

A Primer on Running for the Orthopaedic Surgeon

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Abstract

Long-distance running has become increasingly popular during the past decades. Many running patients pose questions to their orthopaedic surgeons regarding risks, benefits, and running techniques. This article identifies 11 running-related questions that patients may ask and provides information to help answer those questions. This review discusses data on the health benefits of running, common running injuries, the relationship between running and osteoarthritis, recommendations regarding running after orthopaedic surgery, running shoes, and other questions that may arise when treating the running athlete.

Running is an increasingly popular pastime for Americans, reflected in part by the number of participants in running races. In the United States, the number of race finishers has increased by >360% since 1990, from 4.7 million to 17 million in 2015. The proportion of female runners during that time has grown from 25% to 57% of finishers.¹ In 2015, >509,000 people finished 1,100 marathons (competitive races of 26.2 miles) in the United States.¹

Cardiovascular fitness protects against obesity, chronic disease, brain atrophy (in those at risk of dementia), and cancer.² Physical activity at low levels (92 minutes weekly or 15 minutes daily) has been associated with a 14% reduction in death from any cause and a 3-year increase in life expectancy. Each additional 15 minutes of daily exercise is associated with a further 4% reduction in death from any cause.³ Running can increase cardiovascular fitness and improve physical activity levels, aerobic fitness, and cardiovascular function, as well as metabolic fitness, adiposity, and postural balance.⁴

However, there are risks associated with running, especially at levels and durations considered “above average.” Each year, 19% to 79% of runners report lower extremity running-related injuries, most commonly at the knee.⁵ Orthopaedic (musculoskeletal) injuries in runners can be acute but are more commonly chronic and caused by overuse. The goal of this review is to present evidence-based answers to common questions from runners to guide orthopaedic surgeons in treating and counseling these patients.

Common Patient Questions

What Are the Health Benefits of Running?

Physical exercise is recognized by the American Heart Association and the American College of Sports Medicine as important for preventing and managing chronic diseases, such as cardiovascular disease and type 2 diabetes.^{2,6} The recommendation for adults is 30 minutes of moderate aerobic activity on 5 days a week or 20 minutes of vigorous aerobic

activity on 3 days a week.⁶ The updated recommendations from the American College of Cardiology and the American Heart Association for lowering blood pressure and cholesterol levels are for adults to engage in 40 minutes of aerobic exercise 3 to 4 times a week.² Not only does running meet the criteria for aerobic activity required for overall health benefits but it is also a weight-bearing activity, which helps maintain skeletal health.⁶

In summary: Physical exercise helps prevent and manage chronic disease, and the current recommendation for adults is 30 minutes of aerobic activity on 5 days a week. Running is one such activity that can help meet this recommendation for cardiovascular and skeletal health.

Are There Health Risks Associated With Running?

Acute metabolic and physiologic changes occur in the body while running. These changes include increased breathing rate and depth, increased cardiac output, diversion of blood flow to the exercising muscles, and fluctuations in circulating hormones.⁷ Electrolyte balance is usually well maintained during marathon and ironman triathlon events (post-marathon mean sodium levels are 143 mmol/L, and only 0.6% of triathlon participants have levels <135 mmol/L).⁷ Epinephrine and norepinephrine respond rapidly to exercise, facilitating increased cardiac output and greater release of glucose from the liver. They just as rapidly dissipate in circulation and return to resting concentrations 5 to 10 minutes after cessation of exercise. Lymphocyte concentration, white blood cell count, and platelet count increase with strenuous exercise and can remain elevated for 24 hours after a marathon. With excessive training, however, neutrophil concentration can decrease, which can

make overtrained athletes susceptible to upper respiratory tract and other infections.⁷

Cardiac changes after competing in extreme endurance events (marathons and ultramarathons) include transient acute overload of the atria and right ventricle, transient reductions in the ejection fraction of the right ventricle, and elevated cardiac biomarkers. However, all of these changes normalize by 1 week.⁸ Adverse events, such as sudden cardiac arrest, are rare in marathoners (1 event per 184,000 runners and 1 per 100,000 marathoners compared with 1 per 40,000 college athletes and 1 per 52,630 triathletes)^{8,9} and typically occur during the last quarter of the event distance because of hypertrophic cardiomyopathy. Eighty-six percent of sudden cardiac arrest events occur in men.⁹ The incidence of sudden cardiac death in marathons and half-marathons is 1 per 259,000 participants. Factors associated with survival of cardiac events include initiation of bystander-administered cardiopulmonary resuscitation and diagnosis other than hypertrophic cardiomyopathy. Survivors tend to be older than nonsurvivors and to have run more long-distance races during their lifetimes.⁹ Although catastrophic cardiac events are rare, lifelong vigorous exercise can lead to cardiovascular remodeling.⁸ These structural changes include enlarged left and right ventricular volumes, as well as increased cardiac mass, left atrial size, and left ventricular wall thickness.⁸ Most of these changes are physiologic to accommodate endurance exercise. However, 50% of marathoners have evidence of elevated serologic markers of cardiac damage after completing a marathon, and 40% have a transient rise in serum creatinine consistent with acute kidney injury.⁸ Elite-level endurance athletes most commonly have atrial and ventricular ectopy

and electrocardiographic abnormalities, thought to be caused by chronic remodeling from excessive endurance exercise. However, these abnormalities have not been found to predispose to arrhythmias or sudden cardiac death.⁸

In summary: Although endurance running has been associated with physiologic and metabolic changes, these changes are beneficial or transient, with no evidence of long-term detriment to health.

Are There Musculoskeletal Risks of Running? (How Likely Am I to Get a Running Injury?)

The strongest predictors of running injuries are the total running distance (>65 km per week) and history of injury. Limited evidence exists for an association between injuries and older age (without an identifiable age cutoff), sex (male), leg-length difference, greater knee varus, greater height in male runners, and cross-training in cycling and aerobics.⁵

At any given time, 25% to 36% of runners have a running-related injury. Half of these injuries reduce or eliminate running ability, but 25% result in no running time lost or need for medical attention.¹⁰ The high incidence of lower extremity injuries is consistent with ground reaction forces that are twice as high during heel-strike running as during walking and can, at higher endurance running speeds, approach 3 to 4 times body weight.¹¹

The most common overuse injuries in runners tend to occur about the knee (7% to 50%) and include patellofemoral pain syndrome and iliotibial band syndrome (ITBS).^{5,12} Patellofemoral pain syndrome has recently been retermed “anterior knee pain” as per the recommendations of the International Patellofemoral Study Group.¹³ The next most common injuries are in the lower leg (9% to 32%), the foot (5.7% to 39%), and

the upper leg (3.4% to 39%). Less common sites of injury include the ankle (3.9% to 17%) and the hip/pelvis (3.3% to 12%).⁵ A retrospective review of >2,000 running injuries found that the five most common were anterior knee pain, ITBS, plantar fasciitis, meniscal injuries, and patellar tendinopathy.¹⁴

At the hip, running injuries include ITBS, greater trochanter pain syndrome, snapping hip syndrome, and femoral neck stress fracture. At the knee, runners may present with anterior knee pain (“runner’s knee”), ITBS, or popliteal artery entrapment syndrome. Lower leg injuries include medial tibial stress syndrome, Achilles tendinopathy, gastrocnemius soleus strain, chronic exertional compartment syndrome, and tibial stress fractures. At the foot, running injuries include plantar fasciitis and bone stress injuries (Table 1^{12,14–21}).

In summary: At any given time, 25% to 36% of runners have an overuse injury. These injuries occur most commonly at the knee.

Are Ultramarathons Safe? (How Much Should I Run?)

Ultramarathons are distances longer than the traditional marathon (26.2 miles). From 2011 to 2014, the number of ultramarathon finishers in North America doubled to 76,000 (representing <13% of all marathon finishers).²² Most commonly, single-stage ultramarathon lengths are 50 km, 100 km, or 161 km (100 miles). There are also multistage races in which ultramarathoners run across a region, country, or continent, as well as multiday races that can take 6 to 10 days to complete.²³ Ultramarathoners train and run at a slower pace than marathon runners, and finishers tend to be older (mean age, 45 years) than marathoners.²³ If a runner decides to increase mileage, it is important to do so gradually to avoid

injury because a sudden increase in intensity or quantity of training is associated with many overuse injuries.¹⁹

Ultramarathoners have a similar incidence of injuries to shorter-distance runners, and the types of injuries are similar, although they have a lower incidence of stress fractures than do shorter-distance runners.²² Most injuries sustained by ultramarathoners are considered minor (95%); 74% are skin-related injuries, 18% are musculoskeletal injuries, and 7.5% are medical illnesses.²⁴ However, some ailments, such as exercise-associated hyponatremia (EAH), are thought to be less common but can be fatal. EAH is diagnosed when a patient’s blood sodium concentration (Na^+) is $<135 \text{ mmol/L}^{-1}$ during, or within the 24 hours after, prolonged physical activity. In some studies, the incidence of EAH has been as high as 51% in 161-km ultramarathoners and can be associated with either overhydration or dehydration.²⁵

In summary: Ultramarathoners sustain many of the same overuse injuries as shorter-distance runners but have a higher risk of medical-related issues and lower risk of stress fractures compared with shorter-distance runners.

Is Running Bad for My Joints? (Does Running Cause Osteoarthritis?)

Because of the high incidence of lower extremity and especially knee overuse injuries in runners, many people ask about an association between running and osteoarthritis (OA). A recent systematic review found that running was a risk factor for OA only in elite athletes.²⁶ Another systematic review found that although most elite athletes who play high-impact sports (soccer, handball, track and field, and hockey) are at increased risk of hip OA, long-distance runners are not.²⁷

Studies have shown that running is not a risk factor for and may actually be protective against OA.^{27–30} Williams³⁰ found that nonrunning exercise was associated with a higher risk of OA and need for hip arthroplasty, whereas running notably reduced the risk of OA and hip arthroplasty. This finding was attributed in part to the association between running and lower body mass index.³⁰ However, running also increases the glycosaminoglycan content in knee cartilage and decreases the intra-articular proinflammatory cytokine concentration, suggesting a protective effect at the molecular level of cartilage.³¹ A recent meta-analysis found that runners have 50% lower odds of undergoing OA-related knee surgery compared with nonrunners.³² Although the peak loads in running are higher than those in walking, the short duration of ground contact in running appears to result in per-unit-distance loads no higher than in walking.²⁸

In summary: There is no evidence that running increases the risk of OA at the hip or knee; in fact, running may be protective against OA and the need for related surgeries.

What Kind of Stretching Is Recommended?

It is unclear whether stretching before and/or after running prevents injury. The three types of stretching are static, dynamic, and proprioceptive neuromuscular facilitation (PNF). In static stretching, the muscle is lengthened and held; in dynamic stretching, the muscle is actively lengthened and then held; and in PNF, the opposing muscle is contracted to lengthen the targeted muscle.³³

Static stretching before exercise leads to performance deficits, and deficits are dose-responsive to greater duration of stretching (>60 seconds).³⁴ According to limited research, PNF

Table 1**Common Running Injuries**

Injury	Cause/Description	Treatment
Hip		
ITBS	Can result from friction against the greater trochanter. Is worsened with running on banked surfaces, downhill running, leg-length discrepancies, and genu varum. ¹⁵	Rest, NSAIDs, and physical therapy to treat symptoms. Only rarely is surgery with iliotibial band release or lengthening considered. ¹⁵
Snapping hip syndrome	Can be external (more common, caused by iliotibial band, tensor fascia lata, or gluteus maximus sliding over the greater trochanter) or internal (iliopsoas tendon sliding over the iliopectineal eminence, lesser trochanter, femoral head, or hip capsule).	Rest, NSAIDs, and physical therapy to treat symptoms. Only rarely is surgery with iliotibial band release or lengthening considered (for external snapping hip). ¹⁵
Femoral neck stress fractures	Can present as anterior hip or groin pain that is worsened by running and can radiate to the thigh or medial knee. Women have a higher incidence of femoral neck stress fracture, and patients with a lower body mass index (<19) or higher MRI grade of stress fracture require longer return-to-running times after diagnosis. ¹⁶	Nondisplaced compression-sided or medial stress fractures can be treated nonoperatively. Tension-sided or lateral stress fractures are considered to be at higher risk of displacement and nonunion; hence, early surgical intervention should be considered. ^{15,16}
Knee		
Anterior knee pain (previously known as patellofemoral pain syndrome) ¹³	Excessive hip adduction and hip internal rotation or external rotation weakness have been implicated as causes. These positions theoretically displace the patella laterally against the femur, causing increased pressure at the patellofemoral joint, which leads to pain. ¹² Patients present with anterior knee pain, worse with squatting or prolonged sitting, and may show vastus medialis oblique muscle atrophy or the J sign. ¹⁷	Nonsurgical treatment (activity modification, NSAIDs, and ice) and physical therapy focused on quadriceps and core strengthening and correction of neuromuscular dysfunction. ¹⁸
ITBS	Can be caused by friction at the lateral femoral epicondyle, compression of tissue deep to the iliotibial band, or bursitis. It may present as diffuse lateral pain or lateral knee snapping. ¹⁷	Nonsurgical treatment (activity modification, NSAIDs, and ice) and physical therapy.
Popliteal artery entrapment syndrome	Occurs when the popliteal artery is compressed by anatomic variations at the back of the knee, which can include abnormal origin of the medial head of the gastrocnemius muscle at the intercondylar notch, aberrant fibrous bands, or a medial position of the popliteal artery. Presents similarly to chronic exertional compartment syndrome of the lower leg.	Because of the progressive natural history, as well as the cause of this syndrome, surgery is often warranted. ¹⁹
Lower leg		
Medial tibial stress syndrome	Presents as exercise-induced pain at the mid-to-distal posteromedial tibia. Thought to be caused by abnormal traction of the calf muscles or overloading of the tibial cortex. Risk factors include female sex, high body mass index, uneven running surfaces, sudden increases in running intensity or distances, and excessive foot pronation. ¹⁷	Activity modification, stretching, ice, and NSAIDs. A trial of 6-12 wk of nonsurgical treatment is attempted, and if this fails, rarely is surgical release offered as a treatment. ¹⁷

(continued)

ITBS = iliotibial band syndrome

Table 1 (continued)

Common Running Injuries		
Injury	Cause/Description	Treatment
Achilles tendinopathy	Presents as posterior heel pain with tenderness often 2-6 cm proximal to the tendinous insertion on the calcaneus.	Activity modification, stretching, ice, and NSAIDs.
Gastrocnemius strains	More common than soleus strains because the gastrocnemius muscle crosses two joints and consists primarily of fast-twitch type-IIb fibers. The gastrocnemius can be injured with faster-than-normal running speeds and suboptimal foot touchdown, which lead to alterations in the muscle length and shock absorption. ¹⁹	Activity modification, stretching, ice, and NSAIDs. For severe gastrocnemius strains or ruptures, splinting in plantar flexion for 3 wk can aid healing. ¹⁹
Chronic exertional compartment syndrome	Typically presents with pain at a relatively consistent time/distance after the onset of running and dissipates with cessation of running. Bilateral presentation is frequent. Most commonly, the anterior compartment is involved (45%), followed by the posterior deep compartment (40%). The lateral compartment (10%) and posterior superficial compartment (5%) are less commonly involved.	Activity modification, stretching, ice, and NSAIDs. Surgical fasciotomy of the involved compartment(s) is the definitive treatment of refractive cases that have met appropriate diagnostic criteria. ²⁰
Tibial stress fractures	The most common (approximately 50%) stress fracture seen in runners. As with all stress fractures, results from the mismatch of bone resorption and remodeling caused by repetitive stress and inadequate time to remodel. Patients present with focal pain that increases over time and begins earlier after the onset of running than with other diagnoses, such as medial tibial stress syndrome or shin splints. Radiographs may not clearly show a fracture line in the first 2-3 wk. ¹⁷ Risk factors are being active for <8.5 yr or being female with a body mass index <21 kg/m ² . ¹⁴	Treatment of high-risk (tension-sided or anterior cortex) stress fractures can include non-weight bearing, immobilization, and possible early surgical intervention. ^{17,19}
Foot		
Plantar fasciitis	A degenerative process resulting from repetitive microtrauma of the plantar fascia origin at the heel. Patients present with posterior heel pain, worse with the first steps in the morning or walking barefoot.	Ninety percent of cases resolve with nonsurgical treatment and optional use of foot orthotics and night splints; however, the duration to symptom resolution is long, often 6-12 mo. ¹⁷
Stress fractures	High-risk (high risk of nonunion) stress fractures of the foot include fractures involving the medial malleolus, the base of the second metatarsal, the fifth metatarsal diaphysis (Jones fracture), the tarsal navicular, and the sesamoids. Lower-risk stress fractures can occur in the calcaneus, the shaft of metatarsals 2-4, or the metaphysis of the fifth metatarsal.	Most stress fractures of the foot can be treated with immobilization and non-weight bearing. High-risk stress fractures such as the Jones fracture can be treated with intramedullary screw fixation and bone grafting, resulting in return to play as early as 12 wk. ²¹
ITBS = iliotibial band syndrome		

stretching also appears to impair performance.³³ Dynamic stretching appears to enhance performance before strength and power activities, as well as speed and agility activities, but there is no evidence regarding its effect on endurance activity.³³ There is also no evidence that static or PNF stretching reduces overuse injuries.³⁴

In a systematic review and meta-analysis of randomized controlled trials, stretching had no protective effect against injury, whereas proprioception and strength training did reduce the incidence of injury.³⁵

In summary: Evidence of the benefits of stretching is mixed. It appears that static and PNF stretching may lead to performance deficits, and dynamic stretching may enhance performance in strength, power, speed, and agility activities. However, there is no evidence regarding the effect of dynamic stretching on endurance activity, such as running.

Can Minimalist or Barefoot Running Help Prevent Injury? (What Is the Effect of Shoes on Running Injuries?)

Minimalist running is a relatively recent trend. Minimalist shoes are defined as “footwear providing minimal interference with the natural movement of the foot because of its high flexibility, low heel to toe drop, and the absence of stability devices.”^{36(p.1)} Barefoot running is a subset of minimalist running. Proponents of barefoot and minimalist running suggest that because no shoes or minimal support encourages forefoot running, impact loading is reduced, the foot is strengthened, and more “natural” running mechanics are used.

Running shoes, especially those with large, padded heels, induce a rearfoot strike, producing an initial impact vertical ground reaction force that is 1.5 to 3 times body weight within the first 50 ms of stance. These sudden, high-impact forces are thought to contribute to running injuries, especially tibial stress fractures and plantar fasciitis.³⁷

Since the development of the modern running shoe in the 1970s, the incidence of stress injuries in the foot and lower limb has changed little

despite technological advances in shoe cushioning and support intended to distribute the impact associated with rearfoot running.³⁷ Running shoes with more cushioning and stiffer foot support are believed to limit proprioception and lead to weaker foot muscles and reduced arch strength, which in turn cause excessive pronation and can manifest as plantar fasciitis.³⁷ However, there has been no notable correlation of the type of nonminimalist running shoe with a decrease in injuries, suggesting that runners should choose the shoes they find most comfortable.³⁸

Runners have reported fewer foot and knee injuries after switching from traditional to minimalist running shoes.³⁹ However, there has also been an increased rate of injury at a mean of 6 weeks after making the change.⁴⁰ Barefoot running is associated with shorter step length and higher step frequency, and the obligate anterior strike pattern may explain the higher rates of Achilles tendon, calf, and posterior tibialis strains. A magnetic resonance imaging study found a notably higher risk of developing bone marrow edema in at least one metatarsal during 10 weeks of transitioning to minimalist running compared with patients who continued to use traditional running shoes⁴¹; however, no clear association with increased metatarsal stress fractures has been reported (Figure 1). In women, barefoot running is associated with less hip adduction, internal rotation, and contralateral pelvic drop, which could result in fewer knee symptoms.¹²

In summary: Minimalist and barefoot running appear to lead to fewer foot and knee injuries, but the transition between running with traditional shoes and minimalist shoes or barefoot is associated with an increased injury rate.

Am I Too Old to Run?

In 2015, the mean ages of marathoners were 36 years for women and 40 years for men. Of marathon finishers, 44% were women, and 49% were aged 40 years or older.¹ According to world-record performances, the fastest marathoners are aged 25 to 35 years.⁴² As runners age, marathon completion times increase, with a notable increase after age 70. A substantial decline in aerobic capacity occurs after age 60, making high-level training more difficult to tolerate. However, exercise is somewhat protective against age-related cardiovascular decline. In highly trained distance runners, the decline in aerobic capacity occurs at a rate of 0.5% per decade; whereas in moderately trained or untrained distance runners, the decline occurs at a rate of 1.0% to 1.5% per decade. Although skeletal muscles in middle-aged runners maintain high aerobic potential, decreases in the size of muscle cells and contractile performance still occur.⁴²

In summary: Running may slightly slow the age-related decline in cardiovascular health.

Am I Too Young to Run? (Should Children Run Long Distances?)

Junior marathon participants are defined as those younger than 18 years, and the youngest documented marathon finishers are 7 years old. The question of whether it is safe for children and adolescents to run long distances focuses on whether they are at greater risk of injury because of their immature skeleton, whether they can sufficiently modulate body temperature, and whether they have the aerobic capacity and “running economy” needed for long-distance running.⁴³

Children have a lower leg-to-trunk ratio compared with adults, which theoretically means that more impact

is absorbed over a smaller structure, although adult ratios are reached by ages 10 to 12 years.⁴³ In addition, growing cartilage is more prone to injury than is mature cartilage, and it appears that children are most at risk of injury during periods of rapid growth.^{43,44} However, there has been no documented long-term lower extremity growth arrest in young runners.⁴³

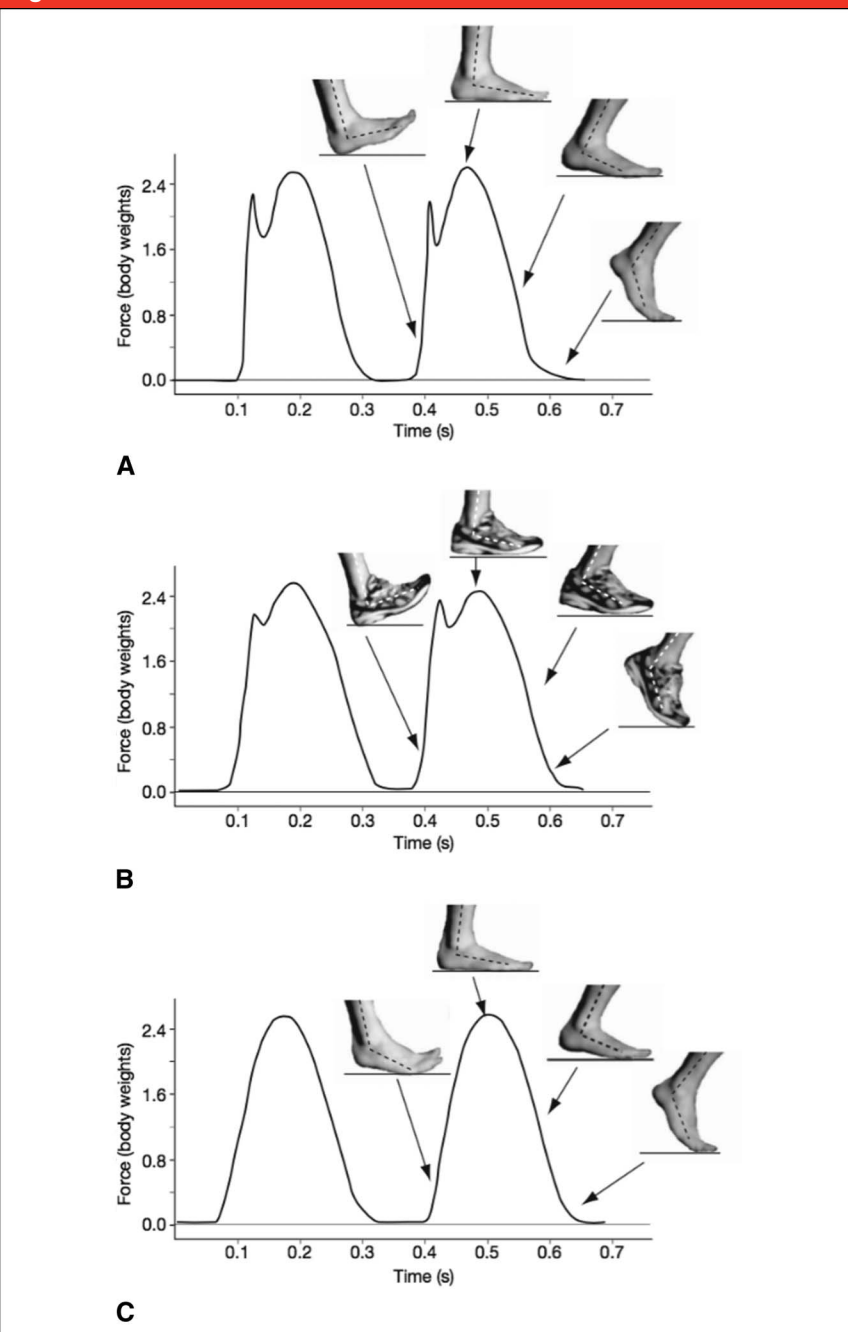
Children are at greater risk of heatstroke because of their developing sweating mechanics and smaller surface area to mass ratio; however, with proper fluid resuscitation, they do not appear to have a high risk of heatstroke during running.⁴³ It has been reported that youth who spend >16 hours a week training are at greater risk of injury, and the amount of time required to train for long-distance races can exceed this.⁴⁴ The American Academy of Pediatrics recommendations on marathon distance running for children state that “if children enjoy the activity and are asymptomatic, there is no reason to preclude them from training for and participating in such events.”^{45(p.800)}

In summary: In children who are self-motivated to run long distances, there is no evidence that suggests it is harmful if they can do so comfortably and pain free.

Is It Safe for Me to Run During Pregnancy and Postpartum?

The first woman to run the Boston Marathon was Roberta Gibb in 1966, who disguised herself in a hooded sweatshirt and men's running shoes to join the race. Historically, it was thought that women were not physiologically capable of running a marathon distance and were thus prohibited from participating.⁴⁶ In 2015, 44% of all marathon finishers and 57% of all distance race finishers were women.¹

Figure 1



Graphs showing the vertical ground reaction forces in rearfoot and forefoot strikes during barefoot or shod running.³⁷ **A**, Rearfoot strike during barefoot heel-toe running. **B**, Rearfoot strike during shod heel-toe running. **C**, Forefoot strike during barefoot toe-heel-toe running. Both rearfoot strike gaits generate a transient impact, but shoes slow the impact rate of loading and lower its magnitude. Forefoot strike generates no transient impact even in the barefoot condition. (Reproduced with permission from Lieberman DE, Venkadesan M, Werbel WA, et al: Foot strike patterns and collision forces in habitually barefoot versus shod runners. *Nature* 2010;463:531-535. Figure 1, p. 532.)

With the increased participation of women in long-distance running, questions about running during and after pregnancy are common.

The 2015 recommendations from the American College of Obstetricians and Gynecologists state that women with uncomplicated pregnancies should be encouraged to participate in aerobic and strength conditioning throughout pregnancy.⁴⁷ Women who were active before pregnancy can perform moderate to strenuous activity with minimal risk, and even those who were not active before pregnancy should begin to exercise because exercise reduces the risks of gestational diabetes and pre-eclampsia.⁴⁷

Although all pregnant women should be evaluated by an obstetrician, orthopaedic surgeons should be aware of the absolute contraindications to aerobic exercise during pregnancy, including severe heart disease, restrictive lung disease, incompetent cervix or cerclage, multiple gestation at risk of premature labor, second- or third-trimester persistent bleeding, placenta previa after 26 weeks' gestation, premature labor during current pregnancy, ruptured chorioamniotic membranes, pre-eclampsia, or severe anemia.⁴⁷

Breastfeeding runners do not have a decrease in breastmilk production, and female runners who breastfeed have a lower incidence of postpartum depression than their counterparts who do not breastfeed.⁴⁸ In a survey of competitive runners, approximately 50% returned to running approximately 4 weeks after childbirth (a period during which physiologic effects of pregnancy persist), and most resumed running within 2 months.⁴⁸

In summary: Running during and after pregnancy is safe for women with uncomplicated pregnancies, and physical activity should be encouraged.

Is Running Recommended After Orthopaedic Surgery?

After injury requiring surgery at the knee, anatomy and running biomechanics are altered.⁴⁹ A systematic review of randomized controlled trials found that after anterior cruciate ligament (ACL) surgery, 39% of studies permitted running in a straight line 3 months after ACL reconstruction, and 51% of studies allowed return to all sports without restriction at 6 months.⁵⁰ Of note, it is the authors' preference not to release athletes back to sport this early after ACL reconstruction, and in fact, strength deficits in the surgical and nonsurgical leg have been shown to persist up to 5 years after surgery.⁵¹ Van Ginckel et al⁵² found that knee cartilage quality was diminished at 6 months after ACL reconstruction; therefore, many patients who return to running after surgery do so with an abnormal knee biologic milieu. Willy et al⁵³ found that runners who underwent partial meniscectomy ran with a reduced knee extensor moment because of altered lower extremity support moments; however, the tibiofemoral joint contact forces were no different than those in healthy matched controls.

There are known high rates of OA in patients who have undergone partial meniscectomy or ACL reconstruction. Longer term studies are needed to clarify the risks associated with high-impact activity (eg, running) in knees with altered anatomy.^{53,54} Keays et al⁵⁴ found that the type and level of sport that patients played after undergoing ACL reconstruction, including whether they ran, were not predictive of the amount of OA patients developed, but that factors pertaining to the initial injury (chondral damage and need for meniscectomy) were predictive.

High-impact activities such as running, while physically possible, are generally not recommended after total

hip or knee arthroplasty because of the increased risks of component wear, loosening, and failure of the prosthesis.^{55,56} Previous musculoskeletal injury and subsequent repair can result in altered kinematics, as is the example of Achilles tendon rupture repair. In these patients, recommendations have been made to avoid activities that put them at risk of knee injury because they may be more prone to such injuries.⁵⁷ After some orthopaedic procedures, such as hip arthroscopy with labral repair, patients have a very high success rate at returning to running.⁵⁸

In summary: Patients with a history of partial meniscectomy or ACL reconstruction no longer have "normal" knees and are at higher risk of developing OA regardless of whether they choose to run. Surgical treatment of other orthopaedic injuries can alter gait mechanics, which can lead to more running injuries. After some procedures, such as hip arthroscopy, patients can reliably return to running.

Summary

Running has become a beloved pastime for many Americans but can also be a source of musculoskeletal injuries. This review gives orthopaedic surgeons, who are often asked for advice regarding running and running injuries, a comprehensive overview of the sport and answers to common running-related orthopaedic questions.

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