1998

An Overview of Compensatory Pronation at the Subtalar Joint and Orthotic Correction

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AN OVERVIEW OF COMPENSATORY PRONATION AT THE SUBTALAR JOINT AND ORTHOTIC CORRECTION

by

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Bachelor of Science in Physical Therapy
University of North Dakota, 1997

An Independent Study

Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Physical Therapy

Grand Forks, North Dakota
May
1998

This Independent Study, submitted by Jacy Greff in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

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PERMISSION

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Department	Physical Therapy
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ACKNOWLEDGMENTS

I would like to thank my parents for being the two most wonderful, supportive, and loving people I know. You both are a blessing. I would also like to thank Mike for being my rock and making me laugh when I didn't feel like laughing. You are my best friend and I love you.

ABSTRACT

Excessive compensatory pronation at the subtalar joint is a common foot disorder that affects a large population of people. It is a disorder that stems from a wide variety of causes including both congenital and acquired as well as intrinsic and extrinsic factors. Excessive compensatory pronation is also the cause of many other disorders which may affect not only the foot but other joints including the knee, hip, and back. The scope of this study will focus on acquired pronation and its causes as well as the proper orthotic choice and prescription to best treat the problem.

This literature review will discuss the anatomy and biomechanics of the foot, paying particular attention to the subtalar joint as compensatory pronation usually occurs at this joint. It will also discuss various acquired causes of subtalar joint pronation. This review will provide information on material characteristics and patient characteristics that must be considered in order to prescribe the correct orthotic. Studies discussing the effectiveness of treating excessive pronation with orthotics will also be presented.

CHAPTER I

INTRODUCTION

The foot is an extremely complex structure that provides a dynamic connection between the body and the ground. It provides both a rigid lever for propulsion and a mobile adapter for shock absorption. Both of these functions are necessary for normal gait. Any alteration in the normal alignment of the bones, ligaments, or muscles of the foot may alter the ability of the foot to perform these functions effectively. The alignment of the structures of the foot also affects the functioning of the entire lower extremity and spine. For these aforementioned reasons, correct alignment of the foot is vital. Foot orthotics are increasingly becoming recognized as an important consideration in the treatment of lower extremity dysfunctions which are related to alignment and mechanical problems.[1,2]

One of the most common problems resulting from incorrect alignment in the foot is abnormal or excessive subtalar joint pronation. Abnormal pronation at the subtalar joint may be thought of as a compensation for an alignment problem in either the foot or somewhere else in the lower extremity.[3] Abnormal pronation may be the result of congenital, acquired, or neuromuscular disorders.[3,4] Orthotic therapy may be used for any of these deformities.

Orthotics serve to help the foot function properly. The orthotic may be thought of as bringing the floor to the foot, thereby eliminating the need for compensatory pronation at the subtalar joint.[5]

When prescribing orthotics certain key factors must be kept in mind. One of these factors is the characteristics of the materials utilized to fabricate the orthotics. The other key factor is the characteristics of the patient for whom the orthotic has been prescribed. Both of these factors must be considered in order to provide the most effective orthotic possible.

This literature review will discuss the anatomy and biomechanics of the foot in an effort to present the reader with a general basis of understanding. The acquired causes of abnormal pronation of the subtalar joint will be presented along with some of the structural and functional changes that occur in the presence of abnormal pronation. General information about orthotics will be presented including material and patient characteristics that are important when prescribing orthotics. The effectiveness of orthotic therapy for the treatment of abnormal pronation will be discussed at the end of this literature review.

The purpose of this literature review is to discuss abnormal pronation at the subtalar joint in detail focusing on the normal and abnormal biomechanics of the foot as well as the various acquired causes of abnormal pronation and the use of orthotics to control this dysfunction. Due to the fact that physical therapists will be called upon to treat patients presenting with this disorder, this information will be of value to them.

CHAPTER II

THE ANATOMY OF THE FOOT

The foot contains 26 bones which contribute to its many diverse requirements.[6] Some of these requirements include providing a stable base of support for the body during various weight bearing activities, providing a rigid lever for push off during ambulation, minimizing rotational forces brought about by more proximal joints of the lower extremity, providing shock absorption as the foot hits the ground, and allowing the foot to adapt to changing surfaces on which it is placed.[6] Due to these requirements, the joints of the foot must be both mobile and stable.[7]

The joints of the foot include the subtalar joint, the midtarsal joint, the tarsometatarsal joints, the metatarsophalangeal joints, and the interphalangeal joints. Basically, the foot can be divided into three sections: the rearfoot, midfoot, and forefoot. The rearfoot is comprised of the talus and the calcaneus which make up the subtalar joint. It is responsible for the conversation of torque of the lower extremity. All of the transverse rotations of the lower extremity are converted into frontal, sagittal, and horizontal motions at the rearfoot. It also has a tremendous influence on the movements and functions occurring at both the midfoot and forefoot.[8]

There is variation in the literature regarding the bones that constitute the midfoot. For the purpose of this study, the midfoot will be described as containing the navicular, cuboid, and three cuneiforms.[9] The midfoot is responsible for the transmission of movement between the rearfoot and forefoot. It also provides stability to the foot.[8]

Variation in the literature regarding the bones of the forefoot also exists. For the purpose of this study, the forefoot will be described as containing the five metatarsals and the phalanges.[9] The forefoot is partly responsible for adapting to the changing ground during ambulation. The ability of the forefoot to accomplish this task is directly dependent on the normal mechanics of the rearfoot.[8]

The rearfoot, midfoot, and forefoot all function together as a unit. Movement at one joint in the complex most certainly will influence movement of the other joints in this complex. Due to this fact, abnormal compensatory pronation at the subtalar joint will undoubtedly cause abnormalities to occur throughout the foot.[8]

The movements of the foot occur around three primary planes of motion. These planes of motion may be described as frontal, sagittal, and transverse. Inversion and eversion occur in the frontal plane, plantarflexion and dorsiflexion occur in the sagittal plane, and abduction and adduction occur in the transverse plane. All these motions occur to some degree in all three planes of motion simultaneously meaning these motions are considered to be triplanar in the foot.

Pronation is actually a combination of abduction, dorsiflexion, and eversion, while supination is a combination of adduction, plantarflexion, and inversion.[8]

Due to the fact that pronation and supination occur primarily at the subtalar joint, this joint will be discussed in the greatest detail. The subtalar joint is the joint formed between the calcaneus and the talus.[6-11] This joint, in most individuals, consists of three articulations including a posterior, anterior, and middle facet.[6-8,10,11] Of the aforementioned facets, the posterior facet is the largest and possesses its own joint capsule. The anterior and middle facets share a joint capsule which also includes the talonavicular joint.[7] Due to the fact that the subtalar joint possesses these articulations, smaller amounts of combined articular surface area exists and therefore less motion is available.[11] When the subtalar joint is stressed in supination, an osseous block is created by the colliding of the anterolateral articulation of the talus with that of the calcaneus. When stressed into pronation, congruency of the three articulations occur thereby limiting further motion. These actions allow the subtalar joint to possess a functional locking mechanism which provides a "uniquely human trait that allows for improved bipedal ambulation."[11]

The axis of motion of the subtalar joint lies approximately 42° to the transverse plane and 23° to the sagittal plane[6,7,10] (Fig. 1). Much variation exists in humans with respect to the axis of the subtalar joint; however, the ranges generally lie between 20° to 68° in the transverse plane and 4° to 47° in the sagittal plane.[6,12] Despite the location of the axis, it does run anteriomedially from the neck of the talus to the posteriolateral portion of the calcaneus. Motion

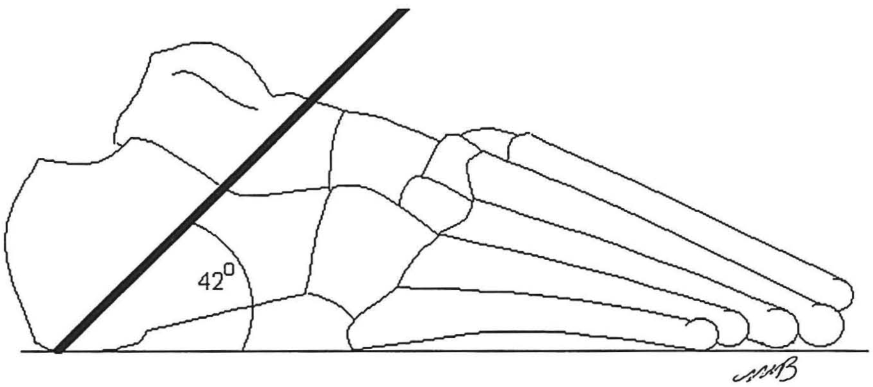

Figure 1: Subtalar joint axis of rotation 42^{o} from the horizontal.

at this axis is triplanar and allows for nearly equal amounts of frontal and transverse plane motion.[8,11] Due to the fact that the axis generally lies very close to the sagittal plane, there is only limited amounts of plantarflexion and dorsiflexion present during the triplanar motion of pronation and supination.[11]

The subtalar joint is extremely stable and is supported by equally strong ligaments. A ligament known as the interosseous talocalcaneal ligament lies within the tarsal canal which is a funnel-shaped tunnel that is formed by concave grooves between the inferior talus and the superior calcaneus. This ligament is extremely strong and checks eversion or pronation. A smaller ligament, known as the ligamentum cervicis, lies lateral to the interosseous talocalcaneal ligament in the tarsal canal. This ligament checks inversion.[6] The medial collateral ligament and lateral collateral ligament of the ankle also cross the subtalar joint thereby providing additional support to this joint. The posterior and lateral calocalcaneal ligaments also provide support to the subtalar joint by checking inversion.[6,7]

The muscles which act at the subtalar joint to help bring about the motion of inversion/supination include the gastroc-soleus complex, plantaris, popliteus, tibialis posterior, flexor digitorum longus, flexor hallucis longus, and the anterior tibialis. The muscles generally responsible for eversion/pronation at the subtalar joint include the peroneus longus, peroneus brevis, peroneus tertius, and he extensor digitorum longus.[7]

The midtarsal joint involves the articulations of the talonavicular and calcaneocuboid joints.[6,8,9] These two joints together provide an S-shaped joint line that serves to divide the rearfoot from the midfoot and the forefoot. Due to the fact that the navicular and cuboid are fairly immobile, motion at this joint comes from movement of the talus and calcaneus on the navicular and cuboid.[6,7] This joint is considered to have two independent axes of motion (Fig. 2). The first is the longitudinal axis which is considered to be nearly horizontal. Movement around this axis is triplanar and produces both supination and pronation. As this axis is nearly horizontal, the inversion and eversion component tends to predominate. The second axis is the oblique axis which also provides the triplanar motion of supination and pronation. Along this axis, the dorsiflexion/plantarflexion and abduction/adduction components predominate. Motion at this axis appears to be more restricted than that of the longitudinal axis.[6]

The foot must function both in weight bearing and propulsion; therefore, a high degree of stability is required. The foot must also be mobile enough to allow it to adapt to various surfaces during standing and ambulation. The foot is given mobility by the various bones and joints of the foot. Due to this mobility, the foot requires arches to help it bear weight. The arches of the foot are designed to help provide absorption and distribution of body weight during changes in weight bearing conditions and ground surfaces.[6,10]

The foot is generally thought to possess two arches that are not present at birth but rather develop as a response to weight bearing. One arch is named the longitudinal arch. It runs form the posterior calcaneus to the metatarsal heads. This arch may be divided into two separate arches, the medial and lateral. The

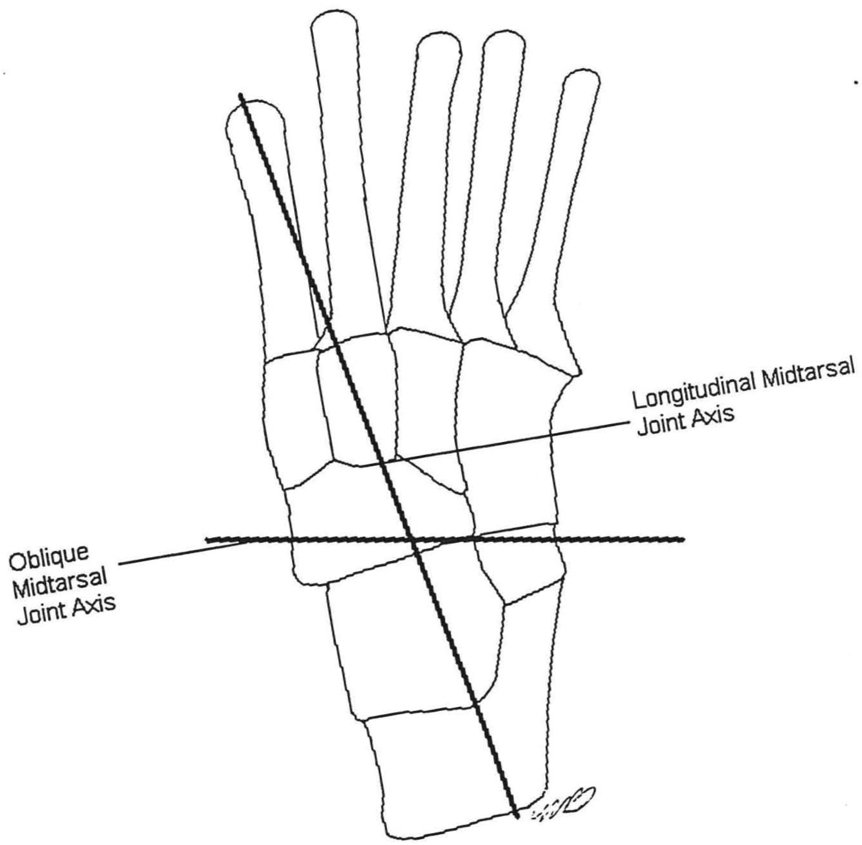

Figure 2: Midtarsal joint axes

medial side is the highest and generally thought of as the most important arch in maintaining the stability of the foot.[6,10]

Another arch contained in the foot is the transverse arch. This arch runs at a 90° angle to the longitudinal arch and is found at the level of the tarsals and metatarsals.[6,10]

The arches are maintained by many factors. One such factor is the shape of the various foot bones in conjunction with how they are arranged. This mechanism alone cannot prevent the arches from collapsing. The arches are also supported by ligaments and muscles. The main supporting ligaments include the plantar calcaneonavicular (spring) ligament, the long plantar ligament, the plantar aponeurosis, and the short plantar ligament. Of these ligaments, the plantar calcaneonavicular (spring) ligament seems to be the most important. This ligament provides support to the talonavicular joint and also serves to check the motion occurring at joints that contribute to the flattening of the arch.[6]

CHAPTER III

BIOMECHANICS OF THE SUBTALAR AND MIDTARSAL JOINTS

The foot provides a necessary dynamic connection between the body and the ground.[13] The function of the foot is extremely complex partly because it involves motion around triplanar axes.[14] The foot serves two major functions; one being a mobile adapter and the other being that of a rigid lever arm. These functions are a necessity for normal gait. When weight is applied to the foot, it pronates thereby becoming a mobile adapter. During this time, the foot allows for accommodation to various terrain and also provides shock absorption. When the foot begins to supinate, it becomes a rigid lever in order to propel the body forward.[13-17]

The subtalar joint is described as a hinge joint with an axis that runs downward, posterior, and lateral. Due to the orientation of this axis, triplanar motion results providing supination and pronation.[13] This joint plays a key role in the conversion of the foot from a mobile adapter to a rigid lever arm during the phases of the gait cycle.[17] The subtalar joint is responsible for converting all rotatory forces of the lower extremity which occur during the gait cycle into frontal, sagittal, and horizontal motions at the rearfoot. The various mechanics that occur at the subtalar joint directly dictate the movements which occur at the midtarsal joint and the forefoot.[7]

The midtarsal joint can be described as a plane or gliding joint between the hindfoot and the midfoot.[13] This joint possesses two axes of motion which may act independently of each other but both of which are directly dependent on the motion at the subtalar joint. When the subtalar joint moves into pronation, the midtarsal joint moves into pronation. This motion causes the two axes of the midtarsal joint to become more parallel thereby allowing this joint to become more mobile or "unlocked." As the subtalar joint moves toward supination, the midtarsal joint moves toward supination also. This causes the axes of the midtarsal joint to converge which creates a more rigid forefoot as the midtarsal joint becomes "locked."[13,16]

The gait cycle describes human locomotion. One full gait cycle is described as the time period between the initial heel strike of one foot and the following heel strike of the same foot.[18] The gait cycle is divided into two phases. One phase is described as stance phase and is comprised of heel strike, foot flat, midstance, heel off, and toe off. The other phase is the swing phase which consists of acceleration, midswing, and deceleration.[16,18,19] For the purpose of this paper, only the subtalar and midtarsal motions occurring during the stance phase will be discussed in detail.

At the initial moment of heel strike, the subtalar joint is slightly supinated. After initial heel strike, as the foot moves into foot flat, the subtalar and midtarsal joints begin to pronate. The talus begins to adduct causing the axes of the midtarsal joint to become more parallel. Due to the adducted position of the talus with respect to the calcaneus, the midtarsal joint remains flexible distal to the navicular and cuboid bones. This flexibility allows for shock absorption and terrain adaptation. By the end of foot flat, a “normal” foot has reached its maximum pronated position.[13,16,18,19]

Following foot flat, the point of midstance is reached. During this period, the foot is converted from a mobile adapter to a rigid lever needed for propulsion. In order to make this conversion possible, the subtalar joint begins to supinate. The talus begins to abduct which in turn causes the axes of the midtarsal joint to converge. This motion causes the midtarsal joint to “lock,” meaning the forefoot locks against the hindfoot at the calcaneocuboid joint. This creates a rigid lever for propulsion which is a necessary component for normal gait. At this point, if continued movement into subtalar supination or midtarsal pronation occurs, stress will overwhelm the restraining ligaments and sublux the calcaneocuboid joint.[13,16,18,19]

Following midstance, the foot moves into the propulsion period which begins at heel off and ends at toe off. During this period, the subtalar joint continues to supinate towards a neutral position. The midtarsal joint continues to stay “locked” allowing the foot to function as a rigid lever necessary for propulsion.[13,16,18,19]

CHAPTER IV

ABNORMAL PRONATION

Pronation of the hindfoot with respect to the forefoot is a common disorder experienced by many.[3,12] Abnormal pronation is a compensation, usually at the subtalar joint, resulting from a deformity in either the soft tissues or osseous structures in the foot, ankle, knee, and/or hip.[3,4,9,12] The deformity of abnormal pronation may be either rigid or flexible. A rigid deformity is described as a foot that remains in a pronated or "flattened" position when the individual is non-weight bearing. A flexible flatfoot is identified by the reappearance of an arch when the foot is non-weight bearing. This is by far the most common of the two.[4,9]

Not only is abnormal pronation divided into a flexible or rigid deformity, but it may also be congenital, acquired, or secondary to neuromuscular disease. Congenital means to be born with or to be present at birth. This may result from either genetic factors or form the position of the fetus in the womb. A few examples of congenital deformities include convex pes valgus, tarsal coalition, congenital metatarsus varus, and talipes calcaneovalgus.[3,4]

Acquired flatfoot means that the deformity or dysfunction developed once weight bearing began. This type of abnormal pronation may be described as either intrinsic or extrinsic to the foot and ankle. A few examples of intrinsic causes include trauma, ligament laxity, bony abnormalities of the subtalar joint, forefoot varus, forefoot supinatus, rearfoot varus, and ankle joint equinis. Extrinsic causes include rotational deformities of the lower extremity and leg length discrepancies.[3,4,20] For the purpose of this paper, only the aforementioned acquired deformities will be discussed in detail.

Intrinsic Deformities

Traumatic flatfoot can be described as trauma to the tibialis posterior tendon which is an important stabilizer of the rearfoot. This tendon has the responsibility of preventing eversion deformities in the rearfoot. When this tendon ruptures, the calcaneus will move into an everted position. This motion can be described as the subluxing of the calcaneus under the talus.[4]

Ligament laxity can also cause abnormal pronation due to the fact that laxity of the ligaments within the foot will decrease the support to the medial arch. The ligaments of concern include the short and long plantar ligaments, the spring ligament, and the plantar aponeurosis. When these structures have sufficient tensile strength, good joint congruency and alignment will be present. If sufficient tensile strength is not present, the medial arch will not be fully maintained and pronation may result.[4]

Bony abnormalities of the subtalar joint create problems with congruity between the talus and calcaneus. The anteriomedial facet and posterior facet are of utmost importance for normal pronation. The anteriomedial facet is of particular importance when discussing the support of the head and neck of the talus. If this particular facet is unable to support the head and neck of the talus, the talus may be pushed into excessive plantarflexion and adduction (abnormal pronation) when the forces of heel strike are encountered.[4]

Forefoot varus is by far the most common intrinsic deformity leading to abnormal pronation at the subtalar joint. Forefoot varus is an osseous deformity in which the forefoot is in an inverted position with respect to the rearfoot when the subtalar joint is in neutral. It is a frontal plane deformity that is compensated at the subtalar joint by eversion of the calcaneus in weight bearing.[3,4,16,20] The calcaneus must evert to get the condyles of the calcaneus on the ground during stance. Once this happens, the subtalar joint must continue to pronate in order to get the first ray on the ground which is necessary for propulsion.[16]

Some common signs and symptoms associated with a forefoot varus deformity include the presentation of a low medial arch during both weight bearing and non-weight bearing. The heels will be everted during stance. The presence of a marked callus under the second, third, and sometimes the fourth metatarsal heads along with a "pinch" callus under the distal medial aspect of the proximal phalanx of the involved metatarsal may also be observed. Hammering of the fifth digit is also usually present along with hallux abductovalgus. The patient may also experience heel pain, medial achilles peritendinitis, hypermobility of the ankle and knee, and sciatica.[21]

Forefoot supinatus is a soft tissue deformity which occurs at the midtarsal joint. This deformity causes the forefoot to supinate.[4,16,20] Forefoot supinatus is often attributed to contracture or spasm of the anterior tibialis muscle. The subtalar joint is forced to pronate in order to bring the forefoot to the floor and increase weight bearing of the first ray.[4,16]

Rearfoot varus can be described as a frontal plant deformity in which the heel is held in varus neutral.[4,20] It will result from any deformity of the lower extremity that causes the heel to strike the ground with greater than two degrees of inversion.[20] Due to the fact that the heel will contact the ground in an inverted position, the calcaneus is forced to move to a more vertical position. This movement of the heel from a varus to a vertical position causes the subtalar joint to pronate.[4]

Some common signs and symptoms associated with rearfoot varus include a mild to moderate callus formation under the second and third metatarsal heads. This is due to the fact that the first metatarsal is unable to bear weight effectively. Exaggerated wear along the lateral border of the shoe may also be noted. Patients may also present with retrocalcaneal bursitis, morning heel pain, hammering of the fifth digit, chronic myositis, or tendinitis of the musculature responsible for decelerating subtalar joint pronation. Other symptoms associated with this deformity include stress fractures of the distal tibia, medial retropatella arthralagies, pes anserine bursitis, and greater trochanteric bursitis.[21]

Ankle joint equinis is described as a general lack of dorsiflexion of the ankle joint while the subtalar joint is held in neutral. This lack of dorsiflexion is considered equinis if the ankle possesses less than ten degrees of dorsiflexion. The most common cause of equinis is generally thought to be decreased flexibility of the gastroc-soleus complex. Compensatory pronation will occur at the subtalar and midtarsal joints to allow dorsiflexion to occur and the foot to clear the floor during ambulation.[4,16,20]

Extrinsic Deformities

The two most common extrinsic deformities that tend to cause compensatory pronation are rotational deformities of the lower extremity and leg length discrepancies.[3,4] Rotational deformities may be further divided into deformities of the thigh and lower leg. An example of a rotational deformity of the thigh is femoral anteversion or medial femoral torsion. This particular disorder produces an in-toeing gait. If this condition persists beyond the age of four or five, compensations throughout the lower extremity will most likely occur. This deformity may lead to the development of external tibial torsion of 22° or more. This development serves to help decrease clumsiness and stumbling during ambulation which occurs with an excessive in-toeing gait. The increased tibial torsion tends to cause an increase in stress to the medial aspect of the foot. This increase in stress in turn causes calcaneal valgus, plantarflexion and adduction of the talus, or abnormal compensatory pronation to occur.[4]

Tibial torsion deformities, either internal or external, are transverse plane deformities. These deformities present as excessive anterior or posterior displacement of the medial malleolus in reference to the lateral malleolus. Internal tibial torsion is described as having an angle of malleolar torsion of less than two degrees while external tibial torsion has an angle of malleolar torsion greater than 20°. Both the above mentioned deformities cause problems with the alignment and function of the bones in the foot. As a result of these problems, compensatory pronation at the subtalar joint occurs.[4]

Leg length discrepancies can be divided into either functional or structural. Structural deformities are true anatomic differences in the length of the bone; i.e., femur, tibia, or both. On the other hand, functional deformities are those due to joint contracture or muscle imbalances. In either instance, biomechanical compensation occurs at the subtalar joint. The subtalar joint on the side of the long limb will pronate in an attempt to shorten the leg.[4]

Structural and Functional Changes that Occur with Abnormal Pronation

Abnormal pronation is a compensation for a soft tissue or osseous deformity.[3,4,12] It should be remembered that compensatory pronation occurs in addition to the normal amount of pronation necessary for ambulation.[4] During the gait cycle, maximum pronation should be reached at foot flat which occurs after approximately 25% of the stance phase is complete. At this point, midstance is reached and the foot should begin to supinate to prepare for propulsion. With excessive pronation, the foot remains in maximum pronation at midstance and may remain so past 50% of the stance phase. The foot resupinates late in stance or possibly not at all. Due to this fact, the foot is unable to effectively absorb the forces of weight bearing. The foot loses its ability to be an effective lever and shock absorber.[3,4]

The first ray is also affected by excessive pronation at the subtalar and midtarsal joints. When the subtalar joint pronates, the talus is forced to adduct and plantarflex. This causes the midtarsal joint to become mobile which in turn increases the mobility of the first ray. This results from the fact that the cuboid, which acts as a pulley for the long peroneal tendon, loses much of its mechanical advantage because it is no longer stable. The long peroneal tendon attaches to the base of the first metatarsal and therefore provides stability to the first ray. Once the pulley system is compromised, the peroneal tendon can no longer stabilize the first ray and a hypermobile first ray is created. When this happens, the first ray loses much of its weight bearing and propulsion functions, the second and third metatarsals are overloaded and calluses form at their bases.[5,9,12]

Individuals with excessive pronation also may suffer from bunions. The additional valgus stress at the first metatarsophalangeal joint, which is present with excessive pronation, tends to create a hallux valgus situation. As the metatarsals spread apart, the pull of the flexor muscles in a straight line causes a bunion to form.[5,9]

Several structural changes occur due to abnormal pronation. One such change is the reduction of the medial arch. The lowering of the arch can cause a slight reduction in the length of the limb as well as an increase in the stress on the plantar ligaments and plantar aponeurosis. These forces can cause micro tears, pain, and inflammation to this area.[3,9,12]

Structural changes may also occur at the plantar surface of the calcaneus, where the plantar aponeurosis attaches proximally. When the tensile stress to the plantar aponeurosis increases, which occurs with excessive pronation, a periostitis occurs. This can lead to a heel spur or outcropping I this area.[12]

The knee is also affected by abnormal pronation. When abnormal pronation exists, the knee may assume a valgus position. This tends to increase the lateral pull on the patella which may eventually lead to patellofemoral tracking dysfunctions. Pain at the knee is not uncommon with excessive pronation.[9,12]

Other structural changes that occur with excessive pronation include a valgus position of the calcaneus, a bulging of the navicular tuberosity in a medial direction and abduction of the forefoot on the rearfoot. The tibia also tends to move in an anterior and medial direction, creating an internal rotation of the talus. The angle of inclination of the calcaneus also tends to decrease which in turn decreases the height of the calcaneus.[3]

Abnormal pronation affects many structures both intrinsic and extrinsic in the foot. These changes can result in deformity, dysfunction, pain, and also affect the function of the foot. The ability of the foot to act as a mobile adaptor, shock absorber, and rigid lever arm are significantly reduced.[3,5,9,12]

CHAPTER V

ORTHOTICS

The foot is a very important and critical part of the lower kinetic chain. It serves many functions via its complex design, including the dissipation and distribution of kinetic forces during the stance phase of the human gait cycle.[22] When the foot is unable to function properly, many problems may arise both intrinsic and extrinsic to the foot. Due to the fact that the mechanics of the foot play such an important role in the mechanics throughout the lower extremity, treatment of foot disorders is very important.[1]

Foot orthotics are increasingly becoming recognized as an important consideration in the treatment of lower extremity dysfunctions which are related to alignment and mechanical problems.[1,22] An orthotic may be defined as a device that helps the foot to function in a more "normal" manner. It does this by limiting potentially harmful subtalar and midtarsal joint motion.[1,22,23] In the case of excessive pronation, the orthotic may be thought of as bringing the floor to the foot, thereby eliminating the need for compensatory pronation.[5] The orthotic serves to realign the foot in relation to the supporting surface thereby reestablishing a normal propulsive pattern.[24] This means the orthotic does not structurally change the flatfoot deformity, rather it serves to help prevent accommodation for this deformity.[22]

The use of orthotics is based on a theory that if the foot is kept in a neutral position throughout the support phase of gait, this will keep the pronatory and supinatory motions within a normal range, thereby abnormal compensations will be kept to a minimum or optimally eliminated.[25]

Indications for orthotic therapy include the following: to decrease impact forces, to cushion the foot, to relieve pressure and pain, and to prevent compensation for biomechanical abnormalities.[24] The only contraindication to orthotic therapy is the use of rigid orthotics with patients who present with such diseases as diabetes or peripheral vascular disease due to their decreased sensation.[24] The goals of orthotic therapy are listed in table 1.[26-28] The criteria orthotics must meet in order to be considered effective are listed in table 2.[29]

Table 1.—Goals of Orthotic Therapy

1. Support the foot in a desired position and redistribute weight bearing patterns for comfort and protection.
2. Provide relief to pressure sensitive plantar areas to decrease pain under bony prominences.
3. Decrease plantar shearing forces.
4. Support or balance the joints of the foot in the position most desirable for weight bearing.
5. Correct functional deformities.

Table 2.—Criteria Needed for Orthotic Effectiveness

1. The orthotic must conform precisely to all contours of the foot, especially the heel, calcaneal, and forefoot inclinations.
2. The orthotic must be rigid enough to maintain the shape, contour, and angular relationships of the foot.
3. The orthotic must control abnormal motion, allow normal motion, and provide proper sequencing and timing of motion.
4. The orthotic must be able to withstand stress and wear.
5. The orthotic must be comfortable to ensure compliance.
6. The orthotic must be adjustable.
7. The orthotic must end proximal to the weight bearing surfaces of the metatarsal heads.
8. The orthotic must be narrow enough to fit on the shoe last and allow the first and fifth rays to function independently.

The anatomy of the orthotic consists of a shell or module and the posts. The shell is the body of the orthotic and it conforms to the plantar contours of the foot. The posts are the corrective portion of the orthotic; they serve to bring the ground to the foot and place the subtalar joint in neutral. They are placed on the forefoot or rearfoot portion of the shell.[29]

Orthotics may be described as being soft, semi-rigid, or rigid. A soft orthotic is usually made from leather, cork, rubber, soft plastic, or plastic foam such as plastazote, PPT, aliplast, and sorbothane. They have many advantages over semi-rigid and rigid orthotics including the fact that they are inexpensive, quick to construct (often done in office), are extremely comfortable with a short adjustment period, and require very little equipment to fabricate. This type of orthotic is usually used for accommodative purposes such as for ischemic, insensitive, ulcerated, and arthritic feet. They serve to provide increased cushioning for shock absorption, decrease plantar surface shearing, and to relieve pressure intolerant areas. They may also be used as a temporary orthotic to determine whether a permanent orthotic is necessary.[5,25,26,28,30,31]

Soft orthotics may also be used to control abnormal motion in cases of mild biomechanical abnormalities. Although their effectiveness for this purpose has been questioned, a study by Eng et al[32] found that soft orthotics do help control abnormal motion. In this study, ten females ages 13 to 17 years were chosen. The criteria were for each to demonstrate a forefoot varus of greater than six degrees, a calcaneal valgus of greater than six degrees, and patella femoral pain. Thirty strides of walking and running on a treadmill were recorded both with the soft orthotic and without the orthotic using an optoelectronic recording technique. The range of motion of the talocrural, subtalar, and knee joint were measured in each plane of motion. Results found that the use of the soft orthotic decreased the range of motion of the talocrural and subtalar joint by one to three degrees in both the frontal and transverse planes. The range of motion in the knee was decreased in the frontal plane during both the contact and midstance phase of walking. The average posting in all the orthotics was 2.2 degrees in the rearfoot and three degrees in the hindfoot. This study demonstrates that soft orthotics may be used to help control abnormal motion in the foot.[32]

Semi-rigid orthotics are usually constructed from rubber, leather, cork, and flexible plastics such as polyethylene, polypropylene, and polyvinyl chloride. They attempt to provide the support of a rigid orthotic while remaining more flexible. These orthotics have the ability to flex under unusual forces and are therefore less likely to break or crack than a rigid orthotic. Fabrication of these orthotics requires the use of a neutral cast. They may be used to provide some comfort but are more commonly used to help control abnormal motion. Semi-rigid orthotics are particularly useful in sports and other situations where correction is required under high impact loading. Some disadvantages are that they tend to be more expensive than soft orthotics, require more equipment and time to fabricate (must be sent to a lab), and are often thicker than rigid orthotics.[2,25,26,28,30,31]

Rigid orthotics are usually made with hard plastics and acrylics, such as Rohadur. They are the most durable and supportive of all the orthotics. They are designed for biomechanical purposes meaning they serve the purpose of limiting or controlling abnormal compensatory foot motion. They allow the patient's foot to function as closely to "normal" as possible.[5,25,26,28,30,31] For example, in a mobile flatfoot which does not become rigid for propulsion, a rigid orthotic may be used to support the foot and allow it to resupinate in late stance for propulsion.[23] These devices are fabricated from a neutral cast. They tend to have decreased shock absorption abilities; therefore, it is recommended that they be worn with a shoe that has a good resilient sole to provide cushioning to the foot. Due to inflexibility, rigid orthotics tend to be used for everyday activities such as walking rather than sports; however, use during sporting activities is not always avoided.[28]

Material Characteristics

When deciding which material to use in orthotic fabrication, it is necessary to have a basic understanding of the physical properties of the materials which are generally used. The composition and molecular arrangement will ultimately determine the material's physical properties, such as its response to heat and cold, hardness, durability, flexibility, compressibility, and resilience.[23] The following section will briefly describe certain key characteristics of the materials used in orthotic fabrication.

Stress, strain, and stiffness must be considered when selecting which material to use for the fabrication of the orthotic. The stress of a material may be described as the "force per unit area that develops in response to an externally applied load." The strain may be described as "the amount of deformation that occurs with loading." The stiffness of a material is "the ratio of stress to strain measured within the range where deformation is reversible and proportional to stress."[2,33]

Hardness is another important characteristic which should be considered. Hardness is measured by indenting the material with some type of spherical object and then grading the indentation. The scale used to grade hardness runs from 0 to 100 with 0 being the softest and 100 being the hardest.[2,33]

Other important characteristics to consider are the material's compression properties and its viscoelastic behavior. Generally speaking, a compressed material will deform and the degree of deformation is considered its compressional strain. Its elastic recovery is the extent to which a material will return to its original form once the deforming force is removed. A material's response to a deforming force and its recovery are time dependent. This means that when a constant force is applied, a gradual increase in deformation takes place. This property is known as creep. The amount of deformation present after recovery is the set. Both of these factors play a role in a material's durability or its ability to withstand changes over a period of time.[2,33]

When designing an orthotic, two major requirements must be met. The first is that "the materials used should not remain in service beyond the limits prescribed by functional or aesthetic requirements."[2] The second requirement is that "the materials should not fail, rupture, or deform within their scheduled lifetime."[2] When prescribing orthotics, it is important to keep in mind that each of the materials used in fabrication possess unique characteristics which will make them desirable in certain situations and not desirable in others.[34] Due to the fact that knowledge of each material's characteristics is necessary to determine which will serve the patient's purpose best, a brief description of the characteristics of the most common materials will follow.

The majority of orthotics used today are derived from plastics.[35] They exhibit a number of characteristics which make them ideal for fabrication.[2] They are synthetically produced by the polymerization of natural raw materials creating a high molecular weight material. It is the orientation of these polymers which give plastics their unique qualities. These polymers are divided into two groups depending on their geometric configuration. The first group is the thermoplastics and the second group is the thermosets.[2,33]

Thermoplastics possess a linear configuration, giving them the ability to be remolded upon heating.[2,33,35] These materials exhibit interesting responses to extremes in temperature. The glass transition temperature is the "point at which the molecular state of the material changes from a liquid to a solid form."[33] The melt transition temperature is the "point at which the material exists in equilibrium between the molten and crystalline state."[33] When exposed to low temperatures, the molecules behave like rigid units, but when exposed to high temperatures, enough energy is produced to permit motion with increased amplitude of the molecules. This increase in motion makes the material remoldable.[2,33,35]

Acrylic is one type of thermoplastic material used in the fabrication of orthotics. Acrylics are comprised of polymers of methyl methacrylate which are completely translucent. This material is stable to outdoor weathering and will not discolor or degrade in the presence of ultraviolet radiation. It is durable, strong, and very rigid. It is one of the most rigid materials used in orthotics today; therefore, it is usually used when rigid control is necessary.[2,33]

Rohadur is a common acrylic used in orthotic fabrication. It demonstrates many favorable characteristics, such as the ability to alter its shape when reheated, it is grindable, it has good shape retention, and it is extremely strong. Rohadur tends to be bulky due to the fact that the thickness to stiffness ratio needs to be increased. Because of the rigidity of this material, it must be thicker in order to prevent breakage. Due to this fact, a patient's shoe must be deep enough to accommodate an orthotic made from this material. The thickness sometimes interferes with patient compliance so this must be kept in mind when prescribing orthotics. Other examples of acrylics include thermolyte, polydor, Eroplex O, novoplast, and flexidur.[33,35]

Polyolefins are another example of thermoplastics. These materials are comprised of solid polymers of unsaturated hydrocarbons. Polyolefins may be further divided into polypropylene and polyethylene. Both exist under the glass transition temperature. Polypropylene is derived from the polymerization of butadiene. It is more grindable, softer, and less brittle than the acrylics. It is resistant to breakage and becomes more flexible with decreased thickness. It has a higher density than polyethylene; therefore, it has a higher degree of elastic recovery or shape retention.[33,35]

Polyethylenes are polymers derived from ethylene oxide. They are less dense than the polypropylene and, therefore, have somewhat poorer shape retention in comparison. Other than this fact, they possess very similar properties. Subortholene, ortholene, and vitrathene are examples of polyethylene.[35]

Vitrathene, which is a polyethylene sheet, is a low density material which is produced by the compression of ethylene in the presence of very high pressures. Polymerization of this material takes place following compression in the presence of very high temperatures while using a force radical catalyst. It is remoldable once heated due to its thermoplastic properties. It is strong, fairly flexible, has a high resilience to compression, and is lightweight. It has negligible water absorption and poor creep properties. It is usually used in the fabrication of rigid or semi rigid orthotics.[2]

Thermosetting materials are characterized by highly cross linked polymers which form a three-dimensional network. Unlike thermoplastics, these materials are not able to be softened and reshaped via reheating because they possess a network configuration. These materials are generally not used alone, but rather in conjunction with other reinforcing materials (composites).[2,35]

Composites are a family of materials made up of thermosetting resin which are reinforced with fibers, such as fiberglass or graphite. They were created to meet the needs of those individuals requiring thin, strong, lightweight materials. The combination of the resin and the reinforcing fibers produces a much stronger material than either would be alone. These materials are ideal for applications in which high strength to weight, stiffness to weight, and stiffness to thickness ratios are required. These materials possess the properties of low coefficient of thermal expansion, good strength, and resistance to corrosion and fatigue. One disadvantage is that they are unable to be reheated and reshaped once forms. This is due to the nature of the thermosetting component.[33,35]

TL-2100 (TL-61) is an example of a composite used for the fabrication of orthotics. This material consists of two layers of carbon graphite and an acrylic core. Using acrylic core makes this composite rather unique because it has the ability of being remolded in the presence of heat. This combination also gives this material the ability to offer the rigidity and shape retention of Rohadur while managing the problem of brittleness and breakage.[33,35]

Foam materials are also used in the fabrication of orthotics. These materials may be further divided into open and closed cell. Open cell foams possess air-filled pockets which communicate with adjacent pockets. An example of this type of material is open cell polyurethane foam. This material is produced by casting a reactive urethane mixture to a desired thickness. It is a pressure absorbing material which makes it ideal for top covers. It may be described as soft, resilient, and protective.[2] It is also easily grindable and has good memory.[33] Polyurethane foams may also be used for forefoot extensions and orthotic fillers.[33]

Closed cell cross linked polyethylene foam is another example of a foam material used in orthotic fabrication. It is referred to as closed cell because it has no communicating air-filled chambers. These materials come in different densities which will dictate their use. High densities are usually used for orthotic shells. Low densities are generally used for top covers which provide protection for plantar lesions. These materials are moldable and possess softness and elasticity. One disadvantage of this type of material is that they do tend to have poor shape retention over time. Some examples of polyethylene foams used in orthotic fabrication today are plastizote, pelite, and aliplast.[33,35]

Different types of expanded rubbers are also used in orthotic fabrication. These, like foams, may also be open or closed celled. Closed cell rubbers consist of a mass of rubber or synthetic rubber with many small pockets of nitrogen gas. They generally have good shape retention and installation. They are most commonly used for soft tissue pathologies.[2,33]

Open cell rubbers are made up of a mass of honeycombed rubber with interconnecting cells. They provide improved evaporation and heat dissipation in comparison to closed cell rubbers. They also have good shape retention as evidenced by the fact that once a force is removed, the cells of the mateiral refill with air and it springs back to its original shape.[2,33]

Reinforced leathers are another type of material used in orthotic fabrication. They are usually reinforced with felt, elastic, cork, or rubber. These leathers possess the benefits of workability and softness. They do, however, have the disadvantages of poor shape retention, wear resistance, and durability. For these reasons, they are generally used in the fabrication of soft orthotics or as a top cover.[35]

Patient Characteristics

When prescribing orthotics, a knowledge of the patient's characteristics is just as important as a knowledge of the characteristics of the various materials used to fabricate the orthotics. Patient related factors which are important determinants of orthotic prescription include diagnosis, age, weight, activity level, and shoe style.[33]

The patient's diagnosis is generally the starting point for orthotic prescription. It is an important determinant when deciding which material and type of orthosis is most appropriate. For example, a rigid orthosis is most advantageous for patients whose problems are related to biomechanical abnormalities (excessive pronation).[33] Patients with decreased sensation in the foot should stay clear of rigid orthotics. This example demonstrates the need for the clinician to be aware of all diagnoses whether they are primary or secondary.[24]

The weight of the patient is an extremely important factor when prescribing orthotics. Vertical forces applied to the orthotic are directly proportional to the weight of the patient; the heavier the patient, the greater the vertical forces applied to the orthotic during weight bearing. This results in a rapid and greater deformation of the orthotic in a heavier set individual. In order to present breakdown of the device, the strength of the orthotic may be increased by using thicker and denser materials for the shell or by laminating additional layers of materials to the area of the medial arch.[33]

The age of the patient must also be considered. Special attention should be given when prescribing orthotics to children and to the elderly. In children, the clinician must determine if the child has developed a proper heel to toe gait as this is necessary for the orthotic to function properly. When prescribing orthotics to the elderly, it is important to observe any atrophy of the fat pad. If atrophy has occurred, forefoot extensions and the use of a foam type material for the shell may be indicated.[33]

The patient's activity level should be noted. Athletes generally have special needs. Those who participate in sports that require a lot of jumping or side-to-side motion need orthotics which are flexible and resist forces on impact. These orthotics must also be durable enough to resist all vertical forces without giving out, undergoing fatigue fractures, or rapid deformation. Polyolefins, foam materials, and the use of a top cover are most commonly used for these individuals.[33]

The shoe style is also very important. Shoes without heel counters, such as sandals, generally do not allow the orthotic to function as it should. When fitting an orthotic into high heels, a thinner material, such as fiberglass or composite materials, should be used as there is generally less room in these shoes. Generally speaking, the outcome of orthotic therapy is dependent on how the shoe and the orthotic function together. For this reason, a good supportive shoe should be chosen.[33]

Posting Principles

As mentioned earlier, posts are the corrective part of the orthotic.[29] Rearfoot posts, as their name would imply, are placed on the rearfoot position of the orthotic shell. They are designed to alter the position of the subtalar joint from heel strike to midstance. A medial or varus post will cause the calcaneus to invert, thereby controlling eversion of the calcaneus and bringing it closer to a neutral position. This action will allow the subtalar joint to pronate "normally" (approximately four degrees). The rearfoot post must control but not eliminate pronation as a certain amount is necessary for gait. The maximum rearfoot post is usually between five to six degrees. If the post is much larger, other problems may arise.[22]

Forefoot posts are designed to support the forefoot deformity by bringing the ground to the metatarsals which reduces or eliminates the need for the subtalar joint to pronate excessively (compensate). These posts are indicated when the forefoot deformity creates problems during the propulsive phase of gait. Full correction of the forefoot deformity is not always necessary. Generally, a 60% correction is sufficient. The maximum forefoot post is between six to eight degrees. Again, beyond this point, other problems may arise.[22]

Common Examples of Orthotic Use

Forefoot varus is the most common deformity leading to abnormal pronation at the subtalar joint. In order to treat this disorder properly, a negative impression of the foot is taken with the subtalar joint held in neutral. This impression is then sent to a lab for fabrication. A rigid or semi-rigid shell is molded from the impression. A wedge or post is placed on the distal medial aspect of the shell. This post should be sufficient enough to bring the sagittal bisection of the rearfoot to vertical.[36]

If the forefoot varus is greater than four degrees, then further action may be taken. In this instance, a compressible post is usually added to the base of the toes. This post is actually a continuation of the forefoot post which extends beneath the metatarsal heads and ends at the base of the toes. This extension is usually made of a flexible material, such as rubber or leather, so as not to limit dorsiflexion of the metatarsophalangeal joints.[36]

In the instance of forefoot varus, a forefoot post serves to prevent compensatory pronation at the subtalar joint. It allows the foot to enter the propulsive period with all of the necessary joints locked and stable. This serves to create a rigid lever arm for propulsion.[36]

Rearfoot varus is another common deformity that results in excessive subtalar pronation. Treatment of this disorder begins with neutral casting and a rigid or semi-rigid shell is then fabricated from the cast. The shell is usually designed to end just prior to the metatarsal heads. A varus post is placed under the medial foot which will act to bring the floor to the foot. The goal of the orthotic is to decrease the need to compensate at the subtalar joint. This is accomplished by designing an orthotic that accurately accommodates the deformity. A well made orthotic does not shift the bony structures, but rather it serves to custom contour a surface that will allow for uncompensated movement.[36]

In the event that an individual would present with both a rearfoot and a forefoot varus deformity, orthotic therapy may still be used. The first step would be to take a neutral impression which accurately captures the forefoot deformity. An orthotic is then designed to control both the rearfoot and forefoot deformities. The forefoot is posted to bring the rearfoot to vertical. After this, a rearfoot post is added to tilt the entire orthotic in a lateral direction. It is also possible to use only one post instead of two; in this instance, the needed forefoot and rearfoot post angles are added together. A post of this size is then added under the medial forefoot.[36]

CHAPTER VI

ORTHOTIC RESEARCH

Various studies have been done to determine if the use of orthotics is an effective means of treating pain, discomfort, and faulty biomechanics of the foot and lower extremity. Some studies are based on subjective results and other are based on more objective findings. A few examples of each will now be discussed.

A study performed by Donatelli et al[1] focused on the effects orthotic use had on the degree of pain relief experienced by patients as well as their ability to return to their previous level of function. These results were based on subjective findings obtained from a questionnaire. Eighty-one patients with such diagnoses as pen planus and chondromalacia participated in this study. A biomechanical evaluation was performed on each subject in order to provide proper orthotic prescription. The subjects were given temporary orthotics initially, and six to eight weeks later, they received permanent orthotics.[1]

After a two-year period, questionnaires were sent out to the original patients and 53 were returned. Results obtained from questionnaires revealed that 96% experienced pain relief when using the orthotics. Ninety-four percent reported that they were still using the orthotics and 52% reported they would not leave home without their orthotics. Seventy percent of the subjects stated they had been able to return to their previous level of activity.[1]

In another study, 180 injured runners were evaluated of which 46% were prescribed orthotics as part of their treatment. Of the individuals who were prescribed orthotics, 78% were able to return to their previous running program. Six of these runners were further evaluated and it was discovered that the orthotics prescribed were able to significantly decrease the amount of pronation and the time spent in pronation during the support phase of running.[37]

In a study conducted by Johnson et al,[39] the effects of semi-rigid orthotics with a combination of rearfoot and forefoot posts on abnormal foot pronation were examined. Twenty-two subjects diagnosed with forefoot varus deformities participated in the study. Static measurements of the subtalar joint and forefoot varus deformity were taken by a single examiner. A Foot Trak two-dimensional motion analysis system was used to determine the calf to calcaneus and calcaneus to vertical angles during all trials on the treadmill. Gait timing information was also gathered by use of a pressure sensitive foot switch. Angular movement information was gathered by filming reflective markers which were placed along the subjects' lower extremities.[38]

All subjects were examined while on the treadmill with a computerized video analysis system. They all participated in five trials which consisted of walking at 4.0 km/h in running shoes alone, in running shoes with unposted orthotics, orthotics with forefoot posts only, rearfoot posts only, and both forefoot and rearfoot posts.[38]

It was discovered that the maximum calf to calcaneus and calcaneus to vertical angles were decreased more by orthotics posted in both the forefoot and rearfoot when compared to orthotics posted only in the forefoot. There was o differences discovered between those trails in which only the rearfoot was posted and those in which both the rearfoot and forefoot were posted. It was also discovered that the maximum calf to calcaneus angle was decreased with posting of any type and with the orthotic shell alone when compared to the shoe only trial. The maximum calcaneus to vertical angle was decreased in all three posting trials when compared to the orthotic shell alone and the shoe only trials.[38]

This particular study reveals that when maximum control of rearfoot frontal plane motion is desired to help control abnormal subtalar joint pronation, combined posting or rearfoot posting alone should be considered as a valid treatment option. These devices, along with forefoot posted devices, provide much better control of rearfoot motion than shoes alone.[38]

Studies have also been conducted to examine the results of biomechanical orthotics and speed on the control of subtalar joint movement. One such study was performed by McCulloch et al.[39] In this particular study, ten subjects diagnosed with forefoot varus and abnormal subtalar joint pronation were examined. Of the ten subjects examined, seven wore rigid orthotics and three wore semi-rigid orthotics.[39]

All subjects were tested both with and without orthotics while walking on a treadmill at two and three mph. A motion analysis system was used to capture three-dimensional motion while each subject was on the treadmill. Temporal data for heel strike, heel off, and toe off were calculated. At heel strike, the rearfoot was inverted approximately 4.39 degrees with the orthotic and 1.08 degrees without the orthotic. The maximum eversion angle of the rearfoot was decreased from 10.30 degrees to 6.95 degrees on the average with the orthotic. The results of this study demonstrate that the use of orthotics decrease maximum pronation by an average of 4 degrees at 2 mph and 2.7 degrees at 3 mph. The use of orthotics was also associated with an increase in instance time measured from heel strike to heel off.[39]

The previously stated studies are just a few examples of research that demonstrate the positive results that can be achieved by use of orthotic therapy. The problem of abnormal subtalar joint pronation is common and at the root of m any lower extremity disorders. Control of excessive subtalar joint pronation should be addressed in order to allow the foot and lower kinetic chain to function as close to normal as possible. Orthotics offer an effective means of controlling subtalar joint pronation. For this reason, they should not be ruled out as a means of treatment.

CHAPTER VII

CONCLUSION

Abnormal pronation of the hindfoot in relation to the forefoot is common and often results in dysfunction throughout the lower extremity.[12] The excessive pronation that occurs at the subtalar joint is in actuality a compensation. Compensation may be described as "a change in structure, position or function of one part of the body in an attempt to adjust to a deviation of structure, position or function of another part of the body."[16] This compensation may be a result of congenital, acquired, or neuromuscular deformities.[4]

This literature review focused on the acquired deformities which may be further broken down into intrinsic and extrinsic deformities. The most common intrinsic deformities include traumatic flatfoot, ligament laxity, bony abnormalities, forefoot varus, forefoot spinatus, rearfoot varus, and ankle joint equinis. The most common extrinsic deformities include rotational deformities and leg length discrepancies.[4,9]

Abnormal pronation causes several structural and functional changes throughout the lower extremity. Some of these changes include the disruption of the gait cycle, hypermobility of the first ray, and patellofemoral tracking dysfunctions. Bunion formation, lowering of the medial arch, and increased tensile stress to the plantar aponeurosis are other changes that occur in the presence of abnormal pronation.[3,4,9]

Orthotics are an effective form of treatment for abnormal pronation. A biomechanical or functional orthotic is a device that may be used to control excessive and potentially harmful subtalar joint pronation. These devices may not structurally change a deformity but rather prevent the accommodation or compensation for the deformity.[22]

A wide variety of materials may be used to fabricate orthotics. Leather, rubber, cork, plastics, and plastic foams are just a few of the materials utilized today. Depending on the type of material used, an orthotic may be soft, semi-rigid, or rigid.[5,25,26,30]

Soft orthotics are usually used for accommodative purposes or as a temporary orthotic to determine the need for a permanent orthotic. Semi-rigid orthotics are usually used for sporting events. They attempt to provide the support of a rigid orthotic while remaining more flexible. Rigid orthotics are usually made of hard plastics and/or acrylics. They are generally used when more control is needed.[5,25,26,30]

When prescribing orthotics, certain material and patient characteristics must be kept in mind. Some of the material characteristics that need to be considered include the stress, strain, and degree of stiffness a material possesses. Hardness, a material's compression properties, and viscoelastic behavior are also important.[2,33]

Some of the patient characteristics that need to be considered include patient diagnosis, age, weight, activity level, and shoe style. Of these characteristics, weight is perhaps the most important as it is directly responsible for the amount of vertical force applied to the orthotic. This means it will have the greatest affect on the material's properties.[33]

The effectiveness of orthotics has been widely studied. Perhaps the greatest downfall of these studies is that the majority of them have been based on subjective outcomes rather than objective outcomes. However, more objective studies are now being performed. Orthotics have been found to decrease motion of the hindfoot particularly in the frontal and transverse planes.[32,38] The maximum eversion angle of the hindfoot has also been found to decrease with the use of orthotics.[39]

As stated previously, excessive subtalar pronation is a common disorder often encountered in the clinic. When attempting to treat this disorder, orthotics should be considered as an effective treatment option. When prescribing orthotics, it is important to consider the anatomy and biomechanics of the foot, characteristics of the materials utilized for fabrication, and the characteristics of the patient for whom the orthotic will be fabricated. One must remember that the foot is our foundation. It must function correctly if we are to function correctly.

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