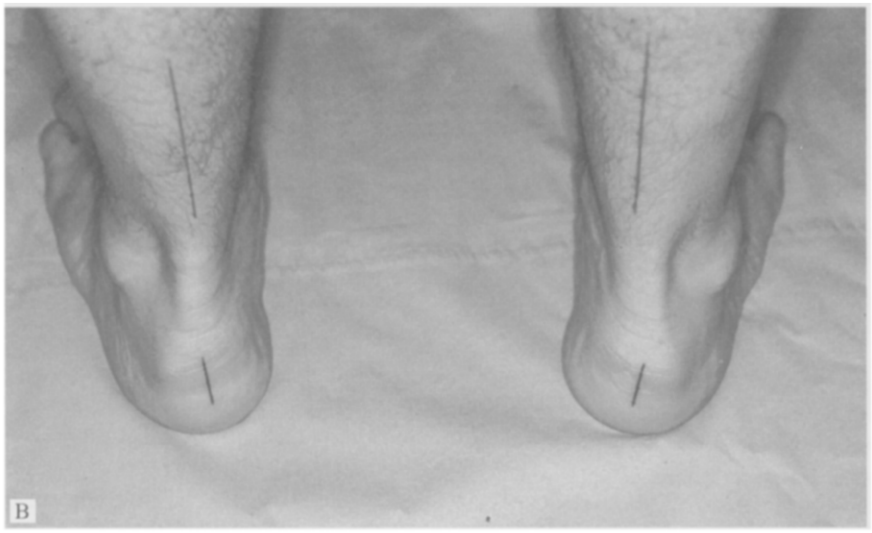
occur results in early knee joint flexion (prior to heel strike of the swing limb) and thus reduced hip joint extension. Insufficient hip joint extension prevents the hip flexors gaining mechanical advantage and thus removes their ability to initiate motion via swing of the limb. As a result, the gluteals and quadratus lumborum on the contralateral side become active in order to help pull the weightbearing leg into swing. This will destabilize the contralateral lower back and sacroiliac joint and may predispose to piriformis over activity. Furthermore, the position of the hip at the time of hip flexor activity means that the leg effectively acts as a dead weight. As the hip flexors are unable to accelerate the leg forwards, they effectively pull the leg downwards, simply exacerbating the effect of the dead weight. This results in a lateral rotation on the spine and trauma to the intervertebral disks. This is summarized as:

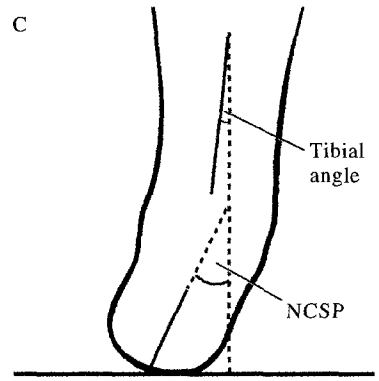
- High gear toe off allows 1st MTPJ dorsiflexion
- 1st MTPJ dorsiflexion initiates the windlass mechanism and prepares the foot for toe off
- 1st MTPJ dorsiflexion is accompanied by ankle joint plantarflexion.
  - — this allows adequate knee and hip extension
  - — adequate hip extension provides mechanical advantage to the hip flexors
- A failure of 1st MTPJ dorsiflexion and ankle joint plantarflexion results in early knee flexion (prior to heel strike of the contralateral foot)
- Early knee flexion results in reduced hip extension
- Reduced hip extension reduces the ability of the hip flexors to initiate swing
- The contralateral gluteals and quadratus lumborum become active to help pull the stance limb into swing. This destabilizes the lower back and contralateral sacroiliac joint
- The contralateral piriformis may attempt to stabilize the sacroiliac joint
- The reduced hip extension converts the stance limb into a dead weight for swing which is exacerbated by hip flexor activity
- The stance limb causes an ipsilateral lateral rotation of the spine, stressing the intervertebral discs.

Whilst this abnormal function is of low magnitude, it is the repetitive nature that causes the problem over a sustained period of time. The average person takes 5000 steps per day, or 2500 per foot, thus subtle imbalances are repeated thousands of times per day. Case history 2 (Box 2) demonstrates some of these concepts.

These examples help to identify how abnormal function effects gait and may predispose to or aggravate pathology. Whilst video analysis is useful in the diagnosis of these abnormalities, much can be observed by the practised clinician.







NCSP = STJ position + tibial position

Fig. 10 Standing foot positions. Have the patient take a couple of steps on the spot so that they are standing in their angle and base of gait. In this resting position, the angle the heel makes to the ground can be assessed and will be inverted, zero or everted. This is known as the relaxed calcaneal stance position (RCSP; A). If the STJ is then placed into its neutral position, the effect of any STJ or tibial abnormality on foot position can be assessed. This is known as the neutral calcaneal stance position (NCSP; B & C). Structural leg length discrepancy should be assessed in NCSP by palpating and comparing the levels of the anterior superior iliac spines (ASIS), the posterior superior iliac spines (PSIS) and the femoral trochanters. NCSP: removes the compensatory motion of the foot allows assessment of the structural leg length; ipsilateral raise of ASIS, PSIS and femoral trochanter indicates a limb length discrepancy. The degree of discrepancy can be assessed by raising the shorter sides with blocks until the legs are level; raising the shorter side until the patient feels level. If a rotation is observed in this position, this often represents a fixed or blocked problem at the sacro-iliac joint. RCSP: allows compensatory foot and pelvic rotations to occur; a rotation in this position may be due to abnormal pelvic or foot function; a rotation at the pelvis in RCSP, that was not present in NCSP, indicates a functional problem that may well benefit from controlling the foot position.

Some key points to help identify dysfunction include:

- Shoulder drop
  — whilst shoulder drop may be the result of a more proximal problem (e.g. scoliosis, shoulder injury, favoured arm etc.), it may also be the result of a postural imbalance (e.g. altered foot function, leg length discrepancy etc.)
- Spinal curvature
  — as above
- Pelvic postural imbalance
  — once again, this may be the result of spinal position or muscle imbalance; however, foot function and leg length discrepancies may also cause this problem

Fig.11 Functional Hallux Limitus. Reduced dorsiflexion of the 1st MTPJ on walking results in a failure to initiate the windlass mechanism and thus instability of the medial longitudinal arch. The arch remains low with the foot pronated. Possible causes of a Functional Hallux Limitus type gait include: a functional limitation at the 1st MTPJ; inflexibility of the Flexor Hallucis Longus tendon; STJ pronation (e.g. rearfoot varus, medially deviated STJ axis); reduced ankle joint dorsiflexion; leg length discrepancy. Some associated disorders include: pronatory disorders of the foot and leg; chronic postural pain; lower back pain.

- Muscle inflexibility
  — inflexibility of muscles in the pelvis and leg may alter foot function.
- Hip abnormality – internal, external rotation
  — as the foot is affected by the leg position, abnormal foot function may result
- Knee abnormality – varum, valgum, flexion, recurvatum
  — as for hip dysfunction; however, abnormal foot function may cause or exacerbate varus and valgus positions
- Ankle equinus
  — this is generally inflexibility of the calf muscle and will effect foot function
- Forefoot equinus
  — a structural abnormality of the foot affecting function
- Subtalar joint abnormality – varum, valgum
  — as for ankle equinus
- Midtarsal joint abnormality – varum, valgum
  — as above although altered pelvis or leg function, that causes altered rearfoot motion, may result in a positional abnormality of the midtarsal joint. This is generally due to soft tissue adaptation
- 1st ray abnormality – dorsiflexion, plantarflexion
  — as for midtarsal joint
- 1st MTPJ abnormality – static, dynamic
  — this may be due to a structural problem within the joint or a functional limitation as a result of general function
- Arch profile
  — again, an altered arch profile may result in altered leg function and vice versa
- Asymmetrical foot shape
  — this generally represents a postural imbalance and may be the result of proximal or distal abnormalities.

Pressure analysis

Whilst there have been methods of analysing the forces beneath the foot during walking for a number of years, the use of this technology is not widespread, primarily due to the cost of the equipment. In more recent years, the development of systems that allow the transducers to be placed within the shoe has enabled practitioners to analyse the effect of orthoses more directly. Much work is still needed to define normality and, indeed, to interpret the information provided fully but this does represent an exciting area for development.

The key areas that can be evaluated using this technology are:

- The centre of pressure
- The velocity of the centre of pressure
- The force time curve
- Dynamic analysis.

Centre of pressure

As the individual force cells load, the system is able to analyse all of the cells in contact at any one time and provide what is essentially an average or balance point. By repeating this process at each recording the path of this line can be plotted in relation to the plantar aspect of the foot (Fig. 13). By analysing the direction of this path and the speed of movement one is able to gain information about how the foot loads. This can then be used to help decide which type and the position of control indicated. By analysing the velocity with which this point moves throughout the step, analysis of symmetry can be made. If one imagines the two feet as being similar to two wheels turning, then a different speed of progression of the centre of pressure for the two

feet would be similar to the wheels turning at differing rates. This may well be a sign of imbalance and need addressing.

Force/time curve

As the cells load and unload, the total force underneath the foot can be calculated over time. This forms a classic force/time curve which has two peaks broken by a central trough (Fig. 14). This provides information about the way the body is passing over the foot and enables comparison between the two feet. This is perhaps the most useful information as it provides a good indication of the symmetry between the two feet and the effectiveness of the pivotal system. Once again, this can be used to help evaluate the effects of control.

In addition to using these criteria, the pattern of cell loading can be analysed dynamically. This is particularly useful in evaluating how the 1st MTPJ and hallux load from mid stance towards toe-off (Fig. 15).

Dananberg and Guiliano (1999) have demonstrated that 84% of patients with chronic lower back pain, who have been prescribed orthoses that have been designed utilizing this technology, significantly improved. This was almost twice the level expected from standard care and lasted for more than 1 year. This assessment can also be of use in determining patients who are unlikely to benefit from orthoses (Case history 3; Box 3). Thus, evidence of the benefits of this technology are becoming apparent but more research and availability are required.

Methods of control

The essential aim of any device is to facilitate more normal function. Thus, many devices will control or limit abnormal function rather than correct. Correction suggests that, when the device is removed, the abnormal function will have resolved. This is rarely the case.

The simplest form of control is by means of an arch support which can either be fabricated for the patient or supplied on standard insoles. These devices limit lowering of the arch and therefore help control pronation. However, this is a physical support rather than a device that is designated to promote normal foot function. Its use is indicated in some instances, particularly the older patient or in cases where midtarsal subluxation is occurring.

Root et al. (1977) attempted to control the underlying deformity by preventing excessive motion. This was achieved by applying angled wedges (known as posts) beneath the heel and just behind the metatarsal heads in an attempt to prevent excessive motion. A simple way of pitching the nature of control is to visualize the deformity and then fill the gap between the foot and the weight bearing surface so that the foot does not have to excessively move in order to contact the ground. In other words, the control is effectively bringing the ground up to the foot (Fig. 17).

It is interesting to note that many patients benefit from these devices which attempt to place the foot nearer to its neutral position, even though this position is not actually achieved during stance. One possible reason for this may be explained if one considers the method of achieving STJ neutral previously described by the author (Prior 1999). If STJ neutral is more or less achieved when the foot is allowed to hang with gravity, then this is effectively a resting position. By placing the foot nearer to this position, it may well be providing functional rest to the associated structures. Thus, symptom relief may occur even though function is not optimal. This would suggest that the amount of control provided may need to be re-assessed once symptoms subside.

Kirby (1992) has described a method of modifying control in patients with a medially deviated STJ axis. Because the whole of the forefoot is lateral to the axis, any control placed at the metatarsal heads would actually pronate the foot further. Thus, all the control is required at the rearfoot. However, as there is a relatively small amount of the foot medial to the subtalar joint axis the degree of control placed here must be significantly greater to exert an effect. He has therefore described a technique of angulating the inside of the orthotic so that the heel is placed on a slope. This is known as the medial heel skive technique.

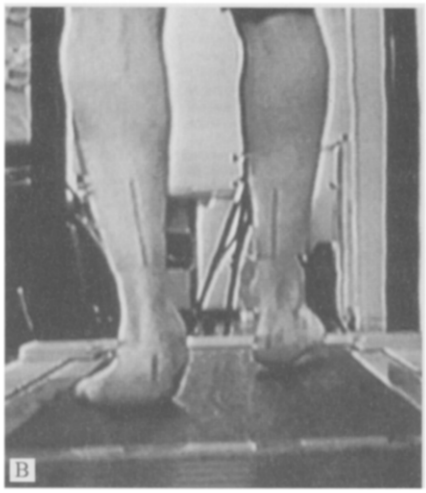
Dananberg has described a method of facilitating normal 1st MTPJ function by allowing plantarflexion of the 1st metatarsal. This technique, known as the kinetic wedge, essentially places a small hollow beneath the 1st metatarsal head allowing, plantarflexion. An alternative method is to place a softer density material in this area, compared to the rest of the forefoot and toes, thus allowing increased plantarflexion.

Types of orthoses

Simple

As the title suggests, these are simple devices whereby the required posts, heel raises, arch supports, etc. are adhered to an insole base which is placed into the shoe. These have the advantage of being quite slim-line and relatively soft.

Another form of this insole involves the use of semi-moulded insole bases, rather like those found in good running shoes, which can have preformed wedges adhered in the appropriate places. These offer an extremely good first line method



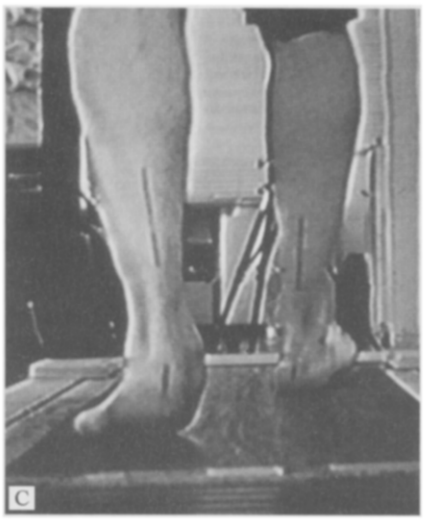


Fig. 12 See Box 2

Box 2 Case history 2

A male patient with chronic ankle and back pain was referred for assessment. He had previously been provided with orthoses to help control excessive pronation. Whilst these had helped, symptoms were still present. Examination revealed the following findings:

- A medially deviated STJ axis on the left side (Fig. 12A)
- Bilateral rearfoot varus
- Bilateral ankle equinus
- A limb length discrepancy (right > left) balanced with a left sided 6 mm raise
- Functional Hallux Limitus.

Video analysis revealed:

- Excessive pronation throughout midstance bilaterally (Fig. 12B) maintained through heel lift (Fig. 12C)
- Functional Hallux Limitus with collapse of the medial longitudinal arch bilaterally (Fig. 12D)
- Early knee flexion and reduced hip extension (Fig. 12E). Note how the swing limb is just about to reach heel strike. The knee and hip should be extended to facilitate efficient hip flexor activity. However, the knee is flexed and the hip is not extended.
- The shoulder on the longer right leg drops on loading (Fig. 12F)
- The shoulders level during stance due to the activity of the quadratus lumborum and gluteals on the left side (Fig. 12G).

As he already had orthoses to help control pronation, heel lifts were placed beneath both devices to compensate for the ankle equinus and an extra 3 mm raise placed beneath the left to partially compensate for the leg length discrepancy. Pressure analysis confirmed that this provided greater equity of the force/time curve although there was still an imbalance. Increasing the extra lift on the left side to fully balance the discrepancy resulted in equal force/time curves for both feet.

Repeating the video analysis revealed a marked improvement in knee and hip extension (Fig. 12H). Furthermore, the patient reported that he was able to walk at a faster speed on the treadmill whilst utilizing less energy. This demonstrates that efficient function was restored. Long term, the patient reported a significant improvement in his symptoms.

Fig. 12 (continued)

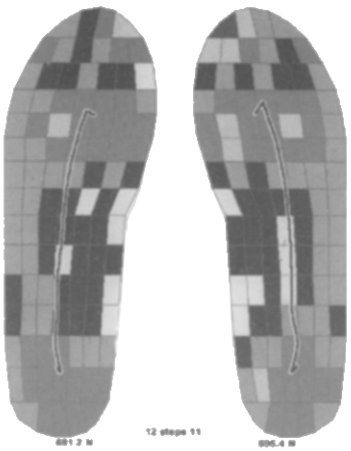


Fig. 13 The centre of pressure line. The centre of pressure is calculated at each scan (50 MHz in this case). This then provides an idea of the direction of force throughout the step.

of control which are cheap and extremely easy to make in clinic. It has been the author's experience that patients who are likely to benefit from orthoses usually have some benefit from these devices in the first instance.

One version of these insole bases has a kinetic wedge incorporated beneath the 1st metatarsal head. Once again, these can have materials added and provide a very good first line of control.

Pre-formed orthoses

There are various types of pre-formed devices which essentially enable more specific control yet are off-the-shelf devices. One type, Formthotics, are full length ethylene vinyl acetate (EVA) devices which can be heated with a hot air gun and moulded to the shape of the foot inside the shoe. Whilst these devices do not provide any basic control it is easy to add control to the device and have the benefit of the mould around the plantar aspect and arch of the foot.

One of the popular types of these devices is made by the Australian Orthotics Laboratory. These devices are once again made from EVA yet incorporate standard control in the rearfoot and forefoot. They are mainly 3/4 length and can be heated inside the shoe to mould to the patient's foot. They are supplied with additional wedges and raises which can further increase the control provided. They come in

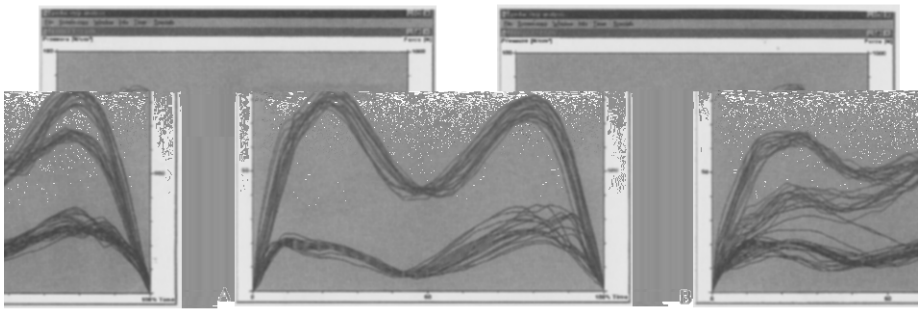


Fig. 14 The force/time curve. The total force beneath the foot is calculated at each scan to provide a force/time curve. This is represented by the upper (lighter) line on the graph and has the two feet superimposed (A), demonstrating symmetry. At heel strike, the centre of mass of the body is falling, thus the force beneath the foot is rising, hence the first peak. As the foot loads, the centre of mass is rising, thus the force beneath the foot is reducing, hence the dip. Finally, towards toe off, the centre of mass is falling again, thus the force beneath the foot is rising again, hence the second peak. In the second example (B), whilst there is a relatively good shape for the curve, there is now some differentiation between the two feet, hence the appearance of more than one curve in places.

various forms and density which can be appropriately chosen depending on the patient's weight, the degree of control required, the activity and the shoe style.

One slightly different version is the multi balance system which provides a semi rigid plastic shell with no basic support. There are then various wedges that can be added to these which are attached in a similar method to Lego®.

These examples are not exhaustive but give an idea of the types of devices and control that can be provided in a simple and cost effective manner.

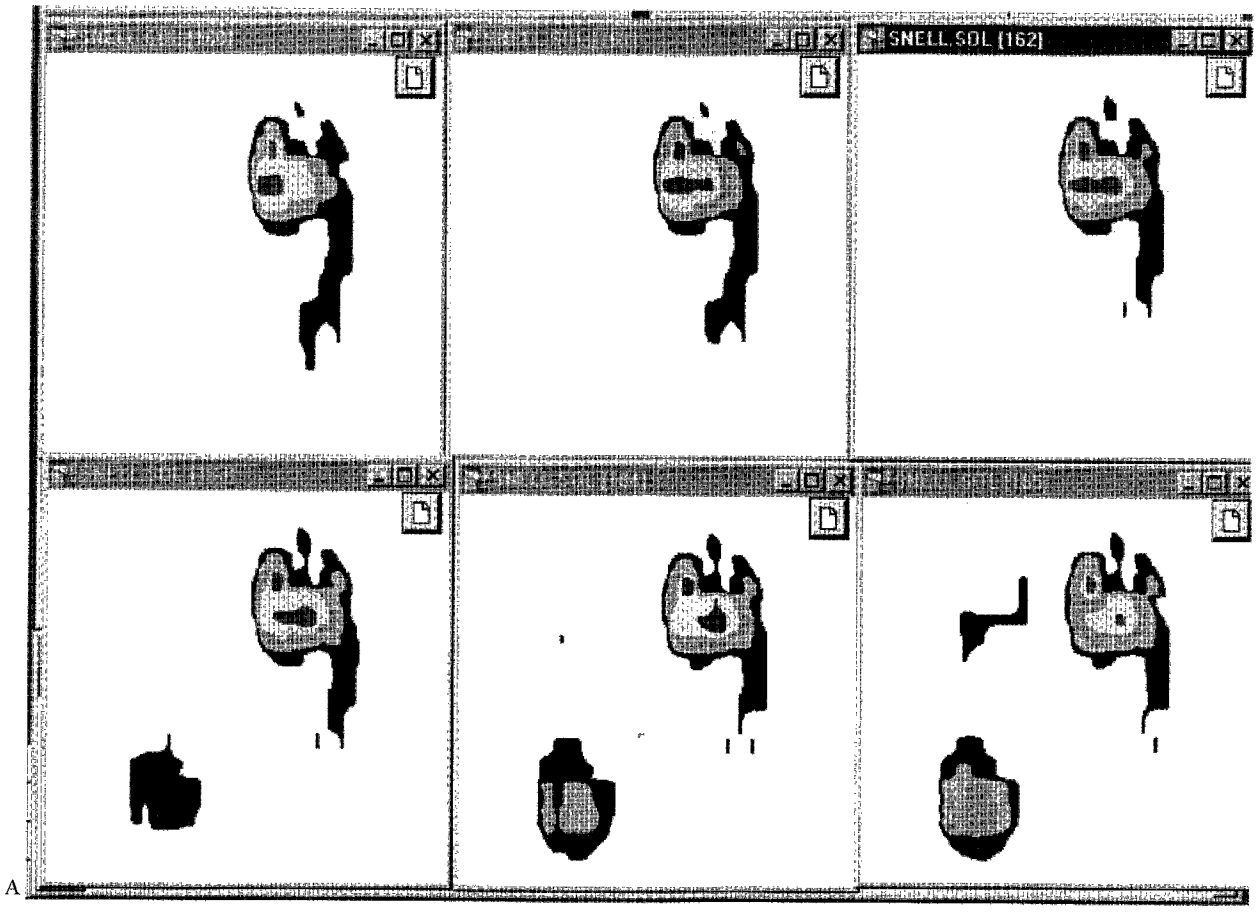


Fig. 15 Dynamic analysis. Analysis of the pattern of loading dynamically can provide information relating to function. In this example (A) the successive frames demonstrate how there is reduced function beneath the 1st MTPJ during latter stance. The weight is transferred to the 2nd MTPJ and hallux, rather than remaining beneath the 1st MTPJ. Orthoses designed to improve 1st MTPJ function are shown to improve loading beneath this area and reduce the transfer to the 2nd MTPJ (B). This patient was suffering from lower back pain and subsequently experienced considerable relief with the orthoses.