Comprehensive Functional Evaluation of the Injured Runner

Christopher T. Plastaras, MD\textsuperscript{a,b,*},
Joshua D. Rittenberg, MD\textsuperscript{a,b},
Kathryn E. Rittenberg, DPT\textsuperscript{a},
Joel Press, MD\textsuperscript{a,b}, Venu Akuthota, MD\textsuperscript{c}

\textsuperscript{a}Rehabilitation Institute of Chicago, Spine and Sports Rehabilitation Center,
1030 North Clark Street, Suite 500 Chicago, IL 60610, USA
\textsuperscript{b}Northwestern University Feinberg School of Medicine,
303 East Chicago Avenue, Chicago, IL 60611, USA
\textsuperscript{c}Department of Physical Medicine and Rehabilitation, University of Colorado School of Medicine, P.O. Box 6510, MS F712, Aurora, CO 80045, USA

Running has been a matter of human function for many centuries; recent anthropologic research supports the fact that the bone and muscle structure of humans makes us the ideal species for endurance running [1]. This article describe the evaluation of this unique bone and muscle architecture in a functional setting. A complete evaluation that identifies the actual tissue injury and the biomechanical factors that lead to development of the injury is emphasized. A suggested sequencing of the evaluation is offered in Box 1.

**History**

Often, a short office form is helpful to collect pertinent clinical information from the patient (Fig. 1). This should include a standard medical history. Additionally, specific questions about previous injuries, potential risk factors, training patterns, and goals should be asked. The athlete should be asked specifically about history of musculoskeletal injuries, such as stress fractures, tendonitis, sprains, and surgeries. For example, patients who underwent anterior cruciate ligament reconstruction with a patellar tendon donor graft may be at particular risk for patellofemoral pain [2]. Often, previous injuries can predict future injuries. A classic example is the female
runner who had previous stress fractures and osteopenia who is at great risk for developing new stress fractures. Runners require additional attention to issues surrounding eating habits, nutrition, and potential eating disorders. A high index of suspicion should be maintained for female athletes who have a history of eating disorders, amenorrhea, and osteoporosis—well-described as “the female triad.” Risk factors for osteopenia or osteoporosis should also be collected, such as previous steroid use, caffeine intake, calcium intake, menstrual history, and family history.

History taking of the injured runner is an art form and often requires open and nonthreatening questions with knowledge of the runner’s vernacular. The usual questions regarding location, duration, onset, course, exacerbating and ameliorating factors, quality, intensity, and previous treatments should be reviewed. Pain and injury can be graded based on the level of discomfort with walking, running, or rest. For example, a runner who has a tibial stress fracture usually complains of pain with running and walking [3]. If the fracture is severe, pain also may occur with rest.

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**Box 1. Sequence of the runner’s evaluation**

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Conversely, pain that improves after warm up but worsens following a run may be more consistent with a tendinopathy.

Training errors are the most common source of running injuries [4]. Injured runners often attempt to train “too much, too soon, too fast.” Therefore, the athlete’s training habits should be investigated in detail. An increasing injury rate has been correlated directly to increased mileage per week, particularly if the athlete runs more than 20 miles per week [5]. A sudden and rapid increase of running mileage is a frequent training error.

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### Runner’s Evaluation Form

**Training History**

- **Level of Competition:**
  - [ ] Recreational only
  - [ ] Recreational competitive
  - [ ] Competitive (HS/college)
  - [ ] Elite

- **Running Surface:**
  - [ ] Treadmill
  - [ ] Street (asphalt)
  - [ ] Sidewalk (concrete)
  - [ ] Trail
  - [ ] Track

- **Cross-Training:**
  - [ ] Biking
  - [ ] Swimming
  - [ ] Weights
  - [ ] Stairs
  - [ ] Yoga/Stretching
  - [ ] Other:

- **Years of running:** __________
- **Running Club:** ______________
- **Pace/mile:** ______________
- **Mileage/week:** ______________
- **Long run:** ______________
- **Runs/week:** ______________
- **Shoe type:** ______________
- **Miles on shoe:** ______________

- **Shoe Insert or Orthotics:** [ ] Yes  [ ] No
- **Are you in training?**  [ ] Yes  [ ] No
  - **Race and Date:** ______________

- **Recent change in your training?**
  - [ ] Increased mileage
  - [ ] New shoes or inserts
  - [ ] Speed work or track work
  - [ ] Hill training
  - [ ] Change in terrain

- **When you run, when do symptoms occur?**
  - [ ] Every step of the run
  - [ ] Worse toward the end of the run
  - [ ] Worse at start & then improves
  - [ ] Only after the run ends (next day)

**Medical History**

- **Date and Description of Injury:** _________________________________________
- **Previous Treatments for Injury:** _________________________________________
- **Past Medical & Surgical History:** _________________________________________
- **Medications:** ___________________________________________________________
- **Allergies:** ___________________________________________________________
- **Prior Musculoskeletal Injuries:** _________________________________________

- **History of stress fractures:** [ ] Yes  [ ] No
  - [ ] Steroid use: [ ] Yes  [ ] No
  - [ ] Osteoporosis: [ ] Yes  [ ] No
  - [ ] Eating disorders: [ ] Yes  [ ] No

- **Female History:** [ ] N/A
  - [ ] Reg. periods: [ ] Yes  [ ] No
  - [ ] Pregnant: [ ] Yes  [ ] No
  - [ ] Age of 1st period: ________
  - [ ] Date of last period: ________

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Fig. 1. Runner’s evaluation intake sheet.
In our experience, college freshmen runners are a high-risk group for injuries; their bodies are not conditioned for an often sudden, and rapid, increase to the 70 to 100 miles per week training program that is popular with elite training regimens. Athletes who participate in “speed work” also are at risk for developing overuse injuries. These shorter duration, increased intensity workouts—which frequently incorporate track sprints—require physical demands on the musculoskeletal system that many endurance athletes are not yet ready to perform. In addition, athletes who train on a treadmill during colder winter months and then transition suddenly to land-based running in the spring frequently encounter injuries. The treadmill cushions shock and assists the contact foot to propel backward, which differentiates it from land-based running. Runners who started a hill or interval training program abruptly also may encounter musculoskeletal problems. Additionally, runners who train on cambered (slanted) surfaces or sand also may be at risk for injury. Questions about warm up, flexibility training, strength training, and cross-training should also be included in the evaluation.

Physical examination

The physical examination of the injured runner must reach beyond the site of tissue injury. The easy part of the examination is identifying the injured structure. Often, runners will come in already knowing their diagnosis because of previous experience, running magazines, books, and web surfing. The more difficult and more important part of the evaluation is identifying the offending biomechanical factors that caused the injury. A treatment strategy can be developed based on the functional deficits that are noted. Muscle imbalances that are common to runners should be identified. In particular, tight soleus/inhibited anterior tibialis and tight hip flexor/inhibited gluteus maximus are common patterns that are seen in runners.

The clinician needs to develop a sequence or flow to the examination, usually starting with a screening gait evaluation and then transitioning to observations while the patient is standing, sitting, supine, side-lying, and prone (see Box 1). A thorough site-specific examination will be performed based on the location of pain. Typically, actual running is assessed last. In runners, routine manual muscle testing is not a sensitive measure of strength deficits. Therefore, the clinician needs to make every attempt to challenge the athlete in weight-bearing and functional positions to uncover deficits. Often, the problem is not apparent until the athlete is fatigued adequately. Runners should be undressed and exposed properly to perform a comprehensive examination. Rolling up a pant leg is unacceptable. This article describes a general framework for the clinician who is examining an injured runner.

Screening gait evaluation

The walking gait analysis is an extremely powerful screening tool. In fact, seasoned clinicians often can make the diagnosis and pick up pertinent
biomechanical factors just with careful observation of gait. The screening gait evaluation starts by asking the patient to walk at a comfortable pace without shoes or socks. Gait should be analyzed from the front, back, and lateral views. First, take note of any obvious asymmetries or antalgic gait patterns. This gives information about possible leg length discrepancy, major joint restriction, or profound muscle weakness. For example, the oft-seen Trendelenburg gait indicates gluteus medius weakness. Next, use a systematic approach to analyze each region of the body. Often, a bottom-up approach is selected, looking at the feet and then progressing proximally. Look for proper heel strike, degree and timing of subtalar and midfoot pronation in loading, as well as supination of the foot in terminal stance. Excessive or prolonged pronation causes obligate tibial and femoral internal rotation which may lead to patellofemoral pain [6]. Video analysis with freeze frame capability can act as a useful adjunct to the clinical gait analysis. Markers may be placed over landmarks, such as the tibial tuberosity, midpatella, and distal femur, to facilitate knee joint frontal plane observation [7].

During the screening gait evaluation, certain gait exaggerations may help to make deficits more easily observable [8]. Long stride gait observation is useful to assess the subject’s ability for rear leg loading in late stance (Fig. 2). The subject should be able to bring his/her center of mass over the foot. This tweak is invaluable in assessing the degree of hip extension and

Fig. 2. Long stride exaggerated gait.
ankle dorsiflexion. A tight hip flexor causes the subject to decrease stride length, limit hip extension, and increase lumbar lordosis. Early heel rise is seen commonly when there is a lack of ankle dorsiflexion, as with gastrosoleus tightness. The exaggerated crouch gait helps to evaluate pronation (shock-absorbing ability), mainly in the sagittal plane (Fig. 3). For example, if the foot and ankle remain in a supinated position through the crouched gait, poor pronation should be suspected. Again, early heel rise occurs with gastrocnemius tightness. Additionally, an exaggerated arm swing gait can be used to assess how the trunk and pelvis are moving in proper sequence. The subject is directed to clasp his/her hands together in front of the body and swing the arms from side to side in the transverse plane while walking. The trunk and pelvis are observed for normal reciprocal movement. Abdominal muscle recruitment problems may arise if the reciprocal pattern is not occurring.

Finally, athletes are asked to walk on their toes and to walk on their heels. When walking on their toes, the plantar flexion active range of motion and strength is assessed. Observing a relative calcaneal inversion at the end range of plantar flexion indicates proper posterior tibialis muscle firing [9].
Walking on the heels evaluates ankle dorsiflexion active range of motion and strength.

**Standing examination**

The primary objective of this part of the examination is to assess the alignment and posture of the spine, pelvis, and lower limb. Runners are observed standing with double leg support in all three planes. The major landmarks are the iliac crest, posterior superior iliac spine, anterior superior iliac spine greater trochanter, lateral malleolus, and the calcaneus. Excessive anterior or posterior pelvic tilt (sagittal plane) can be appreciated when viewing from the side. Frontal plane observations can detect pelvic obliquities and leg length discrepancies. The putative “miserable malalignment syndrome” can be observed in this position. Typically, this is seen in susceptible female runners as increased femoral anteversion, vastus medialis oblique (VMO) atrophy, wide Q angle, and foot pronation. Meisser et al [10] correlated a standing or functional Q-angle of greater than 16° to patellofemoral pain in runners. If desired, VMO atrophy can be measured by taking a circumferential girth of both distal quadriceps. A difference of more than 1 cm can indicate significant quadriceps atrophy [11]. In addition, leg length discrepancy may be a source of injury in runners and should be suspected if there is asymmetrical weight bearing, hip external rotation, knee flexion, and pronation in standing. Patients who have patellofemoral pain also may exhibit “grasshopper eyes” patellae (externally rotated due to patella alta) or “squinting” patellae (internally rotated).

In the static standing position, the foot and ankle can be observed for pes planus (flat foot) or pes cavus (high arched). Viewing the patient directly behind the ankles may show “too many toes” (lateral three toes are visible) which indicates excessive pronation or hip external rotation (Fig. 4). Although pes planus is more common and a relative risk factor for running...
injuries, the existence of pes cavus seems to be a much higher predictor of an overuse running injury [12]. The degree of pes planus can be determined by the navicular drop test, in which the navicular location is assessed in the subtalar neutral position and then with weight bearing. A decrease of greater than 1.5 cm is considered to significant pes planus [13].

Excursion (active range of motion) tests in standing

Active range of motion of the lower limb and spine can be assessed in standing to get a better idea of a runner’s true excursion. A “bottom-up” approach is used, assessing the foot and ankle range first and then progressing to the knee and hip. First, the first metatarsophalangeal (MTP) range of motion is assessed by having the runner actively extend the big toe. Elite runners need an active range of motion of at least 45° of MTP extension to achieve a powerful push-off [14]. Second, a weight-bearing supination and pronation excursion test is done by having the runner plant heels and toes to the ground and then attempt to maximally invert and evert the calcaneus. The first ray should point straight ahead to avoid compensation through the forefoot. Any asymmetry of subtalar motion should be noted. The subtalar neutral position (see later discussion), also can be found in this weight-bearing position. Third, a double leg squat (allowing for the heels to leave the ground) is used to record the knee flexion and ankle dorsiflexion active range. Individuals who have tight soleus muscles demonstrate excessive hip flexion (to maintain their center of gravity over their foot) and an early heel rise. Double leg squat additionally screens for knee abnormalities, such as patellofemoral and meniscal pathology. Fourth, the hip crossover tests are performed to assess the range of hip internal and external rotation (Fig. 5). Finally, the lumbosacral spine motion testing is performed and recorded.

Strength and balance tests in standing

Single-legged squat

Single leg stance and squat test (also termed single-legged squat) is the single most useful and valid dynamic standing test [15]. In this test, runners are asked to lower themselves as far as possible and then return to a standing position without losing balance. The initial frontal plane observation is to detect weak hip abductors by way of a Trendelenburg sign (Fig. 6). Then athletes should be observed performing this maneuver in the sagittal and transverse planes. Excessive hip adduction has been noted in asymptomatic women who perform this test and may represent a risk factor for hip and knee injuries [15]. A lack of knee control also may be demonstrated with this test, termed a “knee wobble.” Increased hip adduction and knee wobbling may be a sign of gluteal muscle weakness in the frontal and transverse planes.
Single leg balance reach tests

Single leg balance reach tests incorporate a single leg squat with a reach in the sagittal, coronal, and transverse planes (Fig. 7) [16]. These tests further help the clinician to identify the planes of motion that are difficult and ones that are preferred. The patient is instructed to stand on one leg and reach the other foot in front of them as far as they are able, but without touching the ground. The same instruction is given to the side (coronal plane) and the side and back with twisting (transverse plane). Frequently, runners perform well with single leg reaches in the sagittal plane but perform much worse with reaches in the frontal and transverse planes. During these reach tests, hindfoot motion can be observed for asymmetry, which indicates restrictions of the subtalar joint or talocrural joint. Reach tests also may reveal weakness of the gluteal muscles—attested by a pelvic drop—and weakness of eccentric quadriceps, often with a compensatory forward trunk lean. Weak hip abductors correlated with iliotibial band syndrome in long distance runners [17]. Commonly, early heel rise on the stance leg can indicate a shortened, weakened soleus muscle. If the athlete is not challenged with reach tests, single leg step downs can be used (Fig. 8). The beauty of these tests is that they also can be used as effective therapeutic exercises [17].

Core stability assessment

The core stability assessment is started by observing the qualitative mistakes made with a power runner pose (Fig. 9). This may include a pelvic drop, knee internal rotation, or excessive foot and ankle pronation. A sophisticated standing core muscle assessment is described by Geraci and
Brown elsewhere in this volume. In essence, the core muscles are assessed in standing in all three planes.

*Provocation and palliative tests in standing*

**Provocation tests**

Hopping on a single leg (hop test) can be used as a provocation test for stress fractures or other bony abnormalities, such as stress fractures. Additionally, the single and double leg squats that were performed earlier serve as a screen for knee, hip, and talocrural pathology. Walking in a deep knee crouch (“duck walking”) has been used in preparticipation examinations for years as a screen for meniscal pathology. Plantar fasciitis may be detected by having the runner exaggerate propulsion at terminal stance to mimic a windlass maneuver.

**Palliative tests**

If pain is provoked during the single leg squat, relieving maneuvers can be performed to ascertain a biomechanical cause. The hip assistance
Fig. 7. Balance reach tests in sagittal (A), frontal (B), and transverse planes (C).
palliative maneuver is performed by forcefully compressing the pelvic girdle by pushing the greater trochanters together as the patient performs a single leg squat (Fig. 10a). Medial patellar glide is a palliative maneuver that is performed by manually guiding the kneecap medially as the patient squats on the painful knee (Fig. 10b). This can be done more formally by applying tape [18]. Finally, a medial arch support (eg, orthosis, your cupped hand, wadded sock) also can serve as a palliative device (Fig. 10c). Pain should be monitored during each of the three maneuvers. Decrement of pain on any of these palliative tests can help to convince the clinician and the patient that intervention at that part of the kinetic chain should be addressed. For example, if pain resolves with hip assistance, functional gluteal strengthening should be a focus of rehabilitation. If medial patellar compression helps, patellar taping should be considered. If medial arch support helps, a motion control shoe or foot orthoses may be helpful.

**Seated examination**

*Inspection and palpation*

In addition to checking routine strength, sensation, reflexes, and seated slump tests, the seated position offers a good opportunity to do an
unloaded foot and ankle examination. First, the runner’s feet should be inspected for calluses, necrotic toe nails, and blisters. In the runner who has foot and ankle pain, a thorough palpation examination can pinpoint tissue injury (Table 1). If pain is noted around the base of the fifth metatarsal, a careful palpation examination and radiograph is required to distinguish peroneal tendonitis, avulsion fracture of the base of the fifth metatarsal, and a diaphyseal (Jones’) fracture [19]. Jones’ fracture often needs to be treated with pinning because of frequent nonunion. Dorsal tenderness with a Tinel’s sign between the third and fourth metatarsals distally is pathognomonic for a Morton’s neuroma. The Windlass maneuver, in which the first MTP and the ankle are dorsiflexed maximally, can bring out the plantar fascia [20].

*Passive range of motion of the foot and ankle*

An open kinetic chain assessment of the foot and ankle joint passive range of motion can yield areas where joint mobilization can be helpful. Subtalar joint mobility is assessed passively by placing the joint in neutral position then inverting and evertting the calcaneus (Fig. 11). Careful note should be made of side to side difference. Restricted subtalar eversion is
common and may cause problems with shock absorption (pronation) during the loading response of the stance phase of running [21,22].

Talocrural joint mobility along with gastrocnemius and soleus flexibility should be assessed. Runners frequently have a tight gastrosoleus complex. Because the gastrocnemius crosses two joints, it is particularly vulnerable to developing tightness. In the authors’ experience, however, the soleus is frequently just as tight as the gastrocnemius in runners. The gastrocnemius length can be measured by dorsiflexing the foot with the knee straight, and the soleus length can be measured by dorsiflexing the foot with the knee bent. Tightness in the gastrosoleus complex (ankle equinus) can lead to a compensatory midfoot and subtalar pronation [23]. Ankle equinus can lead to several running injuries, including plantar fasciitis, Achilles tendinopathy, and medial tibial stress syndrome [23,24]. It is believed that runners require at least 15° to 20° of dorsiflexion for efficient running [9].

Midtarsal motion is assessed with the calcaneus in eversion. This essentially places the midtarsal joints in parallel and unlocks the midfoot (Fig. 12). Midtarsal motion should be eliminated by placing the calcaneus in
inversion. A flexible midfoot in calcaneal inversion and eversion may require orthotic inversion.

Finally, first ray joint play and first MTP joint passive range of motion should be assessed. The first ray joint play is assessed by determining if the

Table 1
Overuse injuries of the foot and ankle based on site of tenderness

<table>
<thead>
<tr>
<th>Site of tenderness</th>
<th>Diagnosis</th>
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</thead>
<tbody>
<tr>
<td>Achilles tendon and paratendon</td>
<td>Achilles tendonitis</td>
</tr>
<tr>
<td>Posterior heel (calcaneus) tenderness</td>
<td>Calcaneal stress fracture or severe disease (in adolescent)</td>
</tr>
<tr>
<td>Retrocalcaneal bursa</td>
<td>Retrocalcaneal bursitis</td>
</tr>
<tr>
<td>Medial calcaneal tuberosity</td>
<td>Plantar fasciitis</td>
</tr>
<tr>
<td>Tarsal tunnel</td>
<td>Extrinsic flexor tendonitis</td>
</tr>
<tr>
<td>Anterior talofibular ligament</td>
<td>Lateral ankle sprain or sinus tarsi syndrome</td>
</tr>
<tr>
<td>Talar dome</td>
<td>Talus stress fracture or osteochondritis dissecans</td>
</tr>
<tr>
<td>Proximal dorsal aspect of navicular (N-spot)</td>
<td>Navicular stress fracture</td>
</tr>
<tr>
<td>Base of 5th metatarsal</td>
<td>Jones’ fracture, peroneal tendonitis</td>
</tr>
<tr>
<td>Lateral midfoot</td>
<td>Cuboid syndrome</td>
</tr>
<tr>
<td>Shaft of metatarsals</td>
<td>March fracture</td>
</tr>
<tr>
<td>Sesamoid</td>
<td>Sesamoiditis or stress fracture</td>
</tr>
</tbody>
</table>
first metatarsal is aligned with the other metatarsals (neutral) or if it is dorsiflexed or plantarflexed in relation to the other metatarsals.

**Knee examination**

In sitting, runners who have knee pain should be assessed for crepitus and patellar tracking. The runner is asked to extend the knee from 90° of flexion to full extension. The patella disengages from the trochlea at the end range of extension; however, if the patella abruptly disengages laterally, this is termed a positive "J-sign." Patella alta and a prominent Hoffa’s pad should be noted because these conditions may predispose runners to patellofemoral pain. In runners who are suspected to have a femoral stress fracture, a femoral fulcrum test should be performed. With this test, one arm is used as a lever point underneath the posterior thigh and the other pushes down on the distal thigh. The seated position offers a good opportunity to palpate the patellar tendon from its origin at the inferior pole of the patella to its

Fig. 11. Subtalar inversion (A) and inversion (B) testing with the foot unweighted.

Fig. 12. Midfoot motion. (A) With hindfoot locked in supination (calcaneal inversion). (B) With hindfoot unlocked in pronation (calcaneal eversion).
attachment at the tibial tuberosity. It can be made to stand out by having the runner actively extend the knee, and then the examiner presses down on the superior pole of the patella. Adolescent athletes frequently have traction apophysitis at this location (eg, inferior pole of patella = Sinding-Larsen-Johansson syndrome; tibial tuberosity = Osgood-Schlater syndrome). Typically, the rest of the knee and thigh examination takes place in the supine position.

**Supine examination**

*Inspection and palpation*

In supine, pelvic landmarks and leg lengths should be reassessed. Straight leg raise is done to assess further for adverse dynamic neural tension and hamstring length. In runners who have shin splints, a palpation examination of the medial tibia can help to differentiate stress fractures from soft tissue injury. Localized, rather than diffuse, pain with palpation and percussion may be a sign of a tibial stress fracture [3].

*Hip examination*

Passive range of motion testing of hip flexion, abduction, internal rotation, and external rotation is assessed in the supine position. The modified Thomas test is a valuable test that should be performed to assess the muscle length of the iliopsoas, tensor fascia lata, and rectus femoris (Fig. 13). Recreational runners frequently encounter problems with tight hip
flexors and quadriceps. A lack of hip internal rotation and abduction may warrant a work-up for hip intra-articular pathology. Provocation tests for hip intra-articular pathology include hip internal rotation with overpressure, flexion-abduction-external rotation (FABER) test, and hip scour test. There are innumerable sacroiliac joint provocation tests that can be performed in supine, side-lying, and prone. No single test has proven to be better than others [25]; however, the authors use the Patrick test, thigh thrust, and Gaenslen test frequently.

Knee examination

The supine examination also includes a thorough evaluation of the knee. Standard knee tests to evaluate for swelling, ligamentous laxity, and meniscal or intra-articular pathology [26] are performed. Finding and palpating the site of tenderness can help to narrow the differential diagnosis (Table 2). Clarke’s test (patellar grind) should be performed to evaluate for patellofemoral pain syndrome. Crossley et al [27] described a three-dimensional method for assessing the mobility and orientation of the patella. This assessment should be done if patellar taping is a consideration. The Noble compression test is a provocative test for iliotibial band syndrome. Typically, this test is performed supine; however, it can be sensitized by performing it in single leg stance (Fig. 14). Tibial torsion can be assessed in the supine position. The knee is placed in the frontal plane by placing the femoral condyles in line, then an imaginary line is drawn between the tibial malleoli. This angle of inclination from the frontal plane becomes the amount of tibial torsion. The most common tibial alignment abnormality is bowleggedness or tibia varum.

Core stability assessment

In the supine position, core stability can be assessed qualitatively by performing a pelvic bridge. The pelvic bridge requires gluteal, hamstring, and

<table>
<thead>
<tr>
<th>Site of Tenderness</th>
<th>Diagnosis</th>
</tr>
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<tbody>
<tr>
<td>Gerdy’s tubercle</td>
<td>Iliotibial band syndrome</td>
</tr>
<tr>
<td>Lateral femoral epicondyle</td>
<td>Iliotibial band syndrome</td>
</tr>
<tr>
<td>Inferior pole of patella</td>
<td>Patellar tendonitis, Sinding-Larsen-Johansson</td>
</tr>
<tr>
<td>Superior pole of patella</td>
<td>Quadriceps tendonitis</td>
</tr>
<tr>
<td>Tibial tuberosity</td>
<td>Ösgood-Schlater</td>
</tr>
<tr>
<td>Medial band</td>
<td>Plica syndrome</td>
</tr>
<tr>
<td>Joint lines</td>
<td>Menisceal pathology</td>
</tr>
<tr>
<td>Patellar facets</td>
<td>Patellofemoral pain syndrome</td>
</tr>
<tr>
<td>Retinaculum</td>
<td>Patellofemoral pain syndrome</td>
</tr>
<tr>
<td>Fat pad</td>
<td>Hoffa’s fat pain syndrome</td>
</tr>
</tbody>
</table>
paraspinal strength. If a proper posterior pelvic tilt is done in addition to the pelvic bridge, abdominal muscles also will need to be engaged. Hamstring cramping during the pelvic bridge can be a subjective sign of gluteal underuse and hamstring overuse. During the bridge, the runner can be asked to extend one leg, balancing on just one planted leg. A side to side difference can be indicative of hip girdle muscle weakness. The upper abdominals of the core can be assessed by having the athlete go from a supine position to a long sit position. Compensatory maneuvers include leading with neck flexion and lifting of the heels. The lower abdominals can be tested using the leg lowering test that was described by Kendall et al [28]. The athlete is asked to keep a reduced lumbar lordosis as he/she lowers the legs from 90° of hip flexion. The hip flexion range in which the athlete returns to lumbar lordosis is recorded. Athletes who have adequate lower abdominal strength should be able to maintain their back flat for at least 45° of hip flexion. These tests serve as an augment to the standing core stability assessment.

**Side-lying examination**

In this position, the greater trochanter is palpated easily for tenderness or swelling. Manual muscle testing of the hip external rotators and abductors
can be performed in the side-lying position. Failure to detect any weakness on manual muscle testing is common in this unloaded position, however, and findings should be compared with the evaluation in the standing position. During resisted hip abduction, the subject frequently will “cheat” by using hip flexor muscles to provide more power. An easy way of sensitizing this test is to perform it with the subject abducting with the hip internally rotated—using more the tensor fascia lata—versus externally rotated—using more of the gluteus medius. More commonly, weakness is seen only when the subject is tested in an externally rotated position. The modified Ober test also is performed to evaluate for iliotibial band tightness (Fig. 15) [28].

Prone examination

Posterior to anterior glide along the lumbar spine and pelvis may indicate discogenic pain, sacroiliac joint–mediated pain, and sacral stress injury. The prone position is an opportunity to perform Ely test for rectus femoris tightness, a common finding in runners. Femoral stretch testing should be performed by passively bending the individual’s knee then adding hip extension as a sensitizing maneuver. Like any dural tension test, the femoral stretch is considered positive if concordant symptoms are reproduced, worsens with dural tension tautness, and improves with dural tension slackening. A formal assessment of femoral torsion (femoral anteversion) can be done in the prone position, particularly if a miserable malalignment syndrome is seen in standing. The knee is flexed to 90° and then the examiner internally rotates the hip until the greater trochanter becomes palpably prominent. The angle of the tibia from vertical becomes the amount of femoral anteversion [29]. Radiographs often are needed to confirm femoral anteversion. Increased femoral internal (medial) torsion causes in-toeing [26].
Subtalar neutral testing

The prone position offers the ideal opportunity to assess for the so-called “subtalar neutral position.” The subtalar neutral position is found by placing the thumb and index finger on the anterior talus, and then moving the calcaneus until talonavicular congruency (talus is felt equally by both fingers) is found (Fig. 16). The importance of the finding of the subtalar neutral position has diminished for multiple reasons. First, the neutral typically is looked for in the open kinetic chain position, which is not a functional position for runners. Second, the assumption that the subtalar neutral is the most efficient and effective position for running has not been validated. The authors use subtalar neutral testing to identify the relationships of the hindfoot to the forefoot and the lower leg. In the authors’ experience, runners who have certain foot types need custom foot orthoses more frequently.

Shoe assessment

Running shoes have evolved into high-tech equipment that often obviates the need for foot orthoses; however, ill-fitting or worn-out running shoes can contribute to overuse injuries [30]. A comprehensive evaluation of the runner involves looking at the athlete’s current and previous pairs of shoes; therefore, the authors ask that runners bring their last two pairs of shoes to the initial evaluation (Box 2).
Running shoes can be divided into three general types: (1) motion control (antipronation), (2) stability (neutral), and (3) shock absorbing (cushioning). The most important determination to make is if the examinee’s foot type fits his/her current pair of running shoes. The age and mileage on the shoes should be ascertained. In general, running shoes tend to wear down after 300 to 500 miles. Shock-absorbing shoes tend to wear down more quickly than motion control shoes, especially if running on wet surfaces and if they are more than 1 year old. Often, runners get shoes that are tight because they fit their shoes with considering the swelling of the foot with running. Shoes that are too loose also can cause problems, such as pistoning of the heel out of the shoe. Certain lacing techniques can help to prevent pistoning and alleviate pressure from the dorsum of the foot.

The last of the shoe also should be determined. The last refers to the material between the shoe and sole as well as the stitching on the material. Individuals who have hyperpronation require a straight-stitched board last, whereas runners who have high-arched feet require a curved-stitched slip last. The amount of midfoot motion that is available with the shoe can be determined by twisting the shoe along its transverse crease. Hyperpronating runners require a stiffer shoe. A stiffer shoe often has antipronation materials, such as so-called “foot bridges” and hard medial arch materials. The heel counter design also can help to control the hindfoot in runners who have heel contact on initial contact (slower runners). Faster runners should not have a heel counter that is built up excessively.

The wear patterns on an older shoe also can offer clues in determining if the shoe fits the foot type. Normally, hindfoot (initial contact) runners have some wear at the lateral portion of the heel because stance phase begins with a supinated foot position. After initial contact, the foot pronates before supinating again. If excessive wear is seen on the lateral aspect of the

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**Box 2. Shoe assessment**

- Determine age and mileage of shoe
- Determine if shoe is too tight or too loose for the size of the foot
- Look at last: straight versus curved
- Look at shoe torsion: stiffness
- Look for anti-pronation materials: foot bridge or medial arch materials
- Look at heel counter and height
- Look for shock-absorbing material
- Look at lacing technique
- Determine type of shoe
- Determine wear patterns: asymmetry
- Determine if type of shoe matches foot type
forefoot, a pes cavus foot with inability to pronate should be suspected. Asymmetric pronation also can be suspected if the heel and midfoot has more medial wear than the other shoe. The most common mistakes that the authors see is that runners get shoes that prevent physiologic pronation and shock absorption. Finally, the lacing technique that is used can help to make the shoe fit the foot more adequately.

Running analysis

Running gait analysis should be a routine evaluation tool for the treating team. When assessing running, it is important to remember that running is biomechanically different than walking and that treadmill running is different than road running. Compared with walking, running requires a greater joint range of motion and has greater eccentric muscle demand. Initial heel contact position varies, depending on speed; slower runners land on their heels, whereas sprinters land on their forefoot. Often in the clinic setting, a treadmill is a convenient way to watch athletes run; however, a video of the runner viewed in multiple planes provides the truest picture of the running form. In the authors’ experience, reflective gait markers further enhance the clinician’s ability to detect transverse plane abnormalities, particularly at the knee and ankle.

A systematic running analysis that evaluates each joint in all three planes is suggested. Initially, observe the runner’s arm swing and posture. Take note of arm position, direction, and amount of swing. Asymmetric or abnormal arm swing may be the result or the cause of a distal kinetic chain dysfunction. Posturally, runners may have an increased lumbar lordosis when compared with walking gait. This often is an indicator of tight hip flexors or inefficient use of abdominal muscles. Stride length should be observed for the amount of hip extension. A forward trunk lean (anterior pelvic tilt) also may be a compensation for tight hip flexors or weak gluteal muscles. Anterior pelvic tilting causes an increased knee flexion angle, and thus, produces more eccentric force loads on the quadriceps [23]. Abnormal pelvic dynamics also may be evident with a lateral pelvic tilt (Trendelenburg sign) during running.

The quality of knee control is determined in the sagittal, frontal, and transverse planes. In the sagittal plane, excessive knee flexion may occur with hamstring tightness or excessive anterior pelvic tilt. In the frontal plane, genu valgus (knee abduction) can be seen. In the transverse plane, control of the obligate tibial and femoral internal rotation with pronation should be observed.

Particular attention is paid to the foot and ankle. Runners are assessed for normal pronation, hyperpronation, or inadequate pronation. In the frontal plane, the calcaneus is observed for adequate and symmetric eversion after initial contact. Adequate pronation allows for attenuation of forces at the foot in loading. Lack of subtalar eversion often prevents
<table>
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<th>Pathognomonic</th>
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<th>Patellofemoral pain syndrome</th>
<th>Iliotibial band syndrome</th>
<th>Tibial stress fracture</th>
<th>Medial tibial stress syndrome</th>
<th>Plantar fasciitis</th>
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<tr>
<td><strong>Physical examination</strong></td>
<td>Tender greater trochanter</td>
<td>Positive Clark’s sign; relief of symptoms with hip assist, medial patellar compression, or arch assist (see figures)</td>
<td>Noble’s compression, Ober’s test</td>
<td>Pain with single leg hop, focal tenderness on tibia</td>
<td>Diffuse tenderness medial to tibial crest</td>
<td>Tender inferior medial calcaneus</td>
</tr>
<tr>
<td><strong>Findings</strong></td>
<td>Weak gluteus medius</td>
<td>Weak gluteus medius; tight gastroc-soleus, hip flexors</td>
<td>Weak gluteus medius</td>
<td>May have dynamic hyper-pronation of midfoot</td>
<td>Dynamic hyper-pronation of midfoot</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pain in lateral hip pain</td>
<td>Anterior knee pain especially going downstairs, Theatre sign</td>
<td>Lateral knee pain, especially worse toward end of run</td>
<td>Complaints of “shin splints” every step of run</td>
<td>Complaints of “shin splints” improve during run</td>
<td></td>
</tr>
<tr>
<td><strong>Clinical symptom</strong></td>
<td>Gluteus medius or tensor fascia lata tendonitis</td>
<td>Patellar cartilage (chondromalacia) and synovium</td>
<td>ITB tendinopathy or possible bursitis at lateral femoral condyle</td>
<td>Tibial cortical bone</td>
<td>Tibial periosteum at muscle origin of soleus/posterior tibialis</td>
<td></td>
</tr>
<tr>
<td><strong>Tissue injury</strong></td>
<td>Weak gluteus medius; tight TFL/iliopsoas</td>
<td>Tight ITB, rectus femoris, iliopectineus, gastroc-soleus; weakness of gluteus medius, rigid subtalal eversion</td>
<td>Tight ITB, rectus femoris, iliopectineus, gastroc-soleus; weakness of gluteus medius, rigid subtalar eversion</td>
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<td>Tight and weak soleus; hallux rigidus</td>
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<td><strong>Biomechanical deficits</strong></td>
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<td>Incongruence of femoral and tibial internal rotation loading response (causing lateral patellar tracking)</td>
<td>Compensated Trendelenburg gait, sometimes pelvic obliquity</td>
<td>Rigid subtalar eversion; dynamic hyper-pronation of midfoot</td>
<td>Rigid subtalar eversion; dynamic hyper-pronation of midfoot</td>
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<tr>
<td><strong>Functional adaptation</strong></td>
<td>Compensated Trendelenburg gait, sometimes pelvic obliquity</td>
<td>Incongruence of femoral and tibial internal rotation loading response (causing lateral patellar tracking)</td>
<td>Compensated Trendelenburg gait, sometimes pelvic obliquity</td>
<td>Rigid subtalar eversion; dynamic hyper-pronation of midfoot</td>
<td>Rigid subtalar eversion; tight hip flexors</td>
<td></td>
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<tr>
<th><strong>Tissue overload complex</strong></th>
<th>Tensor fascia lata and iliotibial band; lateral retinaculum stress</th>
<th>Tensor fascia lata and iliotibial band</th>
<th>Posterior tibialis muscle origination</th>
<th>Posterior tibialis muscle origination</th>
<th>Posterior tibialis muscle origination</th>
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<tr>
<td><strong>Gait findings</strong></td>
<td>Compensated Trendelenburg, external rotation of foot</td>
<td>Hyperpronation</td>
<td>Compensated Trendelenburg</td>
<td>Antalgic gait</td>
<td>External rotation of foot</td>
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<tr>
<td><strong>Radiograph</strong></td>
<td>Normal; sunrise views may show patella positioned laterally in femoral groove</td>
<td>Normal</td>
<td>Normal</td>
<td>May have cortical thickening after 2 weeks</td>
<td>Normal</td>
</tr>
<tr>
<td><strong>MRI</strong></td>
<td>Gluteus medius tendinosis or greater trochanter bursa formation</td>
<td>Normal or early patellar cartilaginous changes</td>
<td>Normal or increased signal at distal ITB near lateral femoral condyle</td>
<td>Increased signal intensity on STIR images [31]</td>
<td>Diffuse signal intensity of tibial periosteum</td>
</tr>
<tr>
<td><strong>Ultrasound</strong></td>
<td>Gluteus medius tendinosis or greater trochanter bursa formation</td>
<td>Normal</td>
<td>Normal or thickened ITB, hypoechoic at distal ITB near lateral femoral condyle</td>
<td>May be painful at site of fracture</td>
<td>Negative</td>
</tr>
<tr>
<td><strong>Bone scan</strong></td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
<td>Focal increased uptake</td>
<td>Fusiform increased uptake</td>
</tr>
<tr>
<td><strong>Rehab pearls</strong></td>
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<td>Patellar taping early; closed chain gluteal muscle strength and dynamic balance</td>
<td>Gluteus medius strengthening, Functional triplanar stretching [17]</td>
<td>Consider pool running or harness-supported running to maintain cardiovascular fitness</td>
<td>“Stomp the bug”; subtalar mobilization; motion control shoe</td>
</tr>
</tbody>
</table>

ITB, iliotibial band; STIR, short T1 inversion recovery.
adequate shock absorption and places excessive strain on kinetically linked structures, such as the knee or hip. Greater vertical impact forces and delayed pronation have been implicated as risk factors for running-related injuries [21,31]. Often, a medial heel whip (during swing phase) running style is seen in runners who have prolonged foot pronation. A lateral heel whip, seen less commonly, results from excessive supination.

Summary

In most cases, a detailed history provides the information that is necessary for the clinician to diagnose the injured runner correctly; however, to treat the injury and guide a successful rehabilitation program, the physical examination must go beyond the standard regional musculoskeletal examination. The victims (tissue injury) and the culprits (biomechanical deficits) must be identified to facilitate treatment (Table 3). Gait and other dynamic assessments help to reveal underlying deficits in function that may have contributed to injury. In short, the entire functional kinetic chain must be considered and weak links identified.

References


