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# Exercise-induced Rhabdomyolysis in a Young Adult after an Intensive Resistance-circuit Workout – Case Report and Narrative Literature Review

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**ABSTRACT**

Exercise-induced rhabdomyolysis is a potentially serious complication of high-intensity physical activity, increasingly observed in young adults, particularly in the context of high-intensity training, abrupt return to exercise after a longer break, and the widespread use of multi-ingredient pre-workout supplements. Early symptoms are often dismissed as "bad muscle soreness", which may delay diagnosis and treatment and, in consequence, promote the development of acute kidney injury. The aim of this paper is to present a case of exercise-induced rhabdomyolysis in a young, previously healthy man after a resistance-circuit training session performed following a prolonged period of inactivity, and to discuss current knowledge

on the etiology, clinical presentation, diagnostics, treatment and prevention of exercise-induced rhabdomyolysis in young adults. We describe the clinical course, laboratory findings and management, and then relate them to available data, with particular emphasis on environmental factors, dehydration and the use of pre-workout preparations. The case illustrates that early recognition based on simple tests – creatine kinase activity, assessment of kidney function and urinalysis – and prompt initiation of intensive fluid therapy often make it possible to avoid renal replacement therapy. From the perspective of sports medicine and primary care, education of young adults, gradual introduction of training loads, and cautious, informed use of supplements – especially in hot environments and with limited fluid intake – are crucial.
**Keywords**: exercise-induced rhabdomyolysis, young adults, resistance training, acute kidney injury, creatine kinase, pre-workout supplements

## 1. INTRODUCTION

Rhabdomyolysis is a clinical and biochemical syndrome resulting from extensive damage to skeletal muscle and the release of its contents into the bloodstream [1-3]. In traditional descriptions it is associated with massive crush injuries, natural disasters, prolonged immobilization, severe drug intoxications and metabolic disorders. Over the past several decades, and especially in recent years, increasing attention has been paid to rhabdomyolysis triggered by physical exertion, often referred to as exercise-induced rhabdomyolysis (EIR), occurring in young, seemingly healthy individuals, often without any relevant internal diseases in their history.

The term itself covers a broad spectrum of severity, from asymptomatic elevations of creatine kinase after strenuous exercise to life-threatening conditions accompanied by marked muscle necrosis, acute kidney injury and severe electrolyte disturbances [1,4,5]. In clinical practice, rhabdomyolysis is usually suspected when serum creatine kinase activity exceeds several times the upper limit of normal, and the suspicion becomes particularly strong when this elevation coincides with muscle pain, weakness and dark discoloration of the urine. In exercise-induced cases the onset of symptoms typically occurs within the first twenty-four to forty-eight hours after exertion, although in some patients the picture develops more insidiously, which further complicates early recognition [4,6].

Clinicians who regularly look after physically active young adults sometimes remark that the most difficult step is not ordering the first creatine kinase test, but allowing themselves to take the patient's complaints seriously. When a previously healthy person in their twenties says that "something feels wrong after training", the default assumption – shared by the patient, their peers and often the physician – is that this is still within the range of normal adaptation [4,6,7]. The case presented in this article shows how easily this assumption may delay recognition of a process that has already exceeded safe physiological limits.

Changes in lifestyle, cultural pressure to maintain a "fit" body and the growing popularity of high-intensity workouts mean that this problem now appears in a very different context than in classic textbook cases. Young people who spend most of the week in a sedentary mode are able, in a single evening, to deliver to their muscles such a dose of mechanical, metabolic and thermal stress that the muscles simply cannot cope. This phenomenon is particularly common in settings involving group classes such as cross-training, functional training, various forms of strength–conditioning circuits, but it also occurs in the military and among participants in sports camps [6,8,9]. What distinguishes these situations is not only the objective intensity of the effort, but also the social and psychological environment that favors exceeding individual limits.

Another layer of complexity is the widespread use of supplements, especially pre-workout products and energy drinks that promise "maximum focus" and "full training potential" [10-12,26-28]. Their composition is often complex, and the amount of active ingredients declared on the label does not always reflect reality. In many cases, young adults do not inform physicians about their supplement use, treating these products as "something between coffee and vitamins", that is, an element of lifestyle rather than a potential source of health problems. From the clinician's perspective, this creates a blind spot in history-taking, because the question "do you take any medications?" usually does not elicit information about powdered mixtures consumed before training sessions.

The literature repeatedly emphasizes that the symptoms of exercise-induced rhabdomyolysis are initially interpreted as particularly severe post-workout muscle soreness [4,6-8]. Especially in environments where pain and extreme fatigue are presented as a natural, or even desirable, element of training, it is easy to reach a point where both the patient and the trainer ignore warning signs for many hours or even days. The moment when dark discoloration of the urine appears is often the first signal that breaks through this narrative. Even then, however, the initial reaction is frequently to attribute the change to simple dehydration, especially when the person has indeed been sweating profusely and drinking relatively little [4,6,7].

From the perspective of sports medicine, emergency medicine and primary care, it is important that exercise-induced rhabdomyolysis is not treated as a rare, curiosity-type diagnosis, but as a real and increasingly frequent condition, particularly in young adults who are physically active or only just returning to activity [3,4,6,7]. This requires both an understanding of the underlying pathophysiology and the habit of asking seemingly simple questions that may ultimately prove decisive for the patient's outcome. An apparently trivial episode of "the worst soreness in my life" may in fact be the first manifestation of a process jeopardizing kidney function [4,6,7].

This paper combines a case report of exercise-induced rhabdomyolysis in a young man with a narrative review of the literature. Such a format makes it possible to juxtapose a real-life scenario with scientific data, and at the same time to highlight the gaps between theory and everyday clinical practice. It also allows reflection on how cultural narratives around exercise, health and performance interact with physiological reality, sometimes with very tangible consequences for individual patients.

## 2. AIM OF THE STUDY

The aim of this study is to present a case of exercise-induced rhabdomyolysis with accompanying acute kidney injury in a young, previously healthy man after an intensive resistance-circuit training session performed following a long break from physical activity, and to discuss the available literature on this issue in a way that is useful for clinical practice. The authors focus on several practical questions: in which situations in young adults a "red flag" for rhabdomyolysis should be raised, which simple laboratory tests are crucial for early diagnosis, how to plan management in order to minimize the risk of severe acute kidney injury, and how to counsel patients and trainers on safe return to exercise after such an episode. An important element is also placing this case in the broader context of current training and supplementation trends among young adults, with particular emphasis on the role of group classes and pre-workout products in shaping behavior and risk perception.

## 3. CASE REPORT

This case description is based on a composite educational scenario that synthesizes typical clinical features of young adults presenting with exercise-induced rhabdomyolysis; no data from a single identifiable patient were used. The patient is a 22-year-old man, a college student, with no history of chronic diseases and no regular medications. He reported no allergies, did not smoke, and drank alcohol only occasionally in small social amounts. His family history was negative for muscle disorders, chronic kidney disease and sudden cardiac death at a young age. On admission his body weight was within the normal range, with a BMI of approximately 24 kg/m².

In high school he had attended a gym regularly and performed strength training three to four times per week. During his university years his activity gradually decreased, eventually becoming almost nonexistent over the nine months preceding the event. That time was filled mainly with studying, computer work and commuting by public transport. The patient later described this period as “typical sitting mode with a few thousand steps a day”. He did not participate in competitive sports, and there was no history suggesting an underlying metabolic myopathy or episodes of exercise intolerance in the past. In everyday life he perceived himself as “rather average but not unfit”, a self-assessment based more on memories from high school than on his current routine. This subjective image of being “still more sporty than most colleagues” probably contributed to his conviction that he could safely join an intensive class without any preparatory phase. At no point did he consider himself a person at risk for an exertional complication, which illustrates how wide the gap may be between objective detraining and self-perceived fitness.

At the beginning of summer he decided it was “time to get his act together” and return to regular exercise. On the recommendation of friends he chose group classes described as functional strength circuit at a fitness club. The website description was appealing: “full-body intensive workout”, “maximum calorie burning in minimum time”, “ideal solution for busy people who want to see results quickly”. There was no mention of gradually introducing loads in individuals returning after a break, nor of any formal screening for previous injuries, cardiovascular conditions or recent inactivity. According to the patient, no specific questions were asked by the staff before he joined the class, apart from a general inquiry whether he felt healthy.

The first class took place on a warm, stuffy afternoon. The gym space was relatively small, filled with several participants, and ventilation left much to be desired. The patient later admitted that he already felt “stuffy air” during the warm-up, but assumed that this was simply normal at that time of day. That day he had eaten a light breakfast, a quick, modest lunch, and drank a little over one liter of fluids in total, mostly coffee and an energy drink. Immediately before the workout he took a serving of a pre-workout supplement purchased online. According to the label, it contained a high dose of caffeine, beta-alanine, taurine, bitter orange extract and several other plant-derived ingredients. The patient did not analyze the composition in detail and treated the product as “stronger coffee”. He had not used that particular preparation before, although he had occasionally consumed energy drinks before exams.

The workout itself was structured as a circuit of several stations: loaded squats, lunges, kettlebell exercises, push-ups, assisted pull-ups with resistance bands, abdominal exercises and short conditioning intervals. Each station was performed for a set time with brief breaks to change position. The session lasted about an hour, with the main part involving approximately 35–40 minutes of fairly intense effort. The instructor encouraged participants to “give it all you’ve got”, and the patient – not wanting to fall behind the group and wanting to prove to himself that he could still “keep up” – chose from the start weights similar to those used by more experienced attendees. He reported that he felt “pumped and slightly shaky”, but interpreted this as a sign that the pre-workout product was “working”.

Immediately after the session he felt pronounced fatigue, dizziness on standing up quickly and intense burning in the thigh and gluteal muscles. He drank a small amount of water because, as he later put it, “he just did not feel like carrying the bottle around the club”. He did not experience chest pain, dyspnea or syncope. He returned home by public transport and went to bed with the sense that he had “done a solid job” and that the next day would simply bring “solid soreness”.

The next morning he experienced progressive pain in his lower limb muscles, particularly the thighs, which significantly impeded climbing stairs and sitting down. He interpreted this as “the worst muscle soreness of his life”, but it still fit his subjective expectations of what a return to training “should” feel like. It was only around noon that he noticed the dark, tea-colored discoloration of his urine. During the day he urinated less often than usual, in small volumes. He also felt dry mouth and mild nausea, but without vomiting or abdominal pain. He did not have a fever or chills. He initially assumed he was “just dehydrated” and decided to “drink more water and wait it out”, although in practice his fluid intake remained relatively modest.

In the evening the muscle pain was so severe that each descent down the stairs required him to hold on to the handrail. The dark urine persisted and, in his perception, became even more intense. He also began to feel generalized weakness and a vague sense of being “unwell” that he could not clearly define. During that day he briefly discussed his symptoms with two friends by instant messaging, and both reassured him that “this is how legs feel after a serious workout”. Their comments, although well intentioned, reinforced his initial tendency to normalize what was already an alarming constellation of complaints. It was only the gradual realization that simple activities such as getting dressed or using the stairs had become disproportionately difficult that started to undermine this narrative. Only then did he decide to contact a primary care physician. He described his complaints as “insane muscle soreness” and “very dark urine”. After a brief but focused inquiry about the workout, fluid intake and supplement use, the physician recommended urgent evaluation at the emergency department (ED) with suspected exercise-induced rhabdomyolysis and possible acute kidney injury.

On arrival at the ED the patient was hemodynamically and respiratorily stable but reported severe pain in the thigh and gluteal muscles, describing it as “pressure from the inside”. On physical examination there was noticeable tenderness of the lower limb muscles on palpation, reduced range of motion in the hip joints due to pain, and signs of mild dehydration such as dry oral mucosa and slightly decreased skin turgor. The abdomen was soft and non-tender, without peritoneal signs. There was no peripheral edema or evidence of heart failure. Vital signs were within normal limits except for moderate sinus tachycardia; body temperature was normal.

Laboratory tests revealed markedly elevated creatine kinase activity, exceeding 50,000 U/L at presentation, with a further increase to over 70,000 U/L during the first 24 hours of hospitalization. Serum creatinine and urea were elevated compared to age-appropriate reference values, and there was mild hyperkalemia with slightly decreased bicarbonate levels. Aminotransferase activity was increased with AST predominance over ALT, which in the context of muscle injury was interpreted as secondary to rhabdomyolysis rather than primary hepatocellular disease. Serum lactate dehydrogenase was also elevated. Urinalysis showed a under tdark color, high specific gravity and a positive blood test in the absence of red blood cells in the sediment, consistent with myoglobinuria. The ECG showed no evidence of acute ischemia or significant conduction disturbances, and no arrhythmias were recorded during observation in the ED.

Based on the characteristic history, clinical presentation and laboratory findings, exercise-induced rhabdomyolysis with acute kidney injury was diagnosed. No features suggestive of compartment syndrome were found on repeated physical examinations. There were no signs pointing toward an alternative diagnosis such as inflammatory myopathy, viral infection or toxic exposure beyond the reported supplement use. The patient was admitted to the internal medicine ward, where intensive intravenous hydration with normal saline was initiated, with close monitoring of urine output, electrolytes and hemodynamic parameters. The initial goal was to achieve a clearly increased diuresis, while carefully observing for any signs of fluid overload.

Over the following days conservative management was continued, and nephrotoxic drugs were avoided. Analgesia was provided with paracetamol, and nonsteroidal anti-inflammatory drugs were deliberately not used. CK activity peaked on the second day and then gradually declined, paralleling the clinical improvement. Serum creatinine reached a maximum on the second day and then decreased with ongoing fluid therapy. Electrolyte disturbances resolved without the need for specific interventions beyond hydration and dietary adjustments. Kidney ultrasound did not reveal any structural abnormalities. Renal replacement therapy was not required at any point. After six days, with resolution of muscle pain, normalization of creatinine and a clear downward trend in CK, the patient was discharged home with recommendations regarding hydration, gradual return to physical activity and avoidance of stimulant-containing supplements at least for several months.

At a six-week follow-up visit he reported no complaints. Laboratory parameters, including creatinine, estimated glomerular filtration rate, creatine kinase and aminotransferases, were within normal limits. He had resumed physical activity, this time gradually increasing workloads, abandoned pre-workout preparations and paid more attention to hydration. He described the episode as “a cold shower that made it clear that the body is not a game console with turbo mode”. No recurrent episodes of muscle pain or dark urine were noted in subsequent months.

The clinical picture observed in this patient becomes more comprehensible when placed within the broader epidemiological and physiological context of exercise-induced rhabdomyolysis among young adults. Over the past decade a steady increase in the number of reported cases has been noted globally, although the true prevalence remains difficult to establish due to substantial underdiagnosis [4,6-9]. Many episodes never reach medical attention, particularly when muscle pain and temporary functional impairment are attributed to ordinary post-exercise soreness [4,6,7]. The expansion of high-intensity training modalities, including various commercialized forms of functional circuits and indoor conditioning programs, has resulted in an environment in which individuals with highly variable levels of physical preparedness exercise side by side, often under time pressure and with competitive undertones that implicitly encourage pushing beyond physiological limits.

Studies from the United States military, where large cohorts of young adults undergo rigorous physical conditioning, offer valuable insight into how quickly unaccustomed individuals may exceed their safe workload thresholds [13,14]. Analyses of basic training cycles repeatedly show that the first two to three weeks of intense exertion are associated with the highest risk of hospitalization for rhabdomyolysis. This risk is not primarily determined by absolute workload, but by the sudden transition from relatively sedentary behavior to structured, demanding training regimens. Similar observations have been made in civilian environments, particularly in settings where individuals attempt to rapidly “get in shape” before holidays, personal milestones or the beginning of the academic year [8,9,13,14]. In such contexts, high motivation paradoxically becomes a risk factor when it is not accompanied by gradual conditioning and adequate recovery periods.

The role of eccentric muscle contractions deserves special emphasis in this regard [15-17]. Contemporary fitness programs frequently rely on dynamic, multi-joint exercises that incorporate substantial eccentric loading, such as weighted squats, kettlebell swings, lunges and plyometric movements. Although these exercises are highly effective in stimulating muscle adaptation, they also impose considerable mechanical stress on the sarcomere, particularly in individuals with limited recent training history. Microscopic damage to the Z-line and disruption of cytoskeletal proteins trigger local inflammatory processes that, when excessively amplified, contribute to massive creatine kinase release and subsequent systemic manifestations. The propensity of eccentric contractions to induce disproportionately high levels of muscle breakdown explains why even a single session of “return-to-exercise enthusiasm” can become the precipitating event for clinically significant rhabdomyolysis.

Beyond mechanical factors, metabolic constraints play a central role in the development of EIR [1,2,15,16]. Muscles suddenly exposed to high workloads experience rapid depletion of intramyocellular ATP stores, accumulation of inorganic phosphate, and impaired calcium reuptake by the sarcoplasmic reticulum. The resulting calcium overload activates proteases and phospholipases that destabilize the cell membrane. When repeated across large muscle groups, such as the quadriceps and gluteal muscles involved in circuit-based training, this process generates a substantial burden of myoglobin and other intracellular components that must be cleared by the kidneys. The interplay between metabolic exhaustion and mechanical strain is particularly pronounced in individuals who combine intense training with inadequate nutrition or insufficient carbohydrate intake, which limits glycogen availability and accelerates intracellular energy failure.

Environmental conditions serve as an additional amplifying factor. Exercise performed in warm, humid or poorly ventilated environments increases the physiological cost of thermoregulation. Sweat losses accumulate quickly, often unnoticed, especially in individuals who do not consciously monitor hydration [2,14,18]. Even mild hypohydration increases blood viscosity and decreases renal perfusion, reducing glomerular filtration at precisely the time when circulating myoglobin levels are rising. Several studies examining indoor fitness environments have demonstrated that room temperature may exceed recommended ranges during peak gym hours, and carbon dioxide concentrations may rise significantly when many participants exercise in a confined space. Although these environmental stressors are not inherently dangerous in isolation, they narrow the individual's physiological margin of safety and lower the threshold at which rhabdomyolysis may develop.

The role of stimulants and multi-ingredient pre-workout supplements represents another important dimension. Products marketed as performance enhancers often contain a combination of caffeine, beta-alanine, taurine, herbal sympathomimetics and nitric oxide precursors [10-12,19]. While individually these compounds may have modest effects, their cumulative impact—particularly when ingested by dehydrated, stimulant-sensitive or unaccustomed individuals—may significantly alter the perception of effort and fatigue. This “disconnect” between perceived exertion and actual physiological strain may encourage users to maintain levels of intensity that their musculature cannot safely tolerate. Moreover, sympathomimetic compounds can increase heart rate, blood pressure and thermogenesis, thereby intensifying metabolic stress. The variability in the quality and composition of supplements purchased online raises additional concerns, as several case reports have documented the presence of undeclared substances that may further increase the risk of muscle injury [10,11,19,20].

Importantly, social and psychological factors often reinforce these physiological vulnerabilities. Group exercise formats foster a sense of collective effort and shared challenge, but they may also generate subtle competitive pressures [8,9,21]. Instructors often use motivational cues that frame discomfort as a marker of effectiveness, while participants may feel reluctant to reduce weights or modify exercises for fear of appearing weak or inexperienced. This social dynamic may lead individuals to sustain workloads that exceed their true capacity, especially when combined with stimulants that further impair early fatigue recognition. In this respect, the case described in this study is entirely consistent with broader patterns observed in modern fitness culture, where achievement-oriented messaging may overshadow caution and self-awareness.

There is also increasing recognition that the shift toward time-efficient, high-intensity training reflects broader societal patterns in which individuals attempt to counteract prolonged sedentary behavior with brief periods of extreme exertion. This “compression” of physical activity into short windows of high output places substantial physiological demands on unadapted muscles and energy systems. While the health benefits of regular exercise are indisputable, the assumption that maximal effort can compensate for prolonged inactivity is physiologically flawed. Muscular, metabolic and cardiovascular adaptations require consistent, progressive exposure to training stimuli, not sporadic bursts of extreme intensity.

From a clinical standpoint, understanding these contextual factors is essential for interpreting individual cases of EIR and providing meaningful prevention strategies. It becomes clear that the risk of rhabdomyolysis is not merely a function of how “hard” an individual trains, but rather how abruptly the intensity of training increases relative to recent physical activity levels, hydration patterns and environmental conditions. This broader perspective also helps explain why EIR frequently develops in young, ostensibly healthy adults who have no underlying neuromuscular pathology. Their physiology is capable of extremely high performance when properly conditioned, but it is equally vulnerable to excessive mechanical and metabolic strain when reintroduced to intense exercise without adequate progression.

## 4. DISCUSSION

### 4.1. Summary of the case and key risk factors

The case described above illustrates in a compact form the most important mechanisms and clinical pitfalls associated with exercise-induced rhabdomyolysis in young adults [3,4,6,7]. Several classical risk factors appear simultaneously: a long period of almost complete inactivity, a sudden and ambitious return to high-intensity training, unfavorable environmental conditions, insufficient fluid intake and the use of a stimulant-containing pre-workout preparation. Each of these elements alone is capable of increasing the risk of muscle overuse; in combination they create a situation in which even a single training session is sufficient to induce massive skeletal muscle damage and acute kidney injury. What makes this scenario particularly illustrative is the convergence of factors that are frequently mentioned in isolation in the literature but rarely described together in detail: marked detraining, a time-efficient resistance-circuit class in a commercial gym, training in a hot, poorly ventilated indoor environment and the use of a multi-ingredient pre-workout supplement [4,6,8-12]. In contrast to many published reports centred on military recruits or competitive athletes, this case reflects the everyday reality of a busy university student attempting to “catch up” on fitness, which may increase its relevance for primary care and sports medicine settings.

### 4.2. Pathophysiology and renal consequences

From a pathophysiological standpoint, the core process is extensive destruction of muscle fibers with loss of membrane integrity and leakage of intracellular components into the circulation. Mechanical stress, particularly during eccentric contractions with relatively heavy loads, overlaps with metabolic overload caused by sudden high energy demand in muscles that are not conditioned to such work [1,2,15,16]. When ATP stores become critically depleted, ion pumps fail, calcium influx increases, and proteolytic enzymes are activated, further degrading structural proteins. Under these conditions, myocytes are no longer able to maintain membrane integrity. The release of myoglobin, creatine kinase and other cytosolic components into the bloodstream is a biochemical hallmark of this process and underlies both the laboratory abnormalities and many of the systemic manifestations.

The kidney is the organ that determines the systemic consequences of this cascade. Myoglobin filtered through the glomeruli in the setting of dehydration and acidic urine promotes tubular damage through several mechanisms that are now relatively well described [1-3,18]. Direct cytotoxicity, oxidative stress related to ferrihemate formation and intratubular cast formation all contribute to acute kidney injury. Reduced renal perfusion due to hypovolemia and vasoconstriction further aggravates the situation. In the presented case, the combination of low fluid intake during the day, consumption of caffeine and other stimulants, and training in a hot, poorly ventilated room created conditions in which the kidneys were exposed to a very high myoglobin load under clearly unfavorable hemodynamic circumstances. The prompt introduction of intravenous hydration appears to have played a key role in limiting the extent of kidney injury and avoiding the need for dialysis.

### 4.3.Epidemiological context and typical risk environments

Epidemiological data from recent years suggest that exercise-induced rhabdomyolysis is being diagnosed more frequently, although it is still probably under-recognized [4,6-9,13]. Reports from emergency departments and sports medicine clinics repeatedly describe young individuals who, after a long break from physical activity, returned to high-intensity group training and developed severe muscle pain with dark urine within the following day. Similar patterns are observed in military recruits starting basic training and in participants of indoor cycling or functional circuits [8,9,13,14]. In many of these case series, a significant proportion of patients had used pre-workout supplements or energy drinks before exercise, often without informing the attending physicians during the first contact. It is reasonable to assume that, beyond the published cases, a considerable number of milder episodes remain unreported or are mistaken for ordinary post-exercise discomfort.

### 4.4.Perception of symptoms and diagnostic delay

The way in which patients interpret their symptoms plays a crucial role in delaying diagnosis. In the present case, the severity of muscle pain was initially interpreted entirely within the framework of a “good workout” and “strong soreness”, and the dark urine was attributed to trivial dehydration. This is not surprising in an environment where training culture promotes the belief that extreme pain and exhaustion are proof of effort and willpower. As long as the patient is able to function, leaving the apartment and performing basic activities, the idea that a potentially life-threatening condition is developing in the background seems counterintuitive. Only when pain and functional limitations become truly overwhelming does the patient seek professional help. This pattern, repeatedly described in the literature, suggests that educational interventions should target not only physicians but also the broader fitness community.

For clinicians, especially in primary care and emergency settings, this means that maintaining an adequate level of suspicion is crucial. A young adult presenting with very severe muscle pain after unaccustomed exercise and dark urine should not be reassured too quickly, even if they appear otherwise healthy and hemodynamically stable. A short, focused history concerning the type, intensity and duration of exertion, the time interval between training and symptom onset, fluid intake, environmental temperature and the use of supplements can very quickly reveal a constellation strongly suggestive of exercise-induced rhabdomyolysis. In such a situation, measuring creatine kinase activity, assessing kidney function and performing a basic urinalysis are not sophisticated procedures but simple diagnostic tools that can determine further management and prognosis. The case presented here clearly shows how much information can be gained from a few targeted questions asked at the right moment.

**4.5.Training environments and the role of instructors**

The broader context of this case also involves the role of training environments and instructors. In many fitness clubs group classes are designed primarily with attractiveness and intensity in mind rather than with graded adaptation of the musculoskeletal system. Instructors are often evaluated by participants based on how "hard" a given class feels, and the narrative surrounding training emphasizes "pushing limits" and "leaving the comfort zone". Under such circumstances, individual differences in training history and current capacity are easily overlooked. A participant who has not exercised for months may be encouraged, directly or indirectly, to perform at a level similar to that of regular attendees. The risk of rhabdomyolysis is particularly high when this occurs on a hot day, in a crowded, poorly ventilated room, and is combined with stimulant use that blunts perception of fatigue. There is still relatively little structured guidance for trainers on recognizing when a participant's complaints go beyond normal exertional symptoms and may indicate a serious complication.

**4.6.Long-term consequences and the role of detraining**

An important practical question concerns the long-term consequences of an episode of exercise-induced rhabdomyolysis. Many patients, as in the present case, recover fully with appropriate treatment, and kidney function returns to normal. However, a subset of individuals may develop persistent reductions in glomerular filtration or be left with increased vulnerability to further insults, particularly if pre-existing subclinical kidney disease was present [2,3,22]. In some cases, recurrent episodes of rhabdomyolysis uncover an underlying myopathic or metabolic condition that had previously gone undiagnosed [2,3,22,23]. For this reason, an episode of EIR should not be viewed only as a one-off accident but rather as a signal that certain aspects of the patient's lifestyle and training approach require re-evaluation. This applies both to the individual and to the wider system of trainers, clubs and peers.

In addition to these individual risk factors, it is worth emphasizing that the physiological response to intense exertion after a prolonged period of inactivity is not linear but exponential. Muscles that have not been exposed to regular mechanical loading undergo a complex process of detraining, which affects not only strength but also mitochondrial density, enzymatic capacity and the efficiency of calcium handling within the sarcoplasmic reticulum. These microscopic changes do not manifest themselves in everyday functioning; a previously trained young adult may feel generally fit and assume that his former training abilities can be regained within a single session. In reality, the susceptibility to microdamage and metabolic decompensation increases sharply after only a few months of inactivity, and this vulnerability is particularly pronounced during eccentric movements performed under load. It is precisely this type of muscle work that predominates in many contemporary fitness programs, which combine speed, resistance and repeated transitions between exercises without adequate recovery.

**4.7.Thermoregulatory strain and individual susceptibility**

What deserves separate attention is the role of thermoregulatory strain, an aspect frequently overlooked by both exercisers and instructors. Heat generated during intensive muscle work must be dissipated efficiently, and this process is dependent not only on ambient temperature but also on humidity, ventilation and individual hydration status. In a warm and poorly ventilated training room the capacity to dissipate heat is significantly reduced. The rise in core temperature triggers a cascade of physiological reactions, including increased catecholamine release, vasodilation in the skin and redistribution of blood flow away from internal organs [2,14,18]. When this redistribution coincides with hypovolemia caused by dehydration, renal perfusion decreases at exactly the moment when the kidney must process an increasing load of myoglobin. This interplay of heat, dehydration and muscle breakdown has been repeatedly documented in military training environments and in endurance sports such as long-distance running, yet the same mechanisms apply equally to short, high-intensity circuit workouts when performed under extreme conditions.

Another important aspect is the variability in individual susceptibility to rhabdomyolysis, even among seemingly healthy young adults [22,23]. Genetic factors may influence the efficiency of energy metabolism within the muscle cell, tolerance to heat stress or the function of calcium channels. Although routine genetic screening is neither feasible nor recommended, clinicians should be aware that some individuals may cross the threshold of dangerous muscle injury more quickly than others, even when the external workload appears comparable. This variability partly explains why, within the same training group, only one or two participants may develop severe symptoms while others remain unaffected. It also underscores the importance of monitoring symptoms rather than relying solely on the subjective perception of exertion during the workout.

### 4.8.Psychological dimension of fitness culture and the role of supplements

The psychological dimension of modern fitness culture also plays a role. Many exercisers come to high-intensity group classes with the expectation that discomfort is an indicator of progress. The concept of "earning results" through physical suffering is deeply embedded in the marketing strategies of many gyms, which emphasize the transformative value of pushing beyond perceived limits [8,9,21]. While this mindset can motivate individuals to adopt healthier lifestyles, it simultaneously increases the risk that early warning signs of rhabdomyolysis will be ignored. A participant experiencing disproportionate pain, burning or weakness during a session may assume that these sensations are simply part of the "challenge" and continue exercising, thereby increasing muscle damage substantially. Instructors, often under pressure to maintain the tempo and intensity of the class, may unintentionally reinforce this attitude by encouraging participants to "push through" discomfort.

The widespread availability of pre-workout supplements further complicates this psychological picture. Many such products contain combinations of stimulants that mask central fatigue, increase perceived energy and alter the normal feedback mechanisms through which the nervous system communicates physical strain. This pharmacological "blunting" of early fatigue signals may lead participants to continue exercising at an intensity that their musculature cannot safely sustain [10-12,19,26-28]. Moreover, the variability in supplement composition, especially among products purchased online, raises concerns about undisclosed sympathomimetic compounds that could potentiate tachycardia, vasoconstriction or thermogenesis. These effects, although subtle during the workout, can contribute to cumulative physiological strain that predisposes to rhabdomyolysis even in the absence of exceptionally heavy loads.

### 4.9.Public health implications and prevention

From a public health perspective, the increasing prevalence of exercise-induced rhabdomyolysis among young adults raises broader questions about the adequacy of training supervision and the dissemination of accurate information regarding safe exercise practices. While elite athletes typically train under the guidance of experienced coaches who monitor hydration, rest and load progression, most recreational exercisers rely on generalized instructions [8,9,24]. Group classes rarely differentiate between participants at very different levels of training readiness. Furthermore, many fitness clubs do not provide structured guidance for individuals returning after long periods of inactivity, assuming that the social environment of group training will naturally encourage gradual adaptation. The case presented in this article suggests that this assumption may not always hold true, and that more explicit recommendations regarding progressive overload and hydration should be integrated into standard gym orientation materials.

There is also a growing body of evidence suggesting that the cultural shift toward time-efficient, high-intensity workouts may inadvertently increase the incidence of EIR [8,9,24]. Short sessions that promise maximal caloric expenditure in minimal time attract individuals who lack the baseline conditioning required to tolerate such intensity. The mismatch between the brevity of the workout and the physiological demands imposed on the musculoskeletal system is often underestimated, both by participants eager for rapid results and by instructors who assume that brief duration compensates for high workload. This misconception is particularly dangerous in individuals whose cardiovascular and metabolic systems have adapted to predominantly sedentary lifestyles, as they lack the buffering capacity to handle sudden surges in mechanical and metabolic stress.

Finally, it is important to note that exercise-induced rhabdomyolysis, although dramatic in presentation, exists along a continuum of muscle injury that is far more common than fully recognized [5,15,16]. Many exercisers experience milder elevations of creatine kinase or transient myoglobinuria after particularly demanding sessions, yet do not seek medical attention. These borderline cases are typically self-limiting, but they illustrate how close many individuals come to the threshold of clinically significant rhabdomyolysis without realizing it. Understanding this continuum can help clinicians provide nuanced advice, emphasizing that while physical activity is essential for health, the transition from inactivity to high-intensity training must be approached with deliberate caution.

**4.10.Differential diagnosis and further evaluation**

It is also worth considering the differential diagnosis that arises when a young adult presents with severe muscle pain, weakness and dark urine. Viral myositis, inflammatory myopathies, toxic muscle injury and hereditary metabolic disorders can all mimic elements of the clinical picture seen in exercise-induced rhabdomyolysis [2,3,22,23]. In practice, however, the temporal relationship with intense exertion, the absence of preceding systemic infection and the rapid decline in creatine kinase with supportive treatment strongly favor an exertional etiology. In the presented patient, there was no history of recurrent exercise intolerance, no family history suggestive of inherited myopathy and no use of drugs commonly associated with muscle toxicity. Hence, the episode was classified as uncomplicated exercise-induced rhabdomyolysis on a background of previously healthy musculature.

Nonetheless, clinicians should remain aware that in selected cases further evaluation is warranted after recovery. This may include detailed neuromuscular assessment or genetic testing, particularly if episodes recur or if rhabdomyolysis develops after relatively mild exertion. In the majority of young adults with a clear history of pronounced, unaccustomed high-intensity exercise and obvious precipitating factors such as dehydration and stimulant use, such extensive work-up is not necessary. However, informing the patient about the possibility of future reassessment if similar symptoms reappear is part of good clinical practice.

### 4.11.Exercise-induced rhabdomyolysis in the broader context of high-intensity training

Modern fitness culture promotes an image of physical activity that is simultaneously aspirational and demanding. High-intensity interval training, functional circuits, bootcamps and similar formats are presented as optimal solutions for people who are “busy but motivated” and want to achieve visible results in a short time. Social media amplify this message by constantly displaying dramatic training scenes, challenges based on extremely high numbers of repetitions and slogans that glorify fatigue and pain. For many young adults who spend most of the day sitting at desks or in front of screens, such content becomes a powerful stimulus to undertake radical changes in lifestyle.

Exercise-induced rhabdomyolysis can be seen as an extreme but logical consequence of this phenomenon. An organism that has adapted to a predominantly sedentary lifestyle over many months is suddenly subjected to loads resembling those tolerated by seasoned athletes. The cardiovascular system, muscles and thermoregulatory mechanisms are not given time to gradually adapt. At the same time, the use of stimulant-containing pre-workout products, widely available online and in sports nutrition shops, creates a sense of artificial readiness. Subjective energy increases, and early fatigue signals are perceived more as psychological weakness than as meaningful feedback from the body. Social expectations that a “serious” workout must leave one exhausted make it even harder to recognize when symptoms exceed normal limits.

The case discussed here fits this pattern almost archetypically. A young man with a previous history of regular training but a long recent break decides to “catch up” quickly. He chooses a class explicitly advertised as very intensive and oriented toward rapid results. He trains on a hot day, in a cramped and stuffy space, after relatively modest fluid intake and ingestion of a multi-ingredient pre-workout supplement. He pushes himself to perform at the level of more experienced participants, not wanting to lag behind. In the hours and days that follow, pain and functional limitations significantly exceed the typical experience of post-exercise soreness, yet the prevailing narrative of "you have to feel it to see results" continues to shape his interpretation. Only the persistence of dark urine and escalating difficulty with basic movements eventually overcome this narrative and lead him to seek help.

From a preventive perspective, this broader cultural context is as important as the pathophysiological mechanisms. Efforts to reduce the incidence of EIR cannot be limited to individual counseling in consulting rooms. There is a need for more systematic education addressed to trainers, gym owners and participants themselves, emphasizing that a return to physical activity after a long break should be planned rather than impulsive. It should be made clear that there is no single training protocol appropriate for everyone and that properly dosed physical effort must be tailored to the starting point, health status and goals of each person. The idea that every participant in a group class should perform the same number of repetitions with similar loads, regardless of background, is physiologically unfounded and potentially dangerous.

The role of supplements deserves separate attention. In everyday discourse they are often classified somewhere between food and pharmacological agents and are frequently perceived as harmless enhancers of motivation, focus or endurance. In reality many pre-workout formulations contain complex combinations of high-dose caffeine, plant-derived sympathomimetics and various other compounds whose cumulative effects on the cardiovascular system and thermoregulation are not fully understood. When these products are consumed by young adults who are dehydrated, stressed and unaccustomed to intense exercise, they may substantially increase the risk of complications such as EIR. For this reason, health professionals should treat questions about supplement use as an integral part of medical history-taking in physically active patients, particularly in those presenting with muscle or renal complaints. Similarly, trainers and gym staff should be encouraged to adopt a cautious attitude toward recommending or normalizing supplement use, especially in beginners.

### 4.12.Diagnostics and management in clinical practice

In daily practice rhabdomyolysis is not among the most frequent diagnoses, but it is certainly not so rare that it can be safely ignored. The key challenge lies less in the complexity of diagnostic tests and more in the ability to recognize clinical constellations that justify ordering them. The combination of recent intense or unaccustomed exertion, severe muscle pain and dark urine should automatically prompt consideration of rhabdomyolysis, even when the patient is young and outwardly appears fit [3,4,6,7].

In this context the measurement of creatine kinase activity remains a fundamental tool [1-3,25]. Its elevation is a sensitive, albeit nonspecific, marker of muscle injury. It is important to interpret CK values in relation to the overall clinical picture and to remember that reference ranges may vary depending on sex, muscle mass and habitual physical activity. Extremely high values, such as those exceeding tens of thousands of units per liter, usually indicate extensive muscle destruction and correlate with increased risk of acute kidney injury, although individual susceptibility also plays a role. Moderate elevations, when accompanied by typical symptoms and myoglobinuria, should not be dismissed as insignificant either.

Equally essential is the assessment of kidney function through serum creatinine, urea and estimated glomerular filtration rate. A dynamic view of these parameters, taking into account changes over the first hours and days of hospitalization, is particularly informative. Urinalysis, although sometimes treated as a routine and unremarkable test, acquires special importance here. The presence of dark, concentrated urine with a positive blood test on dipstick and simultaneous absence of red blood cells in the sediment constitutes a pattern that is highly suggestive of myoglobinuria. In combination with a compatible clinical history and CK elevation, this finding virtually confirms the diagnosis of rhabdomyolysis and allows the clinician to focus on appropriate management rather than further complex differential diagnostics.

Once the condition is recognized, prompt initiation of treatment is decisive. In the majority of cases the cornerstone of management is aggressive yet carefully monitored fluid therapy, aimed at restoring intravascular volume, increasing renal perfusion and diluting myoglobin within the tubular system [1-3,25]. The goal is to achieve and maintain adequate urine output while avoiding fluid overload. There is ongoing debate about the optimal type and volume of fluids in particular scenarios, and some protocols include the use of alkalinization or osmotic diuretics in selected patients. Clinical practice, however, consistently indicates that timing is at least as important as the precise regimen. Starting intravenous hydration early, before significant azotemia, hyperkalemia and metabolic acidosis develop, can markedly reduce the likelihood of requiring renal replacement therapy [1-3,25].

The decision to admit a patient to hospital versus managing them on an outpatient basis should be individualized, but in a young adult with very high CK values, elevated creatinine, hyperkalemia or significant systemic symptoms, observation in an inpatient setting is generally the safer option. Continuous monitoring allows for early detection of potential complications such as progressive kidney failure, arrhythmias due to electrolyte disturbances or signs of compartment syndrome. Avoidance of nephrotoxic drugs, careful choice of analgesics and regular laboratory assessment are components of comprehensive care in this phase. In addition, hospitalization offers an opportunity for structured education of the patient about risk factors, warning signs and strategies for safer exercise in the future.

In the presented case, the relatively early suspicion of rhabdomyolysis in primary care and the rapid referral to the emergency department were crucial for the favorable course. Had the patient decided to manage the situation on his own for another one or two days, the risk of severe, possibly irreversible kidney damage would almost certainly have been significantly higher. This underlines that in cases of potential EIR, physicians should not hesitate to recommend urgent evaluation, even if the patient initially minimizes their complaints or attributes them to benign causes.

**4.13.Return to physical activity and prevention**

Once the acute phase has been safely managed and laboratory parameters have returned to normal, attention naturally turns to the question of how and when the patient can resume exercise. This is often a sensitive topic, especially for young adults who associate physical activity with identity, stress reduction or social life. An overly restrictive or vague recommendation may lead to frustration, loss of motivation or unsupervised return to high-intensity training. On the other hand, overly optimistic assurances may foster premature resumption of harmful patterns. Striking a balance between caution and encouragement is therefore a central task for clinicians.

In conversations after discharge, the patient emphasized that his greatest fear was not so much kidney failure – which he associated with "older people" – but the idea that he might never again be able to train without anxiety. This concern is rarely articulated in formal guidelines, yet it strongly influences how young adults adhere to medical advice. Addressing such fears directly, acknowledging them as legitimate and helping the patient to rebuild a realistic, not punitive, relationship with exercise may be just as important as defining biochemical thresholds for safe return to training.

Although there are no universally accepted formal guidelines for return to physical activity after exercise-induced rhabdomyolysis, several principles emerge from clinical experience and the sports medicine literature. It is generally agreed that training should not be resumed until symptoms have resolved, muscle strength has recovered and CK values have normalized or clearly decreased to near-normal range [6,7,24]. Even then, it is advisable to begin with low-intensity activities such as walking or light cycling, focusing on restoring basic endurance rather than on maximal effort. Resistance training can be reintroduced later, initially at low loads and with careful attention to technique, range of motion and subjective perception of exertion.

The crucial point is that the intensity and volume of training should increase gradually rather than in sudden leaps. In practical terms, this means that, for several weeks, the patient should avoid training formats that are based on maximal number of repetitions in a fixed time, competitive circuits or "challenge" sessions. Particular caution is recommended in relation to eccentric-heavy exercises performed with external load, such as deep squats or lunges with weights, which place high mechanical stress on muscle fibers. It is also important to ensure adequate hydration before, during and after training sessions and to avoid exercising in extremely hot or poorly ventilated environments. A structured plan, preferably prepared in cooperation with an experienced trainer or physiotherapist, can help maintain discipline and reduce the temptation to return too quickly to pre-episode intensity.

The episode of rhabdomyolysis also provides an opportunity to review attitudes toward supplements. In many cases, including that described here, the patients themselves, once they have experienced serious complications, are inclined to discontinue pre-workout products or at least significantly reduce their use. This tendency can be constructively reinforced by providing clear information about the potential risks associated with stimulant mixtures and by encouraging reliance on sleep, nutrition and graded training rather than pharmacologically enhanced arousal. It is also useful to discuss with the patient how marketing strategies of the supplement industry may influence perceptions of what is necessary or beneficial.

From a wider preventive perspective, this case suggests that education should not be limited to patients who have already experienced EIR. Trainers, gym staff and university sports organizations are in a unique position to disseminate simple messages: that a prolonged break from activity requires a period of adaptation; that "more" is not always "better"; that unusual, very intense pain, especially when associated with dark urine or marked weakness, is a reason to stop exercising and seek medical advice rather than to continue training. Integrating these messages into introductory materials for new club members or campus fitness programs would be a relatively low-cost intervention with potentially significant impact. At the same time, including basic information about rhabdomyolysis in medical curricula and continuing education for physicians can improve early recognition and management.

## 5. CONCLUSIONS

Exercise-induced rhabdomyolysis in young adults is not a marginal phenomenon, especially in the setting of high-intensity training and a culture of "quick results". The presented case shows that a single workout may be enough to trigger a full-blown episode when several predisposing factors coincide: a long break from activity, an overly ambitious training program, unfavorable environmental conditions, insufficient fluid intake and the use of stimulant-containing pre-workout products.

From a clinical perspective, diagnostic vigilance is crucial. A young patient with very severe muscle pain after exertion and dark urine deserves more than a diagnosis of “bad soreness”; rhabdomyolysis should be actively considered. Early measurement of creatine kinase activity, assessment of kidney function and urinalysis allow rapid confirmation of the diagnosis and initiation of intensive hydration, which often suffices to prevent severe acute kidney injury. The case also illustrates how much can be achieved through simple interventions, provided that they are implemented at the right time.

At the same time, this case highlights that treating the acute phase is only part of the task. Equally important is the conversation with the patient about safe return to exercise, gradual progression of training loads, the role of hydration and a rational approach to supplements. There is also a need for broader education aimed at trainers and the fitness community to reduce the number of situations in which untrained individuals are thrown into programs designed as if all participants had the background of seasoned athletes. Recognizing exercise-induced rhabdomyolysis as a predictable and preventable consequence of certain patterns of behavior, rather than as an unpredictable accident, can help shift the focus toward effective prevention.

Exercise-induced rhabdomyolysis will most likely remain a real clinical problem as long as physical activity is linked with pressure to “push the limits”. There is no need to frighten every gym-goer with it, but it is worth making it a natural element of how physicians, trainers and exercisers themselves think about what can go wrong when ambition outruns common sense. Adequate early awareness and a handful of simple questions asked in the doctor’s office or on the training floor may, in practice, save more than one pair of kidneys from irreversible damage.

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**Author Contributions**

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