Growth and development of foot

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장대현

Growth and development of foot

- Growth
  - Changes in size

- Development
  - Increases and changes in physical, intellectual, emotional, social….. skills

Windows of achievement for six gross motor milestones

World Health Organization

Walking alone

Standing alone

Walking with assistance

Hands-&-knees crawling

Standing with assistance

Sitting without support

Motor m

3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

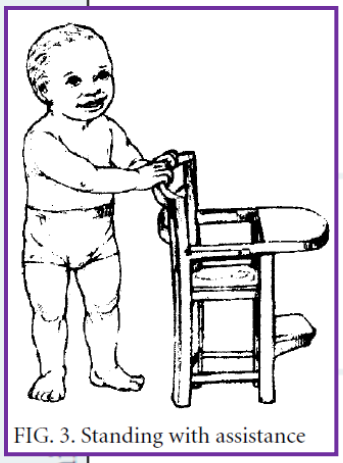


FIG. 3. Standing with assistance

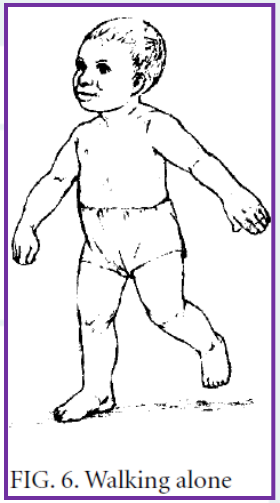


FIG. 6. Walking alone

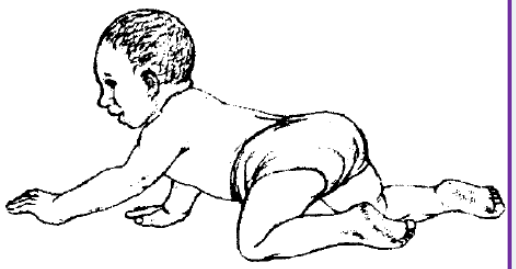
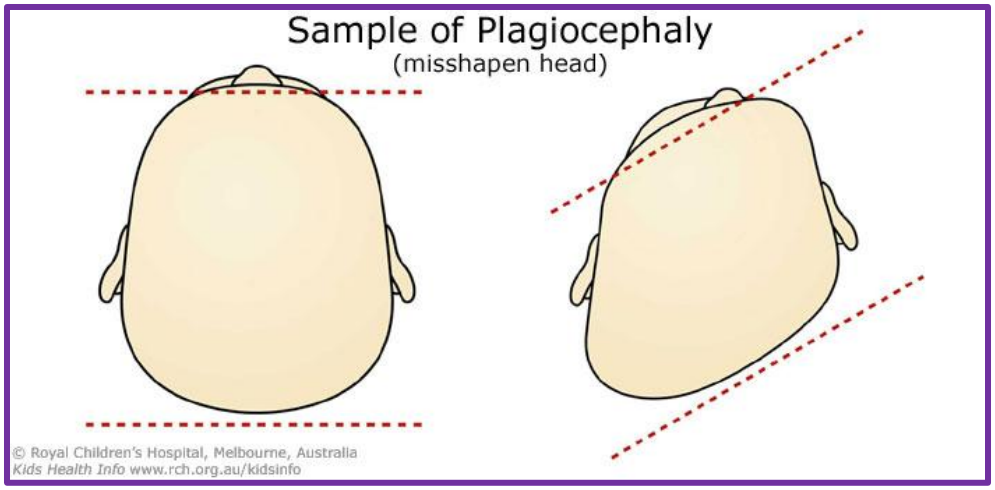


FIG. 2. Hands-and-knees crawling

FIG. 1. Sitting without support

Growth and development of foot

- Nature
  - Heredity
  - Physical make-up
- Nurture
  - Environment
  - Influences such as
    - Height/Weight/Gender
    - Nutrition
    - Footwear
    - First walking age



Growth and development of foot

- Foot
  - Accommodate irregularities of the ground
  - Maintain balance
  - Support weight
  - Shock absorber
  - Generate forward movement
  - Transmit propulsive forces
  - Proprioception

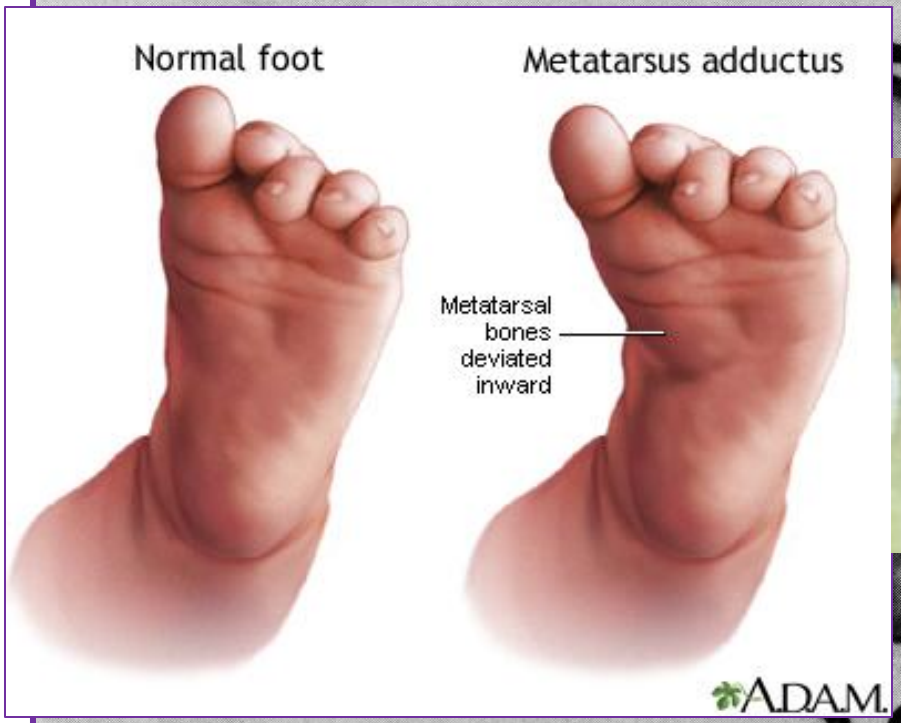
More dynamic
Energy expenditure
Body protection

Contents

- Prenatal development
- Ossification
- Foot of Newborn and infant
- Postnatal development
  - Length
  - Longitudinal arch

Prenatal development

- 28 days: Leg buds appear



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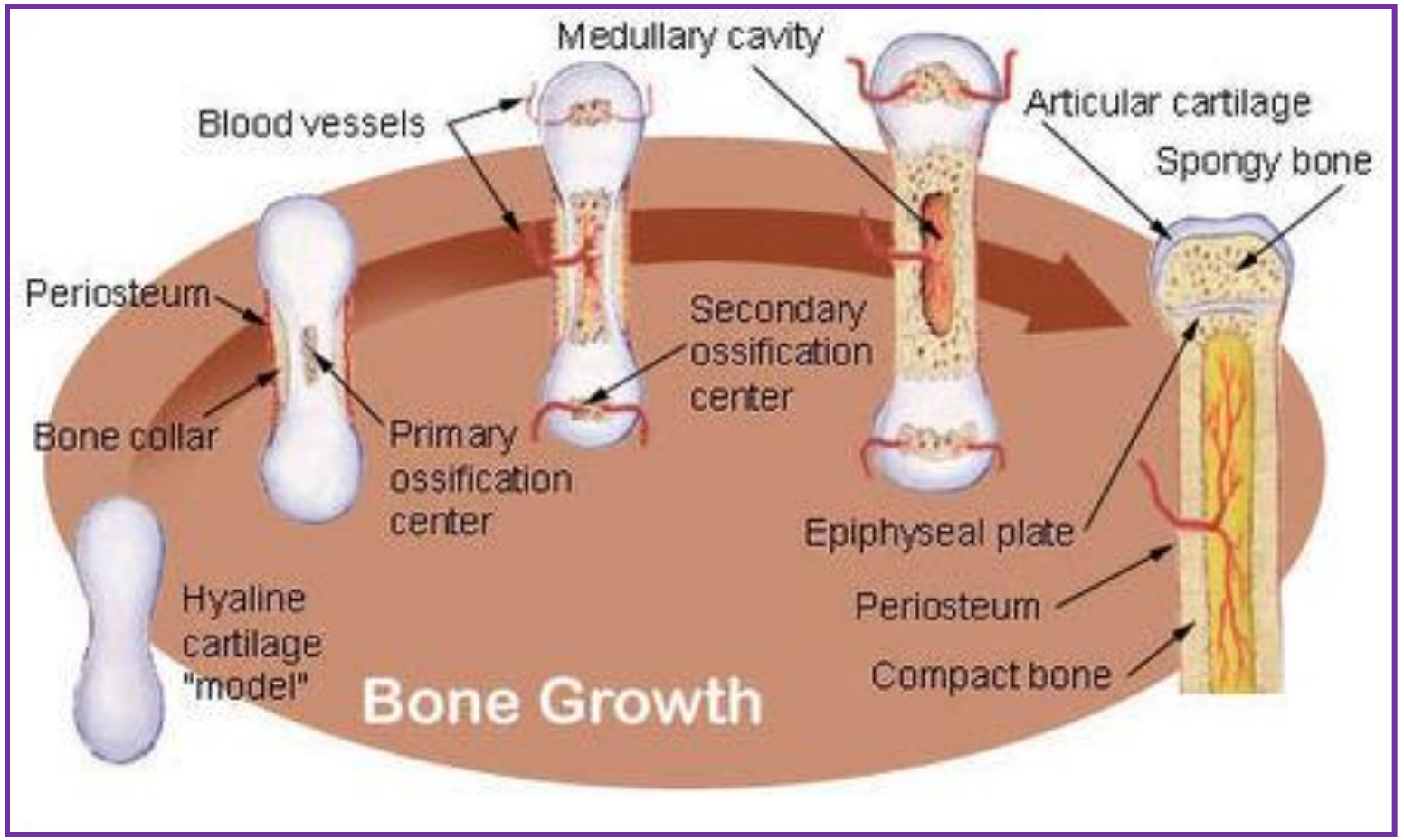
Ossification



Ossification

	Appearance	Union
Metatasals and phalanges	9-15 week fetus - 3-5 years	
Calcaneus - posterior surface	5 month fetus - 6-8 years	
Talus	6-7 month fetus - 8 years	
Cuboid	9 month fetus	
Lateral cuneiform	4-20 month	
Intermediate cuneiform	2-3 years	
Medial cuneiform	2-3 years	
Navicular	2-5 years	

Foot of Newborn and Infant

- 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

Evaluation of early walking patterns from plantar pressure distribution measurements. First year results of 42 children

Comparison of the absolute pressure distribution parameters within the first year ($n = 42$)

	First exam		+3 Months		+6 Months		+9 Months	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
• Forefoot	14.2	2.0	16.8	1.9	17.9	1.9	18.9	1.9
• Hallux	3.6	0.7	3.9	0.8	4.0	0.8	4.4	0.9
• Forefoot	52.7	13.6	68.2	12.7	76.7	11.9	84.4	14.5
• Hallux	17.1	6.1	19.1	8.1	19.5	7.4	22.6	8.2
• Toes 2–5	7.7	4.5	8.2	4.3	7.8	4.1	9.5	5.2
Peak pressure (kPa)								
• Total foot	148.1	40.9	157.9	46.8	169.9	45.0	171.8	42.3
• Hindfoot	109.8	35.2	127.2	48.7	141.7	48.1	143.4	46.6
• Midfoot	73.1	14.8	78.2	17.4	80.1	21.5	74.8	16.5
• Forefoot	87.4	37.1	102.6	26.1	110.0	27.3	110.9	24.8
• Hallux	123.7	40.9	123.5	47.4	124.6	50.2	133.0	43.5
• Toes 2–5	49.4	20.0	54.1	22.6	50.5	18.9	57.3	20.5

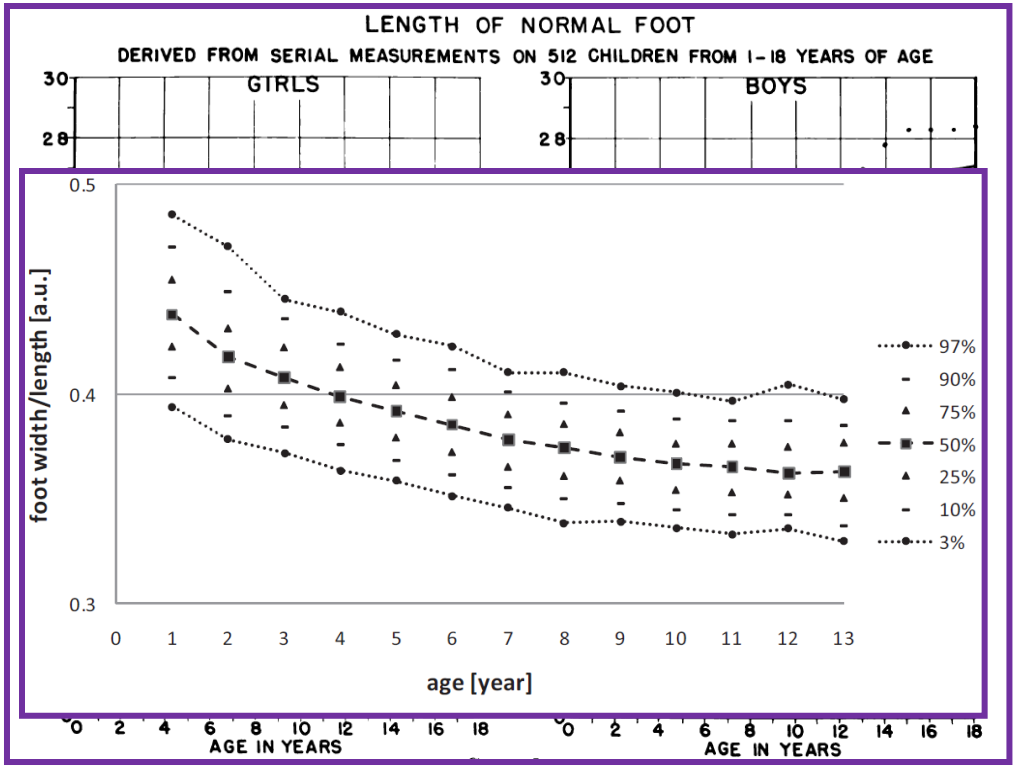
Fat pad and large size of foot increase the loaded area of the plantar surface

Reduces the pressures to protect the sensitive cartilage of the foot skeleton and to reduce shear forces

Gait and Posture 19 (2004) 235–242

Lengths of growing foot

- The average length is 7 to 10 cm at birth.
- The average width is one half its length at birth.
- Half of adult is achieved by the first year.
- By age 10 years, girls reach 90%, whereas boys reach 82%



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1956. 998-990

Gait & Posture 35 (2012) 389-394

Lengths of growing foot

	Gender		Appointment		Age onset of walking		Body height		Body weight	
	p	Beta	*p*	Beta	*p*	Beta	*p*	Beta	*p*	Beta
PP										
Total	0.8104	0.9902	0.2736	1.0271	0.1424	1.0176	**<0.0001**	**1.1009**	**0.0056**	**0.9843**
Hindfoot	0.3015	0.9506	0.3397	1.0308	0.0255	1.0293	**<0.0001**	**1.1348**	**0.0009**	**0.9731**
Midfoot	0.2374	1.0648	0.6252	0.9825	0.2885	0.9860	**0.0003**	**0.9448**	**<0.0001**	**1.0348**
Forefoot	0.8060	0.9902	0.3178	1.0259	0.9219	0.9991	**0.0003**	**1.0709**	0.3984	1.0033
Hallux	0.7699	1.0198	0.5212	0.9806	0.9705	1.0005	**0.0017**	**1.0838**	0.8812	0.9988
Toes 2–5										**0.9704**
CArel										
Total										0.9998
Hindfoot										**0.9960**
Midfoot										**1.0303**
Forefoot										**0.9943**
Hallux										0.9914
Toes 2–5										**0.9753**
MFrel										
Total	0.2096	0.9830	**0.0036**	**1.0247**	0.7359	0.9990	0.5891	0.9968	0.1051	0.9967
Hindfoot	0.2148	0.9703	0.8803	1.0023	0.6985	1.0023	**<0.0001**	**1.0761**	**<0.0001**	**0.9796**
Midfoot	0.1471	1.2298	0.4560	0.9423	0.1102	0.9471	**0.0083**	**0.8793**	**0.0051**	**1.0358**
Forefoot	0.2253	0.9712	0.5157	1.0107	0.3407	0.9933	**<0.0001**	**1.0542**	**0.0012**	**0.9877**
Hallux	0.2237	1.0814	0.6679	1.0141	0.3930	0.9911	**0.0001**	**1.0936**	**<0.0001**	**0.9660**
Toes 2–5	0.3782	1.1138	0.0112	1.1142	0.7972		0.0880		**<0.0001**	**0.9397**
AI	0.1326	1.1555	0.2556	0.9438	0.2283	0.9772	**0.0047**	**0.9167**	**0.0036**	**1.0315**
MFW	**0.0022**	**0.5884**	0.4526	0.0945	0.1240	−0.0734	**0.0023**	**−0.2688**	**0.0047**	**0.0760**
FLmax	0.2253	0.1882	**0.0030**	**0.3167**	0.5752	−0.0158	**<0.0001**	**0.4449**	0.0118	0.0266

A 5 cm difference in height would be related to a longer foot (+0.4 cm) but a lesser foot width (0.3 cm).

K. Bosch et al./Gait & Posture 32 (2010) 564–571

Longitudinal arch

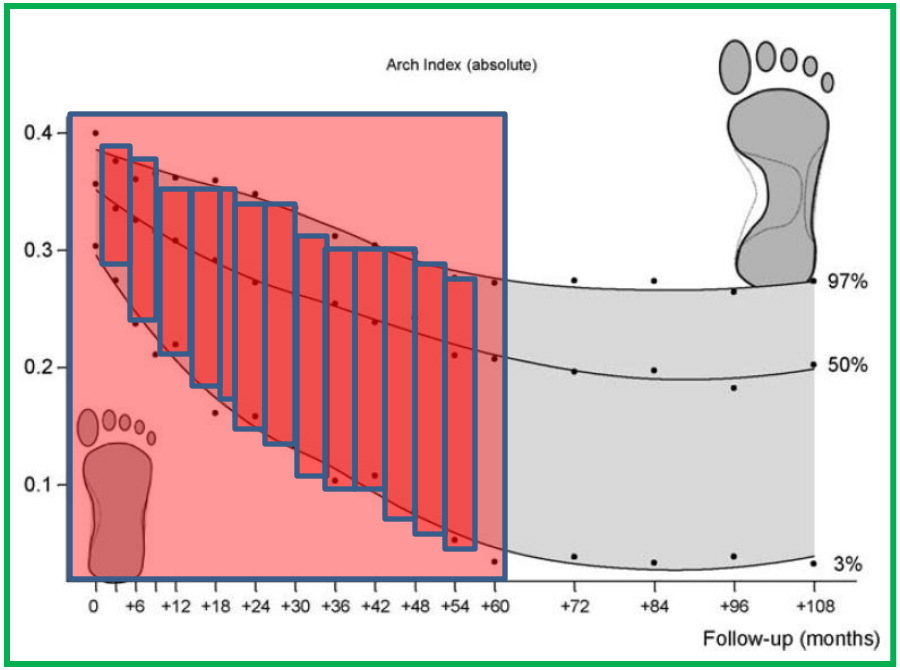
- Debatable

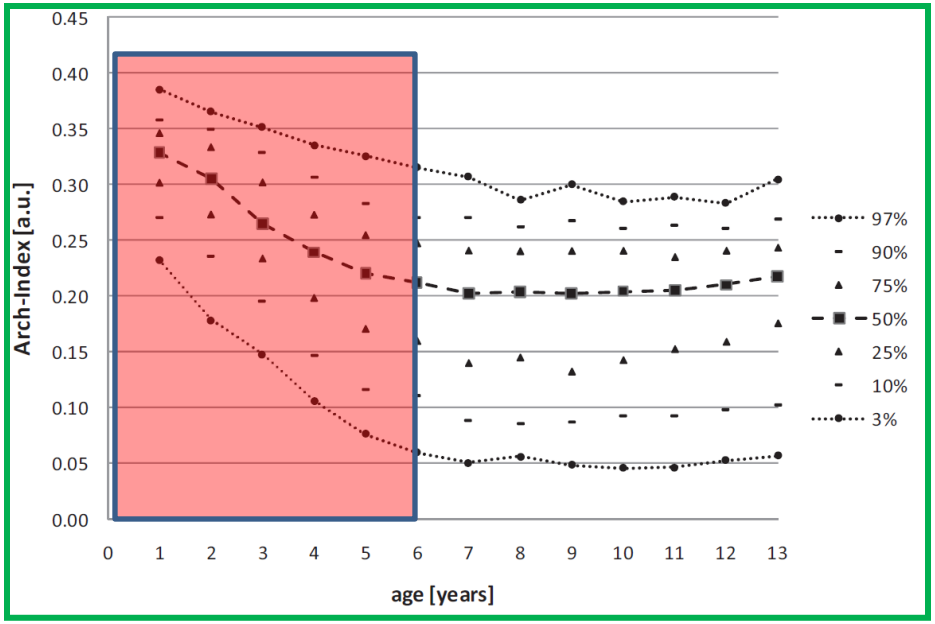
- Arch index

= midfoot contact area/total foot contact area

Static and dynamic foot characteristics in children aged 1–13 years: A cross-sectional study

Development of healthy children's feet—Nine-year results of a longitudinal investigation of plantar loading patterns





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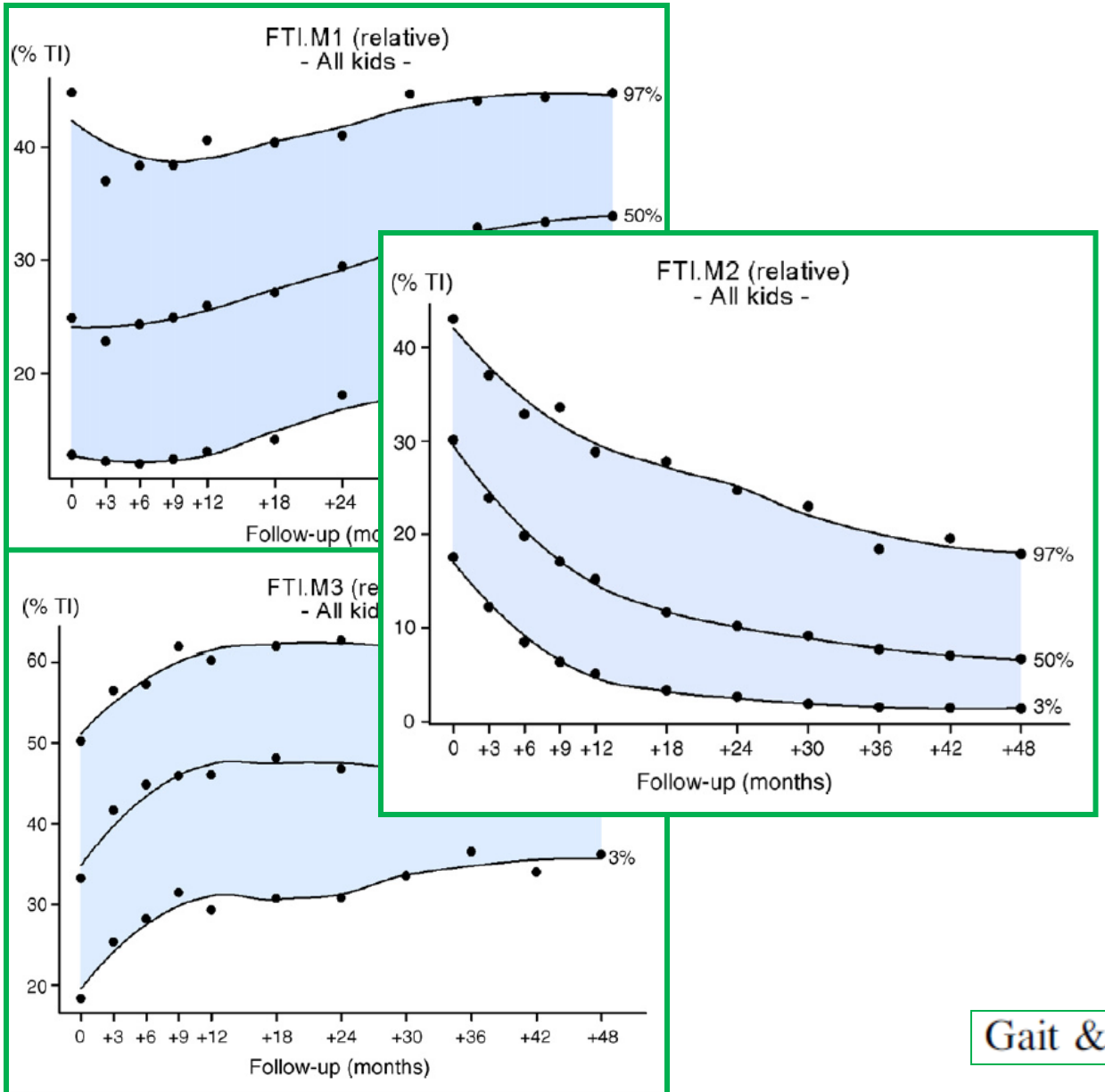
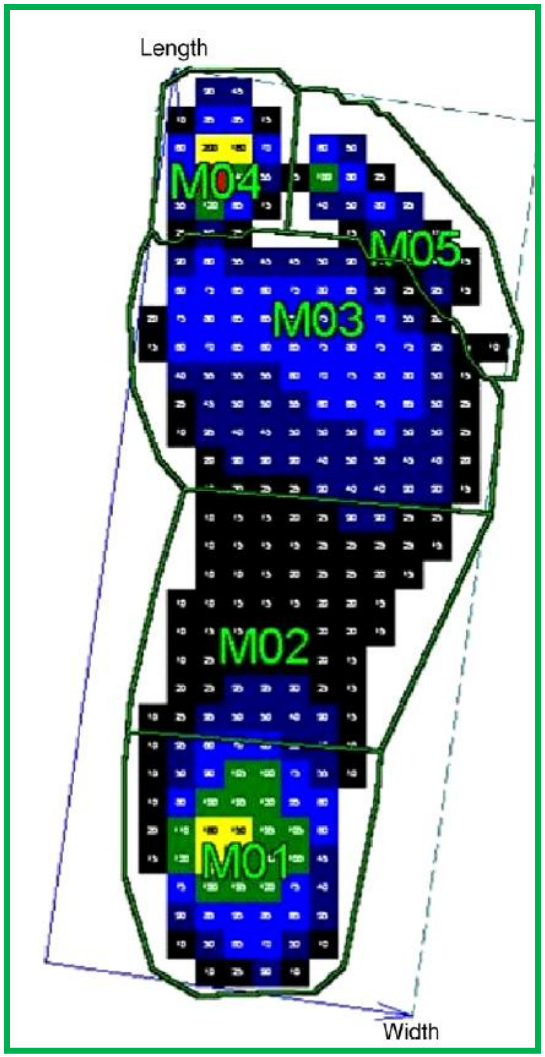
Preliminary normative values for foot loading parameters of the developing child





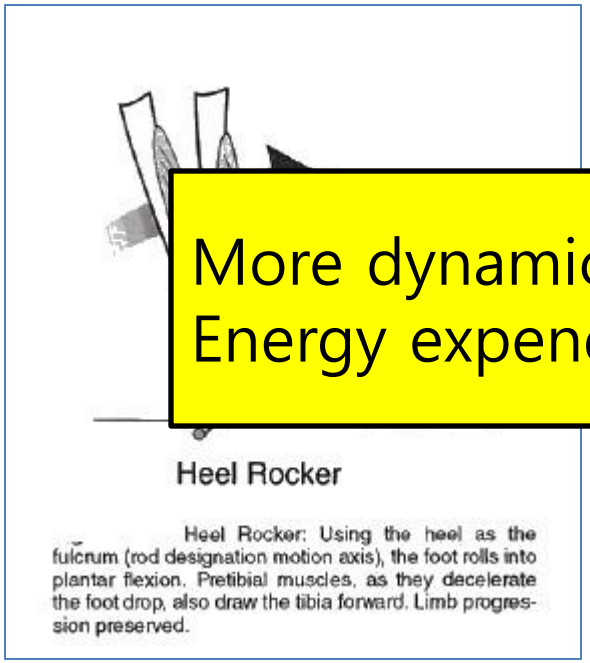
Gait & Posture 26 (2007) 238–247

Development of plantar pressure

- Increased loading on forefoot and heel
- Decreased loading on midfoot
- Fat pad shifts towards the heel and th forefoot

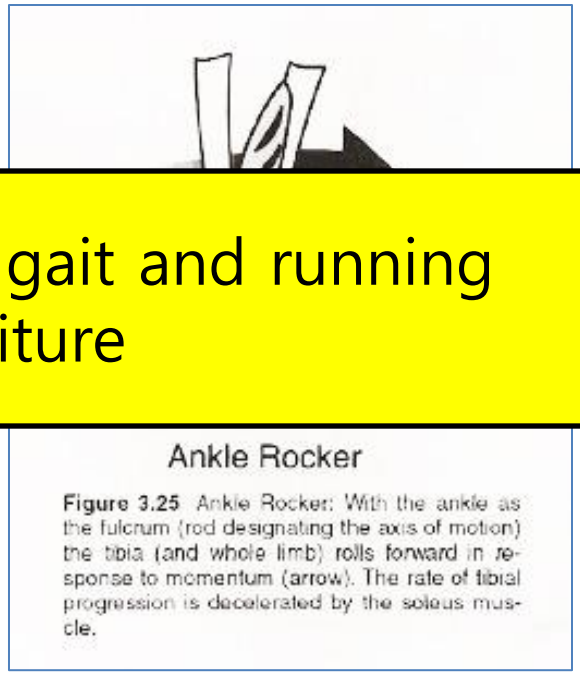
=> More controlled roll-over process

Roll-over process



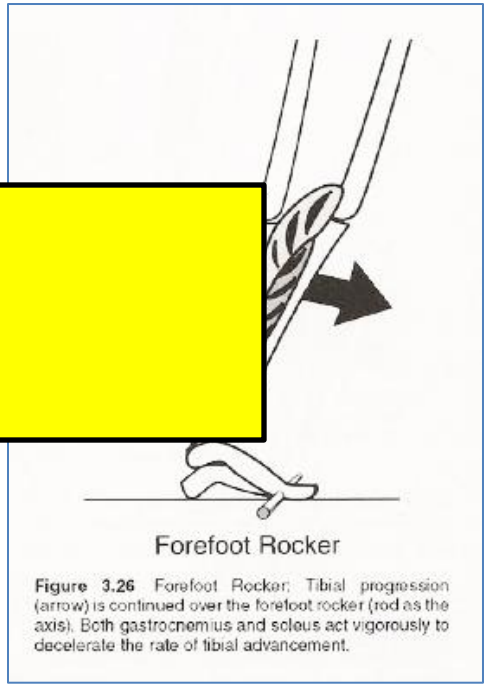
Heel Rocker

Heel Rocker: Using the heel as the fulcrum (rod designation motion axis), the foot rolls into plantar flexion. Pretibial muscles, as they decelerate the foot drop, also draw the tibia forward. Limb progression preserved.



Ankle Rocker

Figure 3.25 Ankle Rocker: With the ankle as the fulcrum (rod designating the axis of motion) the tibia (and whole limb) rolls forward in response to momentum (arrow). The rate of tibial progression is decelerated by the soleus muscle.



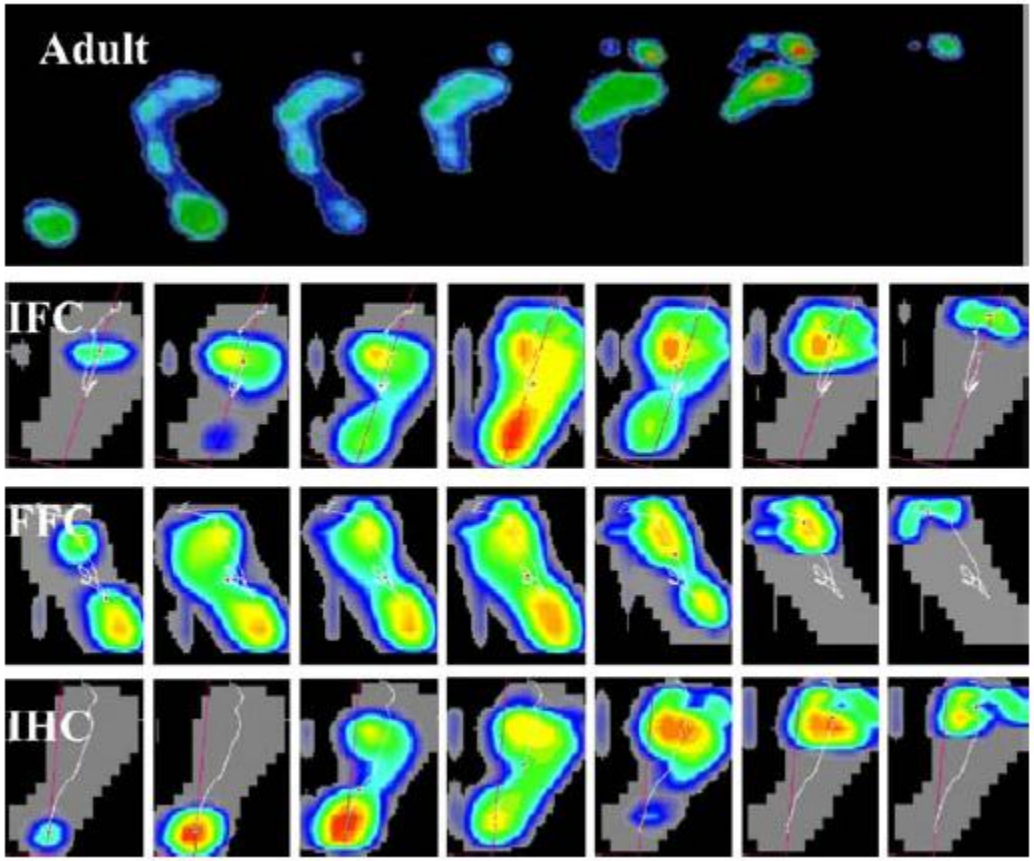
Forefoot Rocker

Figure 3.26 Forefoot Rocker: Tibial progression (arrow) is continued over the forefoot rocker (rod as the axis). Both gastrocnemius and soleus act vigorously to decelerate the rate of tibial advancement.

More dynamic gait and running
Energy expenditure

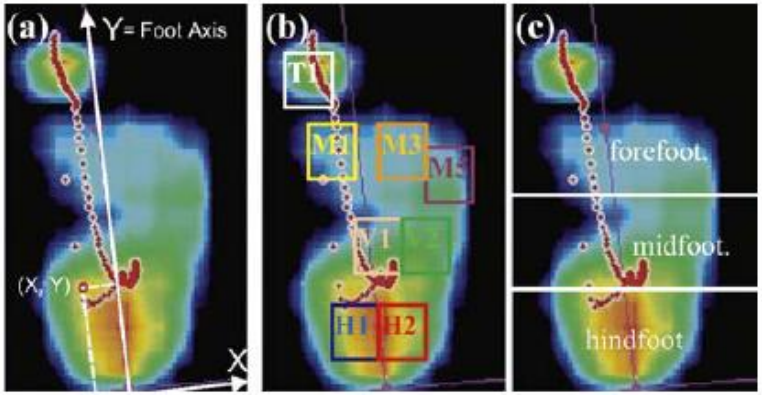
Plantar pressure

- Three types at an initial walking
  - Initial forefoot-contact
  - Flat foot-contact
  - Initial heel contact

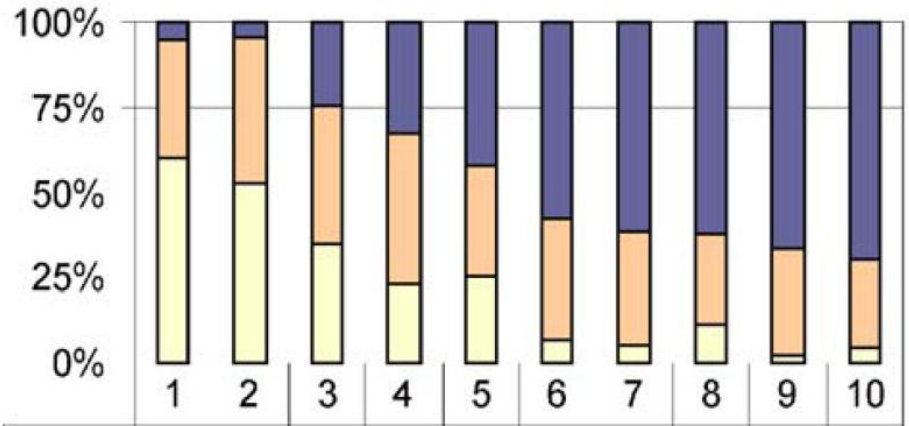


Gait & Posture 23 (2006) 142–148

Changes in foot-function parameters during the first 5 months after the onset of independent walking: a longitudinal follow-up study



(a) Foot Roll-off Patterns



	1	2	3	4	5	6	7	8	9	10
IHC	5	5	24	33	43	58	62	62	67	70
FFC	35	43	41	44	33	36	33	27	31	26
IFC	60	52	34	23	25	7	5	11	2	4

Gait & Posture 23 (2006) 142–148

Evaluation of early walking patterns from plantar pressure distribution measurements. First year results of 42 children

Fig. 3. Example of a child (#43) with a clear development of the arch after 6 months and even more so after 1 year. The gait line shows a smooth pattern after 1 year.

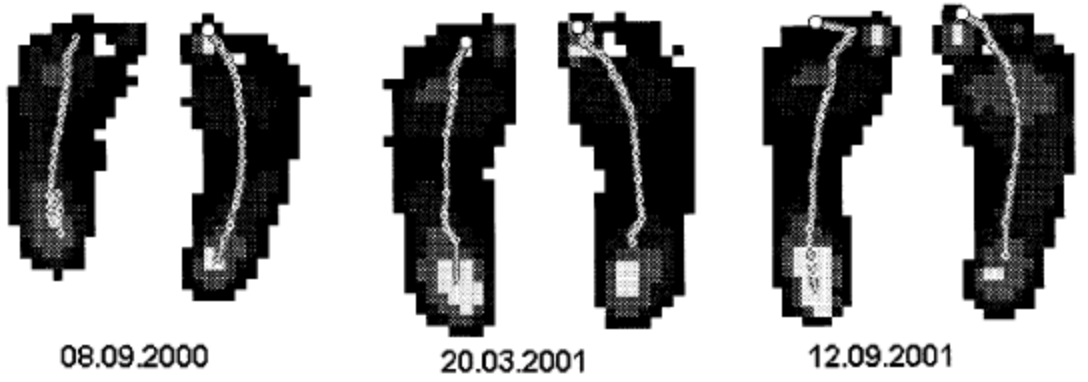
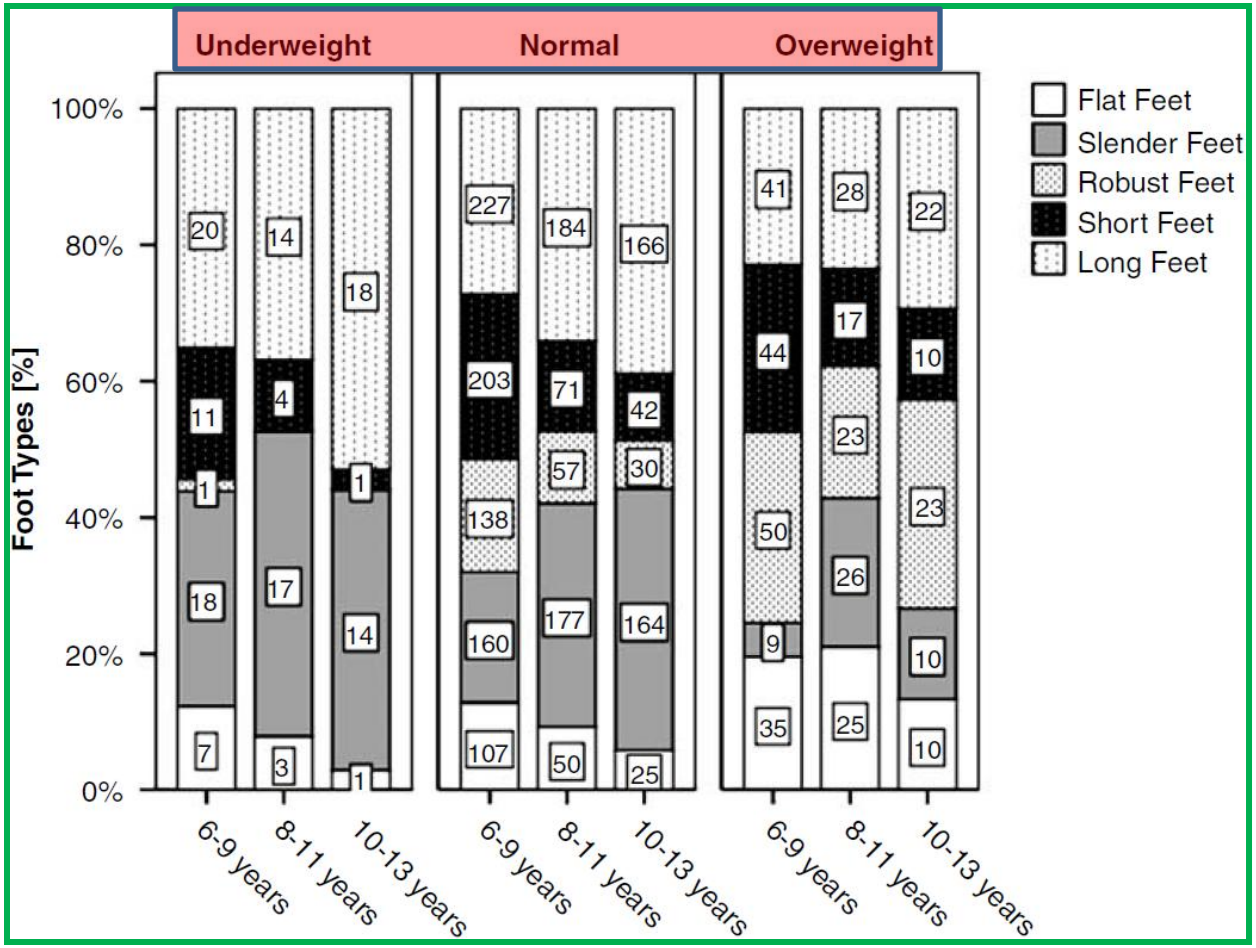


Fig. 5. Example of a plantar pressure pattern with the persisting flat foot pattern (#23).

Gait and Posture 19 (2004) 235–242

Foot morphology of normal, underweight and overweight children

- 1450 boys
  1437 girls
  (2 – 14 years)
  - Flat feet
  - Slender feet
  - Robust feet
  - Short feet
  - Long feet



International Journal of Obesity (2008) 32, 1068–1075

Conclusion

Change of shape and function of foot

Growth and development of foot

Physiologic and pathologic (intervention timing)

Nature and Nurture

Wide inter-individual variability