Post-Exercise Recovery Strategies for Firefighters:
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Firefighting is a physically demanding profession. Thus, firefighters must achieve and maintain adequate physical fitness levels. Performing regular exercise is critical to achieving sufficient physical fitness levels. Firefighters are often encouraged or required to exercise on-and off-duty. Although there are numerous benefits for firefighters that exercise on- and/or off-duty, firefighters must be aware of the potential acute decrements in performance associated with this exercise, as research has indicated that intense exercise can acutely decrease fireground performance (12). Therefore, firefighters should utilize effective recovery strategies to minimize residual fatigue, muscle damage, and soreness. The purpose of this article is to identify and describe methods to improve post-exercise recovery to enhance firefighter preparedness. Furthermore, commonly used, but ineffective methods will be discussed. For the purposes of this article, recovery strategies are stratified into those used immediately after exercise versus strategies used hours or days after exercise.

Immediate Post-Exercise Recovery Strategies—Nutritional Intake
Proper nutritional intake prior to, during, and following exercise is critical to enhance recovery from intense exercise that causes glycogen depletion. Firefighters who exercise regularly should consume about 55 - 70% of daily calories from carbohydrates (15). Prior to exercise, firefighters should consume a small meal, composed of familiar foods with very little fiber to aid in digestion, and consume foods with a low glycemic...
Should Tactical Athletes Run Barefoot?

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All of the military services incorporate a distance run as a component of their physical fitness test (PFT). Because the distance run constitutes 25 – 60% of the total PFT score, interest in optimizing distance run performance is high. One of the downsides of this emphasis is a high rate of running-related injuries (RRIs). Though the primary reason for RRIs appears to be overuse related to excessive frequency/duration of distance run training, it has been argued that running form may also be a contributing factor (20,30,32,39).

Though research into barefoot running has been ongoing for a number of years, interest in barefoot running exploded with the 2009 publication of the popular book, “Born to Run,” by Christopher McDougall (34). The central themes of the book are that humans evolved to be long-distance runners, modern running shoes are a primary cause of RRIs, and barefoot running can both improve running efficiency and prevent RRIs. It has been hypothesized that evolution of a bipedal stance in humans is linked to several anatomical/physiological adaptations for running (31). Though interesting, this hypothesis is not directly testable, and alternative scenarios for the evolution of human bipedalism have been proposed (7). One anatomical feature which has been inferred to be related to running in humans is the gluteus maximus. This muscle is much hypertrophied in humans compared to apes, and it has been suggested this increase in size is an adaptation to running (31). An analysis of gluteus maximus activity patterns using electromyography shows the gluteus maximus is just as active during walking as running, and is also highly active during acceleration, stair/incline climbing, throwing, digging, and lifting (48). Humans are very economical walkers, but running economy is not exceptional in comparison to other mammals (6). The human foot, in particular, seems better adapted to walking than running, so perhaps humans evolved to be “born to walk” rather than “born to run” (11).

Barefoot running is characterized by several biomechanical features which distinguish it from shod running (technical term for running with shoes), though there is some overlap. Typically, barefoot runners exhibit shorter stride length (SL), and greater stride frequency (SF), than shod runners. In addition, barefoot runners usually (but not always) strike the ground with a midfoot/forefoot strike, whereas shod runners usually display a rearfoot strike. As a result, the impact peak typical of rearfoot strike runners is absent from barefoot runners who also have reduced knee flexion, knee adduction, and hip external rotation moments compared to shod runners (1,31,32).

Two hypothesized benefits of barefoot running over shod running have been suggested. The first is that barefoot running is more economical than shod running. The primary determinates of the cost of transport (COT), established from over 20 years of work, primarily in animal models, are the metabolic cost of generating muscular force to support bodyweight, and the rate at which that force is applied (8,14,29). For example, a mouse has a much higher COT than a pony, because mice must generate much larger muscle forces, with a much higher SF. The higher SF results in more rapid activation of muscle fibers, which require higher rates of actin-myosin cross-bridge cycling and recruitment of more fast-twitch muscle fibers with greater usage of adenosine triphosphate (29). Interestingly, ground contact time (the amount of time the foot is in contact with the ground or GCT) correlates very well with COT (9). Several anatomical features which appear to influence COT to a lesser extent include calcaneus length, flexibility, and tendon length (37,45). Training techniques which appear to improve COT include strength training, plyometric training, high-altitude training, and high-intensity interval training (5,15,28,42).

Six out of eight previous studies which compared the COT of barefoot running to shod running concluded there is no significant difference when the mass of the shoe is controlled for (22). An additional study attached small lead strips to the foot/shoe of barefoot and shod runners which varied in mass from 150 – 450 g, and measured the VO2 for both groups (22). These authors concluded that “running barefoot offers no metabolic advantage over running in lightweight, cushioned shoes,” (22).

It has been hypothesized the midfoot/forefoot strike characteristic of barefoot running is more economical than shod run-
ning due to increased elastic energy storage in the longitudinal arch of the foot (32). However, studies which have investigated the effect of strike type on COT have consistently found no differences in running economy relative to strike patterns. One study concluded that barefoot running is slightly (2.41 – 3.32%) more economical than shoe running (36). This study controlled for SF which is likely inappropriate, considering that a higher SF is an intrinsic feature of barefoot running. As noted previously, there is a strong correlation between GTT and COT, so the higher SF characteristic of barefoot running will, if anything, modestly increase the COT (9).

Recent evidence suggests there may be a “cost of cushioning” associated with barefoot running (22). Because there is no shoe cushioning, the foot muscles must be recruited to cushion ground impact, which may increase COT. One recent study utilizing experienced barefoot runners compared the COT of barefoot runners, running in lightweight cushioned shoes, and running on both a rigid treadmill, and a treadmill which had been covered with 10 mm and 20 mm foam padding of the same type used in the cushioned shoes. The COT of the barefoot runners and shoe runners on the rigid treadmill was not significantly different. The COT for the barefoot runners on the foam-coated treadmill was 1.91% less than on the rigid treadmill (46). The authors concluded, “Thus, it appears that the positive effects of shoe cushioning counteract the negative effects of added mass, resulting in a metabolic cost for shoe running approximately equal to that of barefoot running.” In addition, other types of shoe interventions appear to reduce COT (38).

Prevention of running injuries is the second possible benefit of barefoot running. Injury rates in runners are high. One review concluded that 19 – 79% of runners are injured annually (47). Because injuries have significant negative effects on military readiness, reducing RRI would benefit tactical operations (39). Biomechanics of various components of barefoot running have been hypothesized to reduce RRL. Runners wearing shoes typically use a rearfoot strike, and produce a large impact peak on contact. This impact peak is usually reduced/absent in barefoot running (1,32). The higher SF seen in barefoot running has been found to reduce loading rates at the hip and knee joints, which may reduce RRI risk. (27). A rearfoot strike pattern is also associated with an increased risk of developing anterior compartment syndrome of the lower leg (1). Some recent research suggests alteration of footstrike patterns may positively affect injury risk. One study of Army personnel examined ten rearfoot strike subjects who were diagnosed with chronic exertional compartment syndrome. After six weeks of training to adopt a forefoot strike, compartment pressures and pain while running significantly decreased, while running distance significantly increased (17). Two-mile run times were also significantly faster. Another study retrospectively looked at footstrike patterns and injury rates in 52 middle/long-distance runners from a collegiate cross-country team. Approximately 69% used a rearfoot strike pattern, while approximately 31% used a forefoot strike pattern. Those runners who primarily exhibited a rearfoot strike pattern had significantly higher rates of repetitive stress injuries than those subjects who primarily exhibited a forefoot strike pattern (13). A caveat to this study is that out of 23 individual injury types discussed, only two (hip pain and repetitive joint strain) were significantly higher in rearfoot strike runners compared to forefoot strike runners.

There is also evidence that barefoot running may increase the risk of certain RRLs. Recent research indicates tibial strain rate/stresses may be higher in runners who utilize forefoot striking versus rearfoot striking (2,16). Overall loading of the metatarsals may be greater in subjects who use a midfoot strike relative to a rearfoot strike, and relative to SR, barefoot running shifts mechanical stress away from the knees and to the ankles (4,26). Two recent reports have found associations between minimalist footgear which encourages a midfoot/forefoot strike pattern, and incidences of metatarsal stress fractures, calcaneal stress fractures, and ruptures of the plantar fascia (23,41). In addition, Achilles tendon forces are greater during running with a forefoot strike pattern compared to a rearfoot strike pattern, possibly increasing the risk of Achilles RRLs (25).

In military populations, the primary cause of RRLs appears to be related to an overemphasis on distance run training (39). Several papers have presented evidence on how fatigue from excessive distance running may predispose individuals to RRLs. Fatigue may alter running kinematics toward patterns which increase the risk of RRLs (10,18). In addition, muscle fatigue results in increased forefoot loading under the metatarsals and increased tibial tension strains (10,49). One study found periodized strength training significantly attenuated kinematic changes typical of fatigue in long-distance runners, suggesting that strength training may be a useful intervention to prevent RRLs (19). Another study using Australian Army recruits documented significant reductions in lower-limb injuries when running distance was reduced (40).
For tactical athletes who do not wish to go "all the way" barefoot, there are now a variety of “barefoot” shoes that claim to provide the benefits of barefoot running, yet still provide some protection to the feet. Two recent studies suggest runners that use “barefoot” shoes may adopt mechanics similar to those of barefoot running (43,44). Two other studies, however, indicate that some runners who adopt the shoes do not adjust their mechanics, and continue to run with a rearfoot strike pattern, which may increase the risk of a RRI (31,33). More research needs to be conducted to determine how closely “barefoot” shoes actually imitate barefoot running. Some authors have argued that adopting a “barefoot” running form is more important than the type of shoe worn (32).

Based on current evidence, barefoot running appears unlikely to increase distance run performance over lightweight, cushioned shoes. Research has consistently found no improvement in COT between barefoot running and shod running when the mass of the shoe is accounted for. Regarding RRI risk, the evidence is contradictory. Barefoot running may reduce the risk of certain RRIs, but may increase the risk of others. No published study has documented a direct relationship between barefoot running and reduced RRI risk. To date, there is insufficient evidence to recommend barefoot running as a broad intervention for RRI reduction. There is evidence that reducing frequency/duration of running may be an effective tool for reducing RRIs and improving readiness for tactical athletes. More research is clearly needed to assess whether tactical athletes should “go barefoot.”

References