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Masterclass

Foot orthotics in the treatment of lower limb conditions: a musculoskeletal physiotherapy perspective

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Abstract

Orthotic therapy is frequently advocated for the treatment of musculoskeletal pain and injury of the lower limb. The clinical efficacy, mechanical effects, and underlying mechanism of the action of foot orthotics has not been conclusively determined making it difficult for practitioners to agree on a reliable and valid clinical approach to their application and indeed even their fabrication. This problem is compounded by evidence suggesting that the most commonly used approach for orthotic prescription, the (Biomechanical Evaluation of the Foot. Vol. 1. Clinical Biomechanics Corporation, Los Angeles, 1971) approach, has poor validity and many of the associated clinical measurements of that approach lack adequate levels of reliability.

This paper proposes a new approach that is based on two key elements. One is the identification, verification and quantification of physical tasks that serve as client specific outcome measures. The second is the application of specific physical manipulations during the performance of these physical tasks. The physical manipulations are selected on the basis of motion dysfunction and their immediate effects on the client specific outcome measures serve as the basis to making an informed decision on the propriety of using orthotics in individual clients. The motion dysfunction also guides the type of orthotic that is applied. Practical case examples as well as generic and specific guidelines to the application of this clinical assessment process and orthotics are provided in this paper.
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1. Introduction

Musculoskeletal pain and injury is a negative consequence of participating in physical activities, such as walking and running, that are frequently prescribed and recommended to aid in preventing or overcoming the diseases of increasingly sedentary lifestyles. Abnormal lower limb biomechanics are often associated with lower limb musculoskeletal conditions (James et al., 1978; Tiberio, 1987, 1988) and the use of orthotics is frequently advocated in their treatment (Sobel et al., 1999). A popular clinical approach to the prescription and fabrication of orthotics is based on the Root et al. (1971) paradigm (McPoil and Hunt, 1995; Lang et al., 1997; Landorf et al., 2001), which in essence is a mechanical approach based on the premise that correct mechanical alignment of the foot and lower limb is required normal function. The clinical corollary of this concept is that the mechanical approach can be used as a basis to prevent or treat musculoskeletal injuries. Interestingly, recent laboratory evidence questions the ability of orthotics to systematically alter mechanical alignment of the rearfoot (Heiderscheit et al., 2001; Nigg et al., 1999; Stacoff et al., 2000), which seriously challenges the validity of the Root et al. (1971) paradigm.

McPoil and Hunt (1995) reviewed the available literature pertaining to the Root et al. (1971) scheme of evaluating and treating foot disorders. They identified serious concerns regarding the ongoing clinical application of this traditional means of prescribing orthotics. Notably, McPoil and Hunt (1995) reported that several underlying suppositions were not reliable or valid. For example, the notion that the subtalar joint neutral position is the position of the rearfoot during mid-stance

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(Root et al., 1971, 1977) was not evident when evaluated in a gait laboratory (McPoil and Cornwall, 1994). In addition, the physical measurements recommended by Root et al. (1977) to evaluate the foot structure and function were found to be unreliable and hence of little utility to the clinician (McPoil and Hunt, 1995). In response to this mounting evidence against the Root et al. (1971) schema for assessment and treatment of foot disorders, McPoil and Hunt (1995) proposed an alternative model for evaluating and managing foot and ankle problems, which they termed the 'tissue-stress model'. In utilizing this 'tissue-stress model' in the assessment and management of foot and ankle problems, they suggested that the objective of the clinical examination was to identify symptomatic tissues that were undergoing excessive stress and then, in a complimentary manner, to include strategies to alleviate this stress in the treatment program. The inclusion of strategies to alleviate the stress in the identified tissues would be in addition to the conventional physical therapy modalities of exercise to treat impaired muscles and electrophysical agents to reduce inflammation and pain. The strategies that are usually used to reduce stress in symptomatic tissues in the lower limb are external physical devices such as orthotics, strapping tape and braces.

A recent survey of podiatrists, a profession that is widely associated with the prescription of foot orthotics, has shown that despite the evidence reported by McPoil and Hunt (1995), the majority of podiatrists still utilize the Root et al. (1971, 1977) schema when prescribing orthotics (Landorf et al., 2001). The recent survey of Landorf et al. (2001) indicates that the 'tissue-stress model' has not been widely adopted in clinical practice. Indeed, a 1997 Masterclass on the static biomechanical evaluation of the foot referred to the Root et al. (1971) scheme as the basis of the physical examination (Lang et al., 1997). One possible reason for this apparently low uptake of the 'tissue-stress model' is that it may not have provided the practitioner with a conveniently pragmatic approach to the prescription and application of foot orthotics that may be viewed as superior to that proposed by Root et al. (1971, 1977). Furthermore, orthotics often impose an additional significant financial burden onto the client. If for no other reason, it would seem that there is a need for a practical and simple approach to the prescription of orthotics by which both the practitioner and client can readily make an informed decision on their application.

A practical, simple yet seemingly effective approach that we have employed in clinic, termed the treatment direction test (TDT), seeks to overcome the impasse that was highlighted in the preceding section. In brief, the TDT is part of the physical examination that addresses specifically the propriety of prescribing and applying orthotics not only for foot and ankle problems, but also for any lower limb musculoskeletal disorder for which there is a putative biomechanical aetiological basis. It is adjunctive and complimentary to the 'tissue-stress model' of McPoil and Hunt (1995), in that it is an additional physical examination procedure. This Masterclass outlines the TDT by describing it in detail and presenting case studies that provide practitioners with exemplars from which to develop and apply the approach in their clinics.

2. Treatment direction test for foot orthotic therapy: generic overview

The TDT consists of a number of iterations of physical activity performed by the client as well as physical manipulations performed on the client by the practitioner. The express aim is to determine the suitability of orthotic devices in the management of the lower limb musculoskeletal condition (Fig. 1). The central feature of the TDT is the identification of physical activities or tasks with which the client has difficulties, particularly tasks that provoke pain and discomfort. Identification of these tasks occurs in the

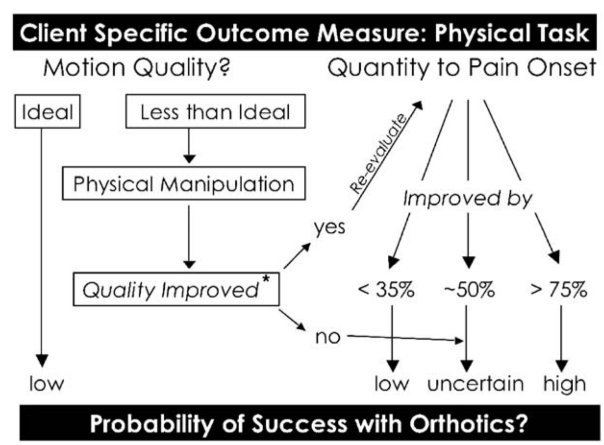


Fig. 1. Flowchart overview of the treatment direction test (TDT) concept designed to enhance the decision making process in orthotic therapy. Note that the key elements are the Client Specific Outcome Measure and the application of a Physical Manipulation. The Client Specific Outcome Measure is usually a physical task that exacerbates the symptoms and is responsible for the client seeking help from the health care professional. The practitioner assesses both the quality of motion and the quantity of motion to the first onset of symptoms. Then by selecting and applying Physical Manipulations (e.g. tape, felt padding), which is specific to the observed motion impairment, the practitioner makes a decision on the basis of this flow chart. Note that to be improved by 75% means that the change from baseline is 75% larger than the baseline measure. For example, if on first assessing the Client Specific Outcome Measure the client could jog for 50 m to first onset of pain, for a positive TDT then the client would have to jog for 87.5 m (i.e. 50 + (75% of 50)) with the specific Physical Manipulation in situ. In practice, the Client Specific Outcome Measure is usually either markedly improved with the Physical Manipulation applied (i.e. no pain with 1000 m jogging) or not.

interview and then verification that the physical activity reproduces symptoms occurs in the physical examination, in most cases at the outset of the physical examination. Following verification that the physical activity is provocative of the client's symptoms, it is essential that the practitioner quantifies the amount of physical activity that is required to bring about the first onset of pain (i.e. a pain threshold test). While doing this, the practitioner also observes the motion of the foot during the physical activity to identify any aberration from normal or ideal motion patterns. In the event that there are aberrant motion patterns, the practitioner then applies specific physical manipulations, which are based on the observed aberrant motions. The foot is, the area of the lower limb to which the TDT will be applied in this Masterclass (noting that TDT concept can be applied to all motion segments of the lower limb). The physical manipulations usually take the form of adhesive strapping tape or temporary felt orthotics. Then, with the physical manipulations in situ, the client is asked to perform the specific pain-provoking physical activities that were previously identified and verified. The TDT is deemed to be positive if there is an improvement in the motion pattern and more importantly if there is a substantial increase of the quantity of physical activity to the first onset of pain (Fig. 1). A positive TDT implies that there will be a positive outcome to orthotic therapy. If there is no change in the amount of physical activity taken to first bring on the pain with the physical manipulation in place, then the TDT is deemed to be negative, meaning that an orthotic is not likely to be successful in this instance. In a practical sense, anecdotal evidence suggests that the likelihood of success with subsequent application of an orthotic is most probably greatest if the improvement in the quantity of physical activity is in the order of 75% of baseline or higher (i.e. substantial improvements). Certainly it would appear logical that if there was only about a 50% change from baseline level (or lower) during the application of the physical manipulation in the TDT it would be likely that there will be a lower level of success with any subsequent application of orthotics.

3. Treatment direction test for foot orthotic therapy: specific application

In dealing with the specific application of the TDT, the following sections will deal with the assessment of patterns of foot motion during gait. The identification of some commonly seen aberrant foot motion patterns and several physical manipulations specific to these aberrant motion patterns will be outlined. Guidelines for orthotic prescription and application, as well as a description of several case studies that will highlight various aspects of the practical application of the TDT will be presented.

3.1. Assessing quality and quantity of the client specific physical activity

To demonstrate a specific application of the TDT, this paper will restrict the physical activity to a walking task. Quantification of the load to pain threshold could then be distance walked, number of steps taken and/or time taken to the first onset of pain. Thus quantification of the task to pain threshold is reasonably simple. The identification of aberrant foot motion during gait is somewhat more difficult and requires a developed observational skill, and if possible, the assistance of a digital video camera by which the motion may be captured and then observed within a slower timeframe. In cases of lower limb musculoskeletal pain in which abnormal pronation has been suggested as a causative factor (Sobel et al., 1999), it is important to observe gait for any deviation from the ideal pattern of motion. A textbook on gait analysis such as that of Perry (1993) is of considerable help when developing higher-level observational skills of motion during gait.

The use of movement diagrams (e.g. Figs. 2–5), in which the x-axis represents time expressed as a proportion of the total gait cycle and the y-axis represents motion, is of considerable value in communicating concepts regarding the identification of aberrant motions. An ideal pattern of motion of the foot during stance phase is shown in a movement diagram in Fig. 2, in which the foot strikes the floor on the posterolateral heel region in a relative neutral position before

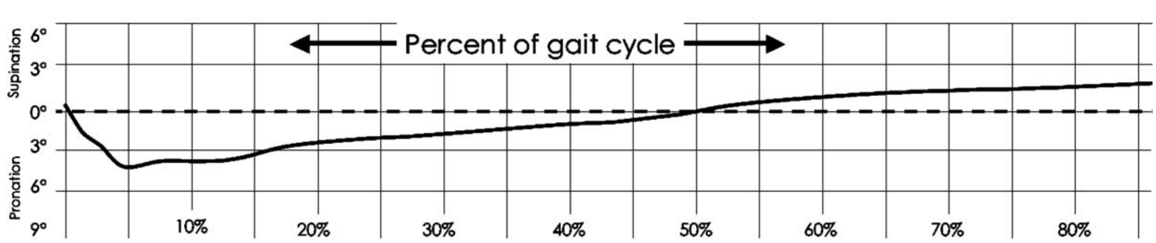
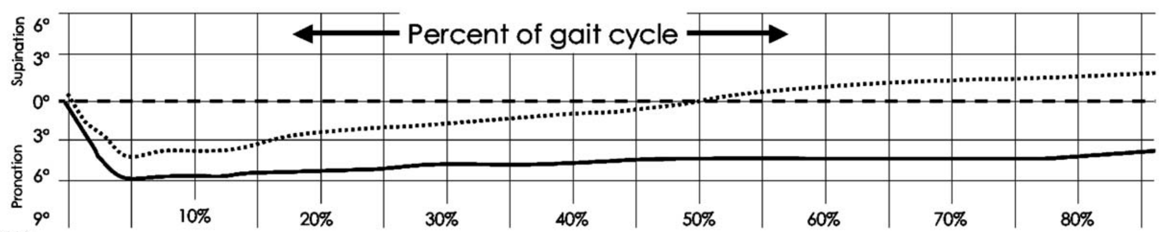
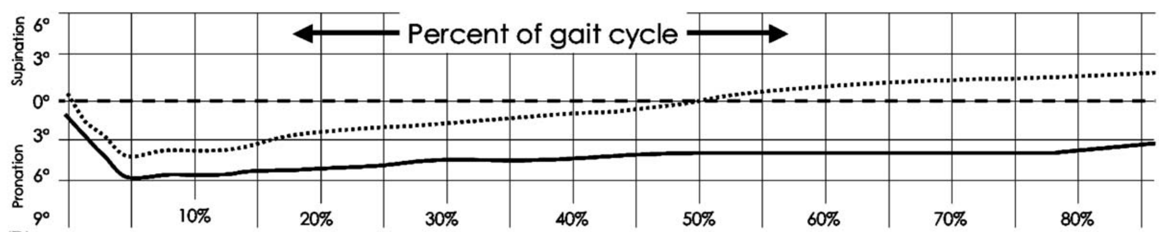


Fig. 2. Movement diagram for the ideal rearfoot motion pattern in the frontal plane (supination-pronation movement of the calcaneum relative to the leg shown on the y-axis representing inversion–eversion, respectively) across time (x-axis, showing temporal characteristics displayed as a percent of total cycle). Adapted from Wright DG, Desai SM, Henderson WH. Action of the subtalar and ankle-joint complex during the stance phase of walking. Journal of Bone and Joint Surgery 1964;46A:361–82.



(A)



(B)

Fig. 3. Movement diagram example of an excessive pronator (continuous line) demonstrating differences from the ideal gait motion pattern of the rearfoot (dotted line). Diagram A shows an ideal contact posture with an initial excessive amount of pronation whereas diagram B shows excessive pronation at contact.

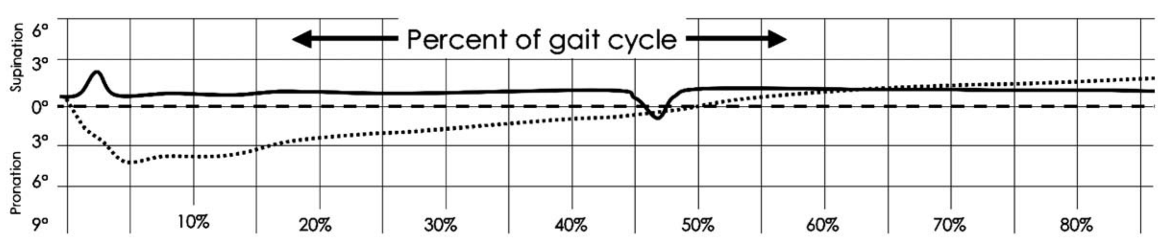


Fig. 4. An example of a supinator pattern of foot motion (continuous line) demonstrating contact in a supinated position followed by a small quick increase in supination soon after. Pronation occurs somewhere later in stance phase and is small and quick. Notice the distinct contrast to the ideal foot motion pattern (dotted line).

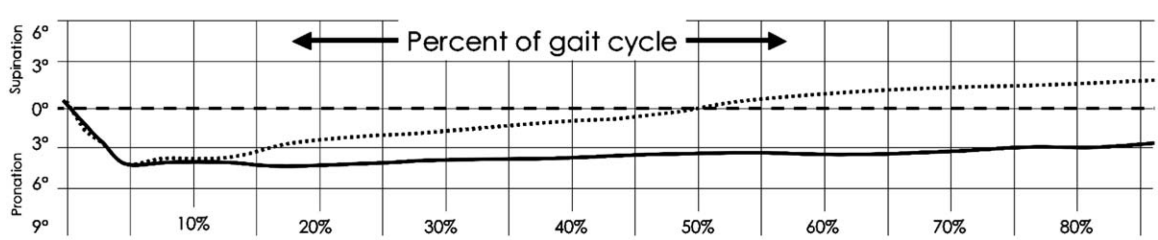


Fig. 5. An example movement diagram of a prolonged pronation motion pattern (continuous line) in which the early stages of stance phase are normal but there is no re-supination during mid-stance. Dotted line is ideal pattern.

undergoing rapid pronation of approximately 3–5° in the first 5–10% of the gait cycle (Perry, 1993). The foot then remains in this position for another 5–10% of the gait cycle before re-supinating towards the middle and end of stance phase.

For lower limb musculoskeletal conditions with a putative genesis in abnormal foot pronation, the identification of non-ideal gait patterns involves observation of the stance phase of gait for both the quantity of pronation (excessive or lack thereof) and also the timing of pronation (early, late). A commonly described abnormality of pronation is excessive pronation, so labelled because the rearfoot undergoes an increased range of pronation during the first part of the stance phase, notably at contact and weight acceptance (Fig. 3). This may or may not be preceded by pronation occurring in terminal swing phase usually observed as floor contact on the medial aspect of the heel.

Another, not so widely described pattern of abnormal pronation is one in which there is not only a lack of pronation but also a markedly different pattern of motion during stance phase. This foot motion pattern during gait is termed a supinator pattern (Fig. 4). This pattern involves a slight but rapid supination (inversion) as its first movement on ground contact and loading such that at foot flat, the rearfoot is relatively inverted to the distal leg and also usually to the floor. This position remains for much of the early part of mid-stance. In those who have some flexibility in their foot, the foot then undergoes a rapid and small amount of pronation in the last part of stance phase, usually at around heel off. The reader will recognize that this is almost opposite to the ideal gait pattern described above and normal patterns reported from kinematic studies.

The previously described motion patterns involve both the initial contact and loading part of stance phase as well as mid-stance through to terminal stance phases of gait. There is also a motion aberration that occurs in mid-stance through to terminal stance, known as prolonged pronation or mid-stance pronation. In this gait pattern the foot motion in contact and loading phases were as for the ideal pattern, but instead of undergoing re-supination the foot remains pronated in mid- to late-stance phase of gait (Fig. 5). This pattern of motion is not to be confused with that which occurs in mid- to late-stance phase of gait in the excessive pronator or supinator patterns of motion, in which there will also be a degree of pronated posture observed.

3.2. *TDT for excessive pronator motion patterns*

There are two basic types of physical manipulations for TDT of excessive pronators, one involving adhesive strapping tape (Hadley et al., 1999; Vicenzino et al., 1997, 2000) and the other utilizing orthopaedic felt (Hadley et al., 1999; Vicenzino et al., 2000). The adhesive strapping tape technique consists of a number of distinct taping techniques that are frequently combined. The most comprehensive form of adhesive strapping tape technique is the augmented low dye, which consists of a modified low dye technique strengthened by addition of reverse sixes and calcaneal slings (Fig. 6 and Table 1). In brief, the augmented low dye is used when there is a requirement to control vertical navicular height (i.e. medial longitudinal arch height), an indirect but reliable and valid measure of pronation (Williams and McClay, 2000), during activities such as jogging for longer than 10 min (Vicenzino et al., 1997). Usually this is restricted to a TDT in the field in which the practitioner has been unable to find an activity that brings on the pain in the clinic (see Table 1: Variations). It is common practice to use as the physical manipulation in the clinic, the minimum amount of tape, such as, 3 reverse sixes or 2 calcaneal slings. Low dye taping may be used where there is localized foot pain, particularly in the arch and heel region where it may be uncomfortable to have the reverse sixes and calcaneal slings passing plantar to the sole of the foot. Full details of this taping technique including indications, contra-indications, research findings summaries and some possible technical variations are shown in Table 1.

The temporary orthotic, constructed of orthopaedic felt or foam, is performed when the taping technique has been shown to relieve pain and improve function. This next stage in the decision making process for orthotic prescription is to evaluate the effectiveness of an in-shoe orthotic device to ascertain if it is as effective as the tape. See Table 2 and Fig. 7 for complete descriptions of the temporary orthotic. In the event that an orthotic, which usually incurs a significant financial burden on the client's behalf, is required in the physiotherapy management of a musculoskeletal condition, it is advantageous to first have demonstrated to the client's satisfaction that an in-shoe device will in practice have the same effect as that of the anti-pronation taping technique. This in-shoe device is usually constructed of a relatively inexpensive orthopaedic felt material, which is easy to customize to the individual. As shown in Fig. 7 the orthopaedic felt is attached to the innersole of the shoe. Key technical points of application of the temporary orthotic are that the distal end of the medial padding should end 5–8 mm proximal to the metatarsal phalangeal joint line. All edges of the padding should be bevelled for comfort and the 'D-shaped' sustentaculum-tali-navicular support pad should commence just proximal to the level of the medial malleolus and extend well past the navicular. It should not be placed in the arch, as this is not an effective location to control pronation. A laboratory study has demonstrated that an anti-pronation temporary in-shoe device was capable of similar mechanical effects, as measured by changes in vertical navicular height, to that of the augmented low dye taping technique described above (Vicenzino et al., 2000).

There is another circumstance in which the temporary felt orthotics may be used and that is when the taping technique produces discomfort or pain at its point of contact with the skin. For example, it is not uncommon for a person who has limited dorsiflexion or a marked forefoot varus to experience pain at the skin–tape interface on the anterior shin region where the reverse sixes and the calcaneal slings anchor.

3.3. *Anti-pronation orthotic application guidelines*

In the excessive pronator foot motion type, it is usual practice to use orthotics that are somewhat inverted (i.e. the angle of the superior surface that contacts the plantar foot surface to the inferior surface of the orthotic that sits on the shoe), often referred to as being varus wedged or posted on the medial side of the device.

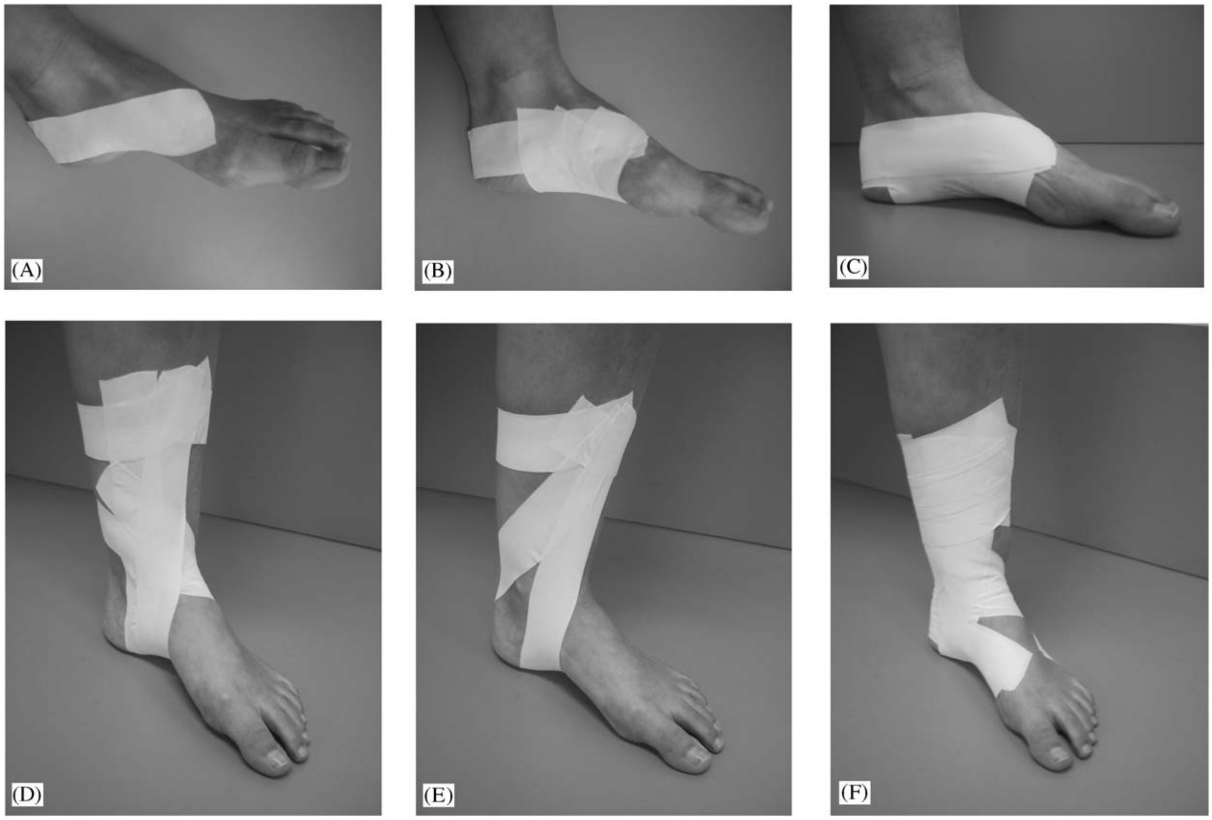


Fig. 6. Sequential images of the augmented low-Dye tape for excessive or prolonged pronator patterns of foot motion, See Table 1 for further detail; (A) Spur tape commences on the medial forefoot proximal to the metatarsophalangeal joint line, wraps around the heel and finishes on the lateral side of the forefoot. This is the first part of the low-Dye technique. (B) Spur and 3 mini-stirrups. The mini-stirrups arise from the lateral side of the spur and end up on the medial side, with each individual mini-stirrup being laid down in a distal to proximal fashion. Usually 4–6 mini-stirrups are required to extend coverage in a distal to proximal manner, to approximately the region of the sustentaculum tali (not shown here). (C) Completed low-Dye taping technique consisting of a spur, 5 mini stirrups and a locking off spur. If an anchor across the forefoot dorsal surface is required, make sure that this is applied in weight bearing. (D) Reverse sixes (2) which start at about the medial malleolus or proximal to it (*not distal to it*) that courses over the anterior ankle, distally down the lateral foot, under the plantar mid-foot and wrapping up under the region between sustentaculum tali and navicular before being laid down on the distal leg to anchor onto the anchor strip located some one third to one quarter the way up the leg. (E) Calcaneal sling commences on the anterior leg at the level of the anchor strip, then courses obliquely distally and across the Achilles tendon and heel region, wrapping under the plantar heel and mid foot regions to then pass up by the sustentaculum tali-navicular regions to anchor off at or close to its origin much like the end part of a reverse six. (F) Augmented low-Dye taping technique consisting of a low-Dye, three (3) reverse sixes and two (2) calcaneal slings.

An example of a pre-fabricated type of an anti-pronation orthotic is the three-quarter length shown in Fig. 8. Pre-fabricated anti-pronation orthotics usually have some degree of varus posting built into the device (e.g. 2–6 degrees) that can be modified by heating (lessen the amount of inversion) or the addition of external rearfoot and forefoot postings (to increase the inversion in the device). The current best level of evidence, which is largely based on laboratory work and not on clinical trials evaluating the efficacy of these types of devices, indicates that it is perhaps the comfort fit of the device and the improvement in performance rather than the effect on the motion that should guide the fitting of the devices (Nigg et al., 1999). Thus, when fitting pre-fabricated orthotics (or custom made orthotics) the practitioner should first fit the orthotic to an acceptable level of comfort and then, once comfortable, the orthotics should be tested in a similar fashion to the TDT explained above. All modifications, whether heating or adding external posts to the device, should be guided by this principle and if it is impossible to make the device comfortable and ameliorate pain and dysfunction, then the client should not be prescribed the orthotic. There are several standard issues to consider in improving the comfort of the device, such as correct sizing (e.g. leading edge ends 5–8 mm proximal to the metatarsophalangeal joint line, lateral border edge) and excessive pressure in the arch areas of the orthotic. The latter is usually remedied by either heat moulding the device and/or by the addition of rearfoot varus or forefoot varus wedges. Once the orthotic is comfortable then the TDT approach of re-evaluating

Table 1
Anti-pronation taping technique. The augmented low dye technique that may be used as a physical manipulation in the Treatment Direction Test. See Fig. 6 for images of tape

Indication:
Pain and dysfunction that exists in a client with an abnormal pronation, either excessive or prolonged.

Purpose and Intent:
To determine if a transient correction of abnormal pronation is associated with a marked amelioration of symptoms and function.

Positioning:

Client	Supine with distal half of lower limb extending off end of treatment table.
Foot	Moderately supinated at the rearfoot with neutral forefoot–rearfoot alignment. The client actively holds this Position.
Therapist	Standing at end of foot with head and torso overhanging the foot.

Taping Techniques and Application Guidelines:
Material:
Rigid adhesive strapping tape 38 mm in width will suit most feet sizes.
Low Dye:

1. *Spur*: commences on the medial side of the forefoot just proximal to the metatarsal phalangeal joint line, while maintaining the rearfoot and forefoot position in the frontal plane, the therapist exerts a slight amount of adduction of the forefoot and plantar flexion of the first ray while laying the tape down on the medial side of the foot and around the heel. The spur then concludes by being laid down on the lateral side of the foot, finishing proximal to the metatarsal phalangeal joint.
2. *Mini-stirrups*: commence on the lateral side of the foot over the spur and course underneath the foot, being careful not to wrinkle the plantar skin, before finishing on the medial side of the foot at the level of the spur. The last portion of the mini-stirrup is laid down while the therapist applies an inversion force to the medial side of the foot with the hand that is not holding the tape. The exception to this is the first mini-stirrup, during which the therapist plantar flexes the first ray. A series of some 4–6 mini-stirrups are applied, commencing distally at a level just proximal to the metatarsal phalangeal joints and moving more proximally with successive stirrups overlapping each previous one by about a half tape width.
3. *Spur lock off*: this tape is exactly like the first one but is used to lock in the ends of the mini-stirrups.

Reverse sixes

4. Anchor strip applied obliquely to a point on the leg approximately one quarter to one third the way proximal to the ankle.
5. *Reverse six*: starts at the medial malleolus or proximal to it (not distal to it) and runs across the front of the ankle distal to the lateral midfoot, under the plantar aspect of the midfoot before coursing up the medial side of foot, ankle and leg to anchor on the anchor strip. It is important to have the final part of the reverse six cover the navicular and sustentaculum tali areas of the mid and rearfoot.

Calcaneal sling

6. Commences on the anterior aspect of the distal leg at the level of the anchor strip, courses distally and posteriorly to wrap obliquely about the Achilles tendon and heel before wrapping underneath the foot (plantarlly).

Lock off tape

7. 3–4 lock of tapes that are exactly the same as the anchor strip but overlay each other by approximately half extend from the anchor strip distally.

Comment:

- Technical issues—It is very important that the position of the foot and ankle is initially obtained and more importantly maintained during the taping technique as failure to do so often results in an inefficient attempt at correcting pronation during gait.
- Ensure that the forefoot is not abducted but rather slightly adducted throughout the taping technique.
- We have shown in a number of studies that this taping technique is superior to others in its effects on arch height, not only immediately after application but also after jogging for 20 min.
- Risk of either allergic reactions to the tape, or excessive skin stress usually as a result of excessive traction, or compression or injury to underlying soft tissues due to excessive compression must be considered during and after the application of the tape, especially if the taping technique is to be in situ for a protracted period of time.
- Always follow contour of underlying body part and soft tissues such that there is even pressure visible under both sides of the tape (widthwise) as failure to do so increase the risk of compression injury to underlying tissues.
- Do not place excessive traction on the tape during its application as this will result in traction stress and possibly injury to the skin.

Variations:

- In some instances, notwithstanding the data in the literature, it appears advantageous to only apply some components of this technique in order to obtain optimal outcomes. For example, is not at all uncommon to use solely reverse sixes or calcaneal slings or low-Dye taping to achieve the desired pain relieving effects.
- If the client is unable to nominate a physical activity that can be reasonably measured in the clinic (e.g., in a runner who runs for 20 min to pain onset), then the anti-pronation taping will need to be applied before the client goes for a run.

Contra-indications:

- Allergic reaction to tape.
- Increased pain with tape in situ

Table 2
Temporary anti-pronation orthotic. See Fig. 7 for illustrations of this technique

Indication:
Pain and dysfunction that exists in a client with an abnormal pronation, either excessive or prolonged.

Purpose and Intent:
To determine if a transient correction of abnormal pronation is associated with a marked amelioration of symptoms and function.

Positioning:

Client	Prone with distal half of lower limb extending off end of treatment table. In Fig. 4 position to allow the following foot position to be assumed.
Foot	Foot perpendicular to floor surface.
Therapist	Sitting at end of foot with head and torso overhanging the foot.

Materials:
Orthopaedic felt with adhesive backing. A thickness of about 5–8 mm seems best to work with. If greater height is needed it can be achieved by layering.

Application Guidelines:
8. Medial footpad (Fig. 7A)

- Approximately measure and cut out a piece of orthopaedic felt length of the foot and approximately one third the width of the foot. Ensure it is oversize.
- Trim the heel end of the pad to the shape of the posterior heel.
- Cut a crescent shape recess into the lateral side of the heel end of the pad to accommodate the heel.
- Trim the length of the pad at its distal end so that it is some 5–8 mm shy of the first metacarpophalangeal joint line.
- Bevel the lateral side of the pad and the distal end for comfort.
- Adhere the pad to the innersole of the shoe.

Sustentaculum tail–navicular pad (Fig. 7B):

- Cut a 'D' shaped bit of orthopaedic felt out making sure it is long enough to cover the area from the medial malleolus to the cuneiforms and wide enough to cover from the medial side of the foot to the cuboid.
- At the heel end of the pad, it is necessary to flatten the curved shape of the 'D'' to accommodate the heel to ensure comfort.
- Lay the pad on the innersole on top the medial footpad so that the lateral extent may be determined and then trim accordingly. Make sure that the finished product does not cover the cuboid.
- Bevel for comfort fir the lateral part of this pad and then adhere it to the innersole over the medial footpad.

Comment:

- Constructing this temporary orthotic whilst observing and fitting to the clinet's foot (as opposed to doing it without the clinet in the room) allows for a customised product with less likelihood of adverse effect.
- Once the padding is adhered to the innersole then place it up against the plantar surface of the foot to check for correct sizing and allowing for any final trimming before initial testing.
- Test the temporary orthotic during gait to ascertain if it is comfortable, if not make necessary modifications by trimming or adding more padding.
- Research has shown that this tecnhique has a similar anti-pronation effect to that of the augmented low-Dye taping technique after 20 minutes of jogging (Vicenzino et al. 2000).

Variations:

- In order to gain better control of excessive pronation it may be necessary to add another medial footpad or a smaller pad on top of the sustentaculum-tali pad.
- If there is only minor prolonged pronation, then the medial footpad may not be needed.

Contra-indications:

- Increased pain with padding in situ, either the client's symptoms or pain induced from direct pressure of the padding.
- Allergic reactions to felt in the past.

the client specific outcome measure is undertaken. Additional, postings may be required at this stage to ensure that the effect is at least the same as for the taping and temporary orthotic.

3.4. Case examples of the excessive pronation TDT applied

Smith et al. (2004) reported a single case of a soccer player with Achilles Tendinopathy in which they demonstrated the application of a TDT. In that case, there was a substantial improvement from 100 m jogging to onset of pain to 1200 m jogging pain free with a single application of several reverse sixes. This improvement was replicated on several occasions and was shown to mirror the improvements gained following the longer-term application of anti-pronation orthotics. This case exemplar was in distinct contrast to an unpublished case study of a triathlete who had a phase III medial tibial stress syndrome of 12 weeks duration (Roy and Irvin,

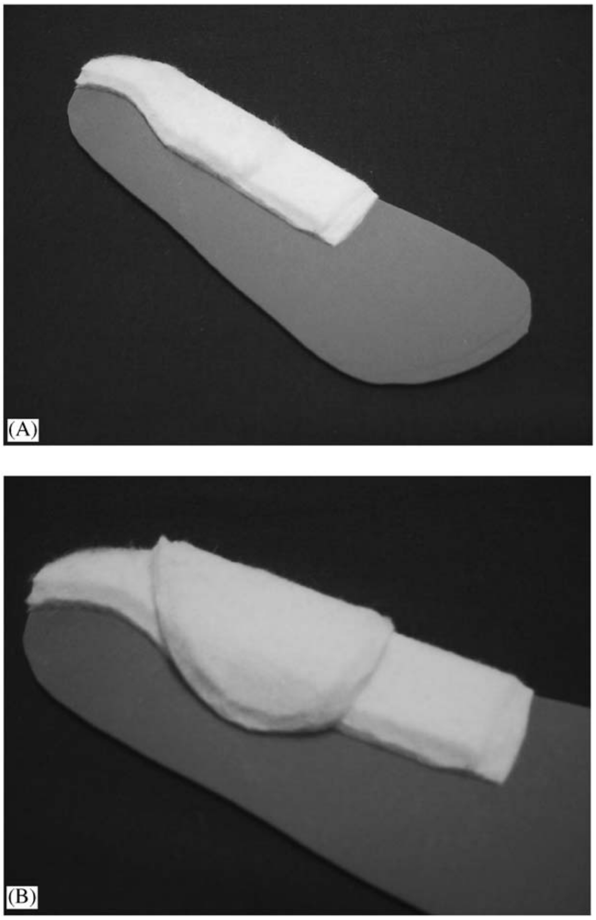


Fig. 7. Sequential images of the components of the temporary anti-pronation orthotic. (A) Medial footpad component of the temporary anti-pronation orthotic constructed of orthopaedic felt adhered to an innersole. (B) Sustentaculum tali—navicular pad overlaid on to the medial footpad to form the temporary anti-pronation orthotic. See Table 2 for further detail.

1983). During jogging this case exhibited excessive pronation and first onset of pain at approximately 400 m of jogging (unpublished case report, Bissett L, O'Meara T, Vicenzino B, 2001). There was no substantial change in the distance jogged to the onset of pain despite a 20% improvement in vertical navicular height with both the application of an augmented low-dye taping technique and pre-fabricated orthotic. That is, there was no improvement following augmented low-dye anti-pronation taping and this was matched by a similar lack of efficacy of a follow up period of protracted use of the anti-pronation orthotic. The improvement in vertical navicular height is commensurate to that reported in several studies of the augmented low-dye technique and temporary orthotic (Vicenzino et al., 1997, 2000), indicating that the lack of effectiveness in influencing jogging distance to pain onset was not due to a lack of mechanical efficacy of the tape or orthotic. These two cases highlight the clinical utility of

Fig. 8. Some examples of three-quarter length off-the-shelf orthotics that are frequently used for conditions associated with abnormal pronation, which are commercially available to practitioners.

the TDT to predict the effectiveness (or lack thereof) of orthotic therapy, but do not constitute sufficient level of evidence to be generalized to the broader clinical context. Further work is required to study the clinical utility of the TDT.

Anterior knee pain of patellofemoral joint origin is another example of a condition that has been reported to be strongly associated with abnormal lower limb mechanics (Williams et al., 2001) and treatment of this condition by the correction of abnormal foot motion with orthotics has been advocated (Eng and Pierrynowski, 1993; Gross and Foxworth, 2003; Saxena and Haddad, 2003), including the use of off-the-shelf prefabricated orthotics (Eng and Pierrynowski, 1993; Sutlive et al., 2004). The ability to predict the outcome following application of orthotics in patellofemoral pain syndrome is an issue that has recently become the focus of several research groups (Gross and Foxworth, 2003; Sutlive et al., 2004). We recently completed a case study of a 30-year-old female with chronic anterior knee pain that highlights the utility of the TDT to predict orthotic outcomes in patellofemoral pain syndrome. In brief, prior to anti-pronation taping, consisting of three (3) reverse sixes and a low-Dye, the client walked down 4 stairs to the first onset of pain, whereas with taping in situ the client was able to walk 62 stairs. This substantial change in client specific outcome measure of pain and function was replicated with the subsequent application of an anti-pronation orthotic of a longer (6 week) follow up period (unpublished data, Shopka B, Yee B, Costanza A, Al-Marooqi Y, Vicenzino B, 2003). That is, the wearing of an in-shoe orthotic device over a protracted period of time ameliorated the anterior knee pain, and most importantly, this success was predicted by the application of the TDT in the physical examination of this client.

4. TDT for supinator motion pattern

There is one predominant physical manipulation for the supinator pattern of foot motion during gait, termed the supinator pad. The supinator pad consists of a piece of foam or orthopaedic felt that is applied to the plantar surface of the foot such that distally it ends approximately 5–8 mm proximal to the metatarsal phalangeal joints, and proximally just distal to the cuboid-metatarsal articulation. Its lateral extent is to the lateral border of the foot and its medial side covers at least the 3rd through 5th metatarsals but not the 1st and 2nd metatarsals. It is shown in Fig. 9 and details included in Table 3. The orthotic that is frequently used in these cases, that is, in the event of a positive TDT, is one that includes the supinator pad in the orthotic. Frequently the supinator pad made of ethyl vinyl acetate (EVA) is simply attached to an innersole of the client's shoes. Alternatively, the supinator pad may be attached to a low density EVA off-the-shelf prefabricated orthotic with only little or no built-in rearfoot varus posting.

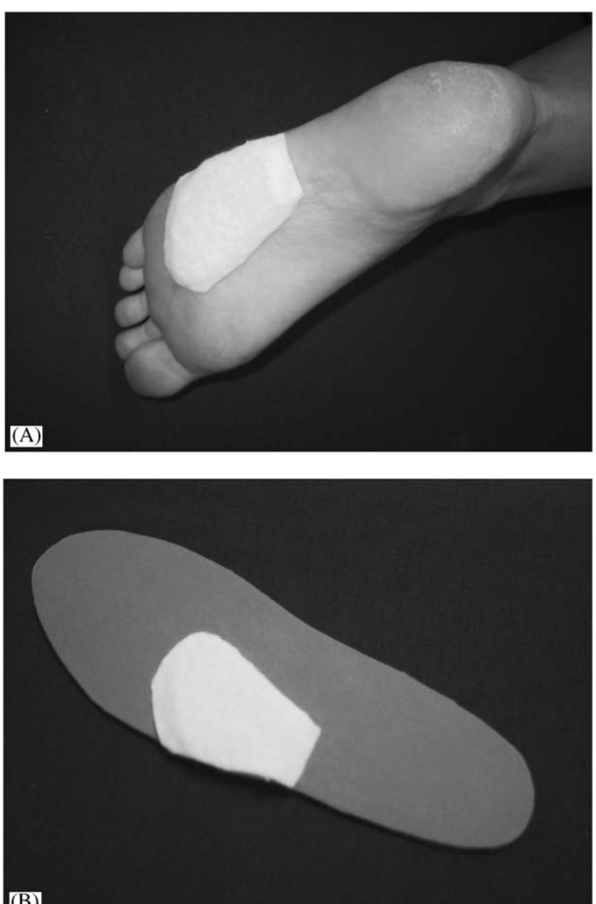


Fig. 9. Physical Manipulation and Orthotic for supinator pattern of foot motion. (A) Supinator pad adhered to the foot as a Physical Manipulation in the Treatment Direction Test. (B) Supinator pad on an innersole as a temporary orthotic. See Table 3 for further detail.

An example of cases that frequently respond favourably to supinator pads are long term or recurrent foot and ankle pain as a result of severe or recurrent ankle sprains in which there is observed a supinator pattern of foot motion during gait. An exemplar case was a patient with diffuse mid-foot pain following several ankle sprains in a period of approximately 24 months in which the acute phase seemed to settle but resulted in the client experiencing disabling pain when walking down stairs and on uneven or sloped surfaces. Several programs of conventional physiotherapy over the preceding 18 months, consisting of sensori-motor re-training (i.e. 'proprioceptive'), had limited impact on this pain and dysfunction, despite showing improvement in balance tasks. At the initial physiotherapy session, on using the TDT for supinator gait pattern it was noted that walking down stairs was pain free, where it had been previously disabling. A simple 4° forefoot supinator pad was fashioned from an off the shelf orthotic addition (Vasyli Forefoot Valgus wedge) and applied to the innersole of the client's shoe with the result being a long lasting improvement in pain and function. This apparently effective management by a simple orthotic was predicted by the application of a TDT in the physical examination. The TDT provides an advantage over other skeletal alignment approaches to orthotic prescription in that it directly assures the client during the practitioner–client interaction of the propriety of applying an orthotic in this specific situation and also by guiding the practitioner in the management of the client's problem by providing individualized data to work with from that client.

5. TDT for prolonged pronation motion pattern

The TDT for prolonged pronation is similar to the excessive pronation. However it should be noted that this motion pattern is difficult to differentiate from normal gait and in some cases from mild cases of supinator type motion patterns, requiring the practitioner to first select either the anti-pronation or supinator TDT approach and then if found not to be suitable to swap to the alternative motion dysfunction TDT. Although this does seem to protract the length of the physical examination somewhat, it would leave the client and the practitioner with little doubt about the appropriateness of proceeding with orthotic therapy or not.

6. Integration of orthotic therapy approach into clinical practice

Other findings on physical examination, such as, muscle tightness and weakness (e.g. of the foot, calf, thigh and hip musculature), and reduced motion of the talocrural, sub-talar and metatarsal-phalangeal joints should also be addressed once the effect of the orthotic

Table 3
Supinator pad

Indication:
Pain and dysfunction that exists in a client with a supinator motion pattern of the foot.

Purpose and Intent:
To determine if a transient correction of abnormal pronation is associated with a marked amelioration of symptoms and function.

Positioning:

Client	Prone with distal half of lower limb extending off end of treatment table. In Fig. 4 position to allow the following foot position to be assumed.
Foot	Foot perpendicular to floor surface.
Therapist	Sitting at end of foot with head and torso overhanging the foot.

Materials:
Orthopaedic felt or foam with adhesive backing. A thickness of about 5 mm seems best to work with. If greater height is needed it can be achieved by layering.

Application Guidelines:
- Cut out a piece of material so that it fits on the lateral plantar surface of the foot, covering the 3rd–5th metatarsals, ending about 5 mm proximal to the metatarsophalangeal joints and commencing about 5 mm distal to the cuboid-metatarsal joint. Taper the proximal end of the pad in towards the cuboid (Fig. 9A), that is, so that the pad does not cover the lateral cuneiform.
- As a physical manipulation adhere the pad to the skin (Fig. 9A).
- As an orthotic, the pad is attached to the innersole or two an off-the-shelf orthotic (Fig. 9B).

Comment:
- It is important to fashion the pad whilst being able to see and feel the foot so that accurate size of the pad is obtained.

Variations:
- If the effect on motion and symptoms is not satisfactory then modify the length proximally of the pad and/or increase its thickness by laying on another 5 mm layer. Felt has the advantage of allowing fine adjustments through the addition or removal of small layers as the need requires.

Contra-indications:
- Allergic reaction to felt
- Increased pain with tape in situ

has been ascertained. It is sometimes the case that full amelioration of all symptoms occurs only after the selective application of exercises and manual therapy is used in conjunction with orthotic therapy. Clinical examination findings and a clinical reasoning process, that is based on prioritizing physical findings and systematically addressing these findings guide the selection of the exercises and manual therapy.

7. Conclusion

The TDT is a simple pragmatic and practical clinical approach to solving the dilemma that confronts the practitioner who manages clients with lower limb musculoskeletal disorders for which there is a putative aetiological basis in abnormal motion patterns of the foot during gait. It is an adjunctive process to the physical examination that seeks to guide the practitioner in deciding if an orthotic is likely to succeed. Importantly, it does not replace but rather complements the conventional comprehensive clinical examination performed by musculoskeletal physiotherapists.

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