

Gait Analysis Overview

Observational gait analysis involves the identification of gait deviations and determinations of the causes associated with each deviation. It follows a thorough physical examination to include range of motion, manual muscle testing, sensory and neurological exams, and skin checks. The treatment team can then plan and recommend corrective actions to improve the situation. The clinical team should be familiar with normal gait, biomechanics, and prosthetic fit and alignment.

Component Parts		Gait Analysis Procedure
I	Observation	It is essential to observe from at least two vantage points. Sagittal-plane motions are best seen from the side, while frontal-plan motions are best seen from the front or rear.
II	Identification of Gait Abnormalities	Abnormalities are defined as any gait characteristic that differs from the normal pattern. Keep in mind that the single most outstanding characteristic of the normal pattern is symmetry. Thus, for the unilateral amputee, deviations are often identified by observing asymmetry, that is, differences in the patterns of the prosthetic and normal sides.
III	Determination of Causes	The obvious place to look is at the prosthesis, as there are many prosthetic causes for gait deviations. However, there are many non-prosthetic causes. The individual patient may have restricted range of motion at one or more joints, muscular weakness, concomitant medical conditions, excessive fear, or old habit patterns, any of which may cause deviant gait.
Analyze the prosthesis, but do not ignore the patient!		

Phases	Description	Joint Positions	Key Muscle Actions
Initial Contact	The moment the foot strikes the ground. In normal gait, usually the heel contacts first ("heel strike").	Hip is flexed Knee is nearly fully extended Tibia is sloped backwards Ankle is neutral	Hip extensors contract Eccentric contraction of knee extensors (to prevent knee hyperextension) Ankle dorsiflexors contract to control foot position
Loading Response	More body weight is transferred onto the limb.	Hip begins to extend Knee flexes to about 15 degrees Foot goes flat (plantarflexes)	Hip extensors contract Eccentric contraction of knee extensors (controls the knee flexion) Eccentric contraction of dorsiflexors (controls the plantarflexion)
Midstance	The opposite foot is lifted. The body advances forward.	Hip extends further Knee extends Tibia rotates forward Foot remains flat As body advances forward, the ankle goes into dorsiflexion.	Eccentric contraction of knee extensors transitions to concentric contraction Plantar flexors contract to keep body advancing forward
Terminal Stance	Begins when the heel rises from the ground	Hip continues to extend Knee is nearly fully extended (but not quite)	Plantar flexors contract to lift the heel and propel the body forward. Gastrocnemius contraction also acts to prevent knee hyperextension.
Pre-Swing	Begins when the opposite limb contacts the ground Ends when the limb leaves the ground ("toe-off")	The hip is its most extended The knee is in slight flexion The heel is off the ground	Hip flexors begin to contract Eccentric contraction of quadriceps (to control knee flexion) Plantar flexors contract
Initial Swing	Foot is lifted from the floor ("toe-off") Ends when the swinging foot is even with the opposite limb.	The hip flexes The knee flexes further The ankle goes from plantarflexion to neutral or dorsiflexed	Hip flexors contract Ankle dorsiflexors contract
Midswing	The swinging foot is even with the opposite foot. Continues until the swinging limb is in front of the body and the tibia is vertical.	The hip is flexed Knee is at peak flexion when feet are even; then extends. Ankle is neutral or dorsiflexed	Active hip flexor contraction lessens Eccentric contraction of hamstrings (to control tibia position). Ankle dorsiflexors continue to contract
Terminal Swing	From when the tibia is vertical to contact of the foot with the ground.	Hip is largely static Knee is nearly fully extended Ankle is neutral or dorsiflexed	Contraction of hip extensors begins Eccentric contraction of knee flexors (to control tibia position and prevent knee hyperextension). Knee flexors begin to contract Ankle dorsiflexors contract

Gait Analysis - Abnormalities in Transtibial Amputation

Gait Abnormality	Patient Related			Prosthetic Related	
	Possible Causes	Additional Evaluation	Interventions	Prosthetic Causes	Additional Evaluation
Pelvic drop The pelvis on the prosthetic side drops on initial contact as if "stepping into a hole"	Contralateral hip abductor weakness	Perform manual muscle test	Sidestepping with prosthesis with or without the theraband Traditional exercises	Prosthetic limb too short	Compare iliac crest heights in standing
				Residual limb has shrunk relative to the socket	Evaluate adequacy of residual limb volume to the socket, and sock ply
				Excessively compliant heel cushion or prosthetic heel keel	Assess heel compliance during manual loading
Swing Phase Limb Effectively Too Long Several possible deviations	Inability to adequately flex the knee on the prosthetic side	Test knee ROM (all other causes are excluded)	Step-ups with prosthetic leg	Prosthetic limb too long	Evaluate pelvic height in standing with equal weight through both limbs Were there changes to contralateral footwear?
Circumduction The prosthetic limb travels in a lateral arch during swing phase	Habit gait pattern (These patterns can be difficult to unlearn even if the primary contributor is addressed)	Review history Rule out other contributors	Repetitive step forward-step back with prosthetic leg (sound leg remains stationary)	Poorly suspended prosthesis	Evaluate pistoning and/or a socket that is too loose
Hip Hike The ipsilateral hip rises during prosthetic swing phase	Residual limb volume increase (unable to seat limb fully within the socket)	Evaluate use of shrinker, medical contributors	Address shrinker usage and medical contributors	Residual limb not fully seated in the socket	Evaluate fit of socket and sock ply management
Vaulting with contralateral limb Ankle plantar flexion and knee extension of contralateral limb during mid stance phase	Weak hip flexors	Perform manual motor testing	Hip strengthening exercises	Excessive ankle plantar flexion of the prosthetic foot	Posterior leaning prosthesis when observed off of the patient
	Genu recurvatum or other structural abnormality increasing knee extension moment in terminal stance			Excess knee extension moment in terminal stance (that is difficult for patient to overcome with hip flexion)	See transfemoral gait abnormality table
Abducted Gait Pattern The prosthetic limb is carried in an abducted position throughout the swing and stance phase	Adaptation for medial compartment knee pain	Knee joint evaluation	Weight shifting activities over prosthetic limb	Outset prosthetic foot can give an apparent abducted gait pattern	Evaluate iliac crest height in standing
	Adaptation for focal residual limb pain	Inspect residual limb integrity	Refer for management of residual limb problems	Prosthesis is physically or functionally too long	Evaluate iliac crest height in standing
	Balance impairment/fear of falling	Evaluate balance and stability	Advanced balance activities	Medially placed foot	Evaluate static prosthetic alignment

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Reduced Toe Clearance Prosthetic toe drags or catches during swing phase	Muscle weakness of the hip and/or knee flexors	Perform manual muscle test	Knee flexion plus bridging with ball Traditional exercises	Prosthetic limb too long	Evaluate iliac crest heights in standing with equal weightbearing on the prosthetic limb
	Reduced range of motion in hip flexion or knee flexion	Test ROM	Stretch accordingly	Inadequate suspension/pistoning	Evaluate adequacy of suspension
	Contralateral hip abductor weakness	Perform manual muscle test	Sidestepping with prosthesis with or without the Theraband Traditional exercises	Residual limb not fully seated in prosthetic socket	Evaluate relationship of the residual limb to the distal end of the prosthetic socket
	Reduced confidence in the prosthesis		Forward/back with sound limb (prosthesis stationary)	Excessive plantar flexion of the prosthetic foot	Evaluate static prosthetic alignment
Foot Slap Rapid plantarflexion of foot after initial contact with heel.	On intact lower limb: poor eccentric dorsiflexion control	Manual motor testing		Single-axis or traditional multi-axis foot: posterior (plantar flexion) bumper is too soft	Evaluate prosthesis; trial harder bumper
				Hydraulic ankle: insufficient dampening of plantar flexion	Evaluate prosthetic settings; trial increased plantar flexion dampening
Premature heel rise at the end of stance phase, with quick "drop off" to contralateral foot.	Hip flexion contracture	Evaluate ROM	Stretching	Foot is too posterior (short toe lever arm)	Evaluate prosthetic alignment
	Knee flexion contracture	Evaluate ROM	Stretching	Foot keel is too soft	Evaluate prosthesis
				Excessive dorsiflexion of the foot or socket flexion	Evaluate prosthetic alignment
Inadequate heel off Insufficient heel rise at end of stance phase	Reduced confidence in putting weight through the toe of the prosthesis	Evaluate gait	Gait training	Foot is too anterior (long toe lever arm)	Evaluate prosthetic alignment
				Foot keel is too stiff	Evaluate prosthesis

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Decreased prosthetic stance time The total duration of stance phase on the prosthetic limb is reduced May be accompanied by short step with the contralateral foot (quickly shifting weight to the contralateral foot).	Residual limb pain	Examine residual limb to identify source of pain	Appropriate modality for pain and gait training	Poorly fitting prosthetic socket	Identify possible signs of poor prosthetic socket fit
	Musculoskeletal pain in proximal structures	Musculoskeletal evaluation to identify source of pain	Address as appropriate	Prosthetic foot alignment	Ensure that there are no underlying alignment abnormalities that contribute to a sense of instability
	Residual limb discomfort	Determine if "normal" discomfort with initial prosthesis training vs. pathologic	Residual limb desensitization Medical or other intervention if indicated	Toe lever too short: hastens transition to contralateral stance	Evaluate prosthetic alignment
	Reduced confidence in the prosthesis	Evaluate gait	Forward/back with sound limb (prosthesis stationary)		
	Balance impairment	Evaluate balance function	Advanced balance activities		
Increased stride width Wide based gait pattern	Poor balance or poor weight-shifting	Check standing balance	Standing balance Weight shift activities	Prosthesis too long	Check leg length at iliac crest
	Hip abduction contracture	Evaluate hip ROM	Stretching exercises	Outset foot	Adjust prosthesis
	Adducted sound limb	Evaluate hip ROM	Stretch adductors and strengthen abductors	Socket too abducted	Check static alignment
	Gait habit		Gait training	Medial wall pressure	Check static alignment
				Medial leaning pylon	Check static alignment

Gait Abnormality	Patient Related			Prosthetic Related	
	Possible Causes	Additional Evaluation	Interventions	Prosthetic Causes	Additional Evaluation
Knee instability Excessive knee flexion on prosthetic side in early stance Patient says "I feel like I'm walking downhill"	Knee flexion contracture	Test knee ROM	Stretch accordingly	Excessive foot dorsiflexion	Evaluate static prosthetic alignment
				Excessive socket flexion (forward tilt on pylon)	Evaluate static prosthetic alignment
	Quad weakness	Perform manual muscle test	Closed chain strengthening exercises while wearing prosthesis	Posterior translation of the foot/pylon (too-long heel lever)	Evaluate static prosthetic alignment, assess heel
				Excessively hard heel cushion or prosthetic heel	Evaluate compression during loading
Knee too extended Excessive knee extension during stance phase Patient says "I feel like I'm walking uphill" If observed, consider whether it is due to a primary cause or if it is a compensation to counteract excess knee flexion moment or other problem	Inadequate knee flexion range of motion / knee extension contracture	Test knee ROM	Stretch accordingly	Excessively compliant prosthetic heel cushion or too rigid forefoot keel	Assess heel compression during manual loading
	Compensation for quad weakness	Perform manual muscle test	Closed chain strengthening exercises while wearing prosthesis	Inadequate socket flexion	Evaluate static prosthetic alignment
	Compensation for hip flexion contracture	Test knee ROM	Stretch accordingly	Excessive plantar flexion of the prosthetic foot	Evaluate static prosthetic alignment
	Compensation for anterodistal residual limb discomfort	Evaluate residual limb	Address contributing factors	Anterior translation of the prosthetic foot/pylon (excess toe lever)	Evaluate static prosthetic alignment
	Short residual limb (causes multidirectional instability due to excess play within socket)	Evaluate socket fit	Consider prosthesis design changes to reduce play in socket	Excess play (multidirectional movement) within socket	
	Genu recurvatum / laxity in knee extension	Evaluate for contributing factors			

Gait Abnormality	Patient Related			Prosthetic Related	
	Possible Causes	Additional Evaluation	Interventions	Prosthetic Causes	Additional Evaluation
Excessive valgus moment at the knee With medial thrust of the proximal socket in mid-stance phase.	Short residual limb may cause poor stabilization of the prosthetic socket	Evaluate residual limb length in conjunction with adequacy of socket fit	No intervention for structural deformity	Excessive lateral translation of the prosthetic pylon/foot	Evaluate static prosthetic alignment
	Ligamentous instability may contribute to this abnormality	Evaluate ligament integrity using typical manual testing techniques	Consider stabilization approaches as appropriate	Excessive valgus angulation at the prosthetic socket pylon junction	Evaluate static prosthetic alignment
				Socket too loose	Evaluate socket fit, location of patella relative to socket brim and contours
Excessive varus moment at the knee With lateral thrust of the proximal socket in mid-stance phase.	<i>A small amount of lateral thrust is within normal limits. It is considered pathological if contributing to problems such as balance impairment, skin breakdown.</i>			Excessive inset of the prosthetic foot	Evaluate prosthetic alignment
				Excessive abduction of socket (brim tilted medially)	Evaluate prosthetic alignment
				Socket too loose	Evaluate socket fit

Gait Abnormality	Patient Related			Prosthetic Related	
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Lateral trunk lean over prosthesis Trunk bends laterally over the prosthesis (compensated Trendelenburg) during prosthetic stance phase	Weak hip abductors	Perform manual muscle test	Side stepping with prosthesis	Inadequate adduction of the socket	Check socket alignment
	Pain at distal lateral residual limb	Examine residual limb to identify source of pain	Appropriate referral	Prosthesis too short	Check prosthesis length at iliac crests
	Gait habit	None	Gait retraining	Outset foot	Adjust prosthesis
	Hip abduction contracture	Assess ROM	Appropriate stretching	Medial wall too high causing pain	Check socket fit
				Gapping at lateral wall of socket	Evaluate socket fit
Trunk lordosis Increased lumbar arch during stance	Compensation for tight hip flexors	Evaluate hip ROM	Stretch hips	Insufficient socket flexion	Check relative to TKA (trochanter-knee-ankle) line; re-assess patient's hip ROM
	Weak hip extensors	Check strength of hip	Strengthening exercises		
	Weak abdominal muscles	Check abdominal muscles	Core strengthening	Posterior wall promotes anterior pelvic tilt	Adjust socket
	Gait habit		Gait training		
Forward trunk lean	Hip flexion contracture	Evaluate hip ROM	Stretch hips	Knee is in unstable alignment	Check TKA line for knee position too anterior
	Lumbar pain with lumbar extension	Evaluate lumbar spine	Appropriate referral		
	Compensation for knee instability	Evaluate patient- or prosthesis- factors that could lead to knee instability	As appropriate depending on primary cause	Stance control mechanism is insufficient	Evaluate prosthetic knee function
Abducted gait Abduction of prosthetic limb with unilateral widened base of support on prosthetic side during stance Also see "General" table	Hip abduction contracture	Assess ROM	Appropriate stretching	Prosthesis is too long	Check leg length at iliac crest
	Weak adductors	Perform manual muscle test	Side stepping with prosthesis	Medial socket wall too high or other reason for medial brim discomfort	Check fit in full weight bearing
	Fear or habit, or insecurity with knee control	Evaluate gait	Weight shifting activities over the prosthesis Gain confidence through increased wear time and gait training	Adductor roll	Assess for proper shrinkage device/application Evaluate socket fit

Gait Abnormality	Patient Related			Prosthetic Related	
	Possible Causes	Additional Evaluation	Interventions	Prosthetic Causes	Additional Evaluation
External rotation of foot on initial contact	Poor residual limb muscle control (decreased stability)	Perform manual muscle tests of hip external rotators and abductors	Strengthen hip external rotators and abductors Resistive gait training	Heel cushion or plantar-flexion bumper is too stiff	Evaluate heel compression during manual loading
	Prosthesis improperly donned, in external rotation	Evaluate alignment of prosthesis in full weightbearing	Teach proper donning of prosthesis	Too much toe-out	Evaluate prosthetic alignment
Knee instability Prosthetic knee has excess or inappropriate knee flexion (depending on the knee) in stance phase. In other words, tendency for the knee to buckle in stance phase.	Weak hip extensors	Test hip extensor strength	Strengthening exercises	Knee axis of rotation is too anterior	Evaluate static prosthetic alignment
	Severe hip flexion contracture	Test hip ROM	Stretching exercises	Heel keel or plantar flexion bumper too stiff	Evaluate heel compression during manual loading
	Heel height of shoes	Evaluate shoes	Change shoes to proper height	Too much dorsiflexion	Evaluate static prosthetic alignment
	Poor weight shift	Evaluate weight shifts	Weight shifting activities with prosthesis	Foot too posterior (too long heel lever)	Evaluate static prosthetic alignment
Excessive terminal impact (Knee vigorously extends in terminal swing; prosthetic foot visibly or audibly “slams” into full knee extension)	Vigorous hip flexion followed by strong hip extension	Listen to the heel strike	Balance activities Weight shifting activities	Insufficient swing control mechanism of the prosthetic knee	Adjust prosthetic knee function
	Compensatory mechanism – patient wants to feel the knee fully extend before putting weight through it	Evaluate balance function	Evaluate balance function Single limb stance Resistive gait training	Excessive extension assist mechanism	Adjust prosthetic knee function
Circumduction, hip hike, or vaulting with contralateral limb In prosthetic swing phase Also see “General” table	Insufficient loading of toe at end of stance phase to release stance control mechanism	Evaluate gait	Further gait training	Prosthetic knee is not properly transitioning to swing phase resistance	Adjust prosthetic knee function
				Prosthetic knee is too stable	Check location of knee center relative to TKA line

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Inadequate knee flexion in Pre-swing	Lack of confidence or training in gait pattern needed to signal prosthetic knee to switch from stance to swing control	Evaluate gait	Gait training	Excessive stability of prosthetic knee	Evaluate prosthetic knee function and alignment
Increased knee flexion (excessive heel rise) in Pre-Swing Heel of prosthesis rises higher than the sound foot in toe off	Strong hip flexors	Test hip extensors strength	Strengthen hip extensors	Insufficient stance control mechanism; tendency for knee to buckle	Evaluate prosthetic knee function and alignment
	Hip flexion contracture	Test hip ROM	Stretching exercises		
Medial/Lateral whip Abrupt medial or lateral movement of the prosthetic heel during swing	Improperly donned	Evaluate socket position	Teach proper donning of socket	Excessive external or internal rotation of socket	Evaluate alignment of the knee axis
	Excessive soft tissue	Assess for proper shrinkage device	Review wrapping technique or use of shrinker	Socket too tight	Assess for proper shrinkage device/application Evaluate socket fit
	Insufficient or poor timing of muscular activation	Biofeedback	Rhythmic stabilization at hips	Inadequate suspension	Modify suspension
				Excessive valgus of prosthetic knee	Evaluate static prosthetic alignment
	Hip flexion contracture	Test hip ROM	Stretching exercises		

For additional information, visit: <https://www.health.mil/About-MHS/MHS-Elements/DVPO/VADOD-CPGs>

Scan the QR Code with your smart device to read the Patient Summary of the 2025 VA/DoD Clinical Practice Guideline for Lower Limb Amputation Rehabilitation.

