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An integrative review of physical, technical, and psychological determinants of performance efficiency in elite Greco-Roman wrestling

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Abstract
Greco-Roman wrestling is physically demanding and technically complicated, requiring high-level integration across various domains. Elite athletes must synchronize high physiological capacities, refined technical skills, and strong psychological traits. This thorough analysis synthesizes diverse research and the latest technological advances on these crucial performance efficiency variables. Elite Greco-Roman wrestlers have superior upper-body muscular strength and explosive power, anaerobic energy systems that support repeated bouts of maximal effort, and aerobic endurance that aids recovery and tournament performance. Complex wrestling tactics are optimized by neuromuscular adaptations including coordination, proprioception, and reaction time, while favorable anthropometric profiles and hormonal balance support athletic output and recuperation. Mastery of throws, clinches, and par terre movements and smart tactical decision-making determine match outcomes. Advanced video analysis and motion capture allow biomechanical assessment and skill improvement. Peak performance requires mental toughness, concentration, emotional management, and effective coping mechanisms for competition-related stress and rapid weight loss. Wearable sensors and machine learning enable real-time performance monitoring and personalised training changes, enhancing athlete readiness and injury prevention. Mapping growth pathways and guaranteeing career success requires longitudinal interdisciplinary athlete profiling. This evaluation advises coaches, practitioners, and sports scientists on holistic, evidence-based training and support systems to improve elite Greco-Roman wrestling performance and well-being.

Keywords: Greco-Roman wrestling, performance efficiency, physiological adaptations, technical mastery, psychological resilience, anaerobic power, tactical strategy, wearable technology, athlete profiling, injury prevention

1. Introduction
Greco-Roman wrestling, one of the oldest and most prestigious combat sports, dates back to the ancient Greek Olympics. Its limitation of grips below the waist emphasizes upper-body power, technical precision, and tactical strategy, distinguishing it from freestyle wrestling. Since the 1896 Olympics, the sport has grown in international events. Russia, Turkey, and Eastern European nations with ancient wrestling traditions have dominated the scene, producing athletes with the physical strength, sophisticated abilities, and mental resilience needed to win competitive fights. Elite Greco-Roman wrestlers' ability to combine and employ their physical, technical, and psychological resources to enhance performance is crucial. Wrestlers must have strong upper-body muscles, anaerobic power, and cardiovascular endurance to sustain high-intensity efforts and dynamic methods throughout matches. Greco-Roman wrestlers have higher upper-body anaerobic power than freestyle wrestlers due to the physical demands of lifting, tossing, and controlling opponents without using legs. This physical training foundation helps execute complex wrestling moves, where explosive power and muscular endurance drive offensive and defensive success.
Technical skills are also important; mastering specialized grips, throws, clinches, and par terre tactics helps wrestlers score and control matches. In competitive bouts, experienced Greco-Roman wrestlers use 10-12 attack options across tactical groups, combining manoeuvring, feints, counterattacks, and powerful throws to score even when fatigued.

Technical versatility, precision, and tactical decision-making training methods are essential for strengthening these competencies and have been linked to match performance.

Psychological traits help exceptional wrestlers stay focused, motivated, and calm under pressure. Studies show that mental abilities including volition, self-confidence, attention, composure, and aggression are most important to wrestling success. Wrestlers also face competition anxiety and the psychological effects of rapid weight loss, which can alter mood, cognitive function, and endurance (Sporting Bounce, 2024). Thus, persistent competitive success requires mental toughness and efficient coping skills, frequently developed through psychological training and assistance. Elite Greco-Roman wrestlers' performance efficiency comes from the dynamic interaction between physical conditioning, technical proficiency, and psychological preparation. Optimal athletes combine physical fitness with skillful technique, psychological resilience, and attention and motivation. Coaches and sports scientists are increasingly emphasizing integrated training that addresses all these elements to maximize peak performance and athlete lifespan.

2. Physiological Determinants of Performance Efficiency

Elite Greco-Roman wrestlers need a wide range of specialized physiological adaptations to execute high-intensity techniques with power, precision, and endurance during demanding bouts and tournaments. Muscular strength and power, anaerobic and aerobic capacity, neuromuscular coordination, body composition and anthropometry, metabolic, and hormonal responses are among these adaptations. This detailed analysis of each category explains its role, mechanics, and training implications for top Greco-Roman wrestling.

Fig 1: Physiological Determinants of Performance Efficiency

2.1 Muscular Strength and Power

Due to Greco-Roman wrestling's rule against holding below the waist, upper-body strength is crucial. Wrestlers control, lift, and throw opponents using their arms, shoulders, chest, back, and core. Maximal strength is needed to overcome an opponent's resistance during clinches and throws, while explosive power allows speedy execution of techniques that can score points or end the match. Elite wrestlers have higher upper-body strength than non-elites, as measured by bench press, pull-ups, and isometric grip strength. As matches feature several rounds of rapid fights with short recuperation times, strength endurance-the ability to maintain high force production across multiple attempts-is crucial. Wrestler conditioning programs emphasize maximal strength (low repetitions, high loads) and muscular endurance (higher repetitions, moderate loads) to build force capabilities and fatigue resistance. Power-force times velocity-is crucial for explosive maneuvers like suplexes, body lifts, and dynamic throws. Plyometric training, Olympic lifts (e.g., cleans, snatches), and ballistic exercises are common in Greco-Roman wrestler training regimens aimed at enhancing the rate of force development and neuromuscular synchronization, which translate into more effective offensive manoeuvres. Strong and powerful wrestlers can overcome opponent resistance, reposition swiftly, and retain beneficial grips and leverage throughout the bout.

2.2 Anaerobic Capacity

In Greco-Roman wrestling, matches consist of short, high-intensity bouts lasting a few seconds to a few minutes, alternating with brief rest or lower-intensity phases. Wrestlers must rely on anaerobic energy sources, which provide quick energy without oxygen. The lactic anaerobic system (ATP-PCr pathway) offers instant energy for powerful lifts and throws lasting up to 10 seconds. Beyond this length, the lactic anaerobic system (glycolysis) generates energy for repeated

bursts up to 1-2 minutes, however lactate generation can cause fatigue.

Elite Greco-Roman wrestlers have great anaerobic power and capacity, allowing them to make many maximal attempts during the match without performance loss. Wingate anaerobic tests and repeated sprint ability tests demonstrate increased energy generation, fatigue resistance, and metabolic recovery. To develop lactate tolerance and phosphocreatine resynthesis, interval exercises emulate both intensity and duration and include repeated high-intensity bouts with controlled recovery periods. Anaerobic adaptations are necessary for offensive explosiveness, defensive strength, counterattacks, and technical execution under fatigue, which is crucial in close bouts that need tactical accuracy.

2.3 Aerobic Endurance

While Greco-Roman wrestling significantly stresses anaerobic energy systems, the aerobic system aids recovery during rest periods inside matches and between bouts in a tournament. A strong aerobic capacity speeds up lactate clearance, phosphagen replenishment, and cardiovascular and muscular function during competition. Elite wrestlers had moderate to high VO2max values compared to non-athletes, showing cardiovascular fitness for repeated high-intensity performance. Running, cycling, swimming, and circuit training are aerobic conditioning exercises for athletes. Supporting prolonged energy generation and faster physiological recovery boosts fatigue resistance and mental alertness. Aerobic endurance indirectly improves technical performance by delaying neuromuscular fatigue, sustaining motor control, coordination, and tactical decision-making.

2.4 Neuromuscular Adaptations

Wrestlers need neuromuscular control-coordination, proprioception, response time, and balance-to perform intricate techniques and react quickly to opponents. Movement patterns, stability during physical engagement, and tactical agility are improved by neuromuscular adaptations. Balance exercises, plyometrics, and sport-specific drills establish sensory feedback mechanisms that help wrestlers anticipate and counter an opponent's moves. Smooth offensive-defensive transitions due to rapid reflexes and fine motor control maximize energy efficiency by reducing wasted motions. These modifications improve performance consistency and reduce injury risk by integrating neural signals with muscle responses.

2.5 Body Composition and Anthropometry

Given Greco-Roman wrestling's weight-class structure, body composition is significant. Elite wrestlers optimize their power-to-weight ratio by maintaining minimal body fat and high muscle mass. This balance maximizes muscle strength and power without extra heft that slows speed or endurance. Height, limb length, and torso size affect leverage, reach, and technique execution. For some throws and locks, longer arms and torso strength are mechanical advantages. Elite wrestlers have distinct anthropometric profiles that correspond with weight category success, suggesting specialized physical development is essential for competitiveness.

2.6 Metabolic and Hormonal Responses

Intense wrestling competition causes metabolic and hormonal stress. Inflammation from exercise, oxidative stress from reactive oxygen species, and stress hormone swings all contribute. Extended cortisol and catecholamine elevations during and after matches mobilize energy substrates but can compromise immunological function and recovery. Conversely, testosterone aids muscle repair and growth. Wrestlers' ability to handle endocrine variations influences their ability to compete in multiple tournaments and train hard. Enhanced antioxidant defense systems, effective substrate utilization, and quick hormonal recovery are essential for long-term sports performance and injury prevention.

3. Technical Determinants of Performance Efficiency in Elite Greco-Roman Wrestling

Elite Greco-Roman wrestlers have exceptional technical skills developed by strategic application, skill development, and adaptation to changing competition demands. Recent research and coaching methods are used to explain these technical aspects in this part.

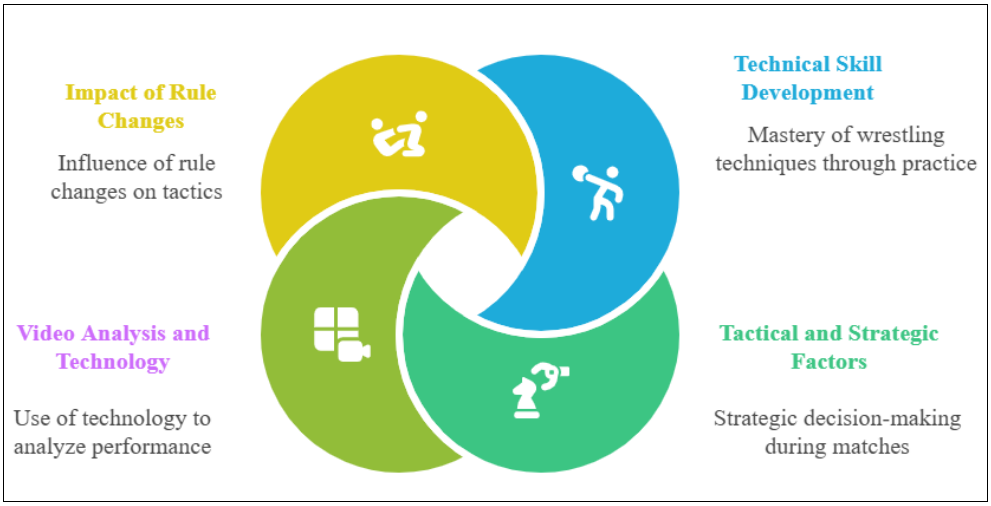

Fig 2: Technical Determinants of Performance Efficiency in Elite Greco-Roman Wrestling

3.1 Technical Skill Development

Throws, lifts, clinches, and groundwork (par terre) are common upper-body moves in Greco-Roman wrestling, requiring coordination, timing, and strength. Elite success requires mastery of these approaches. Wrestlers learn 10-12 core attacks and countermeasures, including high-impact throws like the suplex, arm throws, gut wrenches, and lifting techniques. When executed well, each style requires distinct biomechanical and motor control traits that enable high scoring and good defense. Technical skill is learned by

focused practice with feedback, emphasising repetition, correction, and strategic variation. The motivational climate in training encourages wrestlers to try new tactics and master basic movements. Having a personalized technical repertoire with characteristic "winning moves" increases unpredictability and scoring possibilities in contests.

Biomechanical evaluations help perfect technique execution. Video and motion capture technology measure body postures, force vectors, and centre of mass shifts to provide detailed feedback on movement efficiency and injury risk avoidance (Gierczuk *et al*., 2021) [3]. Applying AI and machine learning algorithms to various data sources helps trainers identify patterns in high-performing athletes and customize technical improvements. To adapt to changing competing situations and opponent styles, wrestlers must develop adaptive motor programs through diversity in training. Thus, deliberate practice must mix technical repetition with unpredictable settings to develop resilient, context-sensitive skill execution (Ericsson *et al*., 1993) [13].

3.2 Tactical and Strategic Factors

Techniques are used in tactical frameworks that manage bout tempo, scoring, and position. Elite wrestlers use match score, remaining time, opponent tendencies, and referee style while making tactical decisions. According to empirical data, wrestlers switch between aggressive offensive bursts to establish early score advantages and more conservative, control-oriented methods during match progression or when leading on points. Balanced peak effort with recuperation, strategic energy management controls assault frequency and intensity to retain technical sharpness throughout rounds. United World Wrestling rule changes have affected tactics. For instance, points for activity and penalties for apathy encourage wrestlers to be aggressive and engaged, changing defensive postures to lead to proactive match control (UWW, 2025). The pace and number of technical efforts have increased, forcing athletes to maintain higher aerobic and anaerobic thresholds and tactical awareness. Wrestlers must grasp their technical strengths and opponent trends to adapt to changing tactics. Thus, scouting and opponent analysis help wrestlers prepare game plans to overcome antagonist tendencies and exploit weaknesses.

3.3 Video Analysis and Technology in Technical-Tactical Training

Video analysis has transformed Greco-Roman wrestling training. Coaches and athletes use video review systems to analyze personal and opponent performances frame-by-frame to find technical shortcomings or tactical tendencies that were missed during live matches. Video analysis improves learning through visual feedback, tactical modifications by showing tendencies and repeating blunders, and psychological preparedness by modeling competing circumstances. Biomechanical examination using high-speed video and 3D motion tracking reveals inefficient movement patterns and injury risks (Gierczuk *et al*., 2021) [3]. AI solutions that automate technical sequence and tactical outcome recognition in huge match footage provide new insights into success and failure. Quantitative methods provide data-driven training and competitive plan modifications, expanding wrestling evidence-based coaching.

3.4 Impact of Rule Changes on Technical and Tactical Performance

New international wrestling rules have changed tactical priorities and technical application throughout contests. Wrestlers now take more risks and move faster due to rule changes that punish stalling and reward continuous motion (United World Wrestling, 2025). Dynamic throw scoring has increased the usage of high-amplitude, technically demanding approaches, forcing athletes to improve strength, balance, and timing under duress. Wrestlers must maximize their technical repertoire to highlight high-point moves while preserving defensive resilience. Strategic risk management has been altered by rule modifications to improve match appeal and fairness, forcing wrestlers to balance aggression with caution, especially in crucial late-match periods. Understanding and reacting to these changing restrictions is essential for elite technological relevance and competitive advantage

4. Psychological Determinants of Performance Efficiency in Elite Greco-Roman Wrestling

Elite Greco-Roman wrestling performance depends on an athlete's psychological ability to bear pressure, concentrate, regulate emotions, and stay motivated. Champions excel in mental toughness, emotional stability, and coping skills in wrestling, a physical and mental sport.

4.1 Key Psychological Attributes and Mental Skills

Wrestlers with greater volition, attention, self-confidence, composure, and strategic organization are frequently recognized (Barbas *et al*., 2010) [2]. Volition-the willpower to work and persevere under tremendous physical and psychological stress-is the most crucial characteristic. Concentration helps wrestlers focus on tactical execution despite distractions and tiredness, while self-confidence boosts resilience and risk-taking during competition. Wrestlers must control their emotions in this physically demanding sport with high stakes and momentum fluctuations. Calmness improves decision-making and technique execution under stress, avoiding anxiety and frustration from degrading performance. Elite wrestlers integrate mental and physical preparation to achieve certain goals (Barbas *et al*., 2010) [2].

4.2 Psychological Stressors and Coping Mechanisms

Wrestlers face specific psychological stressors such competition anxiety and rapid weight loss. Using RWL to compete in lower weight classes might lead to negative psychological effects as tension, irritation, exhaustion, and disordered eating (Sarıakçalı *et al*., 2025) [9]. Coaches and sports psychologists stress the importance of weight control to reduce these effects and maintain mental health. Elite wrestlers blend cognitive tactics like thought control, visualization, and goal-focused attention with behavioral strategies including pre-competition routines and environment adjustment. Wrestlers employ breathing exercises and relaxation to regulate nervous energy.

4.3 Psychological Training and Individualization

Psychological training tailored to temperament and personality improves mental readiness. Wrestlers with sanguine, choleric, phlegmatic, or melancholic temperaments need different mental training methods to boost motivation, emotional control, and attention. Effective psychological training programs combine physical and technical preparation with anxiety inventories and stress responsiveness tests to monitor mental states and tailor interventions. Cognitive-behavioral therapy, mindfulness, imagery rehearsal, and mental endurance training are commonly used to promote

resilience, concentration, and competitive mindset (Sarıakçalı *et al*., 2025) [9].

4.4 Emerging Trends and Challenges

Recent research suggests wrestling regulations have increased psychological demands on psychomotor skills like reaction time and decision-making speed, combined with emotional control. As competition and tactics evolve, wrestlers must exhibit cognitive flexibility and mental agility. Mental health awareness and assistance are growing as athletes endure demands that can cause anxiety, stress, and despair. Wrestling communities struggle to establish comprehensive mental health initiatives due to stigma and resource constraints.

5. Integrative Approaches and Future Directions in Elite Greco-Roman Wrestling Performance

Performance efficiency in elite Greco-Roman wrestling is a complex interaction of physiological, technical, and psychological elements. Recently developed multidisciplinary and integrative techniques that comprehensively analyze athletes and adapt interventions to maximize each feature synergistically are crucial. This section examines integrated athlete profiling trends, performance monitoring technology, tailored training programs, and longitudinal research for sustainable athlete development. It emphasizes injury avoidance in integrated performance models.

5.1 Multidisciplinary Athlete Profiling

Multidisciplinary profiling uses physiological, biomechanical, psychological, and tactical data to improve athlete performance. Such profiling measures an athlete's strength, endurance, anaerobic power, technical skills, cognitive processes (reaction time, decision-making), and mental skills (motivation, emotional regulation). This method helps coaches and sports scientists discover strengths and shortcomings in a system rather than individual disciplines. Profiling includes lab and field testing, video analysis, sensor data, and psychological surveys. Regular monitoring allows dynamic training program adjustments and focused mental preparation and injury risk minimization. Elite programmes move from unidimensional testing to this integrated framework to maximise training ROI.

5.2 Technological Innovations and Wearable Technologies

Real-time biomechanical and physiological monitoring enabled by wearable technology has changed wrestling performance statistics. Accelerometers, gyroscopes, and heart rate monitors measure movement velocity, balance, grip force, muscular exhaustion, and cardiovascular strain during training and competition. Wearables provide real-time feedback for technique correction, pace modulation, and load management, improving technical and physical adaptations. Smart fabrics and sensor-embedded grips help identify injury-prone asymmetries. Machine learning algorithms on huge wearables and video datasets increase athlete preparedness, injury risk, and performance prediction models.

5.3 Personalized Training and Evidence-Based Interventions

Personalised training programmes take into account athletes' physiological profiles, technical skills, psychological traits, and development stage. Data-driven plans balance and prevent overtraining by optimizing volume, intensity, and recovery cycles (Cieśliński *et al*., 2021) [3]. Personalized psychological support strengthens resilience by teaching mental skills based on temperament and stress. Nutritional strategies address physiological and psychological needs to appropriately regulate weight and fuel training adaptations.

5.4 Longitudinal Monitoring and Athlete Development

Over months or years, longitudinal examinations of the same wrestlers reveal how physiological, technical, and psychological characteristics change. These data highlight milestones and performance indicators that influence career success. They help create achievable goals and adapt training to improve long-term performance. These longitudinal insights help periodized training frameworks aligned with competition calendars time peak performance and taper. They also facilitate early identification and intervention for detrimental trends such as overtraining or motivational declines.

5.5 Injury Prevention and Rehabilitation within Integrative Frameworks

The performance model must include injury prevention methods because to wrestling's high-contact, repetitive actions. Joint stability, core strength, and mobility training reduces common injuries. Biomechanical tests and psychological assistance ensure complete recovery and safe reintegration in rehabilitation regimens. Wearables track recovery progress and prevent setbacks. These tactics keep athletic development going while boosting mental resiliency.

6. Results

Elite Greco-Roman wrestlers have great upper-body maximum and explosive strength from systematic resistance and plyometric training. Wingate and repeated sprint tests show higher power and fatigue resistance for wrestling's high-intensity bursts. Secondary aerobic capacity helps elite wrestlers recover between efforts, with elevated VO2max values facilitating prolonged performance.

Neuromuscular adaptations improve proprioception, balance, and reaction time for dynamic posture control and technique efficiency. Anthropometric profile shows ideal lean muscle mass and mechanical benefits in limb and torso proportions for various weight groups. Hormonal and metabolic investigations show acute stress reactions to competition that might hinder recovery if uncontrolled, emphasizing the necessity to balance training load with rest.

Wrestlers use 10-12 specialized maneuvers, and success depends on accurate execution under exhaustion and mastery of “winning” hallmark techniques. Tactics respond to context and rule changes, enabling continuous activity, higher tempo, and aggressive methods. AI-based performance evaluations and video analysis provide objective coaching input and tactical planning. Psychology shows that volition, self-confidence, emotional control, and attentiveness determine competitive effectiveness. To cope with competition nervousness and quick weight loss, wrestlers use a variety of cognitive and behavioral methods. Temperament-based psychological training improves focus and resilience.

Integrating physiological, technical, and psychological data in athlete monitoring personalizes training. Machine learning and advanced wearable sensor technology improve load management, readiness evaluation, injury prediction, and recovery. Developmental milestones and career sustainability are informed by longitudinal tracking. Strength, joint stability, and motor control are supplemented by biomechanical and psychological therapy to prevent injuries.

7. Discussion

The examined evidence shows that top Greco-Roman wrestling performance comes from a harmonic synthesis of physical training, technical skill mastery, and psychological preparation. Physical strength and anaerobic power underpin the sport's explosive demands, but technical execution and tactical understanding are needed. Psychological qualities maintain performance constancy under harsh competitiveness and weight management challenges. Modern biomechanical analysis and video technology enable evidence-based technical skill development. Tactical agility is essential as competitive rules and opponent strategies change. Also important is psychological preparedness, especially mental toughness and stress management, which often requires focused personalized interventions to optimize competitive attitude.

Multidisciplinary, technology-enhanced athlete profile allows accurate, personalized training that emphasizes domain interactions rather than solitary improvement. This method boosts performance, reduces injury risk, and extends sports careers. Development trajectories from longitudinal monitoring inform training periodization and psychological support. Injury prevention is key to athlete availability and performance. Integrative rehabilitation with biomechanical and psychological assistance optimizes competition readiness.

8. Recommendations

1. **Adopt Multidisciplinary Athlete Profiling Frameworks:** Elite wrestlers must be evaluated using physiological, technical, and psychological methods to determine performance factors. Multidisciplinary profile should test muscular strength, anaerobic and aerobic capacity, neuromuscular coordination, biomechanical skill mastery, mental toughness, and stress resilience. Coaching and sports science teams can use this holistic approach to identify individual strengths and weaknesses for data-driven focused intervention and informed decision-making.
2. **Utilize Wearable Sensor Technologies and AI-Driven Video Analysis:** Wearable sensors track heart rate, acceleration, muscle exhaustion, and motion patterns to monitor training load and method execution in real time. AI-enhanced video analysis automates movement segmentation and error identification to improve technical feedback. These devices provide rapid, objective feedback to improve technical skills, training intensity, and athlete workload. Continuous data gathering improves physiological responses and fatigue recognition, minimizing injury risk.
3. **Implement Personalized, Data-Driven Training and Mental Skills Programs:** Trainers should tailor regimens to athletes' physiological capabilities, technical skill level, psychological disposition, and career stage. Periodization must meet individual recovery needs to maximize adaptation and minimize overtraining. Mental skills training for specific psychological profiles improves focus, motivation, emotional regulation, and competition stress management, including rapid weight loss. Visualization, mindfulness, and cognitive-behavioral approaches boost mental resilience and performance.
4. **Prioritize Longitudinal Athlete Monitoring:** Longitudinal athlete tracking reveals development, performance, and early symptoms of overtraining, burnout, and injury. Data-driven competition schedule-aligned periodization models optimize peak performance and tapering. For progressive yet sustainable athlete development, long-term monitoring promotes strategic training content, volume, and intensity modifications. Maintaining career longevity and managing workload throughout Olympic cycles requires this capacity.
5. **Maintain Up-to-Date Knowledge of Competition Rule Changes and Incorporate Tactical Training Adaptations:** Wrestling rules change, affecting tactics and scoring. Coaches and athletes must monitor rule changes to adjust training and competing methods. Replicating the competitive environment in tactical drills and decision-making exercises promotes rapid adaptation and strategic intelligence during matches. Maintaining competitive advantage and synchronizing athlete training with official standards requires understanding these developments.
6. **Develop Integrated Injury Prevention and Rehabilitation Protocols:** Due to the sport's high physical intensity and injury risk, joint stability, flexibility, core strength, and neuromuscular control must be improved. Strength and conditioning programs should target prevalent injuries and improve movement habits. Injury rehabilitation should include biomechanical examinations and psychological support for safe and effective healing. Monitoring rehabilitation progress with technology helps modify return-to-play decisions and reduce re-injury risk.
7. **Foster Interdisciplinary Collaboration Among Coaches, Sports Scientists, Psychologists, Nutritionists, and Medical Staff:** An integrated, multidisciplinary team supports athletes best. Specialists coordinate physical training, technical coaching, psychological preparation, nutritional assistance, and medical care through regular communication and planning. This relationship increases athlete well-being, multidimensional performance, and training and health response. Collaborative frameworks enable integrated decision-making and athlete development route optimization.

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