A Performance Analysis of HYROX: A Review of the Physiologic, Mechanical, and Technical Demands

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ABSTRACT

Hybrid fitness competitions such as HYROX have rapidly gained popularity, blending aerobic endurance running with a variety of high-intensity resistance- and ergometer-based stations in a globally standardized format. The sport's unique structure, comprising eight 1-kilometer runs interspersed with diverse workload stations, presents distinct physiologic, biomechanical, and technical demands. This review synthesizes existing research on hybrid fitness events to identify the key determinants of HYROX performance, emphasizing aerobic capacity, anaerobic power, local muscular endurance, and maximal strength. The aerobic system is foundational, enabling recovery between high-intensity efforts and sustaining performance during the event's prolonged duration. Conversely, anaerobic capacity is critical for executing the high-intensity efforts demanded by each fitness station. Local muscular endurance supports repeated submaximal contractions, while strength and power underpin performance in movements such as sled pushes and running economy. Technical proficiency and injury prevention strategies are also discussed, alongside targeted programming recommendations, including high-intensity interval training, circuit training, and blood flow restriction methods. Despite its growing popularity, limited sport-specific research exists, necessitating further investigation to refine training and performance strategies. This review provides a comprehensive framework for athletes and coaches to optimize preparation and performance in HYROX, contributing to the broader understanding of hybrid fitness competitions.

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INTRODUCTION

"Hybrid fitness" is a novel term that describes the integration of aerobic endurance-based exercise with resistance-based exercise within a workout or training program and, thus, requires the development of a broad range of physical attributes. Hybrid fitness competitions blend elements from various training modalities (high-intensity interval training, strength training, running, etc.) into a race-style format, where athletes must complete the event as quickly as possible. Such competitions have gained immense popularity in recent years, with HYROX emerging as one of the most prominent events in this category. Unlike other fitness competitions, HYROX offers a globally consistent race format, comprising eight 1-kilometer runs interspersed with various short duration (~2–5 minutes), high-intensity stations such as sled pushes, rowing, and wall balls that challenge different strength qualities (i.e., strength-endurance, explosive strength). This combination of strength and aerobic endurance presents unique physiologic demands and makes HYROX a distinctive test of overall fitness, appealing to recreational athletes and elite competitors.

Understanding the demands of a sport is critical for optimizing athlete preparation and performance, a process often facilitated through a needs analysis (28). A needs analysis identifies the physiologic, biomechanical, and technical

KEY WORDS:
needs analysis; functional fitness; hybrid fitness; performance determinants

requirements of a sport, guiding the development of training programs that target key performance indicators (24). Typically, this process is achieved by synthesizing literature on the activity in question. Although needs analyses have been extensively conducted for team sports (52) and individual aerobic endurance events (6), there is a lack of comprehensive data specifically addressing the unique demands of HYROX. This gap in knowledge poses challenges for athletes and coaches aiming to design evidence-based training interventions. However, given the absence of sport-specific research on HYROX, it is necessary to adopt a physiologic plausibility approach–drawing on established principles of exercise physiology and findings from related disciplines. This review synthesizes data from endurance and hybrid fitness competitions to infer performance determinants and training implications for HYROX. Although this approach provides meaningful insights, it is important to recognize the limitations of extrapolating from related disciplines, because variations in movement patterns, energy system contributions, and competition structure may influence specific physiologic demands. Future studies should aim to validate these assumptions by conducting direct analyses of HYROX athletes in controlled settings, particularly regarding training responses, injury risk, and physiologic adaptations over time.

Until research is conducted specifically on HYROX athletes, this review aims to bridge the gap by synthesizing existing literature on hybrid fitness competitions and related disciplines. Many of these events involve similar activities and share comparable strength and aerobic endurance demands. Data from hybrid fitness competitions and obstacle course races may provide valuable insights for practitioners until more HYROX-specific research becomes available. In addition, by drawing from studies on both anaerobic- and aerobic-dominant endurance sports, as well as performance data from actual HYROX events, this review aims to provide a detailed understanding of what it takes to excel in this rapidly growing competition. The primary objectives are to (i) analyze the physiologic, biomechanical, and technical demands of HYROX, (ii) provide evidence-based and practical insights for optimizing training and performance, and finally, (iii) identify areas requiring further research. Ultimately, the findings presented here will serve as a foundation for advancing both practical applications and future research in this exciting and evolving sport.

AN OVERVIEW OF THE SPORT

A HYROX event consists of 8 fitness stations, each interspersed with 1-kilometer intervals, for a total of 8 kilometers of running. Participants are required to complete the stations and run in a fixed order, with the entire event performed against the clock. This format demands proficiency in both aerobic endurance running and various strength- and anaerobic-dominant activities. Unlike other fitness competitions that include varied events, HYROX events follow a specific, repeatable structure, allowing for measurable progression and comparison across races.

Four distinct categories determine the weights, distances, and repetitions required during the race: Open, Pro, Doubles, and Relay. These categories are further divided into male, female, and mixed divisions, each with specific requirements for weights, distances, and repetitions. The Open and Pro categories are individual competitions, with a single athlete completing all prescribed activities. In contrast, the Doubles and Relay categories allow participants to distribute the event activities among 2 and 4 athletes, respectively. A detailed description of the 8 physical stations, the running component, and the required resistances, durations, and repetitions for each category are presented in Table 1.

ENERGY SYSTEM REQUIREMENTS

AEROBIC CAPACITY

Maximal oxygen uptake ($\dot{V}O_2max$) serves as a key determinant of performance in hybrid fitness competitions, given the often heavy emphasis on aerobic endurance-focused activities such as running and ergometer-based stations (19,51). Accordingly, individuals with a higher $\dot{V}O_2max$ completed a hybrid fitness workout–including 400 m running intervals and overhead squats–significantly faster, with $\dot{V}O_2max$ accounting for 68% of the variation in completion times (19). Although no direct studies have quantified the $\dot{V}O_2max$ of HYROX athletes specifically, evidence from elite-level athletes who compete in similar hybrid fitness competitions indicates values of 62.7 ± 3.4 mL/kg/min for male athletes and 55.7 ± 4.2 mL/kg/min for female athletes (55). These values align with those reported for high-level aerobic endurance athletes (33,44), highlighting the critical role of a well-developed aerobic system in this sport. However, the $\dot{V}O_2max$ values reported above fall below those typically observed in athletes participating in prolonged aerobic endurance disciplines, such as cross-country skiing or long-distance running (>70 mL/kg/min) (44), suggesting a greater contribution of alternative physical attributes. Notably, even in sports with a substantial anaerobic component, such as rowing, a high aerobic capacity is considered a fundamental prerequisite (33). This underscores the importance of adequate maximal oxygen uptake in hybrid fitness events such as HYROX. Estimated energy system contributions during HYROX events and other comparable sports are outlined in Table 2.

In addition, heart rate (HR) data collected during longer duration (>40 minutes) hybrid fitness competitions indicate average values of 70–90% of maximum HR (HRmax) (8), further underscoring the sustained cardiovascular demand of these types of events. Figure 1 displays the heart rate trace from an elite male HYROX athlete during competition, aligning with the empirical evidence from related disciplines.

Official data reported on the HYROX website indicates that the total event duration is 55:01 ± 00:57 for the top

Table 1
An overview of the activities involved in a HYROX race and the distances, repetitions, and resistances associated with each event category

Activity	Description	Resistances		
		Males pro	Females pro/males open/ mixed	Females open
Run intervals	8 × 1 km efforts that are completed before each of the 8 stations			
Ski ergometer	1,000 m effort on the ski ergometer	Dampener setting can be adjusted as desired		
Sled push	A weighted sled must be pushed up and back a 25 m course	202 kg	152 kg	102 kg
Sled pull	A weighted sled must be pulled up and back a 25 m course using a rope	153 kg	103 kg	78 kg
Burpee broad jumps	The athlete must complete an 80 m track by performing a chest-to-floor burpee followed by a broad jump			
Row ergometer	1,000 m effort of the row ergometer	Dampener setting can be adjusted as desired		
Farmers carry	The athlete must carry 2 kettlebells along a 200 m track	2 × 32 kg	2 × 24 kg	2 × 16 kg
Sandbag lunges	The athlete must perform walking lunges along a 100 m track with a sandbag carried on the shoulders	30 kg	20 kg	10 kg
Wall balls	The athlete must perform a squat with a weighted ball and throw the ball at marked target on completing the repetition. 100 valid repetitions must be completed	9 kg	6 kg	4 kg

Activities are listed in the order they must be completed.

10 male athletes (Men's Pro category) and 60:24 ± 01:09 for the top 10 female athletes (Women's Pro category) (Table 3; HYROX, Results & Rankings, 2025). Recreational participants in the Open Solo category often take ~70–90 minutes, while Open Doubles competitors complete the event in ~50–70 minutes. Of the total duration, athletes spend approximately 50% (~27–33 minutes) completing the 8 1-kilometer runs, representing a substantial portion of the event (Table 3). Evidence from aerobic endurance-based events of similar duration suggests that while $\dot{V}O_2max$ does not always differentiate between high- and low-level performers, a requisite level of aerobic fitness is essential (6). Instead, superior performance may be more closely tied to anaerobic factors, such as lactate threshold and the ability to sustain high percentages of $\dot{V}O_2max$. Although HYROX includes high-intensity activities such as burpee broad jumps, sled pushes, and ergometer rowing, aerobic capacity plays a key role in recovery between these efforts. Enhanced aerobic fitness supports lactate clearance and phosphocreatine regeneration, delaying fatigue and enabling sustained high-intensity performance (71). Even in the doubles category, where rest periods are more frequent, recovery is likely still incomplete, given that complete resynthesis of phosphocreatine takes 3–5 minutes (28). Together, these data suggest that developing a robust aerobic base is essential for success in HYROX, particularly in solo categories where recovery opportunities are minimal.

ANAEROBIC CAPACITY

Perhaps more critical to HYROX performance is an athlete's anaerobic capacity. Each of the fitness stations requires bursts of near-maximal effort lasting approximately 3–4 minutes (Table 3), which is also evidenced by the HR spikes recorded during competition (Figure 1). As such, the ATP-PC system is crucial to support explosive actions such as sled pushes, burpee broad jumps, and initial accelerations in running and ergometer-based activities. However, the prolonged duration of each station suggests a significant reliance on anaerobic glycolysis for energy production and would imply that a high lactate threshold would provide a clear performance advantage (Table 2).

In aerobic endurance-based tasks lasting 30–60 minutes, the lactate threshold–or, more precisely, the exercise intensity associated with the lactate threshold–has been shown to predict performance among

Table 2
Energy system contributions, physiologic responses, and work-to-rest profiles to various related activities *values are estimated based on existing literature in related activities

Sport	Duration	ATP-PC (%)	Glycolysis (%)	Oxidative (%)	Average HR (%HRmax)	Blood lactate (mmol/L)	Work-to-rest profile	Reference
HYROX® solo	~60–90 min	5-10*	20-30*	60-70*	70-90*	8–12*	Continuous, minimal rest	N/A
HYROX® doubles	~50–70 min	10-15*	25-35*	55-65*	70-90*	6–10*	Intermittent, ~3:1	N/A
Hybrid fitness WODs	~5–30 min	10–20	25–35	50–60	70–90	8–14	Continuous, minimal rest	Rios et al. (54)
Rowing (2000m race)	~6–8 min	~5	~20	~75	90–95	10–16	Continuous	Martin & Tomescu (39)
Middle distance running (10 km race)	~30–40 min	<5	5–10	90–95	~90	4–8	Continuous	Brandon (6)
Team sports (e.g., soccer)	~80–90 min	5–10	10–15	75–85	80–90	3–9	Intermittent, 1:3–1:6	Bangsbo (2)

WOD = workout of the day.

individuals with similar $\dot{V}O_2$max values (14). This relationship likely extends to the sport of HYROX, where a high $\dot{V}O_2$max is a "prerequisite" for competing at an elite level. However, distinguishing performance among athletes at this level is likely determined more by the ability to sustain a high fraction of $\dot{V}O_2$max and effectively mitigate lactate accumulation. Unfortunately, limited direct data currently exist on the blood lactate responses of HYROX athletes, necessitating analogous data from similar activities to infer its role in energy metabolism.

Studies incorporating various high-intensity exercises, such as those found in HYROX, provide relevant insights. For instance, recreational athletes performing a 5-minute near-maximal effort on a ski ergometer exhibited blood lactate concentrations of 8–10 mmol/L (75). Comparable lactate levels (>10 mmol/L) have been reported during various hybrid fitness workouts involving exercises such as running, wall balls, rowing, and burpees–activities featured in HYROX (8,23,69). Notably, many of the hybrid fitness sessions reported in the literature are usually shorter in duration than HYROX events (~20 vs. ~60 minutes), which may permit higher intensities and, thus, greater blood lactate levels in comparison with a HYROX event. Although, when the acute physiologic responses were measured during a 10-kilometer obstacle course race (lasting approximately the same duration as a HYROX event and predominantly involving running), post-race blood lactate values were in the same range (9–10 mmol/L) (53). These findings suggest that HYROX likely elicits comparable anaerobic demands, emphasizing the importance of glycolytic energy system development.

Although anaerobic glycolysis is the dominant energy system in HYROX, the ATP-PC system remains essential for short, high-intensity efforts. Evidence links anaerobic power to performance in hybrid fitness contexts, with maximal anaerobic power (e.g., ski-ergometer sprint speed) strongly correlating with an 800-meter ski ergometer time trial ($r = 0.922$) (61). In addition, higher-performing hybrid fitness athletes exhibit significantly greater peak and average power outputs during a 30-second Wingate test (40). These findings underscore the importance of maximal and near-maximal sprint efforts in training to enhance ATP-PC system function, supporting explosive power and overall performance.

The type of HYROX event likely influences the extent ATP-PC and glycolytic systems contribute to performance. In Solo competitions, limited rest periods may increase reliance on buffering metabolic byproducts, highlighting the importance of lactate clearance capacity. Indeed, intermittent recovery periods of 1 minute during a hybrid fitness circuit have been observed to significantly reduce lactate accumulation (30). Thus, it may be argued that intermittent rest periods, such as those afforded during HYROX Doubles, may enable higher-intensity efforts, potentially increasing the contribution from the ATP-PC system. Future research is needed to clarify these distinctions and optimize training strategies for different HYROX

Figure 1. A representative heart rate (HR) trace from an elite male athlete during a HYROX Pro Singles event. The athlete has an age-predicted maximum HR of 188 beats per minute (bpm). Data were collected from a WHOOP arm strap.

formats. Together, the findings discussed above underscore anaerobic capacity as a fundamental component of HYROX performance, necessitating targeted training to enhance athletes' ability to produce and sustain high-intensity efforts.

LOCAL MUSCULAR ENDURANCE

Local muscular endurance (LME), often referred to as strength-endurance, represents the ability of muscles to resist fatigue and sustain force production under submaximal resistances (28). This quality is typically quantified as the total work or repetitions completed within a given time frame, reflecting both muscular and metabolic efficiency. Although LME is frequently categorized as a strength attribute, its physiologic determinants likely include capillarization and mitochondrial content, which influence fatigue resistance and energy production (56).

In HYROX, several event stations, such as wall balls and walking lunges, place substantial demands on LME. The repetition and distance requirements of these stations require participants to perform prolonged submaximal muscular contractions, often lasting 3–4 minutes (Table 3). Consequently, a well-developed LME capacity, particularly in the lower body, is critical for optimizing performance in these events.

Empirical evidence from high-intensity hybrid fitness research underscores the relevance of LME to athletic performance. Studies examining hybrid fitness athletes have reported strong correlations between LME and workout performance, with correlation coefficients ranging from $r = 0.62$ to 0.89 (68,70). These findings suggest that LME significantly influences an athlete's ability to sustain effort across diverse, high-repetition tasks.

Given these insights, it is reasonable to infer that enhancing LME would directly benefit HYROX athletes by delaying the onset of fatigue. This adaptation allows competitors to complete more repetitions or sustain continuous effort during high-demand stations, reducing the need for recovery pauses and ultimately improving overall event performance. Thus, training programs to increase LME, particularly in the lower body, should be prioritized for HYROX athletes.

MECHANICAL DEMANDS

MAXIMAL AND EXPLOSIVE STRENGTH

Although none of the fitness stations in HYROX explicitly test maximal strength, this is still likely a critical determinant of performance in the sport. A greater capacity to produce force provides a distinct advantage in stations such as sled pushing and pulling, because the sled weights in HYROX are fixed and not individualized to body mass, meaning stronger individuals can generate higher force outputs for faster and more efficient movement. Furthermore, an elevated ceiling of maximal strength reduces the relative intensity of submaximal tasks (43), such as walking lunges and wall balls. This diminishes the neuromuscular strain per repetition, enhancing muscular endurance and maintaining performance across the event (43).

Lower body explosive strength is particularly important for exercises such as burpee broad jumps, where a greater ability to produce force rapidly allows athletes to cover more ground with fewer repetitions, reducing overall effort. Beyond specific stations, maximal and explosive strength are closely linked to improved running economy (45), which is vital given the substantial running component of HYROX. Enhanced strength reduces energy cost per stride, enabling sustained running performance over long distances (21).

Empirical evidence from related hybrid fitness competitions supports the role of maximal strength as a key determinant of performance. For example, a study found that back squat 1-repetition maximum (1RM) accounted for 41% of performance variance in a workout involving barbell thrusters (a front squat combined with a push press) and pullups (21, 15, and 9 repetitions performed for each movement) (19). In addition, back squat 1RM significantly correlated with another workout comprising 5 rounds

Table 3
Time in minutes spent completing each component of a HYROX pro singles race

Event component	Males	Females
Race total	55:01 ± 00:57	60:24 ± 01:08
Run intervals	29:24 ± 01:12	31:18 ± 01:48
Ski ergometer	03:48 ± 00:12	04:18 ± 00:06
Sled push	02:12 ± 00:18	02:24 ± 00:18
Sled pull	03:06 ± 00:18	03:42 ± 00:24
Burpee broad jumps	02:36 ± 00:23	03:22 ± 00:25
Row ergometer	03:57 ± 00:08	04:27 ± 00:10
Farmers carry	01:33 ± 00:19	01:38 ± 00:13
Sandbag lunges	03:06 ± 00:22	03:35 ± 00:21
Wall balls	03:46 ± 00:15	03:41 ± 00:26

Data were obtained from the best performances of the top 10 male and female HYROX athletes as of January 2025.

Data are presented as mean ± SD. Durations are presented as minutes: seconds. Data obtained from the official HYROX website: https://results.hyrox.com/season-7/?pidp=ranking_nav&pid=list_overall.

of a 400 m run and 15 overhead squats (19). Other research observed significant positive correlations between squat 1RM and diverse hybrid fitness workouts, which share similarities with HYROX exercises, such as wall balls, walking lunges, rowing, and burpees (41).

Rate-dependent strength measures also demonstrate relevance. Countermovement jump height and reactive strength index showed moderate-to-strong correlations (r = 0.51–0.89) with performance in hybrid fitness workouts (40). Furthermore, lower body strength has been shown to protect against fatigue-induced declines in high-intensity actions (r = 0.72) in rugby athletes (25), suggesting a role in maintaining performance under HYROX's demanding conditions.

Finally, maximal and explosive strength likely enhances an athlete's capacity to tolerate the high training volumes required for HYROX preparation while reducing injury risk. Stronger athletes demonstrate better resilience to increased workloads and lower susceptibility to injury (36), making these qualities essential for both performance and long-term health. Together, these data strongly advocate for the prioritization of maximal and explosive strength development by HYROX athletes and coaches.

MOBILITY

While mobility may not be a primary determinant of success in HYROX, a requisite level is essential for optimal performance. Specific movement standards, such as achieving hip depth below the knees during wall balls or touching the trailing knee to the floor during walking lunges, highlight the importance of sufficient ankle and hip mobility. Athletes with limitations in these areas may struggle to meet these criteria, risking invalid repetitions or penalties. In addition, reduced ankle range of motion has been linked to poorer jumping performance (46), potentially necessitating more repetitions during the burpee broad jump station, thereby increasing time and energy expenditure.

Despite its role in some stations, improving mobility may not universally enhance HYROX performance. For example, research on rowing performance has shown that flexibility and range of motion do not significantly differentiate higher- and lower-level performers (35), suggesting that mobility beyond normal levels is unlikely to improve performance in ergometer-based stations. Thus, mobility in HYROX seems to serve as a foundational attribute to meet movement standards and prevent inefficiencies rather than as a critical factor influencing success across all events.

BODY COMPOSITION

Although no formal data currently exist on the anthropometric characteristics of top HYROX performers, evidence from related hybrid fitness disciplines highlights the critical role of body composition in optimizing performance. Research on elite athletes from another hybrid fitness competition indicates a strong relationship between body fat percentage and performance outcomes. For example, 1 study demonstrated a significant correlation (R^2 = 0.52) between body fat percentage and time to completion in a hybrid fitness workout lasting approximately 43 minutes, which included two 1-mile runs and bodyweight strength exercises (8). Another study identified body composition metrics, such as body fat percentage, body density (derived from air displacement plethysmography), and muscle mass, as the strongest predictors of performance across various hybrid fitness workouts (37).

These findings suggest that for events such as HYROX, which incorporate bodyweight movements and aerobic endurance challenges, a low body fat percentage and adequate lean muscle mass are essential. Together, they enhance the power-to-weight ratio, enabling athletes to efficiently generate force relative to their body weight. This optimized power-to-weight ratio is likely a key determinant of success in HYROX, underscoring the importance of targeted body composition training and management for competitive athletes in this emerging sport.

INJURY EPIDEMIOLOGY

Currently, there is no published data on the injury incidence specific to HYROX competitors. However, research from other hybrid fitness disciplines indicates an injury incidence rate of approximately 2.3 injuries per 1,000 hours of training (42). Common injury sites reported in these contexts include the shoulder, lower back, and knee (42). Increased weekly training hours and competition frequency seem to elevate injury risk, emphasizing the need for careful management of the training load (42). This is particularly relevant in HYROX, where the concurrent development of strength and endurance qualities requires high training volumes that, if poorly managed, may lead to overuse injuries.

Running-related injuries (RRIs) are of particular concern in HYROX, given the repeated transitions between strength-based exercises and running. Research suggests that fatigue-induced alterations in running gait can lead to asymmetrical loading of the hip, knee, and ankle joints, which may contribute to injury development (26). Patellofemoral pain syndrome (PFP) and iliotibial band syndrome (ITBS) are among the most common RRIs, both classified as overuse injuries (65). Furthermore, Poston et al. (49) reported that hybrid fitness training generally poses no greater injury risk than traditional exercise modalities and may result in lower injury rates than running alone. This suggests that within HYROX, the running component–particularly when performed under fatigue–may be the primary driver of injury risk.

Beyond running, sufficient trunk control is critical across many HYROX stations to maintain stability, optimize force transfer, and reduce injury risk. Movements such as the sled push, sled pull, and farmers carry require strong core engagement to prevent excessive lumbar flexion and lateral instability, which can contribute to lower back strain. Poor core control has been linked to increased injury risk, including lower back pain and lower limb dysfunctions such as knee valgus, a known contributor to conditions such as PFP and anterior cruciate ligament injuries (74). Given the demands of HYROX, athletes should incorporate strategies that enhance trunk stability and mitigate fatigue-related biomechanical compensations to reduce injury risk and improve performance.

To mitigate injury risks, HYROX athletes may benefit from strategies that allow for the concurrent development of strength and energy system conditioning while minimizing overall training volume. Effective periodization, cross-training, and tools such as blood flow restriction (BFR) training could be critical in balancing these competing demands and reducing the likelihood of overuse injuries. Such strategies are discussed in the "Programming Recommendations" section below. Further research is needed to better understand the injury patterns specific to HYROX and to develop targeted injury prevention strategies.

TECHNICAL DEMANDS

Although performance in HYROX is primarily influenced by an athlete's physiologic attributes, technical proficiency is critical in optimizing performance outcomes. An effective technique during ergometer-based stations, such as rowing or skiing, enhances movement economy, reducing energy expenditure and allowing athletes to sustain effort over the event's duration. In support of this, it was noted that elite-level runners significantly improved their performance in assessments of anaerobic and aerobic power performed on a ski ergometer after a 6-month cross-country skiing talent transfer program (63). The lack of change in $\dot{V}O_2max$ implies that performance improvements were related to enhanced technical proficiency, highlighting the need to prioritize skill development and physiologic adaptation in preparing for a HYROX race.

Similarly, sled pushing and pulling involve external resistance that must be overcome through effective force application. Based on biomechanical principles, maximizing horizontal force application is likely beneficial for optimizing displacement of the sled. Engaging large muscle groups, including the glutes, hamstrings, and quadriceps, is essential for maintaining efficiency and minimizing fatigue during these high-resistance tasks. Furthermore, specific stations, such as wall balls, necessitate accuracy to hit designated targets. Mastery of this skill reduces the risk of penalties or invalid repetitions, which could negatively affect overall performance. Addressing these technical demands is vital to complement physiologic preparation and optimize competitive success in HYROX.

PROGRAMMING RECOMMENDATIONS

Training recommendations should be tailored to the athlete's experience level, balancing the development of the key qualities identified above. Table 4 provides an overview of programming recommendations by competitor level. Novice competitors may benefit from a focus on foundational strength and aerobic endurance, whereas advanced competitors require a greater emphasis on explosive strength, anaerobic power, and race-specific simulations.

DEVELOPMENT OF MAXIMAL AND EXPLOSIVE STRENGTH

To optimize performance in HYROX, a comprehensive resistance training program should prioritize the development of maximal dynamic and explosive strength. These attributes are crucial for enhancing running economy (45) and mitigating injury risks associated with the high training loads typical of the sport (36).

A well-rounded program should target the entire body but emphasize lower-body development, given its central role in running and many HYROX-specific movements. Evidence from team sport athletes, who must similarly balance diverse fitness qualities such as strength, muscular endurance, and aerobic capacity, suggests that a training frequency of 2 sessions per week is both effective and practical for achieving these goals (15). Although higher frequencies may further enhance adaptations, 2 sessions per week seem to be a viable approach given common time constraints in applied settings.

Key elements of the program should include the prioritization of compound lifts, such as squats and lunges, performed with high loads and low repetitions. This approach aligns with established guidelines for building maximal strength (28). Incorporating plyometric exercises is equally critical for the development of rate of force development and improved jumping ability, which can directly benefit movements such as sled pulls, burpee broad jumps, and other dynamic tasks in HYROX competitions (18).

HIGH-INTENSITY INTERVAL TRAINING

High-intensity interval training (HIIT) is a core component of conditioning for HYROX athletes, because it allows for the simultaneous development of aerobic capacity and anaerobic power (7). As such, HIIT provides a time-efficient approach for athletes to prepare for the diverse demands of HYROX, which have been outlined earlier in this review. To optimize specificity for HYROX, HIIT sessions should primarily use modalities that mirror event requirements, such as running, ski ergometers, and rowing ergometers. Cycling may also be incorporated as a lower-body conditioning alternative that minimizes musculoskeletal loading, offering recovery benefits while maintaining a training stimulus (64).

Interval training protocols can be tailored to develop specific energy systems, although adaptations occur across a continuum rather than within rigid categories. Short intervals of 15–30 seconds at intensities near or above maximal aerobic speed (MAS) or maximal aerobic power (MAP) primarily target anaerobic power, with contributions from the aerobic system in replenishing phosphocreatine stores and supporting repeated efforts (7). Recent findings, such as those by Thurlow et al. (67), demonstrate that even very short intervals (e.g., <10-second efforts) at maximal intensity can elicit meaningful improvements in aerobic capacity alongside anaerobic qualities such as repeat sprint ability. Conversely, longer intervals of 3–4 minutes, performed at or slightly above critical speed or maximal lactate steady state, emphasize aerobic capacity by promoting sustained oxidative energy system engagement and improving oxygen utilization efficiency (72). This approach is particularly effective for developing the physiologic attributes necessary for prolonged, high-intensity efforts seen in HYROX competition. Therefore, various interval protocols may be used for energy system development in hybrid fitness athletes, although consideration should be given to the athlete's individual profile. Short intervals (15–30 seconds) and repeat sprint intervals (<10 seconds) may be preferable if anaerobic glycolysis development is a priority.

Intensity for short, moderate, and long intervals should be prescribed based on MAS or MAP, which can be determined through maximal efforts lasting 5–7 minutes for each exercise modality (e.g., running, skiing, or rowing), with the average speed or power output serving as a reference for interval targets (16,62). Alternatively, intensity for repeat sprint intervals should be maximal (67).

Selecting work-to-rest ratios is critical in ensuring that athletes achieve the intended physiologic stimulus. For short intervals (≤30 seconds), a 1:1 or 1:2 ratio is commonly prescribed to allow for partial recovery while maintaining high-intensity outputs across multiple repetitions. Shorter recovery periods (e.g., 15 seconds on/15 seconds off) emphasize aerobic contributions because of the incomplete resynthesis of phosphocreatine, while slightly longer recovery periods (e.g., 30 seconds on/60 seconds off) permit greater anaerobic engagement by allowing for higher work intensities to be sustained (7). For moderate-length intervals (30 s–2 minutes), work-to-rest ratios between 1:1 and 2:1 are typically used, with shorter recovery periods facilitating aerobic adaptations (72) and longer recovery periods supporting anaerobic power development (27). Longer intervals (≥3 minutes) generally use a 2:1 ratio (e.g., 4 minutes work/2 minutes rest), which enables athletes to sustain elevated work intensities while allowing for partial metabolic recovery, optimizing aerobic endurance adaptations (58). These considerations are essential in designing HIIT protocols that align with the physiologic demands of HYROX competition.

CIRCUIT TRAINING

Circuit training is arguably the most sport-specific format for preparing athletes for HYROX competitions. This training modality integrates full-body muscular endurance, aerobic power, and anaerobic capacity by combining aerobic activities with low-resistance strength exercises in a sport-specific context (50). Research has demonstrated that circuit-style training can simultaneously enhance both aerobic and anaerobic fitness components, because it challenges multiple physiologic systems within a single session (1,50). Specifically, this format has been shown to improve $\dot{V}O_2max$, lactate threshold, and muscular endurance, key determinants of performance in hybrid endurance events such as HYROX (38).

Despite incorporating strength exercises, circuit-based sessions can elicit a high level of oxygen consumption, with studies reporting values as high as 93% of $\dot{V}O_2max$ (20). Moreover, HR and blood lactate values during exercise are significantly higher during circuit training than during traditional strength exercise (38). Importantly, this elevated cardiorespiratory demand is observed during exercise and translates into meaningful physiologic adaptations over time. For instance, high-intensity circuit training has been found to elicit improvements in both maximal aerobic capacity and anaerobic power, reinforcing its utility in developing the key energy systems required for HYROX competition (11,50).

The design of circuit training programs for HYROX should prioritize high intensities with lower overall volume, a strategy that yields superior results in comparable populations such as MMA athletes (34). These circuits should incorporate work-to-rest ratios ranging from 3:1 to 6:1 to ensure sustained effort and conditioning at or above sport-specific intensities. Target intensities should range from 75 to 95% of HRmax, with session durations spanning 30–60 minutes to align with the time demands of HYROX races. Finally, some evidence suggests there may be an advantage to placing aerobic endurance-based activities before strength-based activities in these integrated circuit-based sessions if maximizing aerobic capacity improvements is a priority (11). By adhering to these programming guidelines, circuit training can effectively prepare athletes for the multifaceted demands of HYROX, enhancing both their physiologic capacity and sport-specific technical performance.

CONTINUOUS AEROBIC TRAINING

Continuous aerobic training can play a valuable role in HYROX preparation, particularly for recovery, improving movement economy, and refining technique (3). These sessions should be conducted at lower intensities, consistent with the principles of polarized and pyramidal training, which are used by elite-level aerobic endurance athletes (9,57). Both approaches dictate that most aerobic endurance training sessions (75–80%) should occur at intensities below the lactate threshold, because these sessions can still provide a stimulus for aerobic adaptation yet minimize the accumulation of fatigue (57). Intensity for such sessions can also be monitored using HR and rating of perceived exertion (RPE), with typical targets being 60–70% HRmax and 3–4 RPE on a 10-point scale, respectively (57).

Continuous aerobic training is most beneficial during the early stages of a preparation period, where the focus is on developing a robust aerobic base to support subsequent higher-intensity training phases (28). During this phase, a pyramidal intensity distribution is recommended, with most training volume at low intensities (Zone 1), supplemented by a smaller proportion of moderate-intensity threshold work (Zone 2) and minimal high-intensity training (Zone 3) (9). This approach enhances aerobic efficiency through long, steady-state runs and continuous tempo efforts, improving running economy and lactate threshold. However, as competition approaches, continuous aerobic training may be minimized to manage overall training load, because it contributes significantly to total volume compared with interval-based methods (7). Traditional periodization models suggest that reducing training volume while increasing intensity optimizes performance closer to competition (28). Accordingly, HYROX athletes should transition toward a more polarized model, replacing some low-intensity continuous work with high-intensity circuit- and interval-based sessions that better replicate race demands. A similar approach is used in team sports, where continuous aerobic training is reduced in-season in favor of HIIT and sport-specific training to maintain aerobic capacity (60). Structuring continuous aerobic training within a periodized framework ensures its strategic application in enhancing long-term performance outcomes for HYROX athletes. A more comprehensive aerobic endurance periodization framework is available in Casado et al. (9).

BLOOD FLOW RESTRICTION TRAINING

BFR training, which involves the application of external pressure to partially restrict arterial inflow while occluding venous return, may present several advantages for HYROX athletes. This modality offers unique benefits in the context of the physiologic and performance demands identified earlier in this review. Importantly, BFR creates an anaerobic environment, accumulating metabolic byproducts such as lactate and hydrogen ions (48). The cuff also prevents these byproducts from being cleared effectively, forcing skeletal muscle to improve the ability to buffer against them and maintain force output. It is understood that this "metabolic stress" drives several important adaptations, such as enhancing mitochondrial content, capillarization, buffering capacity, and preferential adaptation of type I fibers (4,10). This is critical, because the information outlined in previous sections indicates high aerobic and anaerobic demand during HYROX, so improving an athlete's ability to operate for prolonged periods at variable intensities and delay fatigue would be highly advantageous for performance.

The use of BFR during low-load resistance training has been demonstrated to develop muscle hypertrophy, strength, and muscular endurance qualities concurrently, making it a time-efficient approach to target these relevant muscular qualities (32,59). Compared with low-load exercise performed to failure (without BFR), it achieves these outcomes with significantly lower exercise volume (22). Although low-load BFR exercise generates high levels of acute muscle fatigue, it seems that much of this dissipates within minutes of reperfusion (31). A systematic review of 15 randomized controlled trials found that while low-load BFR may induce muscle damage within the first week, it does not cause long-term muscle damage (73). Together, this may explain why recovery timelines are accelerated after this mode of exercise compared with traditional high-load resistance exercise, particularly with repeated exposure to the BFR stimulus. Therefore, the intermittent use of low-load BFR may permit athletes to recover

Table 4
HYROX training recommendations by competitor level

Level	Training frequency	Resistance training	HIIT	Continuous aerobic	HYROX-specific circuit training	Key focus areas
Novice	3–4	1–2×/week Full body sessions building strength in foundational movements ~8–12 repetitions	1×/week Long intervals with 1:1 work-to-rest ratio	1×/week Low-to-moderate intensity (Zones 1 and 2) running	1×/week Shorter duration circuits (15–30 min) involving HYROX stations with 3:1-4:1 work-to-rest ratio	• General strength • Aerobic base • Gain competency in movement patterns • Injury prevention
Intermediate	5–6	2–3×/week Full body sessions targeting maximal strength in key movements (e.g., squat, lunge, hinge) ~3–6 repetitions Low loads with and without BFR to develop LME ~15–30 repetitions	1×/week Long-to-moderate intervals with 1.5–2:1 work-to-rest ratio Short intervals with 1:1 work-to-rest ratio	1–2×/week Low-to-moderate intensity (Zones 1 and 2) running BFR may be used during low-intensity aerobic training	1–2×/week Moderate duration circuits (30–50 min) involving HYROX stations at race pace with >5:1 work-to-rest ratio	• Maximal strength • Local muscular endurance • Aerobic power • Intereffort recovery • Develop technical proficiency in HYROX-specific movements
Advanced	7+	3×/week Full body or upper/lower sessions targeting maximal and explosive strength in key movements (e.g., squat, lunge, hinge), including plyometric exercises ~3–6 repetitions Low loads with and without BFR to develop LME ~15–30 repetitions	1–2×/week Long intervals with 2:1 work-to-rest ratio Short intervals with 1:1 work-to-rest ratio Sprint intervals (<10 s) with 1:3–6 work-to-rest ratio	2–3×/week Low-to-moderate intensity (Zones 1 and 2) running and row/ski ergometry BFR may be used during low-intensity aerobic training	1–2×/week Full race simulations or longer duration circuits (>50 min) at race pace moderate duration circuits (30–50 min) above race pace with >5:1 work-to-rest ratio	• Explosive strength • Local muscular endurance • Anaerobic power • Running under fatigue • Continue to develop technical proficiency in HYROX-specific movements

Novice = 0–1 HYROX completed with <2 y training experience; Intermediate = 1+ HYROX completed or >5 y training experience; Advanced = 3+ HYROX completed or >10 y training experience.

BFR = blood flow restriction; HIIT = high-intensity interval training.

from the high mechanical tension imposed by traditional high-load strength sessions while still providing a stimulus for muscular adaptation (17). Current guidelines for BFR resistance exercise advocate for using both multi-joint and single-joint exercises, with resistances ranging from 20 to 40% of 1RM (47). A fixed repetition scheme of 30, 15, 15, 15 repetitions is frequently used, along with completing some or all sets to muscular failure. The cuff pressure should be individualized based on ultrasound-derived arterial occlusion pressure (AOP), with 40–80% AOP recommended (47). Finally, interset recovery periods should be short (30–60 seconds), with the maintenance of cuff pressure during these periods (continuous application) being the most common approach (47).

Low-intensity aerobic exercises such as walking (66), cycling (13), and rowing (29) have also been combined with

BFR to elicit improvements in aerobic capacity and the peripheral endurance adaptations described earlier. Low-intensity conditioning practices such as this would allow HYROX competitors to manage their training load while still providing a stimulus for aerobic adaptation–particularly for exercise modes that permit "off-feet" conditioning. The studies outlined above have prescribed intensity based on absolute speeds (i.e., 5 km/h) (66) or based on blood lactate- or VO_2max-derived intensities (13,29), which may pose a challenge for many practitioners or athletes looking to standardize intensity across exercise modes and without access to such measurements. Therefore, "low" intensity may be gauged by using RPE (3–4 on a 10-point scale) (58) or by using heart rate reserve (HRR; <50%) (47). During low-intensity aerobic BFR exercise, higher cuff pressures may be used (80–100% AOP) (29,66). However, it may be necessary to gradually build up to these pressures with individuals unaccustomed to BFR training. Readers are directed to Patterson et al. (47) for further details on low-intensity aerobic BFR exercise prescription.

More recently, research indicates that BFR may be combined with high-intensity interval training to improve aerobic power, buffering capacity, and performance during maximal effort tasks (5,10). These studies have based interval intensity on MAP, with 100% being used for 15-second intervals and 60–80% MAP used for longer intervals of 2 minutes. Lower cuff pressures (50–70% AOP) are recommended for BFR HIIT exercise sessions to improve tolerance (5,10). Finally, a 1:1 work-to-rest ratio is advised for short HIIT intervals (5), whereas 2:1 has been adopted for longer HIIT intervals (10). Readers are directed to a recent systematic review for further information on BFR HIIT methodologies and recommendations (12). Together, the above data indicate that BFR may serve as a versatile tool for simultaneously targeting many of the physical qualities relevant to HYROX while also affording athletes the ability to reduce training loads or intensities and thereby reduce injury risk.

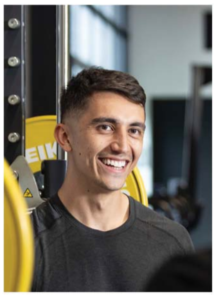
CONCLUSIONS

HYROX represents a challenging hybrid competition requiring concurrent development of aerobic and muscular endurance, strength, and technical proficiency. Key performance determinants include aerobic capacity for sustained effort, anaerobic power for high-intensity bursts, and local muscular endurance to mitigate fatigue during repetitive movements. Strength and power are also vital for efficiency and resilience during both strength tasks and running segments. Effective preparation involves tailored programming, such as high-intensity interval training, circuit training, and blood flow restriction techniques, to enhance sport-specific fitness while managing training loads to minimize injury risk.

Although valuable insights can be drawn from research on hybrid fitness events and endurance-based sports, direct application to HYROX requires caution. Differences in movement mechanics, work-to-rest ratios, and environmental constraints (e.g., fixed sled resistance, standardized event structure) may alter performance determinants compared with other related fitness competitions. For example, while anaerobic energy system contributions are well documented in shorter duration hybrid fitness sessions, the continuous nature of HYROX running segments may shift the balance toward aerobic energy pathways. Similarly, although injury patterns in hybrid fitness athletes suggest common vulnerabilities (e.g., shoulder and knee injuries), the absence of weightlifting elements in HYROX may modify injury risk profiles.

Although insights from related disciplines inform current practices, HYROX-specific research remains sparse. Future investigations should prioritize controlled training interventions to determine the most effective preparation strategies for athletes of varying experience levels. In addition, longitudinal studies are needed to track injury incidence and biomechanical adaptations associated with repeated HYROX participation. Another critical area for exploration is the relative contribution of different energy systems across the event, because this would further refine conditioning strategies and pacing recommendations. Collectively, these research directions will strengthen the evidence base for optimizing training and performance in this rapidly growing sport. Until this is achieved, the strategies outlined herein provide actionable steps for coaches and athletes to optimize performance and advance understanding within this emerging sport.

Conflicts of Interest and Source of Funding: The author reports no conflicts of interest and no source of funding.



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REFERENCES

1. Alcaraz PE, Sánchez-Lorente J, Blazevich AJ. Physical performance and cardiovascular responses to an acute bout of heavy resistance circuit training versus traditional strength training. *J Strength Cond Res* 22: 667–671, 2008.
2. Bangsbo J. Energy demands in competitive soccer. *J Sport Sci* 12: S5–S12, 1994.
3. Barnes KR, Kilding AE. Strategies to improve running economy. *Sports Med* 45: 37–56, 2015.
4. Bjørnsen T, Wernbom M, Kirketeig A, et al. Type 1 muscle fiber hypertrophy after blood flow-restricted training in powerlifters. *Med Sci Sports Exerc* 51: 288–298, 2019.
5. Bourgeois H, Paradis P, Billaut F. High-intensity interval training with blood-flow restriction enhances sprint and maximal aerobic power in male endurance athletes. *Appl Physiol Nutr Metab* 50: 1–11, 2025.
6. Brandon LJ. Physiological factors associated with middle distance running performance. *Sports Med* 19: 268–277, 1995.
7. Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle: Part I: Cardiopulmonary emphasis. *Sports Med* 43: 313–338, 2013.
8. Carreker JDD, Grosicki GJ. Physiological predictors of performance on the crossfit "Murph" challenge. *Sports* 8: 92, 2020.
9. Casado A, González-Mohíno F, González-Ravé JM, Foster C. Training periodization, methods, intensity

distribution, and volume in highly trained and elite distance runners: A systematic review. *Int J Sport Physiol Perf* 17: 820–833, 2022.

10. Christiansen D, Eibye K, Hostrup M, Bangsbo J. The effect of blood-flow-restricted interval training on lactate and H+ dynamics during dynamic exercise in man. *Acta Physiol* 231: e13580, 2021.
11. Chtara M, Chamari K, Chaouachi M, et al. Effects of intra-session concurrent endurance and strength training sequence on aerobic performance and capacity. *Br J Sport Med* 39: 555–560, 2005.
12. Chua MT, Sim A, Burns SF. Acute and chronic effects of blood flow restricted high-intensity interval training: A systematic review. *Sports Med Open* 8: 122, 2022.
13. Conceição MS, Junior EMM, Telles GD, et al. Augmented anabolic responses following 8-weeks cycling with blood flow restriction. *Med Sci Sports Exerc* 51: 84–93, 2019.
14. Coyle EF, Coggan AR, Hopper MK, Walters TJ. Determinants of endurance in well-trained cyclists. *J Appl Physiol* 64: 2622–2630, 1988.
15. Cuthbert M, Haff GG, Arent SM, et al. Effects of variations in resistance training frequency on strength development in well-trained populations and implications for in-season athlete training: A systematic review and meta-analysis. *Sports Med* 51: 1967–1982, 2021.
16. Dabonneville M, Berthon P, Vaslin P, Fellmann N. The 5 min running field test: Test and retest reliability on trained men and women. *Eur J Appl Physiol* 88: 353–360, 2003.
17. Davids CJ, Roberts LA, Bjørnsen T, Peake JM, Coombes JS, Raastad T. Where does blood flow restriction fit in the toolbox of athletic development? A narrative review of the proposed mechanisms and potential applications. *Sports Med* 53: 2077–2093, 2023.
18. de Villarreal ESS, Izquierdo M, Gonzalez-Badillo JJ. Enhancing jump performance after combined vs. maximal power, heavy-resistance, and plyometric training alone. *J Strength Cond Res* 25: 3274–3281, 2011.
19. Dexheimer JD, Schroeder ET, Sawyer BJ, Pettitt RW, Aguinaldo AL, Torrence WA. Physiological performance measures as indicators of crossfit® performance. *Sports* 7: 93, 2019.
20. Di Michele R, Del Curto L, Merni F. Mechanical and metabolic responses during a high-intensity circuit training workout in competitive runners. *J Sports Med Phys Fitness* 52: 33–39, 2012.
21. Dumke CL, Pfaffenroth CM, McBride JM, McCauley GO. Relationship between muscle strength, power and stiffness and running economy in trained male runners. *Int J Sport Physiol Perf* 5: 249–261, 2010.
22. Fahs CA, Loenneke JP, Thiebaud RS, et al. Muscular adaptations to fatiguing exercise with and without blood flow restriction. *Clin Physiol Funct Imaging* 35: 167–176, 2015.
23. Fernández JF, Solana RS, Moya D, Marin JMS, Ramón MM. Acute physiological responses during crossfit® workouts. *Eur J Hum Mov* 35: 114–124, 2015.
24. French D, Ronda LT. *NSCA's Essentials of Sport Science*. Champaign, IL: Human Kinetics, 2021.
25. Gabbett TJ. Influence of fatigue on tackling ability in rugby league players: Role of muscular strength, endurance, and aerobic qualities. *PLoS One* 11: e0163161, 2016.
26. Gao Z, Fekete G, Baker JS, Liang M, Xuan R, Gu Y. Effects of running fatigue on lower extremity symmetry among amateur runners: From a biomechanical perspective. *Front Physiol* 13: 899818, 2022.
27. Gibala MJ, McGee SL. Metabolic adaptations to short-term high-intensity interval training: A little pain for a lot of gain? *Exerc Sport Sci Rev* 36: 58–63, 2008.
28. Haff GG, Triplett NT. *Essentials of Strength Training and Conditioning* (4th ed). Champaign, IL: Human Kinetics, 2015.
29. Held S, Behringer M, Donath L. Low intensity rowing with blood flow restriction over 5 weeks increases $\dot{V}O_2$max in elite rowers: A randomized controlled trial. *J Sci Med Sport* 23: 304–308, 2020.
30. Hernández-Lougedo J, Cimadevilla-Pola E, Fernández-Rodríguez T, et al. Effects of introducing rest intervals in functional fitness training. *Appl Sci* 11: 9731, 2021.
31. Husmann F, Mittlmeier T, Bruhn S, Zschorlich V, Behrens M. Impact of blood flow restriction exercise on muscle fatigue development and recovery. *Med Sci Sports Exerc* 50: 436–446, 2018.
32. Kacin A, Strazar K. Frequent low-load ischemic resistance exercise to failure enhances muscle oxygen delivery and endurance capacity. *Scand J Med Sci Sports* 21: e231–e241, 2011.
33. Klusiewicz A, Starczewski M, Ładyga M, et al. Reference values of maximal oxygen uptake for Polish rowers. *J Hum Kinet* 44: 121–127, 2014.
34. Kostikiadis IN, Methenitis S, Tsoukos A, Veligekas P, Terzis G, Bogdanis GC. The effect of short-term sport-specific strength and conditioning training on physical fitness of well-trained mixed martial arts athletes. *J Sports Sci Med* 17: 348–358, 2018.
35. Legge N, Slattery DK, O'Meara DD, et al. Physical and technical attributes associated with on-water rowing performance in junior and elite rowers. *J Clin Ex Physiol* 13: 405, 2024.
36. Malone S, Hughes B, Doran DA, Collins K, Gabbett TJ. Can the workload–injury relationship be moderated by improved strength, speed and repeated-sprint qualities? *J Sci Med Sport* 22: 29–34, 2019.
37. Mangine GT, Tankersley JE, McDougle JM, et al. Predictors of crossfit open performance. *Sports* 8: 102, 2020.
38. Marin-Pagán C, Blazevich AJ, Chung LH, Romero-Arenas S, Freitas TT, Alcaraz PE. Acute physiological responses to high-intensity resistance circuit training vs. traditional strength training in soccer players. *Biology* 9: 383, 2020.
39. Martin SA, Tomescu V. Energy systems efficiency influences the results of 2,000 m race simulation among elite rowers. *Clujul Med* 90: 60–65, 2017.
40. Martínez-Gómez R, Valenzuela PL, Alejo LB, et al. Physiological predictors of competition performance in crossfit athletes. *Int J Environ Res Public Health* 17: 3699, 2020.
41. Martínez-Gómez R, Valenzuela PL, Barranco-Gil D, Moral-González S, García-González A, Lucia A. Full-squat as a determinant of performance in crossfit. *Int J Sports Med* 40: 592–596, 2019.
42. Montalvo AM, Shaefer H, Rodriguez B, Li T, Epnere K, Myer GD. Retrospective injury epidemiology and risk factors for injury in crossfit. *J Sport Sci Med* 16: 53–59, 2017.
43. Naclerio FJ, Colado JC, Rhea MR, Bunker D, Triplett NT. The influence of strength and power on muscle endurance test performance. *J Strength Cond Res* 23: 1482–1488, 2009.
44. Nevill AM, Brown D, Godfrey R, et al. Modeling maximum oxygen uptake of elite endurance athletes. *Med Sci Sports Exerc* 35: 488–494, 2003.
45. Paavolainen L, Häkkinen K, Hämäläinen I, Nummela A, Rusko H. Explosive-strength training improves 5-km running time by improving running economy and muscle power. *J Appl Physiol* 86: 1527–1533, 1999.
46. Panoutsakopoulos V, Kotzamanidou MC, Giannakos AK, Kollias IA. Relationship of vertical jump performance and ankle joint range of motion: Effect of knee joint angle and handedness in young adult handball players. *Sports* 10: 86, 2022.
47. Patterson SD, Hughes L, Warmington S, et al. Blood flow restriction exercise: Considerations of methodology, application, and safety. *Front Physiol* 10: 533, 2019.
48. Pearson SJ, Hussain SR. A review on the mechanisms of blood-flow restriction resistance training-induced muscle hypertrophy. *Sports Med* 45: 187–200, 2015.
49. Poston WS, Haddock CK, Heinrich KM, Jahnke SA, Jitnarin N, Batchelor DB. Is high-intensity functional training (HIFT)/CrossFit safe for military fitness training? *Mil Med* 181: 627–637, 2016.
50. Ramos-Campo DJ, Andreu Caravaca L, Martínez-Rodríguez A, Rubio-Arias J. Effects of resistance circuit-based training on body composition, strength and cardiorespiratory fitness: A systematic review and meta-analysis. *Biology* 10: 377, 2021.
51. Rawdon CL. Performance variables of obstacle course racing and recommendations for programming in novice and intermediate competitors. *Strength Cond J* 38: 1–17, 2016.
52. Read PJ, Hughes J, Stewart P, et al. A needs analysis and field-based testing battery for basketball. *Strength Cond J* 36: 13–20, 2014.
53. Rey-Mota J, Álvarez DM-C, Onate-Figuérez A, Yañez-Sepúlveda R, Clemente-Suárez VJ. Physiological response and sports injury risk relevant biomechanics in endurance obstacle course races. *Appl Sci* 14: 9604, 2024.
54. Rios M, Becker KM, Monteiro AS, et al. Effect of the fran crossfit workout on oxygen uptake kinetics, energetics, and postexercise muscle function in trained crossfitters. *Int J Sports Perf Physiol* 19: 299–306, 2024.
55. Sauvé B, Haugan M, Paulsen G. Physical and physiological characteristics of elite crossfit athletes. *Sports* 12: 162, 2024.
56. Schoenfeld BJ, Grgic J, Van Every DW, Plotkin DL. Loading recommendations for muscle strength, hypertrophy, and local endurance: A re-examination of the repetition continuum. *Sports* 9: 32, 2021.
57. Seiler KS, Kjerland G. Quantifying training intensity distribution in elite endurance athletes: Is there evidence for an "optimal" distribution?. *Scand J Med Sci Sports* 16: 49–56, 2006.
58. Seiler S. What is best practice for training intensity and duration distribution in endurance athletes? *Int J Sports Perf Physiol* 5: 276–291, 2010.
59. Sieljacks P, Degn R, Hollaender K, Wernbom M, Vissing K. Non-failure blood flow restricted exercise induces similar muscle adaptations and less discomfort than failure protocols. *Scand J Med Sci Sports* 29: 336–347, 2019.
60. Stone NM, Kilding AE. Aerobic conditioning for team sport athletes. *Sports Med* 39: 615–642, 2009.
61. Støren Ø, Sunde A, Helgerud J, et al. Maximal aerobic and anaerobic power and time performance in 800 m double poling ergometer. *Eur J Appl Physiol* 123: 1199–1208, 2023.
62. Stromme SB, Ingjer F, Meen HD. Assessment of maximal aerobic power in specifically trained athletes. *J Appl Physiol* 42: 833–837, 1977.
63. Talsnes RK, Hetland T-A, Cai X, Sandbakk Ø. Development of performance, physiological and technical capacities during a six-month cross-country skiing talent transfer program in endurance athletes. *Front Sports Activ Living* 2: 103, 2020.
64. Tanaka H. Effects of cross-training. Transfer of training effects on VO_2max between cycling, running and swimming. *Sports Med* 18: 330–339, 1994.
65. Taunton JE, Ryan MB, Clement DB, McKenzie DC, Lloyd-Smith DR, Zumbo BD. A prospective study of running injuries: The vancouver sun run "in training" clinics. *Br J Sports Med* 37: 239–244, 2003.

66. Thompson KMA, Gamble ASD, Kontro H, Lee JB, Burr JF. Low- and high-volume blood-flow restriction treadmill walking both improve maximal aerobic capacity independently of blood volume. *Scand J Med Sci Sport* 34: e14534, 2024.
67. Thurlow F, Huynh M, Townshend A, et al. The effects of repeated-sprint training on physical fitness and physiological adaptation in athletes: A systematic review and meta-analysis. *Sports Med* 54: 953–974, 2024.
68. Tibana RA, de Sousa Neto IV, Sousa NMF, et al. Local muscle endurance and strength had strong relationship with crossfit® open 2020 in amateur athletes. *Sports* 9: 98, 2021.
69. Tibana RA, De Sousa NMF, Prestes J, Voltarelli FA. Lactate, heart rate and rating of perceived exertion responses to shorter and longer duration crossfit® training sessions. *J Funct Morphol Kinesiol* 3: 60, 2018.
70. Tibana RA, Dominski FH, Andrade A, De Sousa NMF, Voltarelli FA, Neto IVdS. Exploring the relationship between total athleticism score and crossfit® open performance in amateur athletes: Single measure involving body fat percentage, aerobic capacity, muscle power and local muscle endurance. *Eur J Transl Myol* 34: 12309, 2024.
71. Tomlin DL, Wenger HA. The relationship between aerobic fitness and recovery from high intensity intermittent exercise. *Sports Med* 31: 1–11, 2001.
72. Tschakert G, Hofmann P. High-intensity intermittent exercise: Methodological and physiological aspects. *Int J Sports Perf Physiol* 8: 600–610, 2013.
73. Yang J, Ma F, Wang Q, Cui Y, Zheng J. Effect of blood flow restriction with low-load exercise on muscle damage in healthy adults: A systematic review of randomized controlled trials. *Clin Physiol Funct Imaging* 44: 1–13, 2024.
74. Zazulak B, Cholewicki J, Reeves NP. Neuromuscular control of trunk stability: Clinical implications for sports injury prevention. *J Am Acad Orthop Surg* 16: 497–505, 2008.
75. Zhong F, Chen Z, Gu Z, Wang X, Holmberg H-C, Li Y. Comparison of lactate measurements from earlobe and fingertip capillary blood using biosen S-line and lactate scout analyzers. *Eur J Appl Physiol* 125: 145–156, 2025.