Rehabilitation and Return to Running After Lower Limb Stress Fractures

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Abstract
Lower limb stress fractures are common injuries in runners. In terms of treatment, much of the medical literature has focused primarily on rest and cessation of running, but little has been written about the rehabilitation and functional progression of runners following a lower limb stress fracture. This article reviews the scientific evidence behind common rehabilitation concepts used for runners recovering from these injuries and also discusses sport-specific training modalities such as deep water running and antigravity treadmill training. Overall this article is intended to be a practical resource for clinicians to guide runners in functional rehabilitation and return to running following lower limb stress injury.

Introduction

Lower limb stress fractures account for 80% to 90% of all stress fractures (14) and are common in runners (44). Much of the medical literature on this topic has reported on the etiology, risk factors, and diagnosis of these injuries (28,45). Treatment has been focused on rest and cessation of running, but little has been written about the rehabilitation and functional progression of runners following a lower limb stress fracture. This article is intended to be a practical resource for use by clinicians when advising their patients on functional rehabilitation and return to running after sustaining a stress fracture. We will present the scientific basis for basic rehabilitation concepts used for runners recovering from a stress fracture as well as practical approaches to sport-specific cross-training and return to running.

General Rehabilitation Training for the Runner

Fredericson *et al.* (17) has described a two-phase protocol for rehabilitation of the runner with a lower limb stress fracture. The first phase focuses primarily on rest and pain control. During this period, runners may consider maintaining aerobic fitness through cross-training activities that include cycling and swimming. Additionally, patients may be reintroduced to running with the use of training modalities that off-load the lower limbs such as deep water running (DWR) and antigravity treadmill training (ATT). The second phase focuses on a progressive return to running. As a general rule, runners who have experienced a lower limb stress fracture should be consistently pain free, with ambulation and cross-training for approximately 2 wk before returning to a significant land-based running program (28). See Tables 1 and 2 for a summary highlighting the duration of protected weight bearing and timing of the earliest return to running for the most common lower limb stress fractures. Resumption of running begins not more than half the usual distance and at a slower pace and then gradually increases in distance, duration, and intensity. The intensity (or pace) should be increased only after the runner has allowed enough time to acclimate back to the typical distance and duration of runs. This progression is coupled with a comprehensive rehabilitation program that includes lower limb strengthening, stretching, balance and proprioceptive training, and core and lumbopelvic strengthening with the primary purpose of improving any biomechanical factors that may have contributed to the initial injury.

Resistance Training

Resistance exercises of the lower limb and hip girdle are incorporated often into the rehabilitation of runners with stress fracture. The goals of this training include the development of strength and improvement in bone mineral density (BMD). Much of the evidence for strength training derives from studies demonstrating greater weakness and decreased muscle girth in injured runners compared with noninjured controls (4,33). In a study by Schnackenburg *et al.* (57), female runners with a lower limb stress fracture were found to have significantly lower knee extension torques than their non-stress fracture counterparts. Reduced quadriceps strength may cause some runners to adopt a more extended knee joint position at heel strike. This increased knee stiffness can lead to higher tibial compressive forces

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Table 1.
High-risk stress fractures: initial treatment.

High-Risk Stress Fracture	Initial Treatment (if Stable and Nondisplaced)
Femoral neck (compression side)[a]	NWB × 4 to 6 wk, then PWB→FWB over the next 4 to 6 wk
Anterior tibia	NWB × 6 to 8 wk
Medial malleolus	Pneumatic ankle/leg brace × 6 to 8 wk
Navicular (type 1)[a]	NWB cast × 6 wk
Base of fifth metatarsal (zones 2 and 3)	NWB cast × 6 to 8 wk
Sesamoid	NWB cast × 6 wk

These fractures have a propensity for delayed healing and nonunion; therefore, surgical fixation is not uncommon. Those fractures that appear stable and nondisplaced can be treated cautiously nonoperatively. This table presents general guidelines. However remember that there is significant variability in how quickly a runner can begin cross-training and return to running; thus, evaluating both radiographic and clinical signs of healing before progressing the runner to a higher level of activity is appropriate (17,21,27,28,45,58).

[a] Tension side femoral neck and navicular type 2 and 3 stress fractures are generally treated with urgent surgical intervention.

NWB, non-weight bearing; PWB, partial weight bearing; FWB, full weight bearing.

resulting in greater risk for tibial stress fracture. In a study of 136 military recruits, those with knee extension strength less than 1 SD below the population mean, measured by a 1 repetition maximum leg press, had 5 times greater risk for stress fracture development (33).

In addition to strength gains, a number of studies have shown that resistance training can improve BMD and bone strength (64). Although many of these studies have been focused on postmenopausal women, gains have been seen in younger, otherwise healthy individuals. A recent study demonstrated that after a 24-wk resistance training program, young men between the age of 18 and 23 yr were able to increase their BMD by 2.7% to 7.7% (1). A similar study of young healthy women (age 19.9 ± 0.7 years) showed that after 8 months of resistance training, BMD increased on average by 1.2% in the lumbar spine, which was statistically significant when compared with control participants who did not participate in resistance training (59).

Additionally resistance training has been shown to improve factors associated with running performance. Specifically some studies have demonstrated improved running economy, which is how efficiently a runner utilizes oxygen at a given running velocity (39). Johnston *et al.* (38) compared a 10-wk training program that included resistance training 3 times per week with endurance training versus endurance training alone in 12 female cross-country runners and found that running economy was improved by 4% in the resistance-trained group but unchanged in the solely endurance-trained group.

Muscular Endurance Training

One of the major functions of muscle is to absorb impact forces during running (13,23). Fatigued muscles are thought to be less able to absorb force, and thus, they transmit higher forces to adjacent bone (17,28). Local muscle fatigue has been associated with higher vertical ground reaction forces during the stance phase of running. In a study by Christina *et al.* (8), 11 female runners underwent fatiguing exercises of the ankle dorsiflexors and inverters prior to treadmill running (TMR). They found that the loading rate of impact peak force was higher in postfatigue runs compared to prefatigue runs. As such, building muscle endurance is an essential component of rehabilitation after lower leg stress injury. In general, high-repetition, low-resistance exercises build endurance. For muscular endurance training, the American College of Sports Medicine recommends whole body training two to three times per week (53). Loading intensity varies depending on the skill level of the athletes, with

Table 2.
Low-risk stress fractures: initial treatment and return to running.

Low-Risk Stress Fracture	Initial Treatment	Earliest Return to Land Running (General Guidelines)
Sacrum/pelvis	WBAT	7 to 12 wk
Femoral shaft	WBAT	6 to 8 wk
Posteromedial tibia	WBAT, pneumatic tibial brace if painful with ADLs	Minor injury: days→3 wk
		Severe injury (cortical break): 8 to 12 wk
Fibula	WBAT	2 to 4 wk
Metatarsal	Stiff soled shoe or walking boot	4 to 6 wk

When functionally progressing runners with these low-risk stress fractures, all activity should be titrated to a pain-free level. Reducing but not necessarily totally eliminating weight bearing is reasonable for these fractures in order to facilitate the healing process by mechanically stimulating the bone with progressive stress (17,27,28,35,42,45,68).

novice athletes performing light loads for 10 to 15 repetitions, while advanced athletes train with various loads for 10 to 25 repetitions.

Core and Pelvic Girdle Stability

It has been well documented that core stability plays a central role in athletic function (40). This is particularly true in running, which should be considered a sport of balance, given a runner is balancing repetitively on one leg when in contact with the ground. Strength and neuromuscular control of the proximal segments of the kinetic chain, including the abdominal core and pelvic girdle, provide coordination and efficient movement of the lower limbs, improving the ability to absorb forces (18). Studies have shown that core muscles such as the transversus abdominis and internal oblique activate prior to limb movement (32), suggesting the importance of core stability in limb control. At the pelvic girdle, regaining strength and neuromuscular control of the hip abductors and gluteals in general, as well hip external rotators, is emphasized, as weakness in these muscles can lead to poor femoral control and increased thigh adduction and internal rotation, resulting in an increased valgus moment at the knee and further stress down the distal kinetic chain (34, 49). This has been associated with a number of overuse injuries, including patellofemoral pain and iliotibial band syndrome (9,20,34,43). Strengthening of these muscles has demonstrated improvement in these common running conditions (16). Regarding stress fractures, Pohl *et al.* (51) studied various kinematic and kinetic factors in 30 female runners with a history of tibial stress fracture versus 30 controls and found that excessive hip adduction during the running gait was a predictor of tibial stress fracture. Therefore eccentrically controlling the rate and amount of hip adduction with neuromuscular control and strength of the hip girdle musculature (gluteals) should be a goal in rehabilitating a runner with a lower limb stress fracture.

Balance and Proprioception Training

Neuromuscular training, which involves proprioception, balance, and muscle control, is an essential component of the rehabilitation following musculoskeletal lower limb injury, including stress fracture. Proprioceptive input from muscles, tendons, and joints provide the central nervous system with information to coordinate the complex kinetic chain of muscle activity and joint motion involved in running. This is particularly important to the cross-country or trail runner who will need to adjust to changes in terrain and running surface (18). Balance and proprioceptive training can begin with simple exercises such as standing on one leg. The addition of a rocker board or other unstable surface can progress the runner to more challenging exercises.

Flexibility Training

Flexibility training is aimed at addressing limitations in range of motion and muscle and tendon extensibility that may otherwise impart greater stress to adjacent bones. In running, sagittal plane motion, including hip flexion, knee flexion, ankle dorsiflexion, and subtalar pronation, at initial contact not only keeps the center of mass low but also helps to dissipate forces (13). Range of motion restrictions in any of these muscles can limit the lower limb's ability to accommodate ground reaction forces. Postural muscles such as the gastroc-soleus complex (mainly the soleus), when tight and shortened, can lead to increased traction on the tibial cortex, which can result in medial tibial stress syndrome (18). If repetitive traction persists, a stress fracture may develop subsequently.

Gait Retraining

A recent meta-analysis demonstrated an association of stress fractures with an increased lower limb loading rate but not with an increased ground reaction force (69). Retraining a runner's gait to reduce lower limb loading forces and loading rates has shown promise. Studies have shown that subjects can change their running gait to lessen vertical force impact peaks and vertical force loading rates, and that these gait changes can be maintained at 1 month (11,12). However, the ultimate goal of reducing tibial stress fracture incidence with running gait retraining has not been proven yet.

Cross-Training Techniques

Endurance-trained athletes can experience a 7% decline in their $\dot{V}O_{2max}$ within 2 to 3 wk of cessation of training (10). The goal of cross-training is to maintain cardiovascular fitness during the rest and rehabilitation phases of the treatment program for an injured runner. Common forms of cross-training include swimming, cycling, and use of an elliptical machine. Some studies suggest that incorporating cross-training early in the rehabilitation process even may return athletes to running sooner (42,56,62). In a case report by Knobloch *et al.* (42), a long-distance running female athlete with a sacral stress fracture underwent a rehabilitation program after 2 wk of rest that initially included 60 to 90 min of daily cycling and additional 2 60-min sessions of Nordic pole walking per week. After 2 wk of initial rehabilitation, Nordic pole walking occurred daily for 60 to 90 min, and strength training was incorporated. Running began 7 wk after the onset of pain. In prior studies of sacral stress fractures, it had been reported that the average time to becoming pain free was 6.6 months (36). This report suggested that incorporation of cross-training activities early in the rehabilitation process may have led to an earlier recovery and certainly helped the athlete maintain a certain level of cardiovascular and neuromuscular fitness that may not have been possible without this earlier, and potentially more aggressive, cross-training program.

Interestingly a retrospective study of elite collegiate distance runners by Fredericson *et al.* (19) demonstrated that a prior history of playing ball sports (basketball and soccer) correlated with a nearly half reduced stress fracture incidence later in life. The authors postulated that playing ball sports may load bone more symmetrically and thus distribute bone mass more evenly. The implication of this study is that perhaps incorporating exercises similar to ball sports in the rehabilitation of runners with lower limb stress fracture may be protective.

Although cross-training activities maintain cardiovascular fitness, many are not specific to running. The theory of sport specificity implies that each sport requires certain neuromuscular and metabolic adaptations; and running is no different. Running requires training of muscle groups in a specific coordinated pattern of actions, speed of movement, range of motion and aerobic utilization. As will be presented, DWR and ATT are cross-training methods that address these issues.

Cross-training can be initiated during phase 1 of rehabilitation while the patient is resting from the load bearing of running. As the athlete returns to running, it can be used to replace running on days where rest from aggressive loading/weight bearing is indicated.

Deep Water Running

DWR is a form of cross-training that addresses runner sport specificity and can be an effective form of training for runners following lower limb stress fracture. DWR allows the runner to simulate the mechanics of running, achieves similar metabolic response to on-land running, and has been shown to maintain on-land performance. Several properties of water allow it to be an ideal training setting for the injured runner. Buoyancy decreases the weight of the submerged body placing less pressure on bones and soft tissue structures. Hydrostatic pressure has been postulated to aid in cardiovascular function by promoting venous return (66,67). Drag forces provide resistance needed for cardiovascular and neuromuscular training without placing undue stress on the lower limbs.

Studies have demonstrated that lower, but similar, levels of maximal aerobic performance to on-land running can be achieved with DWR (7,61,63,65). Wilbur *et al.* (65) compared cardiorespiratory performance measures ($\dot{V}O_{2max}$, ventilatory threshold, running economy) between male runners who were assigned to a 6-wk training program of either DWR or TMR and observed no significant difference between the two groups. Town and Bradley (63) found that DWR-trained varsity cross-country runners reached $\dot{V}O_{2max}$ and maximum heart rate values 73% and 86% of TMR, respectively, when asked to perform exercise to volitional exhaustion. The reduction in these cardiorespiratory physiologic parameters found in DWR compared to TMR is not as pronounced in those with previous running experience (and possibly better mechanics) and is still adequate for training and cardiorespiratory fitness. The decrement in $\dot{V}O_{2max}$ is related likely primarily to the muscle recruitment pattern difference between the two training options. (DWR uses the smaller muscle mass of the upper body and does not use the large calf musculature as much as in TMR since there is no push off.) Heart rate in DWR is reduced generally due to the water temperature. In cooler water, HR is as much as 15% less than land-based running at the same intensity; however, in warmer water, HR is almost equivalent. However even with a reduced training HR, the aerobic benefit still occurs (and at a lower HR) (Table 3).

What is potentially even more important to your running athlete patient is that DWR training programs have demonstrated efficacy in maintenance of running performance on land. In one study, 2-mile run times remained similar after 6 wk of DWR training (without any land-based running) compared to 6 wk of regular land-based training (15). A similar study revealed that 4 wk of only DWR can maintain 5-km race performance on land (6). In other studies of 4 to 8 wk of DWR training programs, runners maintained $\dot{V}O_{2max}$, anaerobic threshold, land running economy, and leg strength (24,30,65).

The practicalities of DWR are described in detail by Wilder (66) but are reviewed briefly here.

To properly perform DWR, the water level should be at the shoulder with the body in a slightly forward position. Arm motion is identical to that on land, with primary motion at the shoulder. No contact is made with the bottom of the pool. The ideal pool temperature for easier sessions of DWR (and other forms of water exercise) is 84°F to 91°F (29°C to 33°C), as Nakanishi *et al.* (46) determined this to be the temperature range for water thermoneutrality during exercise. However for submaximal exercise intensities, this thermoneutral temperature is lowered to 79°F to 84°F (26°C to 28°C), which is a temperature range most pools are kept (3). Wearing a flotation device allows for a more natural run form and should be encouraged to help the runner adhere to proper technique. This allows more sport specificity mimicking more typical muscle recruitment patterns. However it should be noted that wearing a flotation device reduces $\dot{V}O_{2max}$ by 16% and training HR by 15%, but it still allows for a training effect (25).

Comparing the kinematics of DWR with land running demonstrates a significantly greater amount (50% to 87%) of hip flexion achieved in DWR (41). This finding is of uncertain clinical significance but may mean DWR can increase stress across the hip and potentially lead to injury. Thus, as in any new form of training, the novice should gradually acclimate to DWR training by introducing it slowly to allow acclimatization to the different neuromuscular recruitment patterns, particularly in those runners with hip injuries (hip and pelvic stress fractures).

The intensity of a DWR program can be guided by percentage of maximum HR, rating of perceived exertion, and cadence. One of the more specific exertion scales to DWR is the Brennan perceived exertion scale, which spans from 1 (very light) to 5 (very hard). A level 3 would correspond to the effort needed to run a 5- or 10-km road race (66). If the runner uses cadence as a measure, it is important to note that due to water viscosity, stride frequency is reduced in DWR by 30% to 40%.

When training a runner in a DWR program, it is important to realize that perceived exertion is higher during DWR for a given heart rate or level of oxygen consumption (61). Due to the higher perceived exertion and the lower heart rate while water running, a high percentage of DWR workouts should be at a harder effort than would be if training on land. If doing only steady effort water running sessions, the effort would not be high enough to maintain fitness (50). Thus, in order to maintain fitness during water running, it is necessary to include intervals, tempo, and/or fartlek training (52).

Given the sport specificity and its ability to maintain running fitness, DWR is used commonly by coaches at the first sign of injury as a preventive measure as well as to maintain

Table 3.
Differences in physiologic parameters (nine studies) (54).

	Treadmill	DWR
$\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1})	53.1 to 67.0	46.8 to 58.4
Maximum HR (bpm)	183 to 198	157 to 180

#1: 5 min easy warm-up, 5 x 2:30 hard/30 sec recovery, 1 min easy, 5 x 45 sec hard/15 sec recovery, 2 min easy, 5 x 2:30 hard/30 sec recovery, 5 min cool-down,

#2: 5 min easy warm-up, (2X) 10 X 30 sec max/30 sec recovery, 1 min easy, 10 x 60 sec max/30 sec recovery, 5 min cool-down,

#3: 5 min easy warm-up, 4 x 3 min hard/30 sec recovery, 1 min easy, 5 x 90 sec max/30 sec recovery, 1 min easy, 4 x 30 sec hard/30 sec recovery, 5 min cool-down.

The workouts progress throughout the following weeks while also introducing antigravity treadmill training with the goal of gradually transitioning to ground running.

Figure 1: Sample DWR workouts.

fitness while recovering from injury. A sample program may be 6 to 8 wk in length, utilizing DWR 4 to 6 times a week intermixed with ATT (see the next section). The program can be shortened or extended as needed. DWR workouts are generally between 45 and 90 min and include a short warm-up and cool-down. Effort is determined most commonly by perceived exertion. Sample workouts are shown in Figure 1. These workouts emphasize hard efforts with short rest to allow for some, but not full, recovery.

In addition, DWR can be used for training the uninjured high-mileage runner who wishes to maintain higher weekly mileage by using DWR on recovery days as a supplemental training tool.

Antigravity Treadmill Training

ATT is an emerging technique for the rehabilitation of runners with lower limb injury. Antigravity treadmills were first designed by National Aeronautics and Space Administration to help implement exercise programs for astronauts. Connected to the treadmill is an air-filled pressure-controlled chamber that surrounds the lower half of the body from the waist down, unweighting from 100% of body weight (BW) down to 20% of BW in 1% increments (Fig. 2). According to a major manufacturer of these treadmills (Alter-G Inc., Fremont, CA), ATT has been used to rehabilitate a number of conditions including stroke, Parkinson's disease, osteoarthritis, and lower limb injuries (2). Saxena and Granot (56) compared the use of ATT versus traditional rehabilitation in 16 patients who underwent surgery of Achilles tendon rupture and insertional repair. They found that the 8 patients in the ATT group returned to ground running 2 wk earlier than the control group after running at 85% of one's normal BW, but they noted that the difference between the two groups was not statistically significant.

Unfortunately there have been no studies comparing the use of this device to conventional rehabilitation programs for lower limb stress fractures. However Tenforde *et al.* (62) reported on the successful application of ATT for returning a collegiate runner with pelvic stress fracture to high-level competition just after 10 wk of initial diagnosis.

The downside to running with weight support is that it can be less metabolically demanding. However Grabowski and Kram (26) found that certain velocity and BW support combinations may decrease peak ground reaction force (PGRF) but still provide similar aerobic training as normal weight running, thus protecting the athlete from stress to lower limbs during rehabilitation and potentially provide the same level of training. For example, based on their study, if a person normally runs at 3 $m \cdot s^{-1}$ with no BW support, they could run at 5 $m \cdot s^{-1}$ with 43% BW and achieve equal metabolic demand but decrease their active PGRF by 32%.

There have been few published protocols of ATT for lower limb stress fractures. For a runner using ATT to return to ground running, a sample program would begin by determining what percentage of BW was acceptable. Typically the starting point is between 50% and 65% BW. The athlete remains at that predetermined BW percentage for a minimum of 1 wk. Increases can occur from 5% to 10% BW weekly. Many of the typical land-based training runs can be transferred to the antigravity treadmill, which is a difference contrasted with DWR training programs, which should typically have workouts at a harder effort than on land training. Long runs, fartleks, intervals, tempo, and recovery runs can all be done with ATT, provided that the proper BW percentage is used. It is important to stress that the runner should have no pain either during or following use of the antigravity treadmill. Once the runner reaches 85% to 90% BW, ground running can be introduced slowly by adding up to 10 to 20 min every other day.

As noted, the intensity of an ATT program is guided by unweighting. Ideally percentage of BW would be adjusted

Figure 2: Antigravity treadmill.

so that there is no pain during or after an exercise session. ATT allows the athlete to continue training during rehabilitation and gives both the athlete and coach/trainer the ability to control these sessions. It also may provide the opportunity for increased volume over more traditional forms of cross-training. ATT can be used also for training the uninjured high-mileage runner who is limited by risk of training volume.

As mentioned previously, there have been no studies comparing the use of ATT to other conventional rehabilitation programs. However famed running coach Alberto Salazar has used ATT successfully with his elite Oregon Project Team in Eugene, OR, which, in turn, has trickled down to the running masses with ATT being used in physical therapy and sports medicine clinics as well as training and performance centers nationwide.

Return to Running Programs

Several return to running programs have been proposed for lower limb stress fracture (17,27,43). Each emphasizes starting at a level that is between one third and one half of the runner's normal distance and pace. Rest days are incorporated into this progression, alternating between days of running. Most programs recommend following the 10% rule, which is to limit increases in weekly mileage by no more than 10%. Although this rule is well known among runners, there is only level 3 evidence to support this advice (27,37). In fact, a study by Buist *et al.* (5) demonstrated no difference in injury rate between a group of novice runners who trained for a 4-mile running event under a 13-wk training protocol that followed the 10% rule versus runners who underwent a more aggressive ramp-up during an 8-wk training schedule.

Harrast and Colonno (28) have published a return to running program as shown in Figure 3. This program, along with most previously published programs, is designed for the non-elite runner who does not have access to alternate training modalities such as ATT, hence the more gradual ramp-up in time/distance. As noted in the prior section, with ATT, the transition to land running typically can ramp-up more quickly since the runner already has been acclimating to lower limb loading with partially weighted running. The initial attempt at land running should not occur until the runner has reached approximately 85% to 90% BW with ATT.

Other training considerations and modalities

An important element to any injured runner's rehabilitation program is to address and treat any other intrinsic and extrinsic factors that may have predisposed them to injury. For example, in women with lower limb stress fractures, it is essential to evaluate for the presence of any components of the "female athlete triad" including low BMD, menstrual irregularities, and energy deficiency and or disordered eating (31). If there is a history of stress fracture or the fracture is of cancellous bone, a BMD assessment is indicated. If low bone density is found, appropriate treatment of the source (energy balance and nutritional issues or metabolic bone disease) is mandatory (47). Condition of training equipment also should be evaluated. It has been reported that training in shoes older than 6 months is a risk factor for stress fracture (22). This is related likely to the decreased shock absorption capability of the shoe as it ages. A general rule of thumb that many coaches and trainers suggest is changing running shoes every 300 to 500 miles logged to limit excessive risk for lower limb overuse injuries (28).

Electrical stimulation and ultrasound have been described as modalities to assist with fracture healing. Using electrical stimulation for bone growth has some support in delayed unions and nonunions but only minimal support from uncontrolled trials in the treatment of stress fractures (55). Therapeutic ultrasound has been demonstrated to decrease healing time in acute tibial shaft and distal radius fractures but not necessarily in stress fractures (29). Bisphosphonates are used commonly in the treatment of postmenopausal osteoporosis but are not common in the treatment of stress fractures. However there is one report of intravenous pamidronate used to assist five female collegiate basketball players with tibial fatigue fractures in returning to play more quickly (60).

Conclusion

Returning an injured runner to land-based training is a combination of art and science, though there is an increasing scientific knowledge base to make some evidence-based recommendations. After the initial diagnosis of a stress fracture, a search for medical, biomechanical, and training program causes for the injury should ensue with the goal of educating the runner on factors contributing to the injury as well as correcting what is possible, from a medical, biomechanical, or training program standpoint. While rehabilitation progresses to correct the potential biomechanical sources predisposing to injury, sport-specific cross-training is necessary to maintain cardiorespiratory fitness and idealize the transition back to land running when appropriate.

Two sport-specific cross-training methods for injured runners include deep water run training and ATT. They are useful tools for any clinician who treats runners. In addition to the greater specificity of exercise, they allow for reduced stress on injured tissue and joints, allow maintenance of cardiorespiratory fitness, have a training effect, and potentially can decrease injury risk from overtraining. Both

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Week 1	5 min	b	10 min	b	15 min	b	b
Week 2	15 min	b	20 min	b	25 min	b	b
Week 3	25 min	30 min	b	30 min	35 min	40 min	b
Week 4	45 min	c	--	--	--	--	--

a. Runs should occur on softer surfaces during the initial return-to-run phase
b. Non-impact activity on off days, which can be the same form of cross-training that the athlete was performing before resume land running
c. Gradual increase in distance and intensity depending on the runner's goals over weeks 4-6

Figure 3: Return to running training program (28).

DWR and ATT thus can be helpful for the rehabilitating injured runner who needs rest from land-based running to heal, as well as the high-mileage runner who is looking for a supplemental training modality with less risk of overuse injury.

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