Lower Limb Biomechanics Summary

The Kinetic Chain: How Foot Mechanics Influence the Knee, Hip and Lumbar Spine

The foot is the foundation of the kinetic chain. Mechanical events at the foot — pronation, supination, forefoot loading — create rotational and translational forces that propagate proximally through the tibia, knee, femur, hip, and lumbar spine. Understanding these relationships allows the clinician to reason beyond the site of pain and address the biomechanical driver.

1 The Gait Cycle: Phases and Key Events

Phase	% Gait Cycle	Key Mechanical Event	Clinical Relevance
Initial contact (heel strike)	0–2%	Heel contacts ground; subtalar joint in slight supination; tibia in neutral or slight external rotation	High loading spike on calcaneus and Achilles. Bevel sole reduces plantarflexion moment. Assess contact point: lateral heel = normal; central = pes planus variant.
Loading response	0–10%	Rapid subtalar pronation; tibia internally rotates; femur follows into internal rotation; forefoot loads medially as arch lowers	Pronation is normal and shock-absorbing here. Excessive or prolonged pronation loads tibialis posterior, plantar fascia, Achilles, and medial knee.
Midstance	10–30%	Centre of mass passes over foot; subtalar joint should approach neutral; Windlass mechanism begins; ankle plantarflexes to decelerate forward tibial progression	Inadequate resupination in midstance loads plantar fascia and first ray. RCSP assessment reflects position at this phase.
Terminal stance / toe-off	30–50%	Heel rises; Windlass mechanism engages fully (hallux extension tightens plantar fascia); foot supinates and becomes rigid for propulsion	Functional hallux limitus interrupts Windlass — leads to compensatory midfoot collapse. FHL is a key finding at propulsion. First MTPJ must achieve ~65 degrees extension.
Swing phase	60–100%	Foot cleared from ground; limb advances; hip flexors, hip abductors and ankle dorsiflexors work to prevent foot drop and maintain clearance	Reduced ankle dorsiflexion in swing = compensatory hip hiking or circumduction. MTSS and anterior compartment loading can increase during swing phase.

2 Kinetic Chain: Foot to Spine

Foot Mechanism	Proximal Effect	Associated Conditions	Orthotic Strategy
Excessive subtalar pronation	Tibial internal rotation -> knee valgus -> increased hip adduction -> contralateral pelvic drop	Medial knee pain (MCL, medial compartment OA); PFPS; GTPS; MTSS; low back pain (asymmetric)	Rearfoot posting (varus); medial heel skive if RCSP > 4 degrees. Address hip abductor strength.
Prolonged pronation past midstance	Windlass mechanism delayed; first ray elevation; hallux dorsiflexion limited; forefoot compensation	Plantar fasciitis; peroneal tendinopathy; functional hallux limitus; bunions	Increase rearfoot control; Morton's extension if FHL confirmed; kinetic wedge for 1st ray loading.
Forefoot valgus (everted forefoot)	Lateral forefoot contact; lateral ankle loading; supination moment maintained into midstance	Lateral ankle instability; peroneal tendinopathy; 5th metatarsal stress fracture; IT band syndrome	Lateral forefoot post (valgus wedge); lateral heel flare; supination-resistant footwear.
Forefoot varus (inverted forefoot)	Medial forefoot contact; pronation to achieve medial forefoot ground contact in late stance	Plantar fasciitis; 1st met stress; hallux valgus; tibialis posterior tendinopathy	Medial forefoot post; intrinsic forefoot posting if casting captures forefoot position.
Reduced ankle dorsiflexion (ADF < 10 degrees)	Compensatory midfoot collapse or early heel rise; increased knee flexion demand; anterior knee pain	Plantar fasciitis; PFPS; anterior ankle impingement; Achilles tendinopathy	Heel raise (4–6mm) to accommodate deficit; address gastrocnemius-soleus complex tightness.
Hallux rigidus / FHL	Compensatory midfoot collapse at toe-off; increased loading of lesser metatarsals; tibial rotation compromise	Metatarsalgia; stress fractures; plantar plate injury; low back pain from gait asymmetry	Stiff-soled footwear with forefoot rocker; Morton's extension; offload lesser metatarsals.

3 Lower Limb ROM Reference Values

Joint / Measurement	Normal Range	Clinically Reduced if...	Implications if Reduced
Ankle dorsiflexion (knee extended)	10–15 degrees	< 5 degrees	Gastrocnemius tightness; compensatory midfoot collapse; heel pain; PFPS
Ankle dorsiflexion (knee flexed)	15–20 degrees	< 10 degrees	Equinus contracture (both gastroc + soleus); significant functional limitation; higher plantar fascia load
First MTPJ dorsiflexion (weight bearing)	65–75 degrees	< 50 degrees (functional limitus); < 20 degrees (structural rigidus)	Windlass impairment; hallux rigidus; plantar plate stress; compensation at midfoot
Subtalar inversion	20–30 degrees	< 15 degrees	Rigid subtalar; tarsal coalition screening indicated
Subtalar eversion	5–10 degrees	< 3 degrees or asymmetric	Sinus tarsi impingement; tarsal coalition; PTTD stage III or IV
Hip internal rotation	35–45 degrees	< 20 degrees	FAI screening; increased femoral torsion; GTPS risk
Hip external rotation	40–50 degrees	< 30 degrees	Piriformis tightness; hip OA screening; affects foot progression angle
Knee extension	0 to -5 degrees hyperextension	Loss of full extension or fixed flexion deformity	Increased posterior capsule loading; altered gait mechanics; knee OA progression

4 Key Muscle Roles and Clinical Testing

Muscle / Group	Primary Role in Gait	Effect of Weakness	Assessment Test
Tibialis posterior	Deceleration of pronation in loading response; inversion at toe-off; arch support	Excessive and prolonged pronation; PTTD; medial column collapse	Single-leg heel raise: ability to perform 20 reps = normal. Observe for inversion at peak rise.
Gastrocnemius / soleus	Decelerate forward tibial progression in midstance; generate push-off force	Weakness: reduced propulsion, early heel rise compensation. Tightness: equinus; heel pain; PFPS	Single-leg calf raise x 20 for strength. Lunge test for dorsiflexion range.
Peroneus longus	Plantarflexes 1st ray; stabilises lateral arch; controls forefoot eversion	First ray elevation; loss of medial forefoot loading; lateral column overload	Resisted eversion + 1st ray plantarflexion. Compare side to side.
Gluteus medius	Contralateral pelvic stability in single-leg stance; decelerates hip adduction	Trendelenburg gait; increased knee valgus; GTPS; PFPS; IT band syndrome	Trendelenburg test; single-leg squat: observe knee position over 2nd toe.
Hip flexors (iliopsoas)	Advance limb in swing; stabilise lumbar spine in single-leg stance	Tightness: anterior pelvic tilt; increased lumbar lordosis; hip flexion contracture	Thomas test for hip flexor tightness. Modified Thomas for rectus femoris.
Quadriceps (VMO)	Decelerate knee flexion in loading response; stabilise patella medially	VMO weakness: lateral patellar tracking; PFPS; anterior knee pain	Single-leg squat control; observe for Valgus collapse at the knee.

Orthotic prescription addresses the mechanical environment but does not replace muscle function. Where muscle weakness or inhibition is identified, orthotics and exercise must work together. A device that controls pronation without addressing weak hip abductors will under-deliver for conditions driven by the proximal kinetic chain.