Developmental Flatfoot—Part 2

This commonly occurring musculoskeletal condition is often overlooked or neglected.

BY JOSEPH C. D'AMICO, DPM

Goals and Objectives

To instill a knowledge and appreciation of the developmental flatfoot.

To discuss the role of neuro-motor immaturity and ligamentous laxity as etiologic factors in its production.

To present and emphasize its accompanying pathomechanics.

To appreciate the pathologic effects of excessive pronation on the superstructure.

To be able to offer a management rationale for this condition.

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*Following this article, an answer sheet and full set of instructions are provided (pg. 128).—**Editor***

***Editor's Note:** In Part 1, Dr. D'Amico discussed the ontogeny and etiology of flatfoot. In Part 2, he discusses the pathomechanics and management of this condition.*

Neuromotor Immaturity

The nervous system of the newborn is immature and does not achieve the initial stages of maturation until one to two years after birth.[35] The myelinization process begins in the fourth to sixth fetal month; however, the nerve fibers in the lower extremity are the last to receive their myelin coating.[57] Functional maturity and resultant coordination are directly related to the degree of myelinization that has taken place at any point in the continuum. Usually, it is not until six years of age that most organ systems of the lower extremity motor mechanism are completely developed and adult coordination is demonstrated.[57]

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It is this neuromotor immaturity that characterizes the gait of the beginning walker. Gait observation of the 9-15 month old child reveals

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a wide base of gait with short bursts of forward progression (Figure 1). This wide base of stance and gait increases lateral and postural stability. The typical knee and hip flexed positions of the early walker serve to lower the center of gravity, providing further stability. The feet are markedly pronated, i.e., more of the plantar aspect is in contact with the ground. This pronated foot position increases the number of plantar proprioceptors in contact with the weight-bearing surface, logically improving proprioceptive feedback mechanisms for balance and stability.

The function of the lower extremity musculature is to reinforce skeletal integrity and to relax ligamentous tension during locomotion and stance. This function is achieved by exerting sufficient tension to resist undesirable motions that would either disrupt joint integrity or promote hypermobility. In an excessively pronated foot, the first body system to exhibit excessive activity is the musculotendinous apparatus. The efficiency of this functional unit is dependent upon a) proper muscle strength and length, b) precisely sequenced phasic activity, c) balanced synergistic and antagonistic muscle function, d) the innate mechanical efficiency of the tendon and e) proprioceptor activity.[29] In a pronated foot, proprioceptors respond to the stimulus of ligament stretch by innervating muscle contractions by reflex action to the extent necessary to relieve the tension.

Figure 1: The stance position of the beginning walker is characterized by a wide base of gait, knee and hip flexed positions with arms out at sides in an attempt to maintain balance. The feet are pronated, enabling increased proprioceptor contact with the supporting surface. Note left foot toe flexion.

Ligamentous laxity is the most commonly ascribed etiology for pediatric flatfoot in the orthopedic literature.

The Ligamentous System

The function of the ligamentous system in the foot is to secure the osseous framework. Ligaments are the "living" cement that help to prevent the osseous segments from becoming displaced. A developmental inability to accomplish this function results in foot instability and deficiency (Figures 2, 3).

At birth all children are loose-jointed. This laxity peaks at two to three years of age and then gradually diminishes.[64] The prevalence of joint hypermobility in school age children ranges from 8-39%.[65-67] Most children outgrow these lax ligaments; however, the incidence in adults has been estimated as low as 2% in males and 6% in females to as high as 35% in males and 57% in females.[68] At an early age, it is impossible to determine which children will outgrow this laxity and which children will be left with a significant musculoskeletal deficiency.

Ligamentous Laxity

Ligamentous laxity should have sufficiently diminished to be clinically insignificant by 6-8 years of age in females and 8-10 years of age in males, although continued reduction occurs throughout adolescence.[69] Beyond this point only individuals with severe degrees of ligamentous laxity retain essentially unrestricted ranges of motion.[64,70] When there is a history of familial joint laxity, it is likely that the child will similarly be affected and it is even more likely when both parents display lax ligaments. Schuster and Port hypothesized that individuals with high degrees of ligamentous laxity and accompanying severe pronation suffer from defects in hormonal metabolism.[71]

Ligamentous laxity is the most commonly ascribed etiology for flexible flatfoot in the pediatric patient.[11,64,69,72-75] Schuster qualifies this by stating that only the generalized familial ligamentous laxity with associated hyperextensible knees, elbows, and wrists is the responsible etiology for "unusually" flat feet in children.[76]

As far back as the 1920s, Dudley J Morton linked medial longitudinal arch collapse in conjunction with lax ligaments and a short first metatarsal.[77] According to Trott, when ligaments are lax, there is nothing to prevent medial, anterior, and plantarward displacement of the talar head with resultant flatfoot deformity.[78] While this is true, it is the strength and alignment of the osseous segments that primarily and predominantly determine foot morphology.[9,20,37,79,80]

Arch Morphology

Arch morphology is derived from the intrinsic alignment of the tarsal

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bones, which in a normal foot act as individual wedges that are forced together during weight-bearing, creating a stable structure.[5,8,9,73,81-86] In an abnormal foot, these tarsal units are separated, thereby creating a weak, unstable horizontal beam.[87] Ligaments serve to restrict and maintain this osseous framework along with the additional reinforcement and stabilization provided by the musculotendinous apparatus.[5,82,83,86,87]

In the developing child, the inability of the ligaments to secure the osseous framework and restrict excessive motion results in instability with concomitant overworking of the musculotendinous apparatus. Since ligaments are expansile and not contractile in nature, prolonged tension, e.g., as occurs in an excessively pronated foot, permanently deforms and elongates these structures. Subsequently, abnormal foot function in the form of excessive pronation and medial displacement of body weight will be encouraged at the expense of normal osseous development (Figure 4).

Dudley Morton was the first to link medial longitudinal arch collapse with lax ligaments and a short first metatarsal.

Figure 2: Positive thumb-to-wrist test for ligamentous laxity in a 2 ½ year old

Figure 3: The weightbearing feet of this same child. Note the "way too many toes" sign.

The height of the arch should not be used as a criterion to determine the amount and extent of pathology present in the foot and is an unreliable indicator of foot function.[81] Both the high and the low-arched foot may function well; however, it is only through thorough musculoskeletal examination along with detailed history-taking that this can be determined.[87] It is the degree of collapse or deviation from its inherent structure that the foot undergoes upon weight-bearing along with medial displacement of body weight that is primarily responsible for symptomatology and deformity, not medial longitudinal arch flatness itself.[14,81,88,89]

Pathomechanics

The developmental flatfoot is an excessively pronated flexible flatfoot with maximum calcaneal eversion noted upon weight-bearing. Accompanying abnormal subtalar and midtarsal joint pronation is a medial displacement of the line of weight-bearing (Figure 4). During gait, this medial displacement or center of force is carried medially instead of centrally as in a normally functioning foot. Prolonged tension on the spring ligament results in permanent elongation and deformation. The talocalcaneal and talometatarsal angles are increased and the calcaneal inclination decreased.

Pathologic superstructural influences have a long-term pathologic effect on the developing musculoskeletal system. These effects include, but are not limited to: altered application of force and overworking of the peroneus longus and posterior tibial tendons, adaptive contracture of the Achilles, tibialis anticus and peroneus brevis tendons, medial stress, strain and permanent deformation of medial collateral ligaments of the ankle and on the knee, abnormal, medially displaced epiphyseal forces, internal limb rotatory forces, knee and hip flexion, increased Q angle, increased lumbosacral angle, poor posture, and more.

The developmental flatfoot is immature, malaligned, and subject to the deforming effects of gravity and the environment in which it must function.

All of these forces are taking place in a child whose osseous structures are immature and plastic and thus susceptible to deformation or

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reformation if intervention is undertaken.

Management

The developmental flatfoot is immature, malaligned, and subject to the deforming effects of gravity and the environment in which it must function. Pathologic forces are being applied to extremely malleable weight-bearing segments of the musculoskeletal system at a time when it is undergoing marked ontogenetic changes. The effect of these forces is delay of normal development, retention of in-utero positions, progressive deformity, dysfunction, and disability. The major dynamic functional deficits of the developmental flatfoot are an excessively mobile adaptor and an inability to function as a rigid lever at a time when it should be stable.

It is the strength and alignment of the osseous segments that primarily and predominantly determine foot morphology.

Statistically, it is an inefficient, inappropriate base of support for the superstructure. Therefore, the management objectives for the excessively pronated developmental type flatfoot should be to stabilize and align the osseous and soft tissue structures, neutralize excessive pronation, encourage rigid lever function, improve super-structural alignment and promote ideal development (Figure 5 a,b).[17,28,29]

There is widespread belief that flexible flatfoot in children corrects itself spontaneously and that treatment is unnecessary. As Arthur J Helfet points out, a visit to an adult orthopedic foot center will rapidly dispel any such illusion.[22] Helfet reiterated a study of 3,000 three-year old children in a Galilee kibbutz of which 80% had flat feet, none of which were treated and most of the time walked barefoot. At the age of 16, it was found that 21% of the boys and 19% of the girls still had flat feet.[22]

Although there has been much debate and controversy as to whether or not the asymptomatic flexible pediatric flatfoot should be treated, one would be hard-pressed to find a clinician who disagrees with conservative intervention in those children who are symptomatic.[72,73,90-95] The real question here is not whether or not to treat an asymptomatic flexible flat foot but whether or not to treat an excessively pronated foot.

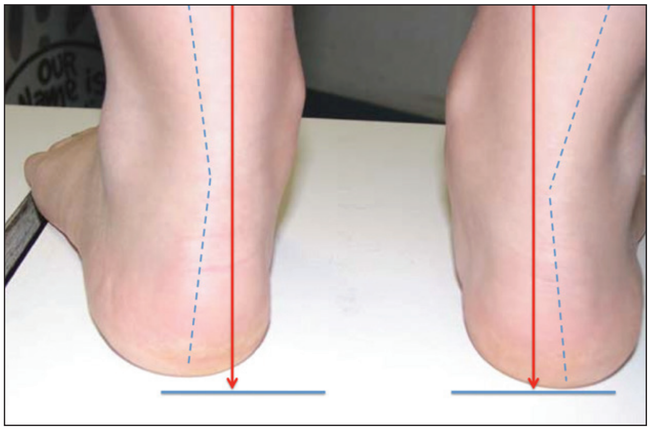

Figure 4: Medial displacement of the line of gravity in this excessively pronated developmental flatfoot. Note the degree of forefoot abduction and lateral concavity

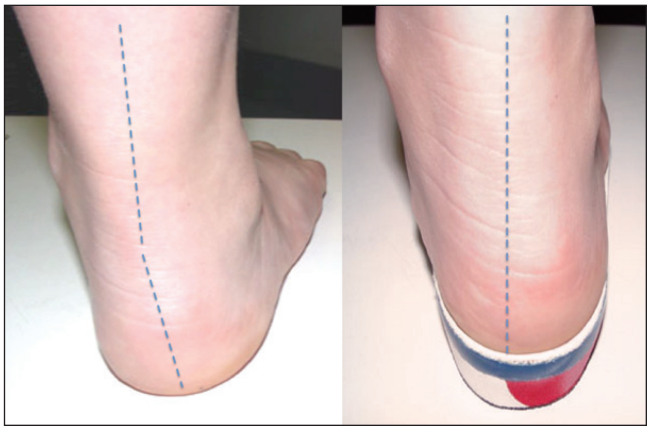

Figure 5 (a, b): Successful realignment of the osseous and soft tissue structures in this young child. Maintenance of the foot and ankle in corrected alignment during growth and development will result in bony remodeling and concomitant improvement in function.

The notion that absence of symptoms equates with normal function is completely mistaken. In fact, the attendant malfunction, i.e., excessive pronation, regardless of the underlying pathology, is the same in the symptomatic as well as in the asymptomatic foot. Furthermore, it is not enough to ascertain the presence or absence of foot pain in the flexible flat-footed child in determining whether or not treatment should be rendered, but also whether or not foot dysfunction is producing ankle, knee, hip, or back pain, and therefore would fall into the symptomatic category, "justifying" conservative management.

And what about the asymptomatic pediatric flexible flatfoot with a short Achilles tendon? Has this contracture been present since birth or has it evolved secondary to an everted calcaneal position as a result of excessive pronation with secondary adaptive shortening? In this case, if the excessive pronation were treated initially, then the treatment-permitted pathology (i.e., gastocnemius/soleus equinus) would have never developed.

The pathologic effects of excessive pronation as a compensatory result of inherent structural deficiencies are obvious and restricted not only to static malalignment of the foot and ankle but to the superstructure as well.[13-16,96]

This, in turn, creates a dynamic functional abnormality that nega-

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tively affects the entire musculoskeletal system.[97] Why then is it acceptable to leave an excessively pronated pediatric flatfoot untreated when that same foot in an adult would be treated? Since most experts agree that the morphology of the foot should achieve its adult form by seven to eight years of age, there is a very limited window of opportunity to influence development in a positive manner. Waiting to see which children will "grow out of it" and which ones won't can be a very risky proposition.

Trott, in his article on children's foot problems, states, "If it is possible to maintain the bones of the foot in normal relationship to one another during the growing years, regardless of whether the eventual outcome is a good arch or a flatfoot, the end result should minimize arthritic changes later in life."[12]

Studies Pro and Con

There are a number of studies that demonstrate the benefits of early conservative management of the flexible pediatric flatfoot.[31,34,60,91,93,98-103] There are also a number of "studies" in which the consensus is that there is limited evidence supporting the use of prescription foot orthoses in the asymptomatic pediatric flatfoot.[103-106]

One of these "negative" radiographic studies on the use of shoes, inserts, and UCBL-type devices in the treatment of 129 flatfooted children all under six years of age concluded there was no difference between control and treated patients and that wearing any such device or modification for three years does not influence the course of flexible flatfoot in children.[107]

Upon closer look, it can be seen that all radiographic parameters had a positive correlation between the initial angle and change in radiographic angle with intervention. Those patients with the largest initial angle had the most change independent of method of treatment. Additionally, the UCBL group started with a greater deformity but ended with a smaller deformity. Finally, even though equinus was identified in this group of children, it was never utilized in the study. Eliminating the equinus subjects might show an even greater positive change due to the UCBL device.

Some of the negative studies assessing the effectiveness of custom foot orthoses on the developing asymptomatic pediatric flatfoot do not mention or fail to assess and address the relationship of the forefoot to the rearfoot, the rearfoot to the leg, or the presence or absence of equinus influences. As a result of these shortcomings, when the device is fabricated, there is no prescribed correction for forefoot or rearfoot deviation, relegating it to the category of "custom" insole or arch support but not a functional foot orthosis.

With that being said, there are very limited studies on the effects of orthotic intervention in the excessively pronated, asymptomatic pediatric flexible flatfoot that take into account resultant or attendant pain or deformity in the skeleton it is designed to support and transport. This is a critical oversight since abnormal foot function negatively impacts superstructural form and function.[13-15,17,109,110] A recent study of 38 children with flexible flatfeet, excessive pronation, limb length discrepancy, and scoliosis treated with rigid orthoses, stretching, and strengthening revealed improvement in all areas.[96]

Additionally, there are no long-term double-blind studies in the asymptomatic developmental flatfoot that trace the effects of various forms of non-operative intervention versus lack of intervention over a 30-, 40-, or 50-year time span.[91] In many instances, it takes this long for neonatal musculoskeletal deficiencies that have been developmentally imbedded and left untreated to produce symptomatology either in the foot or in the superstructure. Absence of evidence should never be construed as evidence.

It is generally agreed that ontogenic osseous development in the foot regarding basic form and position is complete by 7-8 years.

The major dynamic functional deficits of the developmental flatfoot are best represented by an excessively mobile adaptor and lack of propulsive rigid lever.

Evidence Without Perspective

Medicine is not only a science but also an art, and this is never more true than in the case of the conservative orthopedic management of pediatric orthopedic foot deformities such as talipes equinovarus, skew foot, metatarsus adductus, metatarsus varus, calcaneovalgus, and most pertinently the asymptomatic, excessively pronated flexible flatfoot. Experience, skill, knowledge, impression-casting facility, extensiveness, and accuracy of history taking and biomechanical examination technique (including at least observational gait analysis), choice of laboratory, choice of materials, choice of shell thickness, degree and type of posting, etc., all influence clinical outcomes as well as study data.

An additional factor to consider when evaluating articles is whether or not the level of pediatric foot care

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delivered and the training required to provide this care is commensurate with that of practitioners in the United States. Are the abilities and decision-making capabilities in breadth and depth hampered by education, residency, or licensure? Do these factors influence the study?

These are some of the questions that should be asked when assessing articles that seem to contradict logic and clinical experience. Evidence based medicine is only as accurate as the "evidence" it is based on and is not completely reliable without perspective or content.

Treatment pathway directives, "red light green light" guidelines for when to treat an asymptomatic pediatric flatfoot are much too simplistic and lack broad substantive, long-term, meta-analysis substantiation.[105] Without longitudinal evidence that one form of treatment is better or worse across a variety of outcome modalities, the responsibility is on the medical profession to treat early and prevent complications.[111]

Furthermore, evidence based medicine and consensus-best therapy are being used to propagate "recipes" for patient care that do not allow for variation in comorbidities and other factors.[112]

As in the treatment of any pediatric deformity, the earlier treatment is instituted, the more favorable the prognosis.[37,60,98,113,114] Early intervention in the development flatfoot is an established conservative approach to the management of excessive pronation and its sequelae in a generation whose feet may have to last 100 years or more! Those who advocate treatment only in symptomatic individuals fail to recognize the importance and long-term consequences of excessive pronation, not only on the foot, but on the superstructure as well.

Most of the biomechanical problems seen in the developmental flatfoot are objective clinical findings without current subjective complaint. Furthermore, absence of symptoms is an unreliable indicator of optimum foot function in any age group. This is especially true in children. Excessive pronation is a poor postural position that sets the stage for future dysfunction and deformity and is abnormal at any age.[7]

The finding of a prominent, palpable medial talar head in the flexible pediatric flatfoot warrants treatment as early as infancy.

Excessive pronation should always be neutralized, and if it can be visualized, it is excessive. Periodic monitoring of the excessively pronated immature foot will not improve pedal development, function, or alignment. If a prominent head of the talus can be palpated medially, the likelihood of permanent deformity is sufficient to warrant treatment as early as infancy.[37]

There are many immediate and long-term benefits of early and continued intervention in the conservative management of the developmentally challenged foot, including structural realignment, improved function, and reduced superstructural stresses (Table 1).

TABLE 1: Benefits of Early Intervention in the Developmentally Challenged Foot

- Restoration of lower extremity musculature normal function
- Redirection of pathologic epiphyseal stresses to normal pathways
- Improved direction of COF and COG
- Improved postural complex alignment
- Reduced lumbar and cervical lordosis
- Reduced dorsal kyphosis
- Decreased lumbosacral angle
- Decreased Q angle
- Decreased talar declination
- Decreased angle of Kite
- Increased calcaneal inclination
- Increased propulsion
- Decreased midstance
- Vertical calcaneus
- Rectus forefoot
- Locked midtarsal joint
- First ray stability
- Knee and hip extension
- Increased height

Summary

Developmental flatfoot is the most commonly occurring, most often overlooked or neglected, inconspicuous musculoskeletal condition affecting the foot of the child under six years of age. Recognition of the fact that the developmental flatfoot is the logical precursor of foot and limb dysfunction, deformity, and subsequent disability later on in life encourages the astute practitioner to intervene early in its conservative management. **PM**

Author's Note: *Special thanks and a note of appreciation to Paul Tremblay, medical librarian at the New York College of Podiatric Medicine, for his assistance in obtaining many of the articles referenced, as well as to Stanley Beekman, DPM for his analysis of the Evans: "The Flatfooted Child: To*

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Treat or Not to Treat" article, and to R Paul Jordan, DPM for his thoughts, contacts, and comments.

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CME **EXAMINATION**

SEE ANSWER SHEET ON PAGE 129.

1) What is the most commonly ascribed etiology for pediatric flatfoot in the orthopedic literature?
- **A) ligamentous laxity**
- **B) tarsal coalition**
- **C) birth trauma**
- **D) limb length discrepancy**

2) Which one of the following practitioners was the first to link medial longitudinal arch collapse with lax ligaments and a short first metatarsal?
- **A) Dudley Morton**
- **B) Merton Root**
- **C) Henry DuVries**
- **D) Herman Tax**

3) Foot morphology is determined first and foremost by which one of the following?
- **A) ligaments**
- **B) muscles**
- **C) tendons**
- **D) strength and alignment of the osseous segments**

4) Which one of the following describes the developmental flatfoot?
- **A) immature**
- **B) malaligned**
- **C) subject to the deforming effects of gravity**
- **D) all of the above**

5) What is the effect of pathologic forces applied to the foot and ankle while undergoing development?
- **A) delay of normal development**
- **B) retention of in-utero positions**
- **C) progressive deformity and dysfunction**
- **D) all of the above**

6) The major dynamic functional deficits of the developmental flatfoot are best represented by which one of the following?
- **A) excessively mobile adaptor and lack of propulsive rigid lever**
- **B) poor shock absorption and lack of propulsive rigid lever**
- **C) abbreviated heel contact and increased propulsive phase**
- **D) poor shock absorption and increased propulsive rigidity**

7) Management objectives for the developmental flatfoot include which of the following?
- **A) stabilize and align the osseous and soft tissue structures**

Continued on page 128

B) neutralize excessive pronation
C) improve superstructural alignment
D) all of the above

8) It is generally agreed that ontogenic osseous development in the foot regarding basic form and position is complete by what age?
A) 4-5 years
B) 7-8 years
C) 10-12 years
D) 14-16 year

9) Which of the following factors influence clinical outcomes in the conservative management of the excessively pronated flexible pediatric flatfoot?
A) clinical experience
B) impression-casting methodology and facility
C) orthotic prescription and laboratory fabrication accuracy
D) all of the above

10) Which one of the following findings in the flexible pediatric flatfoot warrants treatment as early as infancy?
A) prominent, palpable medial talar head
B) patella aligned with ankle
C) lateral convexity
D) excessive dorsiflexion

SEE ANSWER SHEET ON PAGE 129.

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EXAM #8/18
Developmental Flatfoot—Part 2
(D'Amico)

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1.	A	B	C	D	6.	A	B	C	D
2.	A	B	C	D	7.	A	B	C	D
3.	A	B	C	D	8.	A	B	C	D
4.	A	B	C	D	9.	A	B	C	D
5.	A	B	C	D	10.	A	B	C	D

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