Study Guide 4

This guide covers chapters 7 and 8. First you learn the reasoning that keeps patients safe: triage, the questions that matter, how to read a test with sensitivity, specificity and likelihood ratios, the red flags that must never be missed, the yellow flags that predict chronic pain, and how fast to refer. Then you learn what posture can and cannot tell you, the gait cycle phase by phase, the gaits that localize a lesion, the functional tests that measure fall risk and what the evidence says about sitting and lifting. Work one chapter at a time, do the arithmetic in each worked case yourself, and finish with the ten board style self-test items.

WHAT THIS GUIDE COVERS

- Chapter 7 · diagnostic triage, OPQRST and the review of systems, mechanical versus nonmechanical pain, neurogenic versus vascular claudication, the two by two table, likelihood ratios and pretest probability, special tests and the neurological screen, myelopathy, red flags for cancer, infection, fracture, cauda equina and vascular causes, yellow and other flags, STarT Back, referral urgency, imaging and SBAR.
- Chapter 8 · the plumb line and postural types, why static posture predicts little, forward head posture and crossed syndromes, leg length and scoliosis, the gait cycle and its eight phases, rockers and muscle roles, spatiotemporal measures and gait speed, antalgic, Trendelenburg, steppage and central gaits, Romberg, functional tests, motor control and learning, disc pressure, workstations and lifting.

CHAPTER 7

Exam Logic and Red Flags

Read it in full: **Chapter 7 in the textbook**. See it in motion: **Exam Logic and Red Flags Walkthrough** and **Exam Logic and Red Flags Lab**.

What to know

The history is the most powerful diagnostic tool in spinal care. It sorts the patient and sets the **pretest probability**, which governs how every later finding is read. It has two goals: diagnostic

(what is causing this, and is anything dangerous?) and relational (what does this person fear and expect?).

Diagnostic triage sorts patients into three bins. Serious spinal pathology (cancer, infection, fracture, cauda equina syndrome, axial spondyloarthritis, visceral or vascular causes) is about 1% of acute low back pain in primary care; osteoporotic fracture is the most common member and infection the rarest. Radicular syndromes are about 5 to 10%. Nonspecific pain is about 90%, which means no single tissue can be reliably named, not that the pain is imaginary. Each bin has its own plan.

The history skeleton: chief complaint, OPQRST (onset, provocation and palliation, quality, region and radiation, severity, timing), past history, medications (corticosteroids raise fracture and infection risk; anticoagulants raise bleeding risk), family and social history (including injection drug use), a review of systems and the patient's ideas, concerns and expectations. Morning stiffness over 30 minutes suggests inflammatory disease. Ask plainly about bladder, bowel and saddle sensation, with a short explanation of why you ask everyone.

Mechanical pain changes with posture, movement and load. **Nonmechanical** pain is constant, progressive, present at rest and at night, or comes with fever, sweats or weight loss: a prompt to look harder. Night pain that eases when the patient changes position is mechanical. Somatic referred pain is deep, dull, usually above the knee, without deficit. Radicular pain is sharp and banded, often below the knee and worse in the limb; radiculopathy adds objective loss.

Neurogenic claudication (lumbar stenosis) is brought on by walking and standing in extension, eased by sitting or bending forward, easier uphill, tolerated on a bike, with normal pulses and numbness or heaviness: the shopping cart sign. **Vascular claudication** (peripheral artery disease) comes at a fairly fixed distance, eases with standing still within minutes, is worse uphill and with cycling, and comes with reduced pulses and calf cramping.

The exam tests the hypotheses from the history, in order: observation and vital signs, inspection, palpation, range of motion, neurological exam, special tests and related regions (hip, shoulder, abdomen, pulses). **Sensitivity** = a / (a + c), true positives over all with the condition. **Specificity** =

d / (b + d), true negatives over all without it. **SnNout**: a negative sensitive test rules out. **SpPin**: a positive specific test rules in.

LR+ = sensitivity ÷ (1 − specificity); **LR−** = (1 − sensitivity) ÷ specificity. LR+ above 10 or LR− below 0.1 shift probability a lot; 5 to 10 or 0.1 to 0.2 moderately; 0.5 to 2 barely at all. Combine with pretest probability: an LR+ of 5 takes 1% to about 5% but 40% to about 77%. Reliability (kappa) matters too: motion and position palpation are low to fair, pain provocation is better. Clusters, such as three or more positive SI provocation tests, beat single tests.

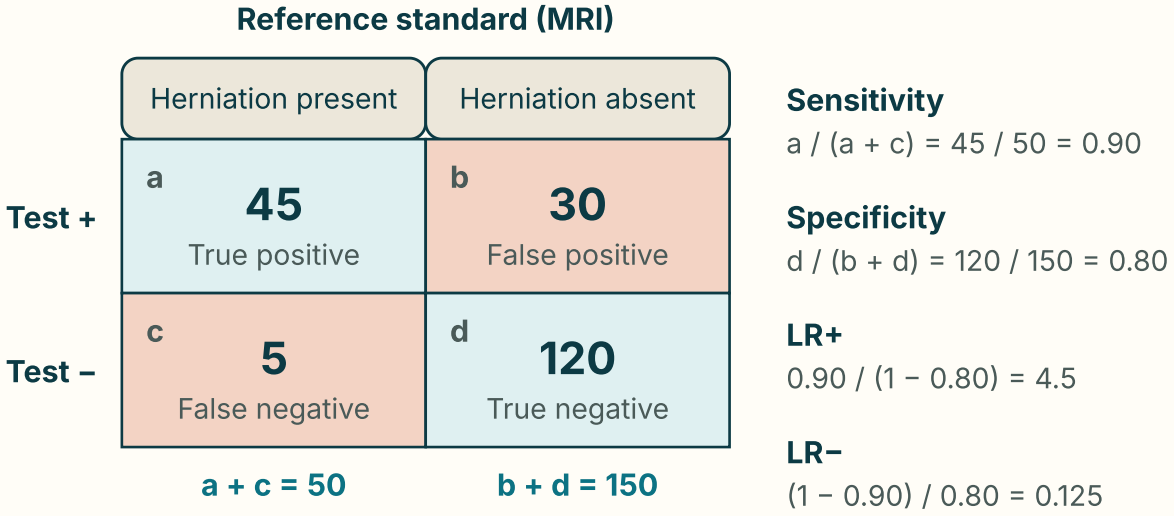
Special tests: SLR sensitivity about 0.9 and specificity about 0.25 (rule out); crossed SLR about 0.3 and 0.9 (rule in); Spurling low to moderate sensitivity, high specificity; upper limb tension test high sensitivity, low specificity; distraction relief moderately specific. The neurological screen matches roots to muscles, reflexes and skin. **Degenerative cervical myelopathy** is the most common cause of cord dysfunction in older adults: clumsy hands, trouble with buttons, nondermatomal hand numbness, unsteady gait, plus Hoffmann, Babinski, clonus and hyperreflexia. It means no cervical manipulation, referral and usually MRI.

Red flags are prompts, not diagnoses. Most primary care back pain patients have at least one, and most single flags have likelihood ratios near 1. Weigh them: a **history of cancer** is the strongest single flag (LR+ about 7 to 15); age over 50, weight loss, failure to improve in about a month and progressive night pain add modestly. Spinal cancer is usually metastatic (prostate, breast, lung, kidney, thyroid) through the valveless Batson's plexus; multiple myeloma is primary. Thoracic pain deserves respect. Add **safety netting** to every plan.

Infection (osteomyelitis, discitis, epidural abscess; Staphylococcus aureus most common; Pott disease worldwide) is suspected from risk factors: injection drug use, immunosuppression, recent infection or spinal procedure, catheter or dialysis. Fever is often absent, and the classic triad of back pain, fever and deficit is present in only a few at first. Order ESR, CRP and MRI urgently. Fracture flags: age over 70, long term corticosteroids, significant trauma and a contusion. After neck trauma use the Canadian C-spine Rule (high risk: age 65 or more, dangerous mechanism, limb tingling; then low risk features; then active rotation of 45 degrees each way) or NEXUS (no imaging only if all five are absent: midline tenderness, intoxication, altered alertness, focal deficit, distracting injury).

Cauda equina syndrome: saddle anesthesia, bladder dysfunction (retention is the most consistent finding in established cases), bowel and sexual dysfunction and bilateral leg symptoms. CES-I (incomplete, altered urinary sensation) has a much better outcome than CES-R (retention), so any suspicion means same day emergency MRI and surgical assessment. AAA: older male smoker with deep, constant, nonmechanical back pain; a pulsatile mass, low blood pressure or fainting suggests rupture. Cervical artery dissection: new unusual neck pain or headache, then the five Ds and three Ns with ataxia, or partial Horner syndrome with carotid involvement. Positional vertebral artery tests are not a reliable screen.

Yellow flags signal risk to recovery, not to the body: fear avoidance, catastrophizing, kinesiophobia, low expectation of recovery (one of the strongest predictors), depression and anxiety, passive coping. Orange flags are psychiatric disorders; blue flags are perceptions of work; black flags are system barriers. The nine item **STarT Back Tool** stratifies low, medium and high risk; stratified care improved disability and was cost effective. Referral urgency: **emergency** same day (CES, dissection or stroke, cord compression with new deficit, symptomatic AAA, sepsis), **urgent** within 24 hours to a few days (suspected cancer or infection without neurological change, fracture, progressive radiculopathy, UMN signs), **routine** within weeks. When in doubt, choose the faster tier. Routine imaging is not recommended for acute nonspecific low back pain. Write referrals with **SBAR**: situation, background, assessment, recommendation.



SnNout: high sensitivity, few false negatives, so a negative result rules out.
SpPin: high specificity, few false positives, so a positive result rules in.

Read sensitivity down one column, specificity down the other. With 45 of 50 true cases caught and 120 of 150 non cases cleared, this test has a sensitivity of 0.90 and a specificity of 0.80, so its LR− of 0.125 makes it better for ruling out than its LR+ of 4.5 is for ruling in.

LOCK THESE IN

- Triage: serious about 1%, radicular 5 to 10%, nonspecific about 90%.
- Sensitivity = a/(a+c); specificity = d/(b+d). SnNout, SpPin.
- LR+ = sens/(1 − spec); LR− = (1 − sens)/spec. Over 10 or under 0.1 is decisive.
- SLR: sensitive (about 0.9), not specific (about 0.25). Crossed SLR and Spurling: specific.
- History of cancer is the strongest single red flag (LR+ about 7 to 15).
- CES: saddle anesthesia, urinary retention or change, bowel and sexual change, bilateral leg symptoms: same day.
- Yellow flags threaten recovery, not the body. Low expectation of recovery is a strong predictor.
- Urgency tiers: emergency same day, urgent within days, routine within weeks. SBAR.

Red flag patterns and next steps

Condition	Most useful flags	Usual next step
Malignancy	History of cancer; age over 50 with weight loss, night pain, failure to improve	Urgent imaging and labs; emergency if new neurological signs
Infection	Injection drug use, immunosuppression, recent infection or procedure; fever; focal pain	Same day or urgent: ESR, CRP, cultures, MRI
Fracture	Age over 70, long term steroids, significant trauma, contusion	Radiographs; Canadian C-spine or NEXUS after neck trauma
Cauda equina syndrome	Saddle anesthesia, urinary change or retention, bowel or sexual change, bilateral legs	Emergency department the same day
Abdominal aortic aneurysm	Older male smoker, nonmechanical deep pain, pulsatile mass	Emergency if symptomatic
Cervical artery dissection	New unusual neck pain or headache; five Ds, three Ns, ataxia	Emergency services; no manipulation
Inflammatory spondyloarthritis	Onset before 45, stiffness over 30 min, better with exercise, alternating buttock pain	Routine to urgent rheumatology

Test statistics and the flag colors

Item	Definition or value	Use
Sensitivity	a / (a + c)	High: negative result rules out
Specificity	d / (b + d)	High: positive result rules in
LR+	sensitivity / (1 − specificity)	How much a positive raises the odds
LR−	(1 − sensitivity) / specificity	How much a negative lowers the odds
Red flag	Serious pathology	Medical investigation or referral
Orange flag	Psychiatric disorder	Mental health referral
Yellow flag	Beliefs, emotions, behaviors	Education, graded activity, psychologically informed care
Blue flag	Perceptions about work	Workplace communication, modified duties
Black flag	System and context barriers	Recognize and coordinate

Worked cases

WORKED CASE 1 · BUILDING A TWO BY TWO TABLE

A new test is checked against MRI in 200 patients. Of 50 with a herniation, 45 test positive. Of 150 without one, 120 test negative. Find sensitivity, specificity and both likelihood ratios. Is it better for ruling in or ruling out?

STEP 1 · FILL THE TABLE

a (true positive) = 45, c (false negative) = 5, b (false positive) = 150 − 120 = 30, d (true negative) = 120.

STEP 2 · SENSITIVITY

45 ÷ 50 = **0.90**.

STEP 3 · SPECIFICITY

120 ÷ 150 = **0.80**.

STEP 4 · LIKELIHOOD RATIOS

LR+ = 0.90 ÷ 0.20 = **4.5**. LR− = 0.10 ÷ 0.80 = **0.125**.

STEP 5 · INTERPRET

LR− of 0.125 is a moderate to strong rule out; LR+ of 4.5 is a small to moderate rule in. The test is better for ruling out.

WORKED CASE 2 · WHY PRETEST PROBABILITY MATTERS

A test has an LR+ of 5. Patient A has a 1% pretest probability of the condition; patient B has 40%. Both test positive. Find each posttest probability.

STEP 1 · CONVERT TO ODDS

Odds = p ÷ (1 − p). A: 0.01 ÷ 0.99 = 0.0101. B: 0.40 ÷ 0.60 = 0.667.

STEP 2 · MULTIPLY BY THE LR

A: 0.0101 × 5 = 0.0505. B: 0.667 × 5 = 3.33.

STEP 3 · CONVERT BACK

p = odds ÷ (1 + odds). A: 0.0505 ÷ 1.0505 = about **5%**. B: 3.33 ÷ 4.33 = about **77%**.

THE LESSON

The same positive result leaves patient A unlikely to have the condition and makes it likely for patient B. The history, which sets the pretest probability, decides what a test means.

WORKED CASE 3 · ASSIGNING REFERRAL URGENCY

Three patients: (1) a 58 year old treated for prostate cancer six years ago, with five weeks of constant thoracic pain, worse at night, 4 kg weight loss and a normal neurological exam; (2) a man with sciatica who now has numbness when wiping and a weaker urine stream since yesterday; (3) a 40 year old with six weeks of nonspecific back pain, high STarT Back risk and no red flags.

STEP 1 · PATIENT 1

Cancer history is the strongest single flag, with nonmechanical night pain and weight loss but no neurological change: **urgent** referral for imaging and labs, with safety netting about leg weakness or bladder change.

STEP 2 · PATIENT 2

Saddle numbness and urinary change suggest early cauda equina syndrome: **emergency**, same day MRI and surgical assessment, before retention develops.

STEP 3 · PATIENT 3

No red flags; risk is psychosocial: **routine** care, physical treatment combined with psychologically informed approaches. Imaging would not help.

STEP 4 · WRITE IT UP

Use SBAR. For patient 1 the recommendation reads: please assess urgently and consider thoracic MRI and blood tests; advised to attend the emergency department if leg weakness or bladder change develops.

TRAPS PEOPLE FALL INTO

- **Reversing SnNout and SpPin.** Sensitivity is about the sick, so its strength is a negative result. Specificity rules in.
- **Treating any red flag as an alarm.** Most single flags are weak. Weigh them in combination, in context and over time.
- **Reading night pain as sinister.** Pain that eases with a change of position is mechanical. Constant, progressive night pain is the concern.
- **Waiting for retention before acting on CES.** Outcomes are far better if decompression happens before retention. Act on early features.
- **Trusting a negative positional test for the vertebral artery.** These tests have poor validity. Screen for symptoms of ischemia instead.
- **Ordering an MRI for yellow flags.** Yellow flags threaten recovery, not the body. Imaging can add fear by showing age normal findings.
- **Calling vascular claudication stenosis.** Vascular pain eases with any rest and is worse uphill and cycling; neurogenic pain needs flexion or sitting.
- **Assuming fever must be present in infection.** Fever is absent in a substantial minority. Risk factors drive suspicion.

Chapter 7 self-test · ten items

1. A 29 year old has low back pain after moving furniture that eases with walking and worsens with long sitting. There are no leg symptoms or red flags. How should she be triaged?

A. Serious pathology needing urgent labs
B. Radicular syndrome needing imaging
C. Nonspecific mechanical back pain
D. Inflammatory back pain needing referral

C. Nonspecific mechanical back pain Pain that changes with posture and movement, with no leg symptoms or red flags, fits the nonspecific group: reassurance, staying active and conservative care, no imaging.

2. A test has 95% sensitivity and 50% specificity. Which statement is correct?

A. Its LR− is 0.1, a strong rule out
B. Its LR+ is 19, a strong rule in
C. Its LR+ is 0.1, a strong rule in
D. Its LR− is 0.5, a weak rule out

A. Its LR− is 0.1, a strong rule out LR− = 0.05 ÷ 0.50 = 0.1, a strong rule out. LR+ = 0.95 ÷ 0.50 = 1.9, nearly useless for ruling in.

3. A 72 year old walks farther leaning on a shopping cart, is more comfortable going uphill and rides an exercise bike without pain. Pedal pulses are normal. What is the most likely cause of his leg pain?

A. Somatic referred pain from a lumbar facet joint
B. Trendelenburg gait from weak abductors
C. Vascular claudication from artery disease
D. Neurogenic claudication from lumbar stenosis

D. Neurogenic claudication from lumbar stenosis Relief with trunk flexion, easier uphill walking, tolerance of cycling and normal pulses all point to stenosis rather than peripheral artery disease.

4. Which single red flag carries the most diagnostic weight for spinal malignancy?

A. Pain at night that eases on turning
B. A previous history of cancer
C. Failure to improve after one week
D. Age over 50 years

B. A previous history of cancer A cancer history has the highest positive likelihood ratio, roughly 7 to 15. Age, night pain and slow recovery add modestly, mainly in combination.

5. A 34 year old who injects drugs has severe, unrelenting thoracic pain with focal spinous tenderness. His temperature is normal. What is the best next step?

A. Order a plain radiograph in six weeks
B. Urgent ESR, CRP and MRI for possible infection
C. Reassure him because he has no fever
D. Manipulate the segment and review him in a week

B. Urgent ESR, CRP and MRI for possible infection Injection drug use is a key infection risk factor, and fever is absent in a substantial minority. Severe focal pain with risk factors warrants urgent blood tests and MRI.

6. An alert 70 year old was rear ended at low speed and has neck pain. Under the Canadian C-spine Rule, what follows?

A. No imaging, because the crash was low speed
B. No imaging, if NEXUS midline tenderness is absent
C. Range of motion testing before any decision
D. Imaging, because age 65 or older is high risk

D. Imaging, because age 65 or older is high risk Any high risk factor (age 65 or older, dangerous mechanism, limb tingling) mandates imaging before the rule moves on to low risk features.

7. A patient with sciatica reports new numbness when wiping and difficulty starting urination since this morning. What is the correct urgency?

A. Emergency, same day MRI and surgical review
B. Routine, at the next scheduled visit
C. Urgent, within a few days through her doctor
D. Routine, after six weeks of conservative care

A. Emergency, same day MRI and surgical review Saddle numbness with urinary change suggests early cauda equina syndrome. Outcomes are best before painless retention develops.

8. A 67 year old man who smokes has deep, constant back pain that does not change with position. What should the clinician add to the exam?

A. A straight leg raise on both sides
B. A Spurling test toward the painful side
C. An abdominal exam for a pulsatile mass
D. A Trendelenburg test on each leg

C. An abdominal exam for a pulsatile mass Nonmechanical deep back pain in an older smoker raises abdominal aortic aneurysm. A pulsatile mass, low blood pressure or fainting suggests rupture.

9. A patient with back pain believes he will never get better and has stopped all activity for fear of harm. What kind of flags are these?

A. Black flags about compensation systems
B. Yellow flags that threaten recovery
C. Red flags that need urgent imaging
D. Orange flags that need psychiatric care

B. Yellow flags that threaten recovery Fear avoidance and low expectation of recovery are yellow flags. They predict chronic disability and call for education and graded activity, not imaging.

10. A 66 year old with neck pain has clumsy hands, trouble with buttons, brisk reflexes and a positive Hoffmann sign. What is the right plan?

A. Cervical manipulation and home exercises
B. Reassure him and review again in six weeks
C. Night splints for carpal tunnel syndrome
D. Avoid manipulation; refer urgently for MRI

D. Avoid manipulation; refer urgently for MRI Upper motor neuron signs with hand clumsiness indicate degenerative cervical myelopathy. Earlier decompression is linked to better recovery.

CHAPTER 8

Posture, Gait and Movement

Read it in full: **Chapter 8 in the textbook**. See it in motion: **Posture and Gait Walkthrough** and **Posture and Gait Lab**.

What to know

In the traditional ideal side view the plumb line passes through the earlobe, the cervical bodies, the acromion, roughly the lumbar bodies, through or just behind the hip near the greater trochanter, slightly in front of the knee and slightly in front of the lateral malleolus. Gravity then holds the

knee in extension, pushes the hip into extension against the iliofemoral ligament and tips the body forward at the ankle, so the calf works at a low level and the body sways gently.

Classic postural types give a shared vocabulary. **Kyphotic lordotic**: more kyphosis and lordosis, anterior pelvic tilt, forward head. **Flat back**: less lordosis, posterior tilt. **Sway back**: pelvis shifted forward of the line, hips extended, long kyphosis, upper trunk leaning back. **Military**: more lordosis with a flat thoracic spine.

Static posture predicts little. Sagittal curves are weakly or not linked to back pain, slumped teens do not reliably develop more pain, and head posture overlaps heavily between people with and without neck pain. Reasons: normal variation is wide, posture is not static, tissues adapt, pain is multifactorial and visual rating is unreliable. Marked new changes still matter: an **antalgic lateral shift** with acute disc irritation, a rigid flexed posture with stenosis or spondyloarthritis, a growing hump with osteoporotic fractures. The best posture is the next posture.

Forward head posture is measured by the **craniovertebral angle** (a horizontal line through C7 and a line from C7 to the tragus; smaller means more forward). The 27 kg at 60 degrees figure is from a model; the step from load to injury is not shown. Janda's **upper crossed syndrome** (tight upper trapezius, levator scapulae and pectorals; weak deep neck flexors, lower and middle trapezius and serratus anterior) and **lower crossed syndrome** (tight hip flexors and lumbar extensors; weak abdominals and gluteals) are useful descriptions with limited evidence that they cause pain.

Leg length inequality can be anatomical or functional. A few millimeters is almost universal and harmless; differences over about 20 mm may matter, and imaging is the reference standard. **Scoliosis** is a lateral curve with rotation, a Cobb angle of 10 degrees or more; adolescent idiopathic scoliosis affects about 2 to 3% of adolescents, with larger progressive curves more common in girls. On the **Adams forward bend test** a structural curve shows a rib or lumbar hump, and about 7 degrees on a scoliometer is a common referral threshold. A functional curve straightens on sitting or bending.

The **gait cycle** runs from initial contact of one foot to the next initial contact of the same foot: one stride, two steps. Stance is about 60% and swing about 40%. Two double support periods of about

10% each (20% total) frame about 40% single support, which equals the other leg's swing. Double support shrinks with speed and vanishes in running, where a flight phase appears.

Eight phases: initial contact (0%), loading response (0 to 10%), midstance (10 to 30%), terminal stance (30 to 50%), preswing (50 to 60%), initial swing (60 to 73%, knee peaks at about 60 degrees), midswing (73 to 87%) and terminal swing (87 to 100%, hamstrings decelerate the leg eccentrically). In loading response the ankle plantar flexes about 5 to 10 degrees under eccentric dorsiflexor control and the knee flexes about 15 to 20 degrees under eccentric quadriceps control. Hip abductors hold the pelvis level in single support. Arms swing opposite to the legs, and the center of mass rises and falls about 4 to 5 cm.

Three **rockers**: heel (loading response; dorsiflexors lower the forefoot eccentrically), ankle (midstance; soleus and gastrocnemius control tibial advance eccentrically) and forefoot (terminal stance; calf push off, the largest burst of power, with the windlass mechanism stiffening the foot). Spatiotemporal norms: speed about 1.2 to 1.4 m/s, cadence 100 to 120 steps per minute, step length 0.6 to 0.8 m, stride 1.2 to 1.6 m, step width 5 to 13 cm. **Speed = step length × cadence.** Gait speed is the sixth vital sign: below about 0.6 m/s goes with dependence, below 0.8 m/s with limited community walking, about 1.0 m/s or more with independent community walking, and crossing a street needs about 1.2 m/s.

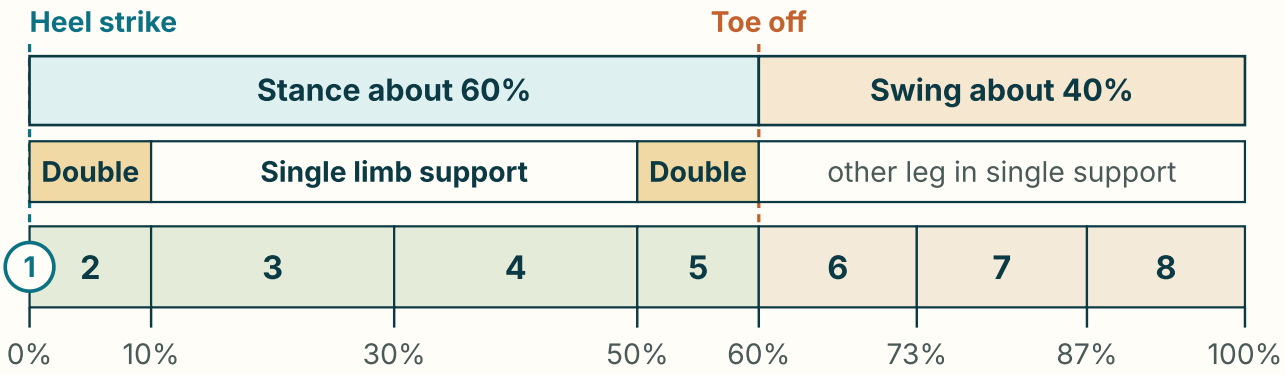
Abnormal gait comes from pain, weakness, restricted motion or neurological control. **Antalgic**: short stance on the painful side, a short step with the sound leg, sometimes a lean over a painful hip. **Trendelenburg**: weak gluteus medius and minimus (superior gluteal nerve, L4 to S1) let the pelvis drop on the swing side; the compensated form leans over the stance leg; bilateral weakness gives a waddle. The side that stands is the side that is weak. **Steppage**: high stepping to clear a dropped foot from fibular palsy, L5 radiculopathy or neuropathy; inversion and hip abduction are spared in fibular palsy but often weak in L5.

Central gaits: hemiplegic circumduction (stroke), spastic scissoring (cerebral palsy, myelopathy), Parkinsonian (stooped, shuffling, reduced arm swing, turning en bloc, festination, freezing), cerebellar ataxic (wide, staggering, unsteady even with eyes open), sensory ataxic (wide, stamping, worse in the dark) and magnetic (normal pressure hydrocephalus, with incontinence and cognitive decline). A positive **Romberg** (steady eyes open, sways eyes closed) tests

proprioception, not the cerebellum. Mechanical patterns: gluteus maximus lurch backward, quadriceps avoidance, vaulting, short leg gait and the flexed stooped gait of stenosis.

Movement tells more than posture. **Timed Up and Go**: rise, walk 3 m, turn, return, sit; about 10 seconds or less is typical, 12 seconds or more (13.5 in some studies) suggests fall risk. Berg Balance under about 45 of 56 suggests fall risk. The Functional Movement Screen (seven tasks, out of 21, 14 or below proposed as risk) predicts injury poorly. Feedforward transversus abdominis activation can be delayed in back pain, but changes vary (many people brace more), and motor control exercise works about as well as other exercise, not better. Centralization is favorable; flexion relaxation is often lost in chronic pain; cervical joint position error over about 4.5 degrees suggests poor proprioception. Motor learning: cognitive, associative and autonomous stages; external focus, variable practice, fading feedback and specificity.

In vivo L4 to L5 pressures (one volunteer): lying 0.10, relaxed sitting 0.46, relaxed standing 0.50, upright sitting 0.55, standing bent forward 1.10, lifting 20 kg with knees bent 1.70, lifting 20 kg with the back flexed 2.30 MPa. Sitting is not the worst position, and high pressure does not mean harm. Workstation advice (monitor about an arm's length away, top at or slightly below eye level; keyboard at elbow height; breaks about every 30 minutes; sit-stand alternation) helps modestly. Keeping the load close matters most when lifting; there is no convincing evidence that lumbar flexion during lifting alone causes pain, that technique training prevents it, or that back belts prevent it. The lifting equation uses a 23 kg load constant. Adults need 150 to 300 minutes of moderate (or 75 to 150 vigorous) activity a week plus strength work on two or more days.



1 Initial contact (0%)
2 Loading response (0 to 10%)
3 Midstance (10 to 30%)
4 Terminal stance (30 to 50%)
5 Preswing (50 to 60%)
6 Initial swing (60 to 73%)
7 Midswing (73 to 87%)
8 Terminal swing (87 to 100%)

Double support shrinks as speed rises and disappears in running, replaced by a flight phase.

Stance, swing and the two double supports. At normal speed stance takes about 60% of the cycle and swing about 40%, framed by two double support periods of about 10% each. Five phases belong to stance and three to swing.

LOCK THESE IN

- Plumb line: earlobe, acromion, lumbar bodies, greater trochanter, slightly in front of knee and lateral malleolus.
- Scoliosis: Cobb 10 degrees or more; forward bend hump means structural.
- Gait: stance about 60%, swing 40%, two double supports of about 10% each.
- Rockers: heel, ankle, forefoot. Early stance shock absorbers: dorsiflexors and quadriceps, eccentric.
- Speed = step length × cadence. Below 0.8 m/s is a risk; street crossing needs about 1.2 m/s.
- Trendelenburg: the side that stands is the side that is weak (gluteus medius, superior gluteal nerve).
- Positive Romberg (worse with eyes closed) means lost proprioception: sensory ataxia.
- TUG 12 seconds or more suggests fall risk. Relaxed sitting 0.46 versus standing 0.50 MPa.

The eight phases of gait

Phase	% of cycle	Key events
Initial contact	0	Hip about 30 degrees flexed, knee near extension, ankle neutral
Loading response	0 to 10	Ankle plantar flexes 5 to 10 degrees (eccentric dorsiflexors); knee flexes 15 to 20 (eccentric quadriceps)
Midstance	10 to 30	Single support; tibia advances; abductors hold the pelvis level
Terminal stance	30 to 50	Heel rises; hip about 10 degrees apparent extension; calf working hard
Preswing	50 to 60	Second double support; plantar flexion 15 to 20; toe off ends stance
Initial swing	60 to 73	Knee flexes to its peak of about 60 degrees
Midswing	73 to 87	Swing limb passes the stance limb; ankle to neutral for clearance
Terminal swing	87 to 100	Knee extends; hamstrings decelerate eccentrically

Gait patterns and what they mean

Gait	What you see	Cause
Antalgic	Short stance on the painful side	Any painful structure
Trendelenburg	Pelvis drops on the swing side, or trunk leans over stance leg	Weak gluteus medius and minimus (superior gluteal nerve)
Steppage	High knee and hip to clear a dropped foot; foot slap	Fibular nerve palsy, L5 radiculopathy, neuropathy
Hemiplegic	Stiff leg swung outward; arm flexed	Stroke or unilateral brain lesion
Parkinsonian	Stooped, shuffling, festination, en bloc turns	Parkinson disease
Cerebellar ataxic	Wide, staggering, unsteady eyes open	Cerebellar disease, alcohol
Sensory ataxic	Wide, stamping, worse in the dark; positive Romberg	Dorsal column disease, B12 deficiency
Magnetic	Feet stuck to the floor, short steps	Normal pressure hydrocephalus

Worked cases

WORKED CASE 1 · GAIT SPEED FROM STEP LENGTH AND CADENCE

A healthy adult walks with a 0.7 m step length at 110 steps per minute. An older patient walks 10 m in 12.5 seconds. Find each speed in m/s and interpret the patient's value.

STEP 1 · APPLY THE FORMULA

Speed = step length × cadence = 0.7 m × 110 steps/min = 77 m/min.

STEP 2 · CONVERT TO M/S

77 ÷ 60 = **1.28 m/s**, inside the healthy range of about 1.2 to 1.4 m/s.

STEP 3 · TIME THE PATIENT

10 m ÷ 12.5 s = **0.80 m/s**.

STEP 4 · INTERPRET

About 0.8 m/s is the threshold for limited community walking and higher risk, and well below the about 1.2 m/s needed to cross a street before the signal changes.

WORKED CASE 2 · READING A TRENDELENBURG SIGN

A patient stands on the left leg, and the right side of the pelvis drops. Which muscles are weak, which nerve supplies them, and what would a compensated gait look like?

STEP 1 · FIND THE STANCE LEG

The left leg is on the ground, so the left hip abductors must hold the pelvis level.

STEP 2 · NAME THE WEAK MUSCLES

The **left gluteus medius and minimus** are failing. The side that stands is the side that is weak.

STEP 3 · NAME THE NERVE

The superior gluteal nerve (L4 to S1) supplies them; causes include nerve injury, L5 radiculopathy, hip osteoarthritis, dysplasia and gluteal tendinopathy.

STEP 4 · DESCRIBE COMPENSATION

In a compensated Trendelenburg gait the trunk leans over the left stance leg, moving the center of mass over the hip and reducing the abductor force needed.

WORKED CASE 3 · SEPARATING THE TWO ATAXIAS

A patient walks with a wide base and is unsteady. Standing with feet together, she is fairly steady with eyes open but sways and nearly falls with eyes closed. Vibration sense in the feet is reduced. Which ataxia, and what causes fit?

STEP 1 · READ THE ROMBERG

Steady with eyes open but unsteady with eyes closed is a positive Romberg sign: vision is covering for lost proprioception.

STEP 2 · COMPARE WITH CEREBELLAR ATAXIA

Cerebellar ataxia is unsteady even with eyes open, with intention tremor, dysmetria or nystagmus.

STEP 3 · NAME IT

Sensory ataxia, supported by reduced vibration sense.

STEP 4 · LIST CAUSES

Dorsal column disease such as vitamin B12 deficiency or tabes dorsalis, and large fiber neuropathy. A new gait change in an older adult is never just getting old.

TRAPS PEOPLE FALL INTO

- **Predicting pain from a slumped posture.** Static posture correlates weakly with pain. Healthy people vary widely.
- **Blaming the side that drops.** In the Trendelenburg sign the weak abductors are on the stance side.

- **Calling any standing curve scoliosis.** A functional curve straightens on sitting or bending. Structural scoliosis keeps a rotational hump.
- **Thinking the Romberg tests the cerebellum.** It tests proprioception. Cerebellar ataxia is unsteady even with eyes open.
- **Saying sitting is the worst position for the disc.** In vivo relaxed sitting (0.46 MPa) is close to standing (0.50 MPa).
- **Teaching lifting technique as injury prevention.** Training workers in technique has not prevented back pain; keeping the load close reduces load most.
- **Overselling movement screens.** The Functional Movement Screen predicts injury poorly.
- **Mixing up step and stride.** One stride is a full cycle of one foot and contains two steps.

Chapter 8 self-test · ten items

1. In ideal standing alignment, where does the plumb line fall relative to the knee?

A. Slightly behind the knee center
B. Directly through the kneecap
C. Well behind the back of the knee joint
D. Slightly in front of the knee center

D. Slightly in front of the knee center The line falls just in front of the knee, so gravity holds the knee in extension and the quadriceps can stay mostly relaxed.

2. A standing lateral curve disappears when the patient sits, and there is no rib hump on forward bending. What is the best interpretation?

A. Structural adolescent idiopathic scoliosis
B. A functional curve, likely from leg length
C. A Cobb angle above 10 degrees
D. A curve needing bracing right away

B. A functional curve, likely from leg length A curve that corrects when the leg length difference is removed by sitting, with no rotational hump, is functional rather than structural.

3. At normal walking speed, roughly what share of the gait cycle is stance?

A. About 60%
B. About 50%
C. About 40%
D. About 80%

A. About 60% Stance is about 60% and swing about 40%, with two double support periods of about 10% each.

4. Why does double limb support disappear in running?

A. Swing falls below half of the cycle
B. The heel rocker is no longer used
C. Stance falls below half of the cycle
D. Cadence drops below 100 steps per minute

C. Stance falls below half of the cycle As speed rises, stance shortens below 50%, so the feet are never on the ground together and a flight phase appears.

5. A patient has an audible foot slap just after heel strike. Which muscle group is weak?

A. The quadriceps
B. The calf plantar flexors
C. The ankle dorsiflexors
D. The hip abductors

C. The ankle dorsiflexors In loading response the dorsiflexors lower the forefoot eccentrically. When they are weak, the forefoot slaps down.

6. During right single leg stance, the left side of the pelvis drops. Which muscle is most likely weak?

A. Left gluteus medius
B. Right gluteus maximus
C. Left quadratus lumborum
D. Right gluteus medius

D. Right gluteus medius The abductors of the stance leg hold the pelvis level. When the right ones fail, the unsupported left side drops.

7. A patient with foot drop also has weak ankle inversion and weak hip abduction on the same side. Where is the lesion most likely?

A. The femoral nerve
B. The L5 nerve root
C. The common fibular nerve
D. The S1 nerve root

B. The L5 nerve root Inversion (tibial nerve) and hip abduction (superior gluteal nerve) share the L5 root but not the fibular nerve, so their weakness points to the root.

8. A 74 year old has a stooped posture, small shuffling steps that speed up, reduced arm swing and turns en bloc. Which gait is this?

A. Parkinsonian gait
B. Magnetic gait
C. Cerebellar ataxic gait
D. Hemiplegic gait

A. Parkinsonian gait Festination, reduced arm swing and en bloc turning are typical of Parkinson disease and parkinsonism.

9. An 80 year old takes 16 seconds to complete the Timed Up and Go. What does this suggest?

A. A normal result for this age group
B. Lumbar stenosis that needs urgent MRI
C. Cervical myelopathy that needs surgery
D. Higher fall risk; assess balance further

D. Higher fall risk; assess balance further Times of about 12 seconds or more (13.5 in some studies) suggest increased fall risk.

10. Which advice about lifting is best supported by the biomechanics in this chapter?

A. Wear a back belt at work daily
B. Never flex the lumbar spine
C. Keep the load close to the body
D. Always squat and never stoop

C. Keep the load close to the body Keeping the load close shrinks its moment arm and reduces spinal load most. Belts and technique training have not prevented back pain.

ONE PAGE

Cram sheet

Everything from chapters 7 and 8 in one place. Cover the right column and see if you can rebuild each row.

Numbers to know

Item	Value	Note
Triage shares	Serious about 1%; radicular 5 to 10%; nonspecific about 90%	Primary care low back pain
Morning stiffness	Over 30 minutes suggests inflammatory disease	Spondyloarthritis onset before 45
LR thresholds	LR+ over 10 or LR− under 0.1 decisive; 0.5 to 2 barely helps	Combine with pretest probability
SLR	Sensitivity about 0.9, specificity about 0.25	Crossed SLR about 0.3 and 0.9
Cancer history	LR+ about 7 to 15	Strongest single red flag
Fracture flags	Age over 70, long term steroids, trauma, contusion	Osteoporotic fracture most common serious finding
Canadian C-spine	High risk: age 65 or more, dangerous mechanism, limb tingling	Active rotation 45 degrees each way
Scoliosis	Cobb 10 degrees or more; AIS 2 to 3% of adolescents	Scoliometer about 7 degrees to refer
Leg length	Over about 20 mm may matter	A few mm is almost universal
Gait phases	Stance about 60%; swing 40%; double support about 10% twice	Knee peaks at about 60 degrees in initial swing
Gait norms	Speed 1.2 to 1.4 m/s; cadence 100 to 120; step 0.6 to 0.8 m; width 5 to 13 cm	Center of mass rises 4 to 5 cm
Gait speed risk	Below 0.6 dependence; below 0.8 limited; 1.0 or more independent	Street crossing about 1.2 m/s
TUG	10 s or less typical; 12 s or more fall risk	Berg under about 45 of 56
Joint position error	Over about 4.5 degrees	Common after whiplash
Disc pressure (MPa)	Lying 0.10; sitting 0.46; standing 0.50; upright sitting 0.55; bent 1.10; lifts 1.70 and 2.30	One volunteer

Item	Value	Note
Lifting equation	Load constant 23 kg	Reduced for distance, height, twist, frequency
Activity guideline	150 to 300 min moderate or 75 to 150 vigorous a week	Strength on 2 or more days

Equations

Name	Formula	Use
Sensitivity	a / (a + c)	Rule out when high (SnNout)
Specificity	d / (b + d)	Rule in when high (SpPin)
LR+	sensitivity / (1 − specificity)	Effect of a positive result
LR−	(1 − sensitivity) / specificity	Effect of a negative result
Odds	p / (1 − p); posttest odds = pretest odds × LR	Then p = odds / (1 + odds)
Gait speed	Step length × cadence	Convert m/min to m/s by dividing by 60

Rules that are not equations

Topic	The rule
Red flags	Common and mostly weak alone; weigh combinations, context and failure to improve.
CES	Saddle numbness or urinary change means same day emergency MRI; do not wait for retention.
Dissection	New unusual neck pain or headache with five Ds, three Ns or ataxia: emergency, no manipulation.
Myelopathy	Clumsy hands, gait change, Hoffmann, clonus: refer, avoid cervical manipulation.
Flags	Red: body. Orange: psychiatric. Yellow: beliefs. Blue: work. Black: systems.
Urgency	Emergency same day; urgent within days; routine within weeks; when in doubt, faster.
Imaging	Not routine for acute nonspecific back pain; MRI for infection, cancer, CES, root compression.
Posture	Static posture predicts pain weakly; the best posture is the next posture.
Trendelenburg	The side that stands is the side that is weak.
Romberg	Worse with eyes closed means lost proprioception, not cerebellar disease.
Lifting	Keep loads close; technique training and belts have not prevented back pain.

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