Dehydration, Cramping, and Exertional Rhabdomyolysis: A Case Report With Suggestions for Recovery

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Objective: We present a case of severe dehydration, muscle cramping, and rhabdomyolysis in a high school football player followed by a suggested program for gradual return to play. Background: A 16-year-old male football player (body mass = 69.1 kg, height = 175.3 cm) reported to the ATC after the morning session on the second day of two-a-days complaining of severe muscle cramping. Differential Diagnosis: The initial assessment included severe dehydration and exercise-induced muscle cramps. The differential diagnosis was severe dehydration, exertional rhabdomyolysis, or myositis. CK testing revealed elevated levels indicating mild rhabdomyolysis. Treatment: The emergency department administered 8 L of intravenous (IV) fluid within the 48-hr hospitalization period, followed by gradual return to activity. Uniqueness: To our knowledge, no reports of exertional rhabdomyolysis in an adolescent football player exist. In this case, a high school quarterback with a previous history of heat-related cramping succumbed to severe dehydration and exertional rhabdomyolysis during noncontact preseason practice. We provide suggestions for return to activity following exertional rhabdomyolysis. Key Words: Heat illness, Creatine Kinase, acclimatization

Although relatively uncommon, acute exertional rhabdomyolysis is a problem encountered by athletes as a result of extreme or novel physical demands placed on the musculoskeletal system. Athletic trainers and physical therapists should be knowledgeable of the signs and symptoms of exertional rhabdomyolysis as mild cases may be misdiagnosed as a result of clinicians’ lack of awareness.1-4 Exertional rhabdomyolysis results from the degeneration of skeletal muscle caused by excessive exercise.5 When skeletal muscle membranes are damaged, their intracellular contents enter the bloodstream and can cause potentially serious sequelae, including acute renal failure and death.3 Individuals exercising in hot and humid environments are even at greater risk due to the effects of dehydration and hyperthermia. Muscle damage and necrosis primarily occur in dehydrated, untrained athletes.
individuals during downhill walking, running, or resistance-training exercises.\textsuperscript{1,3} Musculoskeletal pain and tea-colored urine\textsuperscript{5} is usually the primary symptom/sign reported by patients experiencing rhabdomyolysis. In the United States, 26,000 cases are reported annually.\textsuperscript{6} Most of the cases involve military/safety trainees,\textsuperscript{7-11} long distance runners,\textsuperscript{11,12} weight lifters,\textsuperscript{13} but less commonly, football players.\textsuperscript{14} Exertional rhabdomyolysis has been previously reported in adolescents\textsuperscript{15} and none in adolescent American football players. Because the recovery process of individuals with rhabdomyolysis has not been well documented, we present advice concerning an appropriate program for safely returning to vigorous activity. The purpose of this paper is to (1) present a unique pathophysiological injury involving severe dehydration, muscle cramping, and exertional rhabdomyolysis in a high school football player and (2) describe an example of an appropriate return to play program for athletes recovering from exertional rhabdomyolysis.

Case Report

Case History

We present a case that occurred on the second day of high school preseason football training in a 16-year-old Hispanic male (mass = 69.1 kg, height = 175.3 cm) quarterback who initially presented to the Certified Athletic Trainer (ATC) with severe muscle cramps that spread from his legs to trunk. The athlete reported to preseason practices well acclimatized with indoor (primarily)/outdoor conditioning (self-reported) for the previous 8 weeks and reported no previous history of hospitalization for exertional heat illness, medical conditions, recent illnesses, medications, or sport supplementation. He had recently completed a quarterback passing camp with mean ambient temperature = 86.80 ± 0.84°F and mean relative humidity = 70.4 ±2.7%. The athlete reported to the ATC after the morning session on the second day of two-a-days with ambient conditions of 86.80 °C and 70.40% relative humidity. He complained of severe muscle pain and cramping in his lower legs and hamstrings that progressed into his lower back and abdominal muscles. The treatment consisted of water consumption as tolerated, a carbohydrate-electrolyte beverage, and mild stretching of the affected muscles. The athlete stated that throughout the 3.5 hour practice, he consumed water during the three breaks and estimated to have consumed approximately 6 to 8 oz at each break. During treatment, painful and spasmodic involuntary contractions began to affect the larger muscles groups of his lower back and abdominal muscles, along with the previously mentioned lower legs. Ice bags were then immediately placed on the cramping muscle groups to desensitize the involuntary muscle contractions. Vital signs were closely monitored every 15 minutes for approximately 1 hour and were considered within normal limits.

The emergency medical response was contacted; however, they delayed the athlete’s transport to the emergency department for an additional 2 hours. When the paramedics arrived and evaluated the athlete, they advised the athlete to return home and drink ample fluids. The paramedics were reluctant to transport the athlete to the hospital for further evaluation and the possible implementation of aggressive fluid replacement. It was not until the athlete once again began to experience severe abdominal and lower back cramps that the paramedics called for an ambu-
The athlete’s transportation to the hospital occurred within 15 minutes of the ambulance’s arrival, bringing the total elapsed time from initial evaluation to hospitalization approximately 3 hours.

Upon arrival to the emergency department, intravenous (IV) fluid was administered (Table 1) and a complete hematology, chemistry, and urinalysis report was ordered. At this time, after at least 3 hours of oral rehydration prior to urinalysis, the urinalysis report was negative for hemoglobinuria and the urine (volume = 700 mL; specific gravity \( \leq 1.005 \) µG) was clear and had a straw colored appearance. Blood analysis revealed creatine kinase-myoglobin (CK-MB) levels at 17.2 ng·mL\(^{-1}\) (normal = 0.6–6.3 ng·mL\(^{-1}\)), peaking at 3363 IU·L\(^{-1}\), well above normal range (26–174 IU·L\(^{-1}\)). CK levels are presented in Figure 1. Blood urea nitrogen (24 mg·dL\(^{-1}\)) and creatinine (1.6 mg·dL\(^{-1}\)) were also elevated above normal ranges. Calcium was also found to be slightly elevated at 10.8 mg·dL\(^{-1}\) (8.6–10.3 mg·dL\(^{-1}\)), but potassium was within its normal limits. Sodium and chloride were not reported at this time. The athlete was maintained on a fluid replacement therapy, and two additional blood reports were ordered throughout the course of the evening. The athlete received 8000 mL of intravenous saline in addition to 900 mL by mouth, bringing the total fluid intake to 8900 mL with 700 mL excreted by the urinary system (Table 1) during his 24 hours in the Emergency Department. The athlete’s additional blood analysis continued to demonstrate elevated CK-MB and CK levels (Figure 1), at which time the attending physician opted to transport the athlete to the children’s hospital for further treatment of dehydration and to rule out rhabdomyolysis as a differential diagnosis.

Differential Diagnosis

Emergency department physicians recognized significant dehydration and muscle cramping in this athlete; however, until CK testing revealed mild rhabdomyolysis, physicians continued to suggest that the athlete was merely suffering from severe dehydration, heat stroke, or myositis. Because rhabdomyolysis is not often associated with noncontact physical activity, CK testing was required for a definitive diagnosis.

Admission to the children’s hospital occurred approximately 15 hours after emergency department admission. Upon physician evaluation, the athlete maintained strict volume intake of 120 mL·hr\(^{-1}\) of IV fluid. A new series of laboratory exams followed to rule out rhabdomyolysis. The results of the urinalysis for our athlete produced no traces of myoglobinuria, hematuria, or hemoglobinuria, and a 1.015 µG specific gravity with a clear and yellow color. Although urine specific gravity appeared to be normal, patients suffering from renal dysfunction tend to have urine specific gravity equal to that of blood plasma (1.008–1.010 µG), regardless of changes in the patient’s sodium and water intake.\(^{16}\) Our athlete remained hospitalized while further testing was completed and the diagnoses of severe dehydration and exertional rhabdomyolysis were confirmed.

Case Evolution and Denouement

The CK test (Total CK, CPK, creatine phosphokinase) is a laboratory exam ordered if a patient complains of muscle pain or general body weakness or if a myocardial
### Table 1  Hydration Status of the Cramping Athlete Once Transported to Emergency Department After Several Hours of Carbohydrate-Electrolyte Beverage Consumption

<table>
<thead>
<tr>
<th>Time</th>
<th>Body Mass (kg)</th>
<th>Fluid Consumed (mL)</th>
<th>Fluid Excreted (mL)</th>
<th>Urine Color</th>
<th>Urine Specific Gravity (μg)</th>
<th>Urine Osmolality (mmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (Pre-Practice)</td>
<td>69.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1 Emergency Department</td>
<td>70.5</td>
<td>8900</td>
<td>700</td>
<td>4</td>
<td>1.005</td>
<td></td>
</tr>
<tr>
<td>Day 2 Children’s Hospital</td>
<td>68.0</td>
<td></td>
<td></td>
<td>4</td>
<td>1.015</td>
<td></td>
</tr>
<tr>
<td>Day 3 Children’s Hospital (Discharged)</td>
<td>69.0</td>
<td>2422</td>
<td>2760</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RTA Day 7 (Pre-Practice )</td>
<td>67.2</td>
<td></td>
<td>4</td>
<td>1.034</td>
<td>994</td>
<td></td>
</tr>
<tr>
<td>RTA Day 7 (Post-Practice)</td>
<td>65.9</td>
<td>73</td>
<td>75</td>
<td>6</td>
<td>1.036</td>
<td>906</td>
</tr>
<tr>
<td>RTA Day 8 (Pre-Practice)</td>
<td>67.4</td>
<td>43</td>
<td>75</td>
<td>3</td>
<td>1.033</td>
<td>981</td>
</tr>
<tr>
<td>RTA Day 8 (Post-Practice)</td>
<td>66.6</td>
<td>43</td>
<td>75</td>
<td>3</td>
<td>1.032</td>
<td>931</td>
</tr>
</tbody>
</table>

RTA = Return to activity
Figure 1 — Total plasma creatine kinase over time for an adolescent American football player with severe dehydration and exertional rhabdomyolysis (mean ambient temperature = 86.80 ± 0.84 °F; mean relative humidity 70.4 ± 2.7%).
infarction is suspected. Testing for CK is the most reliable diagnostic indicator for rhabdomyolyis.\textsuperscript{17} In our case, CK analysis revealed CK levels peaking approximately 12 hours after the end of exercise and then declining around 24 hours. The CK levels at 36 hours had further reduced (Figure 1). The athlete’s electrolytes were within normal limits and the athlete was discharged after consultation with a nephrologist on the second day of hospitalization. Upon discharge, the patient’s medical records indicated a final diagnosis of severe dehydration and exertional rhabdomyolysis with no renal complications.

The athlete was cleared by the physician and returned to practice on day 7 and participated in all activities, although the athlete had 2.8\% body mass loss (compared to preexercise) at the time of return to activity and incurred a maximum loss of 4.6\% body mass throughout the course of the condition and treatment (Table 1). The ATC was advised to monitor return of symptoms and the athlete was encouraged to take frequent water breaks throughout practices and consume supplemental fluids while at home. For approximately 2 weeks after his return to full activity, the athlete consumed 16 oz of carbohydrate-electrolyte beverage prior to and following each practice to supplement water intake. Although the athlete struggled to maintain his body fluid balance during football practice, his return to participation has not triggered any additional bouts of muscle cramping or dehydration.

**Discussion**

**Dehydration and Heat Cramps**

Dehydration in athletes occurs because of inadequate replacement of sweat loss during and following training and competition.\textsuperscript{18} While performing physical exercise in hot weather, it is important that athletes replace the fluids lost through sweat by drinking equal quantities of water.\textsuperscript{19} Sweat losses that are not replaced by fluid and electrolyte intake lead to dehydration that may negatively impact athletic performance and lead to electrolyte imbalance. Heat cramps are extremely painful muscle spasms that occur most commonly in the calf and abdomen, although any muscle can be involved. Although conclusive evidence is lacking, heat cramps are likely the result of a sodium chloride deficit.\textsuperscript{20} Heat cramps are also one of the most common clinical problems encountered by medical professionals dealing with athletes, especially marathon and triathlon athletes.\textsuperscript{21} We were unable to accurately report our athlete’s electrolyte balance at the time of the incident as the athlete had consumed a carbohydrate-electrolyte beverage several hours before his first blood and urine samples were collected.

**Etiology of Exertional Rhabdomyolysis**

Exertional rhabdomyolysis is one of the most common forms of rhabdomyolysis\textsuperscript{2} and is characterized by muscle necrosis and release of intracellular contents such as myoglobin and creatine kinase into the bloodstream.\textsuperscript{4} Clinically, rhabdomyolysis is characterized by symptoms of nausea, vomiting, agitation, weakness, and muscle pain, along with tea-colored urine.\textsuperscript{4} Acute renal failure is one of the most serious late-stage complications of rhabdomyolysis occurring in as many as 33\% of patients.\textsuperscript{1}
Dehydration causes muscle damage and necrosis, especially in untrained participants performing unaccustomed eccentric or weight bearing exercise against gravity in high temperature ambient environments. Blood flow to active skeletal muscle becomes significantly reduced with dehydration during prolonged exercise in the heat. Blood flow to exercising muscles declines significantly with dehydration, due to a lowering in perfusion pressure and systemic blood flow rather than increased vasoconstriction. This thermoregulatory response to exercise causes tissue and muscle hypoxia, depletion of adenosine triphosphate, and eventually muscle cell necrosis and cell death if the process is not reversed in time.

Exercise against gravity or with an eccentric component has been associated with elevated levels of plasma CK in the circulatory system. Elevated CK levels provide the most sensitive enzyme marker for muscle damage and is extremely important in the diagnosis of rhabdomyolysis, as CK is one of the proteins that is released into the blood stream from the skeletal muscle when injury to the muscle occurs. In patients suffering from severe cases of rhabdomyolysis, CK levels may increase to 100,000 IU/L or more, with normal levels ranging from 26 to 174 IU/L. In our case, the maximum CK levels were 3363 IU/L at midnight of the day of the incident (Figure 1), clearly above normal but relatively low and related to a mild case of exertional rhabdomyolysis. In addition to elevated levels of CK, rhabdomyolysis typically includes elevated levels of blood urea nitrogen and creatinine as a result of acute renal failure from dehydration and myoglobinuria.

Treatment and Prognosis of Exertional Rhabdomyolysis

Once rhabdomyolysis is diagnosed, early fluid replacement is necessary to preserve renal function and to prevent acute renal failure. Initially, rhabdomyolysis is treated with high-volume IV fluid replacement, administered at a rate of 1.5 L·hr⁻¹, which is usually about 200 cc·hr⁻¹·liter⁻¹ bag. Patients may require as much as 4 to 10 L of normal saline in the first 24 hours to maintain circulation and stabilize blood pressure. Skeletal muscles can recover from episodes of rhabdomyolysis with minimal permanent damage, and recovery with return to play must be dependent on severity of muscle damage and pain.

Uniqueness of Our Case

Most reported cases of exertional rhabdomyolysis have involved military personnel, law enforcement, fire department trainees, or recreational athletes. In each case, strenuous exercise caused rhabdomyolysis because of either a lack of patient experience and fitness level, unaccustomed intensity levels, unaccustomed duration levels, or the type of muscle contraction performed during the exercise. In our case, a 16-year-old male athlete was participating in a typical preseason football camp when he developed severe dehydration and a mild case of exertional rhabdomyolysis. This case appears to be the first documented case of severe dehydration and mild rhabdomyolysis occurring in an adolescent athlete. The athlete was acclimatized and had been participating in conditioning, consisting of running sprints and non-contact football specific drills. This athlete likely had a poor understanding of his individual fluid needs based upon his sweat rate, fluid consumption, and the extreme environmental conditions of South Florida. Examination of this athlete’s hydration
status three days post-incident (Table 1) reveals that he failed to rehydrate during practice and, depending on his exercise intensity, was potentially at risk of relapse during this time. We speculate that this well-conditioned athlete reported to football preseason already dehydrated and after several days of football practice in the hot, humid conditions of South Florida, succumbed to severe heat cramps, which lead to his mild exertional rhabdomyolysis. A careful balance between intensity of exercise and individualized fluid replacement was necessary for this athlete to successfully return to play.

Considerations for Recovery and Return to Play

Rhabdomyolysis must be recognized as a serious condition and if not recognized and treated appropriately, could lead to acute renal failure. In order to prevent a relapse of rhabdomyolysis and depending on the severity, a progressive rehabilitation program that is closely monitored should be employed. Prior to beginning the rehabilitation program, a series of questions should be asked (see below) to determine the severity of the injury and readiness to proceed. All muscle pain and discomfort, flu-like signs and symptoms, fever, blood and urine CK, and myoglobin levels should be back to normal. In order to determine that there is not a delayed peak in blood or urine levels of CK and myoglobin, the athlete should exhibit normal levels for at least 2 to 3 days prior to resuming any type of activity.

Guidelines for Returning to Physical Activity and Sport Training Following Exertional Rhabdomyolysis

Prior to return to activity, ask the following questions:

- Is the athlete afebrile?
- Does the athlete feel good (no flu-like symptoms)?
- Is the athlete well hydrated?
- Are the CK levels within normal limits?
- Is myoglobin no longer present in serum and urine?
- Is urine color clear or pale yellow, or less than 4 on a urine color chart?
- Has muscle pain diminished to no pain?

If the answers to all the questions are YES, then the athlete may resume a mild physical activity under the supervision of a health care professional. If the answer to any of these questions is NO, the athlete must not begin activity, until all signs and symptoms have cleared.

Some general exercise strategies should include ensuring the athlete is properly hydrated before, during, and after exercise; that extremes in environmental conditions are avoided until the athlete is heat acclimatized; that diuretics are avoided; and that a well balanced diet is maintained. Initial return to activity after an episode of rhabdomyolysis should included an avoidance of eccentric exercises, downhill walking/running, and weight training, with a progressive increase in intensity at the athlete’s tolerance. To decrease the incidence of relapse, the health care professional should monitor blood and urine values as well as subjective signs and symptoms. An important part of the reconditioning program necessary for a safe return to play
should be an individualized fluid replacement protocol and a generalized conditioning program (including aerobic and anaerobic training) in order to prevent recurrent incidents of dehydration, cramps, and exertional rhabdomyolysis.

We have not found the specific reconditioning program or return-to-play guidelines for recovery from exertional rhabdomyolysis. Our suggested protocol must be individualized based upon the athlete’s extent of muscle injury, pre-incident level of fitness, and previous weight training experience. We suggest a 15-week program for recovery and return to play; however, the length of the program should be adjusted (longer or shorter) according to the individual’s needs, severity of injury, and tolerance. We recommend the aquatic environment for early rehabilitation of exertional rhabdomyolysis because it reduces the eccentric load of gravity on the muscle and effects of gravity on movements while allowing pure movement at the joints. For example, a biceps curl on land uses the biceps muscle concentric contraction for flexion and a biceps muscle eccentric contraction for extension. Submerged in the water, a biceps curl uses the biceps muscle concentric contraction for flexion and a triceps muscle concentric contraction for extension. Without equipment usage in the water, pure movements are concentric-concentric actions, not concentric-eccentric as on land. Recovery of lower limb muscles after downhill running is improved with aquatic exercise, which promoted recovery of muscle power, decreased muscle soreness and muscle stiffness, and improved whole-body reaction time more quickly compared to conditions without aquatic exercise. Transition from the aquatic environment during early rehabilitation of rhabdomyolysis should include gradually increasing the duration and intensity of exercise on land to include light weight training (Table 2).

Since weight training has an eccentric component during a normal movement, the athlete should be monitored closely for signs and symptoms of relapse as weight training is reintroduced. Each individual’s exercise program should be monitored and adjusted according to their post-exercise responses. Proper technique should be emphasized and any alteration in technique should be considered a sign of fatigue or pain. Increases in load should be considered when the athlete is able to complete the exercise session without signs of fatigue and there is no report of delayed onset muscle soreness the next day. When reintroducing weight training into the exercise program, determine the one-repetition maximum (1RM) or estimate the 1RM by using a 10RM load; this is accomplished by the same method that the 1RM is calculated except using a lighter load following established guidelines. The athlete should start at a lower relative intensity (≤ 67% of 1RM) and higher repetitions (12 to 20) to improve muscular endurance. As endurance improves, the relative intensity should be increased to a moderate level (67 to 75% 1RM) with a moderate number of repetitions (8 to 12) to build base strength and size. It should progress to a strength-power intensity (75 to 90% of 1RM) with low repetitions (2 to 8) that mimics more sport related strength and explosion. Progression of the resistance training program should be based on the athlete’s ability to complete the repetitions and sets in good form without increased muscle soreness. Individuals will progress at their own pace, the program described is the progression, and the rate of the progression may vary based on individual strengths and weaknesses. In general, the recommended program is designed to perform the same workouts for two consecutive workout days before changing or modifying the workout to ensure a gradual progression of intensity and volume (Table 2).
<table>
<thead>
<tr>
<th>Weeks from Onset of Rhabdomyolysis</th>
<th>Recommended Activities and Environment</th>
<th>Intensity</th>
<th>Precautions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weeks 1 to 2; once all signs/symptoms and laboratory results have been cleared</td>
<td>Workout 5 days/week with no more than two days off between workouts (except for Week 1)</td>
<td>60% HRR</td>
<td>Avoid eccentric activities, DH, WT, and exercise outdoors in warm/hot humid environment.</td>
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<tr>
<td></td>
<td>Aquatic exercise, swimming, walking, and jogging without equipment; Week 1: workout 3 days Week 2: workout 5 days</td>
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<tr>
<td>Week 3</td>
<td>Aquatic exercises may begin to add hops and jumps and nonbuoyant resistance; increase intensity; begin eccentric with buoyant resistance.</td>
<td>60 to 75% HRR</td>
<td>Begin some eccentric loading by adding buoyant resistance in water, avoid DH, WT, and exercise outdoors in warm/hot humid environment.</td>
</tr>
<tr>
<td>Week 4</td>
<td>Indoors in climate-controlled environment: Begin walking and running on a flat surface, followed by aquatic exercises. Outdoors in warm/hot humid environment: no more than 20 minutes of continuous walking/running with progressive increase in intensity every 2 days.</td>
<td>60 to 70% HRR on land 70 to 80% HRR in water</td>
<td>Avoid DH and WT; record BWT pre- and post-workout and rehydrate* accordingly; shorts/shirts, no pads/equipment.</td>
</tr>
<tr>
<td>Week 5</td>
<td>Indoors in climate-controlled environment: Increase intensity of walking/running on flat surface, followed by aquatic exercises, 5 days/week. Outdoors in warm/hot humid environment: no more than 30 minutes continuous walking/running with progressive increase in intensity every 2 days.</td>
<td>70 to 80% HRR</td>
<td>Avoid DH and WT; record BWT pre- and post-workout; rehydrate accordingly; shorts/shirts; no pads/equipment.</td>
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(continued)
<table>
<thead>
<tr>
<th>Weeks from Onset of Rhabdomyolysis</th>
<th>Recommended Activities and Environment</th>
<th>Intensity</th>
<th>Precautions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 6</td>
<td>Indoors in climate-controlled environment: Begin to introduce incline and</td>
<td>60 to 80%</td>
<td>Avoid DH and WT; record BWT pre- and post- workout; rehydrate accordingly;</td>
</tr>
<tr>
<td></td>
<td>decline walking/running, followed by aquatic exercise. Outdoors in warm/hot</td>
<td>HRR</td>
<td>shorts/shirts; no pads/equipment.</td>
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<tr>
<td></td>
<td>humid environment: no more than 40 minutes, 10 minutes of interval training</td>
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<tr>
<td></td>
<td>followed by 30 minutes of continuous walking/running with progressive increase in intensity every 2 days.</td>
<td></td>
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</tr>
<tr>
<td>Weeks 7 to 8</td>
<td>Indoors in climate-controlled environment: Introduce circuit WT program</td>
<td>WT- 50</td>
<td>Progress slowly with WT; begin with 1 set of 10 to 15 repetitions to 3 sets by end of Week 8.</td>
</tr>
<tr>
<td></td>
<td>3 days/week with one exercise per body area; walking and running all patterns, followed by aquatic exercise. Outdoors in warm/hot humid environment.</td>
<td>to 67% of preinjury 1 RM</td>
<td>Avoid DH; record BWT pre- and post-workout; rehydrate accordingly; shorts/shirts; no pads/equipment; water break every 20 minutes.</td>
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<td></td>
<td>Week 7: no more than 50 minutes, 20 minutes of interval training followed by 30 minutes of continuous walking/running with progressive increase in intensity every 2 days.</td>
<td>HRR as required for sport.</td>
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<td>Week 8: no more than 60 minutes, 10 minutes agility training, 20 minutes of interval training followed by 30 minutes of continuous walking/running with progressive increase in intensity every 2 days.</td>
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</table>
Weeks 9 to 10
Indoors in climate-controlled environment:
Increase circuit WT program 3 days/week with two exercises per body area; walking and running all patterns, followed by aquatic exercise.

Outdoors in warm/hot humid environment:
Week 9: no more than 70 minutes, 15 minutes agility training, 25 minutes of interval training followed by 30 minutes of continuous walking/running with progressive increase in intensity every 2 days.
Week 10: no more than 80 minutes, 20 minutes agility training, 30 minutes of interval training followed by 30 minutes of continuous walking/running with progressive increase in intensity every 2 days.

WT- 65 to 75% of preinjury 1 RM
HRR as required for sport.
Progress slowly with weight training; begin with 1 set of 8 to 12 repetitions to 3 sets by end of second week.
Record BWT pre- and post- workout; rehydrate accordingly; shorts/shirts; no pads/equipment; water break every 20 minutes.

Weeks 11 to 12
Indoors in climate-controlled environment:
Increase circuit WT program 3 days/wk with 2 to 3 exercise per body area; walking and running all patterns, followed by aquatic exercise.

Outdoors in warm/hot humid environment.
Week 11: 80 minutes, 20 minutes agility training, 30 minutes of interval training followed by 30 minutes of continuous walking/running with progressive increase in intensity every 2 days.
Week 12: 80 minutes, 20 minutes agility training, 30 minutes of interval training followed by 30 minutes of continuous walking/running with progressive increase in intensity every 2 days.

WT- 75 to 85% of preinjury 1 RM
HRR, as required for sport.
Progress slowly with weight training; begin with 1 set of 6 to 10 repetitions to 3 sets by end of second week.
Record BWT pre- and post- workout; rehydrate accordingly. Wear pads for 20 to 30 minutes, then remove for remainder of workout.

(continued)
### Table 2 (continued)

<table>
<thead>
<tr>
<th>Weeks from Onset of Rhabdo-myolysis</th>
<th>Recommended Activities and Environment</th>
<th>Intensity</th>
<th>Precautions</th>
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<tr>
<td></td>
<td>Workout 5 days/week with no more than two days off between workouts (except for Week 1)</td>
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<tr>
<td>Weeks 13 to 14</td>
<td>Indoors in climate-controlled environment: Continue circuit WT program as tolerated using aquatic exercise to prevent delayed onset of muscle soreness; may begin to add plyometric training. Outdoors in warm/hot humid environment: Sport specific practices and return to full practice with team (with limited pads) – OR 80 minutes: 20 minutes agility training, 30 minutes of interval training followed by 30 minutes of continuous walking/running with progressive increase in intensity every 2 days.</td>
<td>HRR &amp; WT, as required for sport.</td>
<td>Continue slow progression in WT, plyometrics. Record BWT pre- and post- workout; rehydrate accordingly; wear pads for 60 to 80 minutes then remove for remainder of workout.</td>
</tr>
<tr>
<td>Week 15</td>
<td>Outdoors in warm/hot humid environment: Progress duration to the length of practice that will be expected for return to play.</td>
<td>70 to 85% HRR, as required by sport.</td>
<td>Record BWT pre- and post- workout; rehydrate accordingly; water break every 20 minutes; wear pads for entire practice.</td>
</tr>
</tbody>
</table>

**Notes.** HRR = Heart Rate Reserve, calculate using Resting Heart Rate (HRrest) and Maximum Heart Rate (HRmax = 220 – age) to calculate % HRR = ((HRmax – HRrest) ×%Intensity) + HRrest following established guidelines; DH = downhill walking/running; WT = weight training; RM-repetition maximum or weight lifted comfortably tolerated and can be estimated using a 10RM following specific guidelines; BWT = body weight. *Rehydrate with the same volume of fluid lost as body weight changes. Interval training should include a work to rest interval equal or 1:1 allowing the athlete to train at a near maximal level for a greater amount of time.
Following the development of strength, plyometrics would be added to the workouts. The progression for introduction of plyometrics are jumps in place, standing jumps, multiple jumps, multiple hops, bounding, box jumps, and then depth jumps. Beginning the plyometrics in the pool prior to performing on the land may decrease the muscle soreness and loads experienced by the muscles, yet prepare the muscle for the stress when transitioning to land. A normal progression from low to high volume with a recovery of 48 to 72 hours between plyometric workouts is recommended. Box jumps and depth jumps provide larger eccentric loads on the muscles but have an increased risk of delayed onset muscle soreness compared to concentric training. These more advanced plyometrics would be one of the last types of exercise to be added to the exercise program.

In addition to the general return to play exercise progression, a compounding issue of hot and humid environmental conditions must be discussed. For an athlete to be prepared to return to exercise in hot, humid conditions following exertional rhabdomyolysis, several issues must be addressed (Table 2). The ATC must ensure that there is (1) an appropriate hydration status maintained at optimal levels to prevent relapse; (2) a gradual increase in the duration of exposure to a hot, humid environment and intensity of training; (3) an appropriate progression of clothing, equipment, and pads; and (4) cooling at appropriate intervals between bouts of exercise/training to improve recovery. The environmental acclimatization can be overlapped with the return to play which incorporated pool time as well as weight training (Table 2). The pool time can also be considered as part of the cooling therapy, which may facilitate recovery for the next day’s workout. In general, the exercise timing and progression must be modified based on individual athlete responses and tolerance.

**Conclusion**

Exertional rhabdomyolysis is the most common form of rhabdomyolysis and the potential for athletes to develop this potentially severe disorder may not be widely recognized. Although additional evidence is needed, relationships may exist between dehydration, heat cramps, and exertional rhabdomyolysis. For safe recovery from exertional rhabdomyolysis, a gradual re-introduction to physical activity with individual an individualized program addressing the duration, intensity, and exposure to heat and humidity is necessary to prevent relapse or further incidents of exertional heat illness or exertional rhabdomyolysis.

**References**


