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Biomechanics of Gait and Running

I. Normal Gait

STANCE (60-62% gait cycle)

Initial Contact: The moment the foot contacts the ground.

Loading Response: Weight is rapidly transferred onto the outstretched limb, the first period of double-limb support.

Midstance: The body progresses over a single, stable limb.

Terminal Stance: Progression over the stance limb continues. The body moves ahead of the limb and weight is transferred onto the forefoot.

Pre-swing: A rapid unloading of the limb occurs as weight is transferred to the contralateral limb, the second period of double-limb support.

SWING (38-40% gait cycle)

Initial Swing: The thigh begins to advance as the foot comes up off the floor.

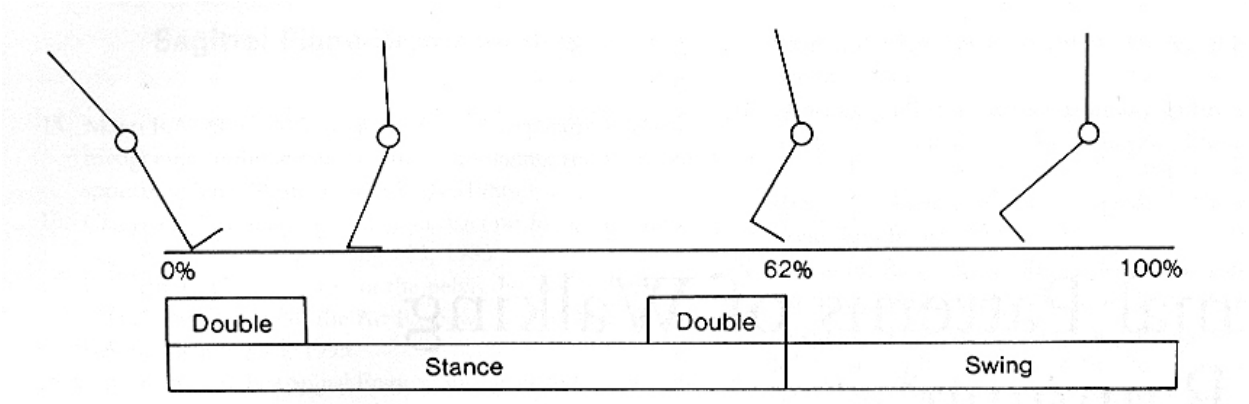
Mid Swing: The thigh continues to advance as the knee begins to extend, the foot clears the ground.

Terminal Swing: The knee extends, the limb prepares to contact the ground.

The Functional Phases of the Gait Cycle							
Stance (62%)				Swing (38%)			
IC	LR	MS	TS	PSw	ISw	MSw	TSw
Weight Acceptance		Single Limb Support		Swing Limb Advance			

II. Normal Stride Characteristics

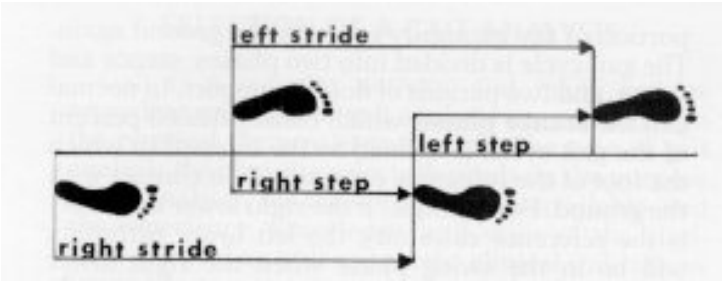
A. Cadence: steps / time

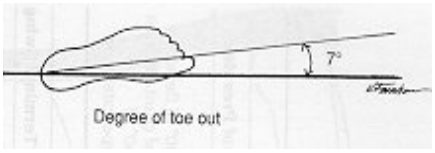


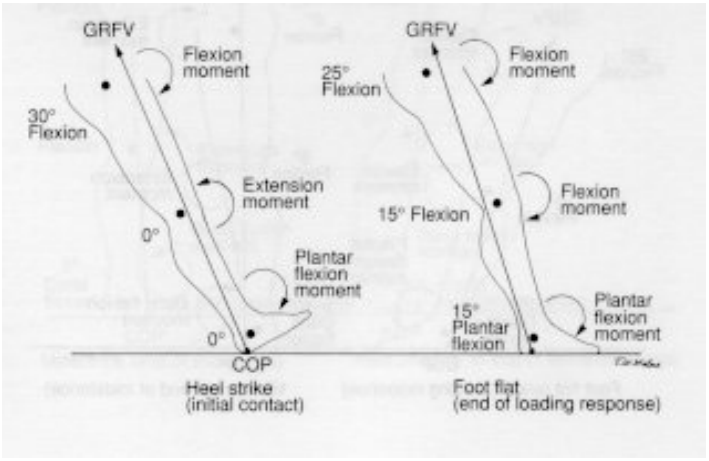
Adult: approx. 2 steps/sec
Females (20 - 69 years old): 121 ∀ 8.5 steps/min
Males (20 - 69 years old): 111 ∀ 7.6 steps/min

B. Velocity: distance/time
Adult: 1.4 m/sec
Females (20 - 69 years old): 79.3 ∀ 9.5 m/min
Males (20 - 69 years old): 82.1 ∀ 10.3 m/min

C. Stride length: right heel strike to right heel strike
Adult: 1.5 m
Females (20 - 69 years old): 1.32 ∀ .13 m
Males (20 - 69 years old): 1.48 ∀ .15 m







III. Abnormalities during **Weight Acceptance**:

Joint	**Deviation: Possible Cause**

Trunk	Backward lean: To decrease demand on hip extensors (glut max) Forward lean: Due to increased hip flexion (joint contracture or mm weakness) Lateral Lean: R/L Weak hip abductors
Pelvis	Contralateral drops: Weak hip abductors on reference limb Ipsilateral drops: Compensation for shortened limb
Hip	Excessive flexion: Hip flexion contracture, excessive knee flexion Limited flexion: Weakness of hip flexors, decreased hip flexion
Knee	Excessive flexion: Knee pain, weak quads, short leg on opposite side Hyperextension: Decreased dorsiflexion, weak quads Extension thrust: Intention to increase limb stability
Ankle	Forefoot contact: Heel pain, excessive knee flexion, pf contracture Foot flat contact: Dorsiflexion contracture, weak dorsiflexors Foot slap: Weak dorsiflexors
Toes	Up: Compensation for weak anterior tib

IV. Abnormalities during **Single Limb Support**:

Joint	**Deviation: Possible Cause**
Trunk	Backward lean: To decrease demand on hip extensors (glut max) Forward lean: Due to increased hip flexion (joint contracture or mm weakness) Lateral Lean: R/L Weak hip abductors
Pelvis	Contralateral drops: Weak hip abductors on reference limb Ipsilateral drops: Compensation for shortened limb Anterior Pelvic Tilt: Hip flexion contracture
Hip	Limited flexion: Weakness of hip flexors, decreased hip flexion Internal Rotation: Weak external rotators, femoral anteversion External Rotation: Retroversion, limited dorsiflexion Abduction: Reference limb longer Adduction: Secondary to contralateral pelvic drop
Knee	Excessive flexion: Knee pain, weak quads, short leg on opposite side Hyperextension: Decreased dorsiflexion, weak quads Extension thrust: Intention to increase limb stability Wobbles: Impaired proprioception Varus: Joint instability, bony deformity Valgus: Lateral trunk lean, Joint instability, bony deformity
Ankle	Excessive plantarflexion: Weak quads, Impaired proprioception, ankle pain Early heel off: Tight dorsiflexors, Increased pronation: STJ deformity,
Toes	Up: Compensation for weak anterior tib

V. Abnormalities during **Swing Limb Advance**:

Joint	Deviation: Possible Cause
Trunk	Backward lean: To decrease demand on hip extensors (glut max) Forward lean: Due to increased hip flexion (joint contracture or mm weakness) Lateral Lean: R/L Weak hip abductors
Pelvis	Hikes: Clear swing limb Ipsilateral drops: Weak hip abductors on contralateral side
Hip	Limited flexion: Weakness of hip flexors, decreased hip flexion, hip pain
Knee	Limited flexion: Excess hip flexion, knee pain Excess flexion: Knee contracture, weak quads
Ankle	Excessive plantarflexion: Weak quads, Impaired proprioception, ankle pain Drag: Secondary to limited hip flexion, knee flexion or excess pf Contralateral Vaulting: Compensation for limited flexion of swing or long swing limb
Toes	Inadequate extension:Limited joint motion, forefoot pain, no heel off Clawed/hammered: Imbalance of long toe extensors and intrinsics, weak pf

VI. Running Gait

Variations from walking:

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$
$
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STANCE (30 - 40%)
Foot Strike:

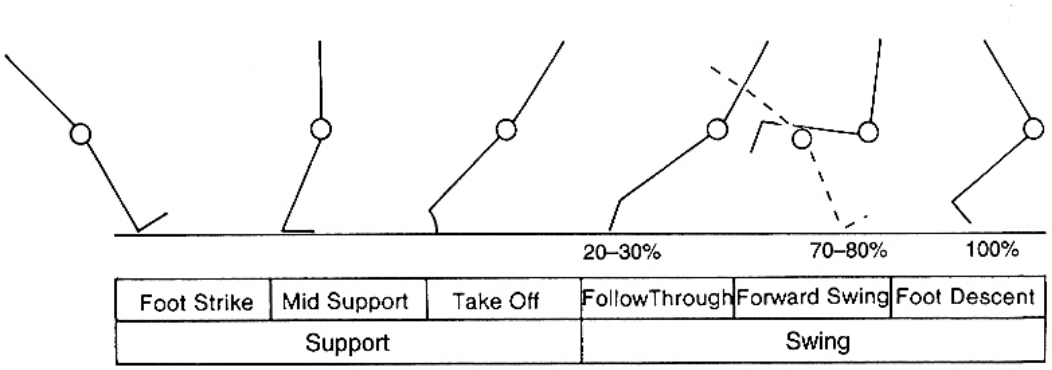
Mid-support:

Take-off (propulsion)

SWING (60 - 70%)
Follow through:

Forward swing:

Foot descent:



VII. Running Faults:

Subject Questionnaire

Name_____ Date_____

Age_____ Height_____

Weight_____

Medical History
Relative to the last year, please circle yes or no in each of the following categories as they relate to the hip and/or legs.

Surgeries	Yes	No
Fractures	Yes	No
Muscle or tendon injuries	Yes	No
Ligament injury	Yes	No
Cartilage injury	Yes	No
Arthritis	Yes	No
Low back pain	Yes	No
Hip pain	Yes	No
Knee pain	Yes	No
Foot or ankle pain	Yes	No
Lower leg pain	Yes	No

Please describe in detail any categories checked "yes"

Does the problem still bother you?

Exercise History

Are you currently running/walking? Yes No

Typical exercise week:

	M	T	W	Th	F	Sat	Sun
Activity							
mileage/ duration							
terrain (hills...)							
run surface (concrete...)							

Do you stretch routinely?

If so, list stretches (areas):

Footwear

Type of running shoe:

Number of miles on current running shoes:

Use shoe inserts/orthotics?

EXAMINATION FINDINGS
Standing
Gait:

	Right	Left
Navicular drop test	_____	_____
Tibial varum	_____	_____
Calcaneal position	_____	_____
Soleus length	_____	_____
L/S Quadrant	_____	_____

Single leg stance (30 sec) _____

Single leg squat (5 reps)_____
Prone

		Right	Left
Calcaneal inversion:		_____	_____
Calcaneal eversion:		_____	_____
Rearfoot position:		_____	_____
FF / RF:		_____	_____
First ray position:		_____	_____
Great toe extension:		_____	_____
Hip joint rotation:	**IR:**	_____	_____
	ER:	_____	_____
Quadriceps length		_____	_____
Dorsiflexion: straight:		_____	_____
bent:		_____	_____

Callus formation: **R:**_____
L:_____
Supine

	Right	Left
Hamstring length	_____	_____
Leg length	_____	_____
Q-angle	_____	_____

Sidelying

	Right	Left
IT Band:	_____	_____
Glut Med strength:	_____	_____
Hip flex strength	_____	_____

WALKING ASSESSMENT

WEIGHT ACCEPTANCE (IC,LR)

- ☐ trunk (lean):_____
- ☐ pelvis (drop):_____
- ☐ hip (flexion):_____
- ☐ knee (position):_____
- ☐ ankle/foot (contact):_____
- ☐ toes (up):_____
- ☐ _____
- ☐ _____

SINGLE LIMB SUPPORT (MS,TS)

- ☐ trunk (lean):_____
- ☐ pelvis (drop,tilt):_____
- ☐ hip (3-plane):_____
- ☐ knee (3-plane):_____
- ☐ ankle/foot (heel-off, STJ):_____
- ☐ _____
- ☐ toes (up):_____
- ☐ _____
- ☐ _____

SWING LIMB ADVANCE (PSW,SW)

- ☐ trunk (lean):_____
- ☐ pelvis (hike, drop):_____
- ☐ hip (flexion):_____
- ☐ knee (flexion):_____
- ☐ ankle/foot:_____
- ☐ toes:_____
- ☐ _____
- ☐ _____

WALKING ASSESSMENT

WEIGHT ACCEPTANCE (IC,LR)

- ☐ trunk (lean):_____
- ☐ pelvis (drop):_____
- ☐ hip (flexion):_____
- ☐ knee (position):_____
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- ☐ toes (up):_____
- ☐ _____
- ☐ _____

SINGLE LIMB SUPPORT (MS,TS)

- ☐ trunk (lean):_____
- ☐ pelvis (drop,tilt):_____
- ☐ hip (3-plane):_____
- ☐ knee (3-plane):_____
- ☐ ankle/foot (heel-off, STJ):_____
- ☐ _____
- ☐ toes (up):_____
- ☐ _____
- ☐ _____

SWING LIMB ADVANCE (PSW,SW)

- ☐ trunk (lean):_____
- ☐ pelvis (hike, drop):_____
- ☐ hip (flexion):_____
- ☐ knee (flexion):_____
- ☐ ankle/foot:_____
- ☐ toes:_____
- ☐ _____
- ☐ _____

RUNNING ASSESSMENT

FRONT

- ☐ arms cross midline_____
- ☐ head down_____
- ☐ lands on heels_____
- ☐ tight shoulders_____
- ☐ excessive hip rotation_____
- ☐ outward toeing_____
- ☐ knee alignment(varus/valgus)_____
- ☐ tibial rotation_____
- ☐ knee control_____

SIDE

- ☐ elbow position (90 degrees)_____
- ☐ tight hands_____
- ☐ head down_____
- ☐ forward bend_____
- ☐ low knees_____
- ☐ increased foot slap_____
- ☐ slow leg turnover_____
- ☐ over striding_____
- ☐ asymmetrical leg swing_____
- ☐ MTP extension_____

REAR

- ☐ pronation/supination_____
- ☐ lateral pelvic tilt_____
- ☐ pelvic tranverse rot_____
- ☐ lumbar SB_____
- ☐ lateral head motion_____
- ☐ thoracic rotation_____
- ☐ scapular position_____
- ☐ center of mass_____
- ☐ foot crosses midline_____

RUNNING ASSESSMENT

FRONT

- ☐ arms cross midline_____
- ☐ head down_____
- ☐ lands on heels_____
- ☐ tight shoulders_____
- ☐ excessive hip rotation_____
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- ☐ lumbar SB_____
- ☐ lateral head motion_____
- ☐ thoracic rotation_____
- ☐ scapular position_____
- ☐ center of mass_____
- ☐ foot crosses midline_____

REFERENCES

Arendt E: Orthopedic issues for active and athletic women. Clin Sports Med 1994; 13 (2):483-505.

Barber FA, Sutker AN. Iliotibial band syndrome. Sports Med 1992; 14(2):144-148.

Beck JL, Wildermuth BP: The Female Athlete's Knee: Clin Sports Med 1995;4 (2):345-366.

Brukner P. Exercise-related lower leg pain: an overview. Med Sci Sports Exerc. 32:3, S1-S3, 2000.

Donatelli R. The Biomechanics of the Foot and Ankle. Philadelphia:FA Davis, 1996.

Fredericson M, Cookingham CL, Chaudhari AM, et al. Hip abductor weakness in distance runners with iliotibial band syndrome. Clin J Sport Med 2000; 10(3):169-175.

Gray GW. Rehabilitation of running injuries. Biomechanical and Proprioceptive Considerations. Top Acute Care Trauma Rehab. 1(2): 67-78, 1986.

Guten GN. Running Injuries. Philadelphia:WB Saunders, 1997.

Munro CR, Miller DI, Fuglevand AJ. Ground reaction forces in running: A reexamination. J Biomech 20:147-155, 1987.

Norkin C, Levangie P. Joint structure and function: A comprehensive Analysis. Philadelphia:FA Davis, 1992.

Orchard JW, Fricker PA, Abud AT, Mason BR.Biomechanics of iliotibial band friction syndrome in runners. Am J Sports Med 1996; 24(3):375-379.

Panni AS. Overuse injuries of the extensor mechanism in ahtletes. Clin Sports Med 2002; 21(3):483-498.

Perry J. Anatomy and biomechanics of the hindfoot. Clin Orthop 177:9-15, 1983.

Perry J. Gait analysis, normal and pathological function. Thorofare, NJ: Charles B. Slack, 1992.

Root ML, Orien WP, Weed JH. Normal and Abnormal Function of the Foot. Los

Angeles: Clinical Biomechanics Corp., 1977.

Shangold M, Mirkin G: Women and Exercise-Physiology and Sports Medicine, 2nd ed. Philadelphia, FA Davis, 1994.

Sommer HM, Vallentyne SW. Effect of foot posture on the incident of medial tibial stress syndrome. Med Sci Sports Exerc. 27:800-804, 1995.

Subotnick SI. Sportsmedicine of the Lower Extremity (2nd ed). Philadelphia:Churchill Livingstone, 1999.

Tiberio D, Gray GW. Kinematics and kinetics during gait. In Donatelli and Wood (eds), Orthopedic Physical Therapy. New York:Churchill Livingstone, 1989.

Walsh M. The Running Course. North American Seminars, Chicago, ILL 2000.