소아 근골격계의 흔한변형
Foot
(이학적 검사와 영상 소견을 중심으로)

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ZEE-IHN LEE

Contents

- Growth and development of pediatric foot
  - change of shape and function of foot
- Common problems of pediatric foot
  - metatarsus adductus
  - flatfoot
  - multiple digital deformities
- Assessment of foot

소아 발의 특징

Change of shape and function of foot

Differences Between the Newborn and Adult Foot

Feature	*Newborn*	*Adult*
Arch	Flatter, less defined	Usually well defined, except in pes planus
Typical joint range of motion	Greater range of motion	Lesser range of motion
End point of range of motion	Soft, subtle, difficult to appreciate	Firm, well defined
Amount of subcutaneous fat tissue	Greater	Lesser

Soft and elastic (flexibility), Triangular shape, Forefoot adduction
More dorsiflexion ROM, Lager size in relation to body weight,
Mid-foot pat pad, Absence of a visible longitudinal arch

Growth and development of foot

- Nature : heredity, physical makeup
- Nurture : environment, height/weight/gender, nutrition, footwear, first walking age
- Wide inter-individual variability
- Foot
  - accommodate irregularities of the ground
  - maintain balance
  - support weight
  - shock absorber
  - generate forward movement
  - transmit propulsive forces
  - proprioception

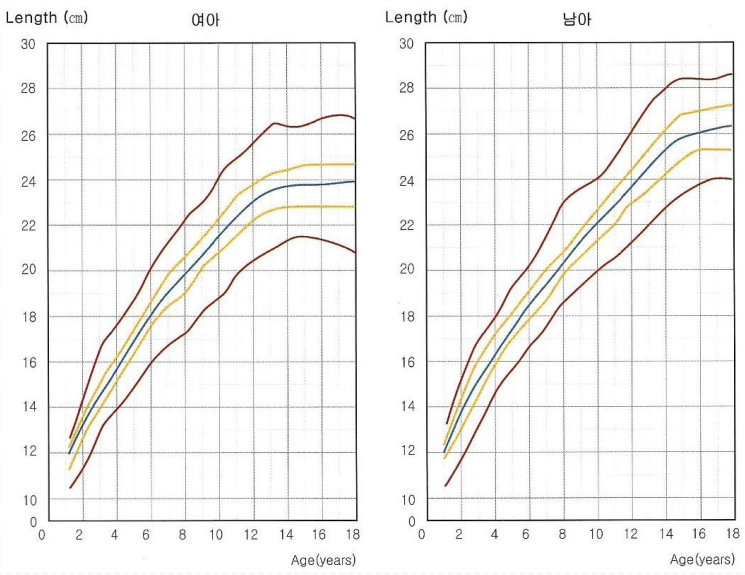
=> Physiologic and pathologic (intervention timing)

소아발의 성장

The rate of growth of the feet *Staheli et al(1987), Gould et al(1989)*

- constant from birth until the mid-teens
- increasing by approximately 2 sizes/yr for the first 4yrs, and then by 1 size annually

(5세까지는 급격하게 성장하다가
속도가 느려져서 여아는 10-12세까지,
남아는 12-14세까지 일년에 약 0.9cm의
속도로 일정하게 성장속도 유지되며
이후 급격하게 감소하여 여아는 약14세,
남아는 약16세가 되면 성장이 거의 멈추게 됨
-> 유아기의 다양한 정상변이,
적절한 치료 시기를 선택이 중요)



Shoes for infants and children with normal feet

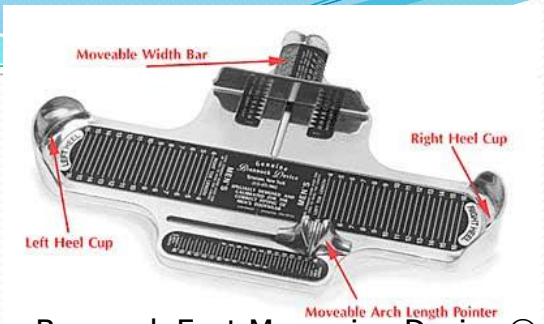
The most effective footwear should be

- Quadrangular : to conform to normal foot configuration, with abundant space for toe
- Flexible: to allow free foot movement
- Flat without elevation of the heel
- Porous : Uppers should be made of leather or unsealed fabric to avoid skin maceration or fungal infections.
- Moderately tractive : Sole friction should be equivalent to that of the bare foot.
  -> slippery(leather) or excessive friction created soles(some rubber soles) should be avoided.



- Light weight: to reduce energy expenditure
- Extended above the ankle in the toddler : to prevent the shoe from slipping off during running.
- Acceptable in appearance : because children are very sensitive about that
- Reasonably priced.

Guidelines for attaining proper shoe fit



Brannock Foot-Measuring Device ®

- Measure both feet with appropriate measuring device.
- Fit shoes on both feet while weight-bearing
- Check for the proper position of the first MP joint. It should be in the widest part of the shoe
- Check for correct toe length. Allow 3/8 to ½ inch between the end of the shoe and the longest toe
- Check for the proper width, allowing adequate room across the ball of the foot
- Look for a snug fit around the heel
- Determine that proper fit over the instep has been achieved by appropriately high vamp, preferably with laces to allow adjustability.

소아발의 흔한 질환

- Metatarsus adductus
- Flatfoot
- Multiple digital deformities
  : polydactyly, syndactyly, overlapping toes 등

Metatarsus adductus

Def) a transverse plane deformity where the metatarsals are adducted at the tarsometatarsal joints(Lisfranc joint)

Incidence) 1-2/1000 live births
one of the most common foot deformities.

Cause)

Unknown

Intrauterine crowding or positioning: compression of the forefoot with the legs flexed across the lower body in later gestation

=> rarely found in premature infants delivered before 30wks of gestation

Clinical features)

- adduction of the forefoot, often with some supination and inability to abduct the forefoot past neutral.
- a convex lateral border of the foot with a concave inner border.
- a prominent styloid process of the 5th metatarsal.
- a wider space between the 1st and 2nd toes and often resulting in a deep crease on the medial midfoot.
- the ankle and heel are generally in normal position with a flexible heelcord
- aggravated by the infant sleeping on his or her abdomen with the knees tucked up and the lower legs and feet rolled inward.

Diagnosis)

- “V”-finger test
  The heel of the foot is placed in the “V” formed by the index and middle fingers : Medial deviation from middle finger at the styloid process
  => metatarsus adductus

Radiologic evaluation

- metatarsus adductus angle
  : Angle formed by the intersection of the bisector of the 2nd metatarsal and the transection of the lesser tarsus

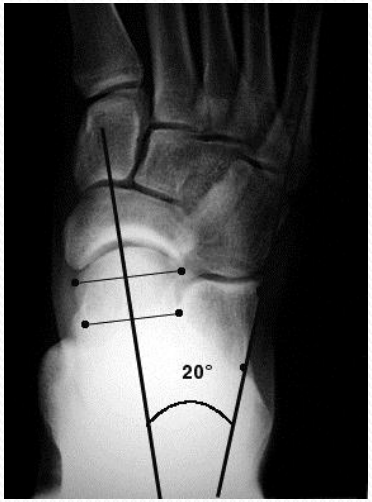
*) Normal range
Birth to 4mo 20-30도, 1 to 3yrs 15-20도, 4 to 6yrs 10-15도

Table 3. Grading of Severity of Metatarsus Adductus Angle (all values in degrees)

	Birth–4 Months	1–3 Years	4–6 Years
Mild	31–40	21–25	16–20
Moderate	41–45	26–30	21–25
Severe	> 45	> 30	> 25

- Talocalcaneal angle(Kite's angle)
  : Angle formed by the intersection of a line bisecting the head and neck of the talus and a line running parallel with the lateral surface of the calcaneus.

  *) Less than 15도
  : strongly suggests talipes equinovarus



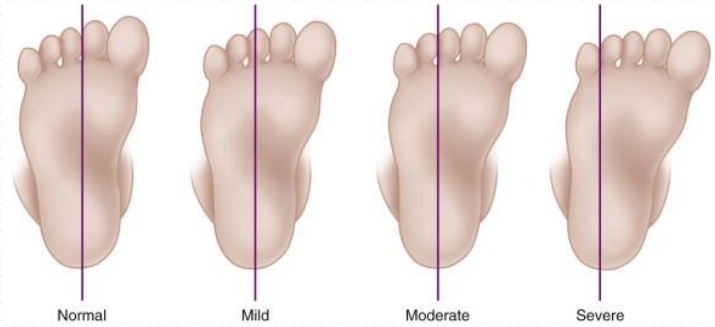
Classification)

- Flexibility

  i. Mild : flexible : passively correctable- abduction beyond the midline heel bisector
  ii. Moderate : semiflexible/reducible- abduction only to the midline
  iii. Severe : rigid - no abduction possible

- Bleck's method (Heel-Bisector angle)

  Normal - heel bisector line through 2nd and 3rd toe webspace
  mild - heel bisector line through 3rd toe
  moderate - heel bisector through 3rd and 4th toe webspace
  severe - heel bisector through 4th and 5th toe webspace



Differential Diagnosis)

- Dynamic hallux varus
  : medial deviation of the 1st MP joint

- Metatarsus primus varus: a midline deviation of the 1st metatarsal bone, resulting in a 20º+ angle between the base of the 1st and 2nd metatarsal bone

- Skewfoot: metatarsus adductus with significant hindfoot valgus

- Tibial torsion
- Internal rotation of the foot
- Clubfoot

Management)

- Treatment is based on the severity of the condition and controversial
- Spontaneous resolution to normal in 85- 90% of cases by age one
- Mild : only observation without active intervention
- Moderate : stretching exercises at every diaper change
  heel is stabilized within notch between thumb and index finger
  => the forefoot is slightly pulled distally, held between thumb and index finger of the other hand, and gently pushed into a corrected position.
- Severe : serial casting and bracing

Journal of Paediatrics and Child Health

REVIEW ARTICLE

Metatarsus adductus: Development of a non-surgical treatment pathway

Cylie M Williams,[1] Alicia M James[2] and Ton Tran[3]

Key Points

1. Metatarsus adductus is a common paediatric foot deformity that may be classified based on ease of correction.
2. Evidence supports no treatment in cases of fully flexibility metatarsus adductus.
3. There is limited evidence for a number of treatment options that may assist clinical judgment when assessing a child with semi-flexible metatarsus adductus.

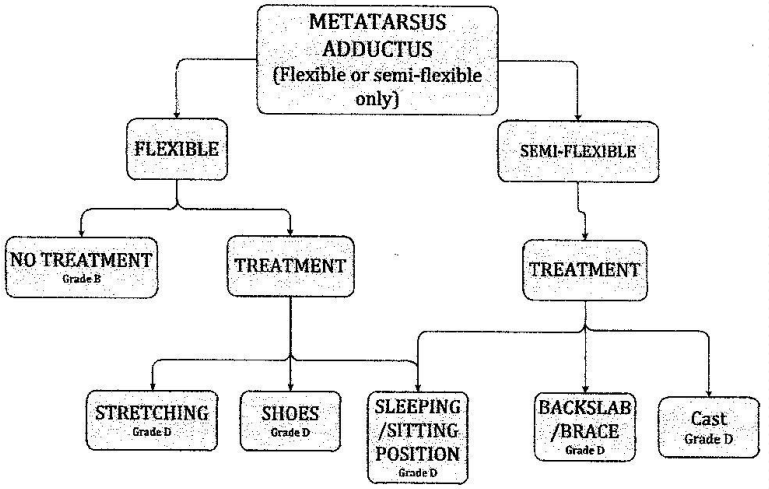
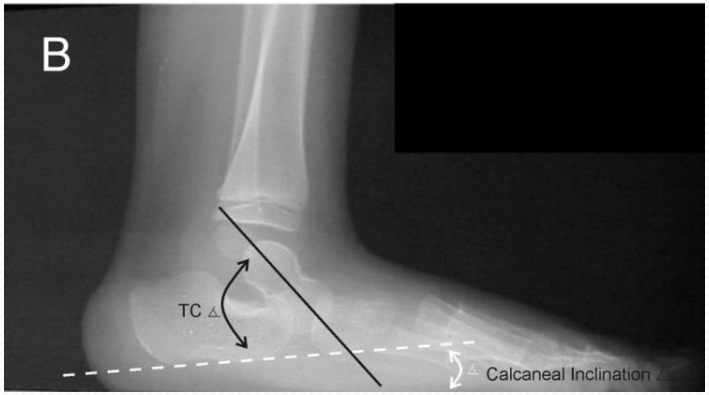


Fig. 2 Treatment pathway.

Flexible flatfoot

- Deformation of feet from hyperpronation caused by loss or immaturity of the medial longitudinal arch.
- The cause: unknown
  - genetic tendency, ligamentous laxity, hypotonia
  - influenced by tibia varum, genu valgum, gastrosoleus contracture, primary ankle joint valgus
  - obesity
- Pediatric flatfoot are mostly physiologic.(약 90% under age of 2)
  * Longitudinal arch develops spontaneously during infancy and childhood. This development occurs naturally and independently of footwear. Development of normal longitudinal arch begins at the age of 3 to 5 years old and completed before the age of 10.
- Nonphysiologic flexible flatfoot
  - progress over time instead of improving or at least stabilizing
  - excessive heel eversion with an unstable talonavicular joint
  - commonly associated with tight heelcord and gait disturbance

Radiographic examination: weightbearing(*A*) AP and (*B*) lateral radiographs



Radiographic flatfoot parameters focus on the relationship of the talus and calcaneus. The midtalar line (solid black line), talocalcaneal angle (TC) and calcaneal inclination angle provide information on the sagittal plane position of these bones on lateral view and transverse plane position on the AP view. In flatfoot, the talocalcaneal angle increases in size both on the AP and lateral radiographs. The talus plantarflexes in flatfoot deformity on the lateral radiograph. The normal midtalar line should pass through the first metatarsal. On the weightbearing AP radiograph, the talar head is no longer covered by its articulation with the navicular. This results in a wide AP talocalcaneal angle (Kite angle). Calcaneal inclination decreases in flatfoot.

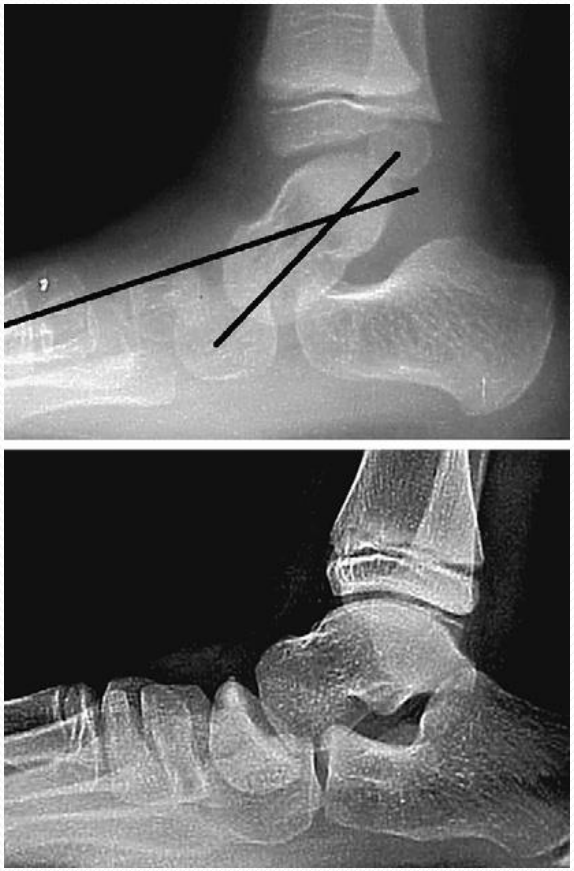
Pathophysiology of flexible flatfoot

Harris EJ. Clin.podiatr Med Surg (2010)

- Identified by abnormal subtalar joint pronation(coronal plane), some degree of transverse plane uncovering of talonavicular joint(transverse plane), and flatness of the medial longitudinal arch(sagittal plane).

Coronal plane dominant pronation without change on the remaining planes. There is marked heel eversion noted clinically. The radiographs show a normal AP talocalcaneal angle and normal lateral talocalcaneal relationship with preservation of the medial column.

Transverse plane dominant pronation. Clinically, the calcaneus is everted to the weight-bearing plane and the forefoot is abducted on the rearfoot. The radiographs show much of the medial talar head uncovered on the AP radiograph, with minimal failure of the medial column in the sagittal plane on the lateral radiograph.

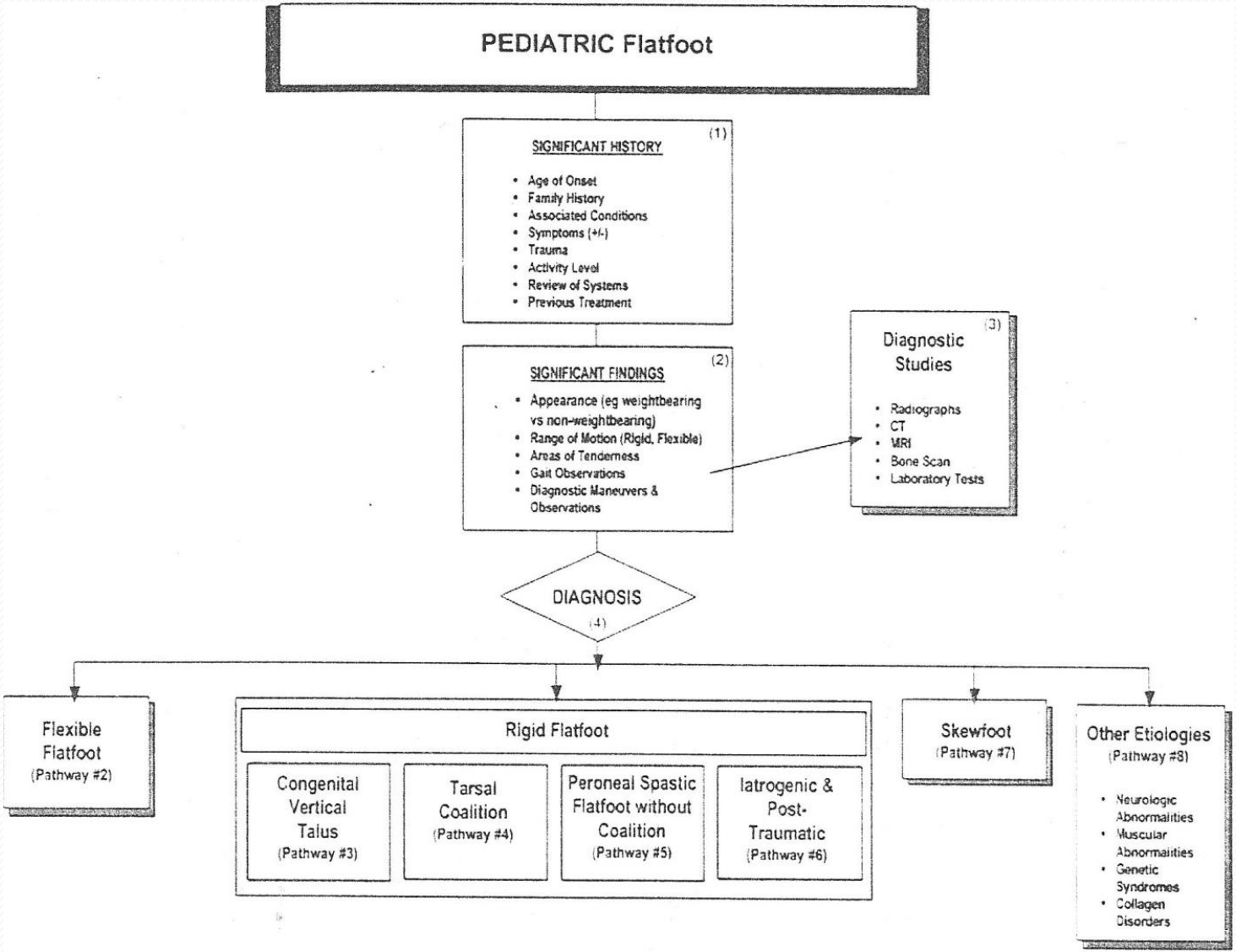


Sagittal plane dominant pronation. Medial column collapse may be at the talonavicular joint or at some point distal.

Triplane pronation. The AP and lateral radiographs show equal signs of pronation. The transverse and sagittal planes are affected.

Clinical practice guidelines for diagnosis and treatment of pediatric pes planus

Harris et al, J foot & ankle 2004



Talipes calcaneovalgus

- The foot turned upwards at the ankle so that the toes lie close to the front of the shin – "up and out" appearance
- can be corrected passively so that the foot can be brought down to a plantigrade position or even into equinus
- about 5 % of all newborns, a positional deformity
- a strong tendency to correct itself spontaneously over a period of 2-3 mo
- generally, the more severe the limitation of ankle plantar flexion, the more treatment is warranted
- Treatment should begin as early as possible
  mild case : stretching at each diaper change
  moderate case 혹은 스트레칭에 실패한 경우
  : splinting or firm, high-top, lace-up shoes
  severe case : serial mobilization casting
  -> bivalved cast or splinting

Congenital vertical talus

- rocker-bottom foot : a rare deformity that must be distinguished from calcaneovalgus
- hindfoot in equinus,
  talus and calcaneus pointing downward
  forefoot dorsiflexed
  -> dislocation of the midtarsal bones on the head and neck of talus
- foot examination : a rigid foot with a reversed arch,
  a convex plantar surface,
  and a deep crease on the lateral dorsal side of the foot
- other abnormalities : congenital vertical talus 환자의 60%에서 가능
  e.g.) arthrogryposis and meningomyelocele
- Surgery is needed in most cases

Polydactyly

- primary cause: genetic

Usually involves border toes, most commonly the fifth Could present as partial (i.e., two nail plates) or complete digit duplication No radiographs needed unless surgery is being contemplated	Surgical: ligation suture (less complex); removal of duplicated structures (more complex) 6-9 mos

Syndactyly(webbed toes)

- genetic: autosomal dominant
- 1/2000-2500 live births

Most commonly affects second and third toes Various levels of webbing, from partial to complete	Problem is more cosmetic, rarely requires treatment If surgery is desired, it should be postponed until child is old enough to take part in the decision

Overlapping toes

- often familial

Usually fifth toe over fourth toe Frequently bilateral Adduction and external rotation of the little toe, dorsiflexed digit Smaller nail plate	Stretching, use of silicone toe spacers, taping Surgical correction in older children, if symptomatic

Curly middle toe

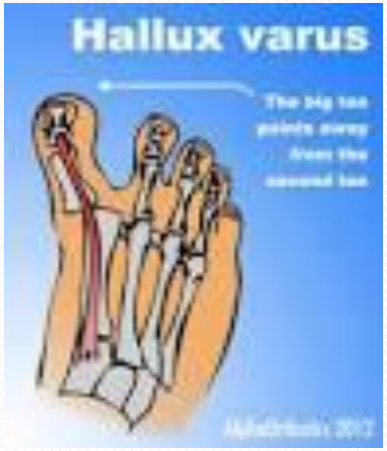
- the 3rd toe curls inwards under the 2nd toe
  => the 2nd toe tends to lie above the level
  of the 1st and 3rd toes.
- Parents generally notice the abnormal posture of the 2nd toe, but it is the 3rd toe that is the cause of the problem.
- This can be safely ignored until the child is at least 2 years old.
- Occasionally a flexor tenotomy is required and provides excellent correction

Metatarsus primus varus

- A forefoot deformity characterized by a midline deviation of the first metatarsal bone, resulting in a 20º+ angle between the base of the 1st and 2nd metatarsal bone

Congenital hallux varus

- a forefoot deformity consisting of medial deviation of the 1st MP joint
- congenital form
  : extremely rare, usually associated with other forefoot malformations
- Pathology : seems to be related to an incomplete duplication of 1st ray, leading to progressive contracture of the medial structures



Assessment of the foot

- Radiographic measurements, qualitative and semiquantitative visual appraisal, anthropometric measurements, footprint analysis

- Dynamic laboratory analyses: gold-standard

- A common approach in clinical practice
  : Classify the foot based on structure and alignment
  (High arch; Neutral foot; Flat foot, Forefoot varus; Rearfoot varus, Equinus)
  -> Infer characteristics of dynamic foot function
  -> Theoretically establish injury mechanisms leading to pathology
  and prescribe therapeutic interventions

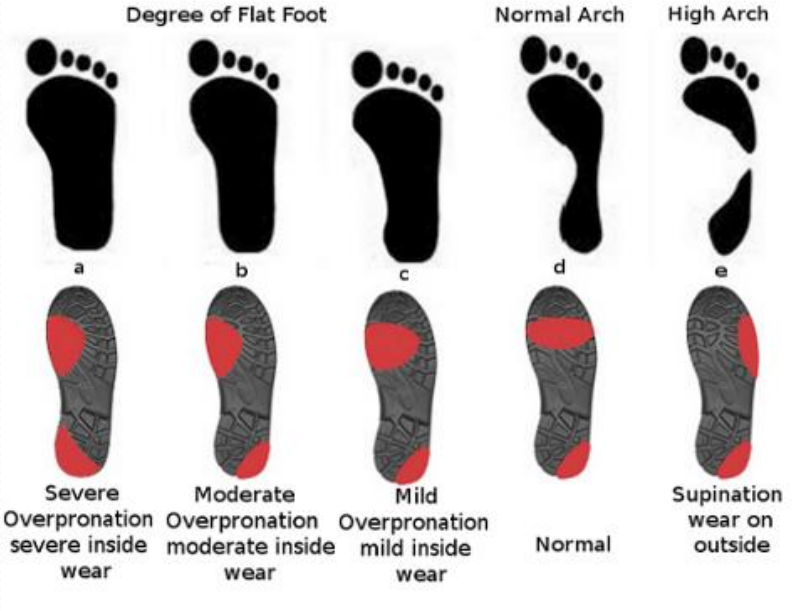
Biomechanical assessment of foot

- Systemic primary examination of each foot
  (standardized primary overview)

  -> Then, assessment should be directed by patient's complaints

1. Observation of the patient's shoes

- beginning of biomechanical assessment
- patterns of sole wear and deformation of the shoe upper and heel counter
  – shoe wearing habits, symptom severity, degree of deformity, abnormal foot mechanics



Calcaneal alignment

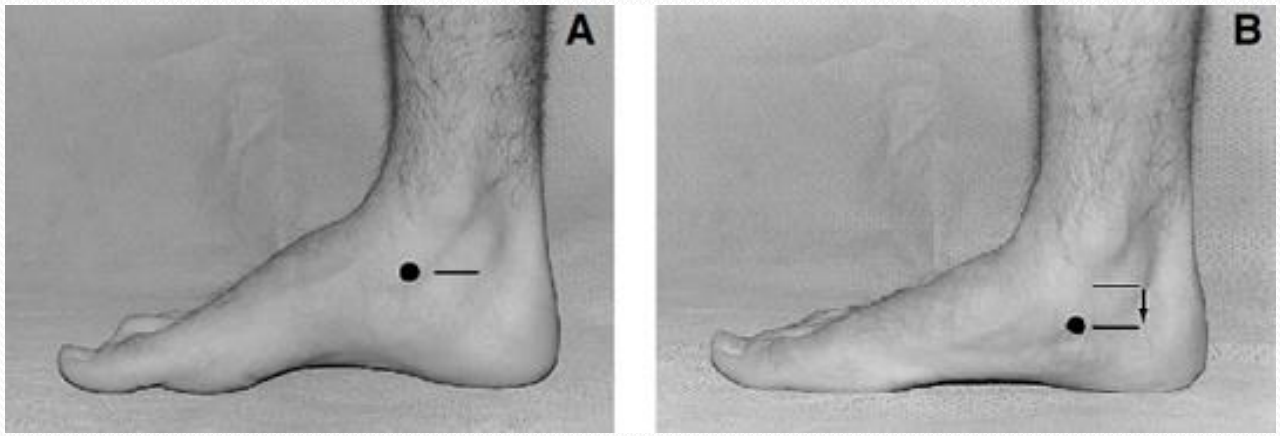
- Resting Calcaneal Stance position(RCSP)
  : Calcaneus bisection using a bimanual technique.

The midpoints of calcaneus were connected in the coronal plane with subjects lying at prone position. After partitioning the calcaneus, the angle between the perpendicular line to the ground and the bisector of the calcaneus was measured with subjects standing to fit the ambulation angle and the ambulation base. Positive and negative values in the resting calcaneal stance position indicated inversion and eversion, respectively.

Navicular drop test

- the sagittal plane displacement of the navicular tuberosity from a neutral position to a relaxed position in standing

- Measurement of navicular drop. The height of the navicular tuberosity is measured in neutral (A) and relaxed (B) stance positions, and the amount of excursion is measured.



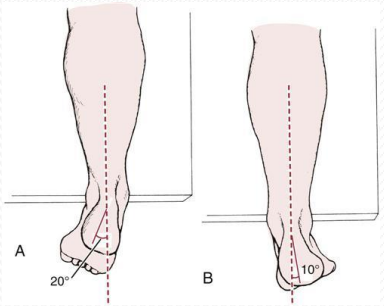
3. Observation of gait

- Side-to-side symmetry
- Foot placement
- Ability to achieve a plantigrade foot
- Avoiding patterns
- The flow of the heel strike-foot flat-heel off-toe off sequence

5. Sitting inspection

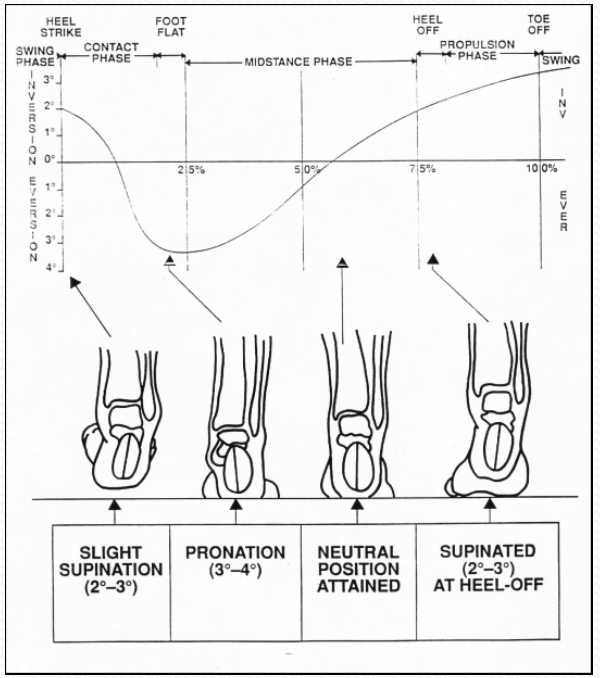
- Inspection of the dorsal and plantar aspect
- Patterns of callus formation indicate areas of high vertical and shear loads and may provide clues as to abnormal foot mechanics

Subtalar joint ROM



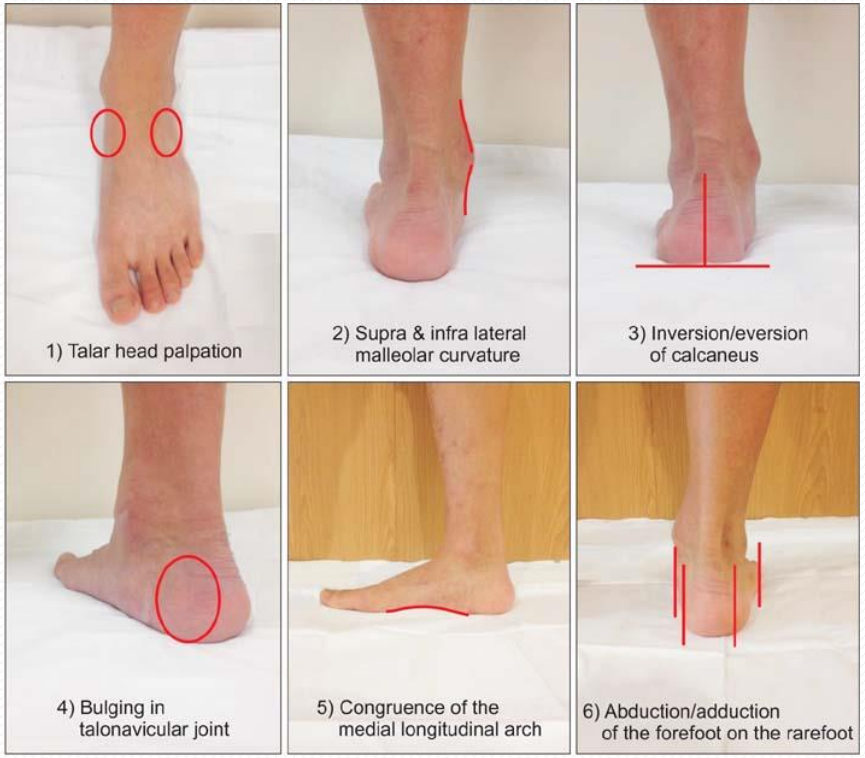
- Average total ROM of STJ
  : 30° of calcaneal frontal plane motion
  (Sup : Pro = 2:1 = 20° : 10°)

- Minimum total STJ ROM for normal ambulation
  : 8°~12° (4°~6° pronation, 4°~6° supination)
  but slightly more pronation than supination required
  : In CKC motion, the talus and tibia move together in the transverse plane
  (external tibial R → talus adduction)
  : Abnormal STJ function affects body structure and function(Joints & muscles of the foot, knee, hip & spine)



Foot posture index(FPI)

- a clinical tool used to quantify the degree to which a foot is pronated, neutral or supinated
- conducted in relaxed stance position with double limb support
- each foot should be scored (scored from -2 to 2)
- Inter-tester reliability 0.62~0.91
- Intra-tester reliability 0.81~0.91

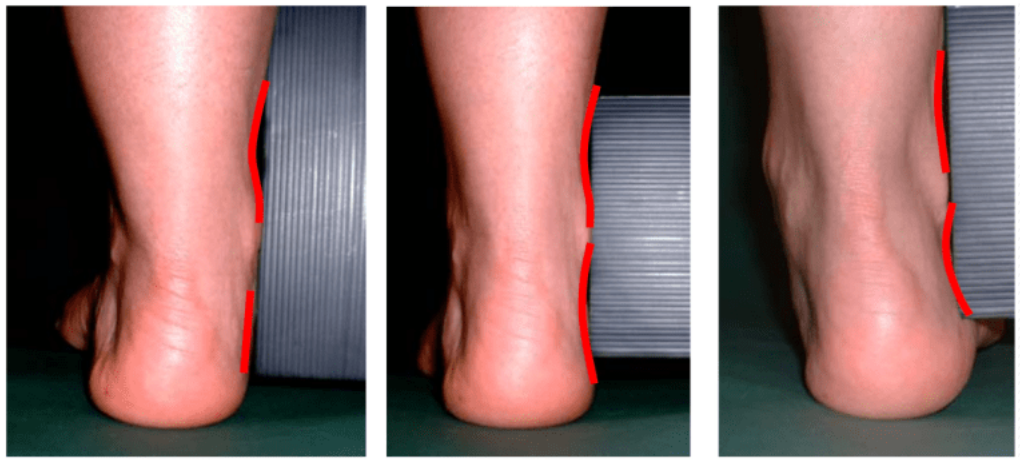


Talar head palpation : palpation for talo-navicular congruence

Score	-2	-1	0	1	2
	Talar head palpable on lateral side/but not on medial side	Talar head palpable on lateral side/slightly palpable on medial side	Talar head equally palpable on lateral and medial side	Talar head slightly palpable on lateral side/ palpable on medial side	Talar head not palpable on lateral side/ but palpable on medial side

Clinical note: *This is not an attempt to determine the so-called subtalar neutral position. For the FPI measure the subtalar joint is* ***not*** *manipulated into the position where the head of the talus is in maximal congruence with the navicular. For the FPI measure the head of the talus is simply palpated in the* ***relaxed stance position*** *and the talar head orientation reported.*
It may however be useful in some cases to move the foot into inversion and eversion while palpating for the talar head as this can aid in determining wether the head is still palpable in individuals on the border between 1 &2 or –1&-2.

Curves above and below lateral malleoli: direct observation of bony segments



Score	-2	-1	0	1	2
	Curve below the malleolus either straight or convex	Curve below the malleolus concave, but flatter/ more shallow than the curve above the malleolus	Both infra and supra malleolar curves roughly equal	Curve below malleolus more concave than curve above malleolus	Curve below malleolus *markedly* more concave than curve above malleolus

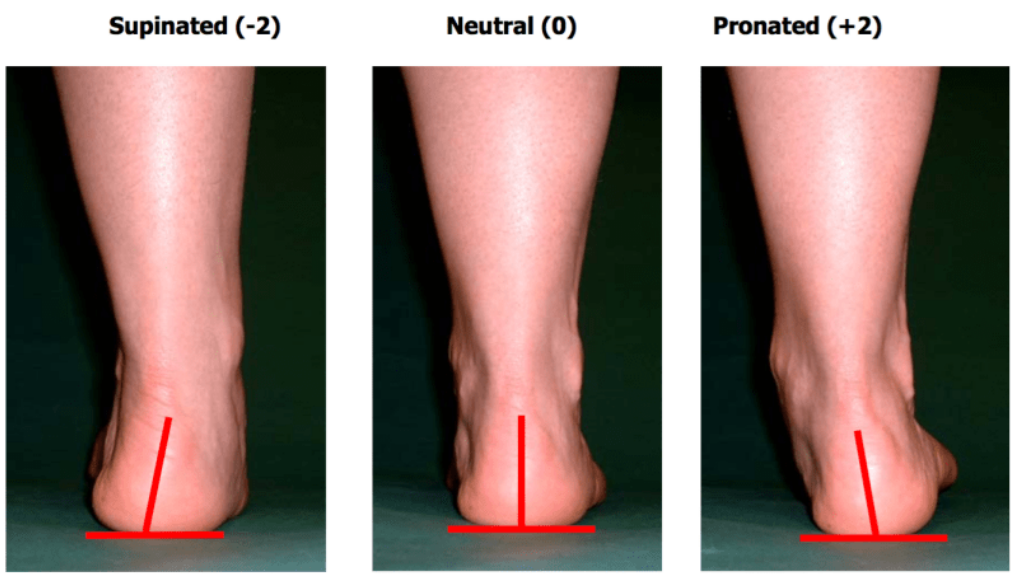
Clinical note 1: For estimating malleolar curvature, it may be helpful to use a straight edge for reference. This can be a set square, ruler or even a pen according to availability.

Clinical note 2: Where oedema or obesity obscures the curvature this measures should be either scored at zero or removed from the assessment and indicated as such.

Calcaneal frontal plane position (Inversion/eversion of the calcaneus)

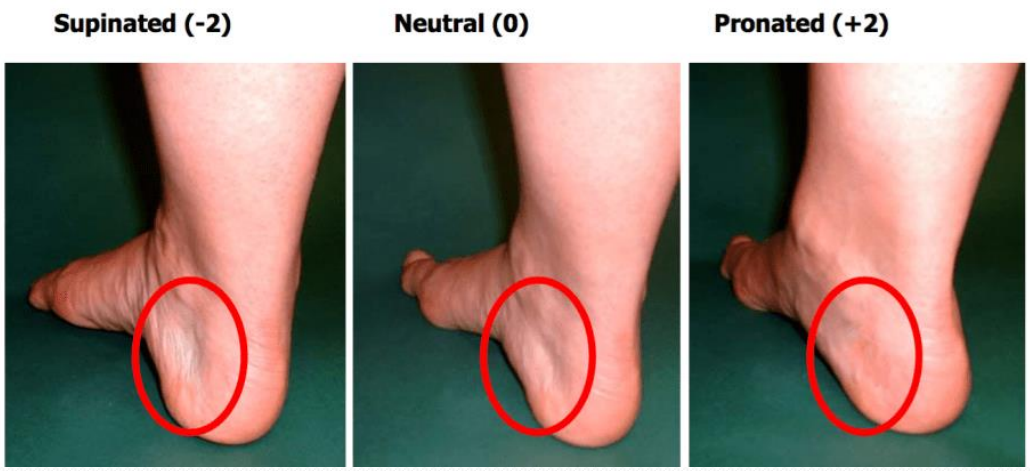
: direct observation of bony segments

: quantifying the relaxed and neutral calcaneal stance positions



Score	-2	-1	0	1	2
	More than an estimated 5° inverted (varus)	Between vertical and an estimated 5° inverted (varus)	Vertical	Between vertical and an estimated 5° everted (valgus)	More than an estimated 5° everted (valgus)

Bulge in the region of TNJ: direct observation of composite bony segments



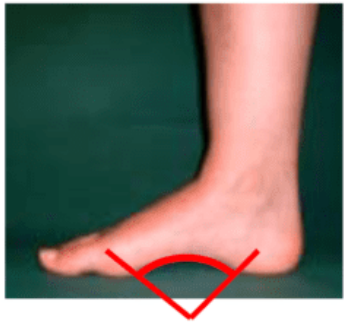
Score	-2	-1	0	1	2
	Area of TNJ markedly concave	Area of TNJ slightly, but definitely concave	Area of TNJ flat	Area of TNJ bulging slightly	Area of TNJ bulging markedly

Clinical note:
Bulging of the TNJ area is a common finding in pronated feet. However, true convexity of the area is usually only seen with highly supinated postures. Unless there is a definite indentation, assigning negative scores to this observation should be undertaken judiciously.

Height and Congruence of the medial longitudinal arch

: direct observation of composite bony segments

Neutral (0)



This observation should be made taking both the arch height and the arch congruence into consideration.

Supinated foot (-2)

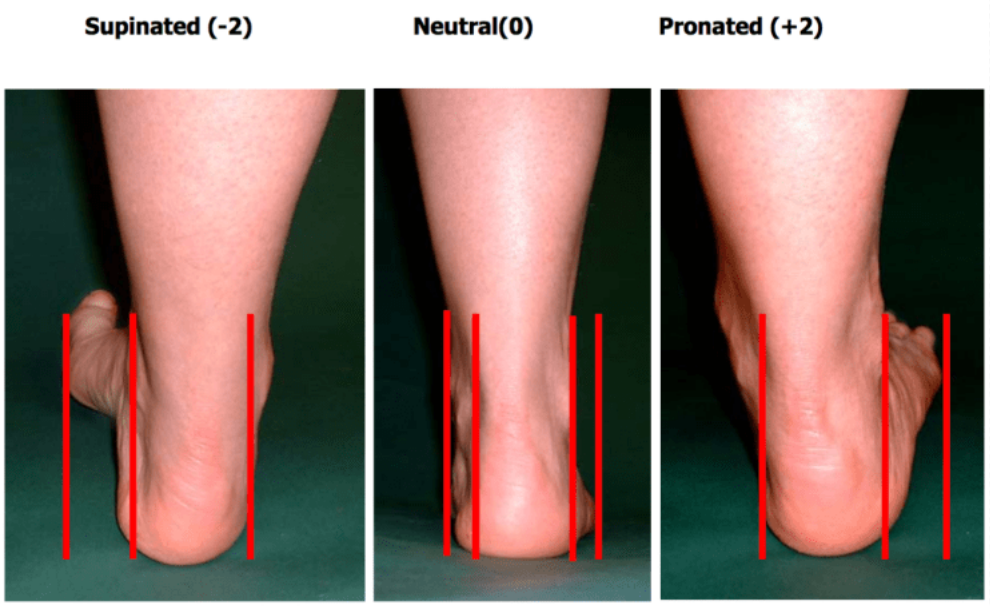
Pronated foot (+2)

Score	-2	-1	0	1	2
	Arch high and acutely angled towards the posterior end of the medial arch	Arch moderately high and slightly acute posteriorly	Arch height normal and concentrically curved	Arch lowered with some flattening in the central portion	Arch very low with severe flattening in the central portion – arch making ground contact

Clinical note: *While simple arch height will usually be the more readily apparent of the two components of this measure, arch congruence is probably more subtle and informative. Careful observation of the arch congruence should be the main element of this measure with arch height factored in secondarily.*

Abduction/Adduction of the forefoot on the rearfoot(Too many toes sign)

: indirect observation of composite bony segments



Score	-2	-1	0	1	2
	No lateral toes visible. Medial toes clearly visible	Medial toes clearly more visible than lateral	Medial and lateral toes equally visible	Lateral toes clearly more visible than medial	No medial toes visible. Lateral toes clearly visible

Clinical note: *This measure should be treated with caution where there is a fixed adduction deformity of the forefoot on the rearfoot in the non-weightbearing state. Normally it is possible to see the toes by the observer raising their angle of view slightly. If the toes are obscured by other structures the mtp joints or more proximal structures can be used as a guide.*

FPI total score

	FACTOR	PLANE	SCORE 1 Date_____ Comment_____	
			Left (-2 to +2)	Right (-2 to +2)
Rearfoot	Talar head palpation	*Transverse*		
Rearfoot	Curves above and below lateral malleoli.	*Frontal/ trans*		
Rearfoot	Inversion/eversion of the calcaneus	*Frontal*		
Forefoot	Bulge in the region of the TNJ	*Transverse*		
Forefoot	Congruence of the medial longitudinal arch	*Sagittal*		
Forefoot	Abd/adduction of forefoot on rearfoot (too-many-toes).	*Transverse*		
	TOTAL			

Reference values

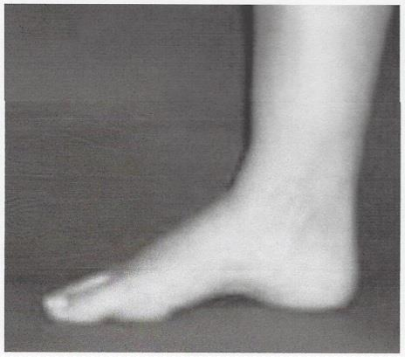
Normal = 0 to +5

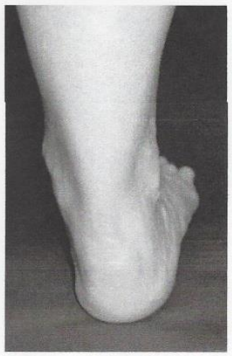
Pronated = +6 to +9, Highly pronated 10+

Supinated = -1 to –4, Highly supinated –5 to -12

Examples

Example 1. Abnormal frontal plane observations predominate in a patient, with transverse and sagittal plane measures reading near neutral.



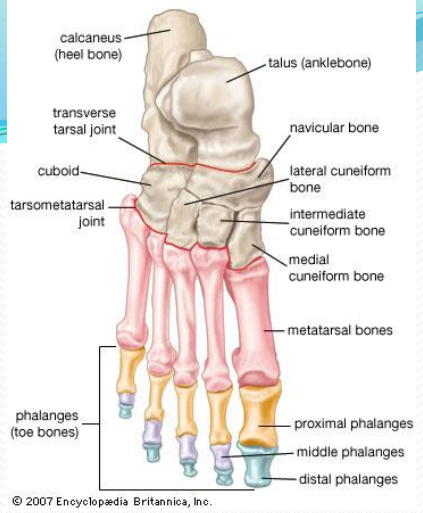


Talar head palpation	*+1*
Malleolar curves	*+1*
Inv/eversion calcaneus	*+1*
TNJ prominence	*0*
Congruence of MLA	*0*
Abd/adduction of FF	*+1*
TOTAL	*+4*

Example 2. The rearfoot factors may be near less marked in a patient while the midfoot/forefoot observations indicate substantial instability in the midfoot.

Talar head palpation	*+1*
Malleolar curves	*+1*
Inv/eversion calcaneus	*+1*
TNJ prominence	*+2*
Congruence of MLA	*+2*
Abd/adduction of FF	*+1*
TOTAL	*+8*

Conclusions



- The foot is a complex structure of 26 bone, 214 ligaments and 38 muscles bearing our bodyweight as we walk every day.

- Pediatric foot : growth and development
  -> Physiologic and pathologic -> intervention timing

- A biomechanical assessment involves an examination of the lower limbs, looking at their structure, alignment, strengths and weaknesses.
  -> can be very helpful in understanding and directing treatment at the cause of the problem.