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## **Biomechanical analysis and metabolic demands of the defensive midfielder in contemporary football: a systematic and applied review.**

Biomechanical analysis and metabolic demand of the defensive midfielder in contemporary soccer: a systematic and applied review

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### **Summary**

This scientific article investigates the physiological adaptations, predominant bioenergetic pathways, and specific biomechanical demands of the defensive midfielder position in modern high-performance soccer. The research problem focuses on the need to understand how the tactical evolution of the game, characterized by an exponential increase in intensity and a drastic reduction in maneuvering space, has altered the bioenergetic and mechanical profile required of these athletes. The overall objective is to analyze the intermittency of high-intensity efforts, the mechanical load imposed by changes of direction and decelerations, and to propose evidence-based physical training protocols that mitigate the risk of injury and optimize performance. The methodology adopted is a narrative and systematic literature review of studies on exercise physiology, kinesiology, and sports training, limited to the period up to 2021. The results indicate that the defensive midfielder covers greater total distances than other positions, with a critical predominance of eccentric deceleration actions that require specific neuromuscular adaptations. It can be concluded that physical preparation should prioritize aerobic power for recovery and reactive strength to withstand the current competitive intensity.

**Keywords:** Football Physiology. Applied Biomechanics. Anaerobic Metabolism. Strength training. Defensive midfielder.

### **Abstract**

This scientific article investigates the physiological adaptations, predominant bioenergetic pathways, and specific biomechanical demands of the defensive midfielder position in modern high-performance soccer. The research problem focuses on the need to understand how the tactical evolution of the game, characterized by an exponential increase in intensity and a drastic reduction in maneuvering spaces, has altered the bioenergetic and mechanical profile required of these athletes.

The general objective is to analyze the intermittency of high-intensity efforts, the mechanical load imposed by changes of direction and decelerations, and to propose evidence-based physical training protocols that mitigate the risk of injury and optimize performance. The methodology adopted is a narrative and systematic bibliographic review of studies on exercise physiology, kinesiology, and sports training, limited to the period up to 2021. The results indicate that the defensive midfielder covers total distances greater than other positions, with a critical predominance of eccentric deceleration actions that require specific neuromuscular adaptations. It is concluded that physical preparation must prioritize aerobic power for recovery and reactive strength to withstand current competitive density.

**Keywords:** Soccer Physiology. Applied Biomechanics. Anaerobic Metabolism. Strength Training. Defensive Midfielder.

## **1. Introduction**

The evolution of football over the last two decades has imposed a drastic reconfiguration and mandatory in the physical and physiological demands of elite athletes, transforming sport into a discipline with extremely high bioenergetic demands. Studies of motion analysis (*time-motion*). *Analysis* consistently reveals that, although the total distance traveled has stabilized at around 10 to 13 kilometers per race, the number of high-intensity actions — including sprints,



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Jumps, tackles, and abrupt changes of direction—this has increased exponentially, requiring a complete reassessment of physical preparation methods. In this complex scenario, the midfield position... The defensive midfielder, popularly known as a defensive midfielder, presents himself as a paradigm. A unique and challenging physiological structure for physical trainers and physiologists. Located in the nerve center. From the field, this athlete is subjected to a constant, hybrid external load: he needs capacity Elite aerobic training to cover large areas of the playing field (volume) and, simultaneously, power. anaerobic explosive fire to execute decisive disarming, transition, and cover actions (intensity). A Physical Education, as the science of human movement, must dissect these variables with precision. surgical intervention is needed to prescribe training that respects positional specificity and individuality. biological.

The scientific and social rationale for this study lies in the alarming incidence of injuries. Muscular and joint injuries observed in midfielders in the world's major leagues. often associated with accumulated fatigue and inadequate physical preparation for the demands The real and chaotic aspects of modern gaming. Specialized academic training in *Fitness Training* and Sports Performance allows us to understand that generic and linear training is clearly insufficient for the elite athlete who operates at the limit of their physiological capabilities. It is imperative to analyze in depth the predominant energy systems – the phosphagen system (ATP-CP) for explosive actions of very short duration and glycolysis/oxidative phosphorylation for recovery between intermittent stimuli – to design training microcycles that are, at the same time, Effective in improving performance and safe for the athlete's physical integrity. Understanding A detailed understanding of the interaction between internal and external load is key to athletic longevity.

This work is structured around five fundamental axes of academic analysis: a bioenergetics of intermittency and the capacity for *Repeated Sprint Ability* (RSA); biomechanics vectorial changes in direction and the impact of ground reaction forces; neuromuscular fatigue and its direct implications for technical and tactical efficiency; ideal anthropometry and body composition. for the function; and post-exercise *recovery* strategies based on physiology. A The methodology revisits classic works of exercise physiology literature applied specifically to... football, seeking to establish an "evidence-based performance" protocol that can serve A guide for professionals in the field. The central hypothesis is that the modern defensive midfielder is a An athlete with mixed physiological characteristics who requires a periodization model that integrates, The development of aerobic power and reactive strength capacity are inextricably linked.

## **2. Applied bioenergetics and the intermittency of effort in midfield**

Football is physiologically classified as a sport of stochastic character and Intermittent, where periods of low intensity, such as walking and jogging, are interspersed.



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Randomly, explosions of extremely high intensity define the game's critical moments.

For the defensive midfielder, this inconsistency is exacerbated by the tactical need to react.

continuously reacting to the movements of both opposing attackers and their own teammates.

The team requires constant metabolic readiness. The aerobic metabolic pathway forms the basis.

physiological process that supports phosphocreatine (PCr) resynthesis during low-intensity intervals.

or passive pauses. A high Maximum Oxygen Consumption ( $VO_{2max}$ ), ideally above 60

ml/kg/min for elite athletes is strongly correlated in the literature with greater capacity.

to maintain the intensity and frequency of *sprints* in the final minutes of the match, delaying the

onset of peripheral and central fatigue.

However, the actions that are crucial to the midfielder's success — the precise tackle,

The leap for a defensive header, the long-range shot, and the acceleration to intercept a pass.

— are predominantly dependent on anaerobic alactic metabolism and the capacity

The neuromuscular system's ability to generate force quickly. The Rate of Force Development (RFD), or the capacity

The ability to generate explosive force in times less than 300 milliseconds is the parameter that differentiates the...

The difference between elite and average athletes depends primarily on the ability to train.

Repeated *Sprint Ability* (RSA), which is the physiological ability to perform successive *sprints* with the

minimal decrease in performance between them. Exercise physiology teaches that tolerance to

Metabolic acidosis, caused by the accumulation of  $H^+$  ions resulting from ATP hydrolysis and glycolysis.

It is fast-acting and highly trainable through specific high-intensity interval training (HIIT) methods.

The work-to-pause ratio (density) in midfield is a critical factor that should dictate the

Prescription of physical training. Unlike full-backs and wingers, who perform long linear runs.

with more defined pauses, the steering wheel performs a multitude of short, intense movements and

Multidirectional movement in extremely small and congested spaces. This demands efficiency.

Upper mitochondrial system for the "cleaning" and reuse of blood lactate as an energy substrate.

a process known as *Lactate Shuttle*. The training should simulate this specific density,

using small-sided games *that* raise the heart rate to zones

near or above the anaerobic threshold, mimicking the metabolic demands of competition without

Excessive joint wear and tear caused by continuous long-distance running in a straight line.

The efficiency of the buffer system (bicarbonate) and the capacity of the conveyors of

Monocarboxylates (MCTs) are responsible for removing lactate from muscle cells into the bloodstream.

Essential peripheral adaptations for the midfielder. During intense game sequences, where the

If the ball remains contested in the central zone for minutes on end, the lactate concentration can reach...

levels higher than 10-12 mmol/L. The athlete who does not possess glycolytic enzymatic adaptations and

Robust oxidative stress will lead to premature fatigue, resulting in loss of fine motor coordination and

Errors in tactical decision-making. Therefore, physical conditioning is not only aimed at endurance,



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but the maintenance of cognitive clarity through metabolic homeostasis under stress.

In addition to classic energy pathways, the running economy *plays* a role .  
a vital role in the defensive midfielder's performance throughout a season. Athletes with  
Better economy of motion means they use less energy to perform the same mechanical work.  
preserving their muscle glycogen reserves for the crucial moments of the match.  
Maximum strength training and plyometrics have proven effective in improving running economy.  
by increasing the stiffness *of* the muscle-tendon complex, allowing for greater  
harnessing the elastic energy accumulated during the stretch-shortening cycle of the stride.  
This demonstrates the inseparable interconnection between strength training and *endurance* capacity.  
in modern football.

Monitoring internal load through heart rate and subjective perception of  
Performance level (PSE) should be cross-referenced with GPS data (external load) to ensure that the training...  
is reaching the target zones of bioenergetic adaptation. For flyers, it is crucial to monitor whether they are not  
not only the total distance, but also the distance traveled in high-speed zones (>19.8 km/h) and the  
number of high-intensity accelerations (>3 m/s<sup>2</sup>). A training program that neglects the  
The specificity of these metrics risks undertraining the anaerobic system or overloading the...  
The aerobic system is trained in a non-specific way, failing to prepare the athlete for the chaotic reality of 90 minutes.  
of the game.

Finally, sports nutrition and strategic supplementation (such as creatine, beta-alanine and  
Nitrates act as indispensable co-factors in optimizing these metabolic pathways.  
A thorough understanding of exercise biochemistry enables physical education professionals and...  
A multidisciplinary team will design pre-, intra-, and post-workout fueling strategies that  
maximize glycogen resynthesis and tissue repair. The defensive midfielder, due to  
Its high volume of play and constant involvement in physical duels has a high caloric demand and  
Increased protein intake should be periodized according to the load of the training microcycles.

### **3. Biomechanical analysis: the mechanics of deceleration and change of direction.**

The biomechanics of a defensive midfielder are fundamentally characterized by a  
an extraordinarily high volume of high-magnitude accelerations and decelerations (Acc/Dec).  
Advanced biomechanical studies indicate that the mechanical load generated by a sudden deceleration  
(braking) can be up to three to six times greater than the load generated by an acceleration of the same  
intensity, due to ground reaction forces and the need to dissipate kinetic energy. For  
The midfielder, who needs to constantly change direction to close passing lanes, must keep up.  
Whether it's the dribbling skills of agile attackers or providing defensive cover, the ability to use eccentric force in...  
Strengthening the hamstring and quadriceps muscle groups is absolutely vital for joint integrity.



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Failure to maintain eccentric strength, especially under fatigue conditions, results frequently in muscle strain injuries or, in more serious cases, in rupture of the Anterior cruciate ligament (ACL) injury, one of the most devastating injuries in sports. The mechanism of ACL injury in non-contact situations generally occurs during combined deceleration with a change of direction and rotation of the trunk, generating a dynamic valgus of the knee that exceeds the tensile strength of the ligament. Preventive training should focus on neuromuscular control of the dynamic valgus, strengthening of the posterolateral hip complex (gluteus medius and maximus) and improvement of landing and braking techniques.

The Change of Direction (COD) movement involves components Complex perceptual-cognitive and motor skills that go beyond simple brute force. Biomechanically, An efficient COD requires a wide support base, lowering the center of gravity to increase stability and optimize the application of lateral force against the ground to generate the vector of Change. Strength training for midfielders should include exercises with force vectors multidirectional and plyometric exercises that emphasize the stretch-shortening cycle (SSC) in frontal and transverse planes, and not only in the sagittal plane, as occurs in linear running traditional.

*Tendon stiffness* should be optimized through plyometric training so that so that the elastic energy accumulated during the landing phase is efficiently reused during the phase of subsequent propulsion. An overly compliant tendon dissipates energy as heat, while a tendon... With ideal stiffness, it acts like a spring, increasing movement efficiency and reducing costs. Metabolic changes of direction. Exercises such as *drop jumps*, hurdle jumps, and exercises Reactive agility is fundamental to developing this specific mechanical quality in midfielders, who perform hundreds of CODs per match.

Asymmetry in strength between the lower limbs is a prevalent and dangerous risk factor. In football, this is often exacerbated by the athlete's foot preference (dominant leg). The assessment Isokinetic testing in elite athletes often reveals significant imbalances between the musculature. Knee flexor and extensor (I/Q ratio) or between the dominant and non-dominant limb. The correction Addressing these deficits through unilateral and functional strength training is a preventative intervention. Mandatory. Unilateral training not only corrects asymmetries but also activates the muscles. It stabilizes the trunk and hip more intensely than bilateral exercises.

The "Core" (lumbopelvic-hip complex) acts as the central link for the transfer of Strength between the lower and upper limbs. For the defensive midfielder, a stable *core* and Strength is essential to winning physical duels (shoulder-to-shoulder loads) without losing dynamic balance. and ball possession. *Core* instability results in energy "leakage" and reduced efficiency in Applying force to the lower limbs, in addition to increasing the risk of injuries in the pubic region.



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(pubalgia) and in the lumbar spine. *Core* stability training should be integrated into

Functional football movements, not just isolated movements performed on the ground.

Finally, the biomechanical analysis must consider the athlete's interaction with the playing surface.

(natural grass, synthetic grass, hybrid) and footwear (soccer cleats). Excessive rotational traction

The risk of injury provided by certain combinations of locks and surfaces can increase the risk of injury.

Twisting movements in the knees and ankles during changes of direction. The Physical Education professional

It should guide athletes on choosing the right equipment and adapt the intensity of their training.

changing direction according to the characteristics of the surface, minimizing the risk of

Joint locking and maximizing mechanical performance.

#### **4. Neuroscience and fatigue: tactical implications for high performance.**

Fatigue in high-performance football is not a purely peripheral phenomenon or

metabolic; it has a significant central neural component that directly affects the

Midfielder performance. Central fatigue, characterized by a reduction in the capacity of the system.

The central nervous system's inability to recruit voluntary motor units manifests itself not only in a decrease in

production of force, but also in the deterioration of higher cognitive functions, such as attention,

Anticipation and decision-making. For a defensive midfielder, whose primary function is tactical awareness and positioning.

In the context of rational space, mental fatigue can be as, or even more, detrimental than muscle failure.

Neurophysiological studies demonstrate that, under conditions of fatigue, there is a decrease

in the speed of nerve impulse conduction and an alteration in muscle activation patterns,

resulting in less coordinated and less efficient movements. This explains why many errors occur.

technical (incorrect passes, poor ball control) and tactical (incorrect positioning, delayed coverage) errors.

These events occur in the last 15 minutes of each half of the game. Endurance training should therefore...

incorporating complex cognitive tasks under a state of induced physical fatigue, training the brain to

Maintain efficient information processing even under conditions of physiological stress.

high.

The ability to maintain focused concentration and peripheral awareness is vital for the environment.

Defensive fielder. Neuroscience applied to sports suggests that "endurance" training

"Mental" or "cognitive resilience" can be achieved through small-sided games with variable rules.

and high demand for information processing. By overloading the cognitive system during the

Physical exertion promotes neural adaptations that increase tolerance to mental fatigue and improve...

the athlete's ability to filter out irrelevant stimuli and focus on the critical visual cues of the game, such as

The opponent's body language.

Neuromuscular fatigue also affects proprioception and dynamic postural control.

increasing the risk of sprains and ligament injuries. When the articular mechanoreceptors and



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Muscle sensitivity is reduced by fatigue, slowing the reflex response time to stabilize.

An articulation in the face of an unexpected disturbance increases dangerously. The inclusion of Balance and perturbation exercises in controlled pre-fatigue states during training can help adapt the sensorimotor system to operate more safely and efficiently at times finals of competitive matches.

Post-game neural recovery is an aspect that is often overlooked in comparison with metabolic recovery. The cognitive stress of a highly competitive match, added Travel and pressure for results can lead to a state of *burnout* or chronic fatigue of the system. Nervous system. Sleep hygiene strategies, heart rate variability monitoring. (HRV) as a marker of autonomic balance and relaxation techniques are fundamental for restore the midfielder's neural readiness for the next training microcycle and competition.

Understanding neural fatigue also influences the strategy for substitutions and rotations. cast analysis. Real-time GPS and accelerometry data analysis allows for the identification of falls. Abrupt changes in the intensity or frequency of explosive actions, signaling that the system The athlete's neuromuscular system has reached its functional limit. The tactical substitution of a fatigued midfielder. It's not just a matter of maintaining the team's physical intensity, but of preserving its integrity. structural aspects of the defensive system, which depend on the clarity and ability to react quickly of that individual. key player.

It is concluded that modern physical training must transcend the hydraulic model of "filling" "The energy tank" and adopt a complex neurobiological model. The midfielder's training A defensive strategy should aim to build an athlete resistant to fatigue at all levels. metabolic, muscular, and neural. The integration between exercise science and cognitive neuroscience is the final frontier for optimizing human performance in elite football, allowing that Technique and tactics prevail over fatigue.

## **5. Anthropometry, body composition, and specific strength.**

The anthropometric profile and body composition of the defensive midfielder have evolved. significantly to keep up with the physical demands of contemporary football. Currently, We are looking for an athlete with a low percentage of body fat (ideally between 8% and 10%) and a Well-developed functional muscle mass that provides power without compromising agility. and resistance. Excess body fat represents dead weight that increases the cost. The energy expenditure of locomotion and the load on the joints during impact phases accelerate fatigue and increasing the risk of chronic overuse injuries.

The power-to-weight ratio is a crucial indicator of performance. The midfielder does not



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It needs to have the excessive hypertrophy of a bodybuilder, which could limit the range of motion and cardiovascular efficiency, but it requires optimal levels of relative strength. Strength training The focus should be on myofibrillar hypertrophy (increased contractile density) rather than hypertrophy. sarcoplasmic reticulum, aiming to increase the capacity for force production per unit mass. muscular. This allows the athlete to be strong in duels and explosive in sprints, maintaining Light enough to withstand 90 minutes of intermittent running.

Regular anthropometric assessment, using protocols such as ISAK (*International The Society for the Advancement of Kinanthropometry*) allows monitoring of morphological adaptations to Training and diet. For midfielders, muscle mass in the lower limbs, especially The muscles used to strengthen the glutes, quadriceps, and hamstrings are fundamental for power generation and joint protection. However, trunk and shoulder girdle strength are also vital for stability in physical contact. and for the efficiency of running biomechanics, acting as a counterbalance during movements. of the lower limbs.

The concept of "Optimal Strength" should guide physical preparation. There is a point from which... The additional gain in maximum strength does not translate into improved performance on the field and may even... to impair fine motor coordination or endurance. The goal is to develop the strength that can be applied. at the specific speeds and timings of football. The transfer of power gained in the room. Strength training for the playing field is performed through complex and contrast exercises, where Heavy force movements are immediately followed by explosive sporting gestures. biomechanically similar.

Biological individuality must be respected when defining body composition goals. Bodybuilding. Midfielders with more defensive and physical characteristics can benefit from a greater muscle mass for physical imposition, while midfielders with greater characteristics Mobility and game planning may prioritize a more slender and robust build. The role of The role of the physiologist and physical trainer is to find the ideal balance for each athlete, adjusting the variables. Training and nutrition to shape the physique to the tactical needs of the position and the characteristics The individual's genetics.

Periodized nutrition plays a central role in manipulating body composition. Body composition. Macronutrient intake should be adjusted according to daily energy expenditure and The objectives of the microcycle (fat loss, maintenance, or lean mass gain). The *timing* of Protein and carbohydrate intake is crucial for maximizing protein synthesis and recovery. Glycogen. Nutritional education for athletes is an integral part of invisible training, ensuring that the body has the necessary substrate to adapt to the stimuli of intense physical training.

In short, building the body of an elite athlete is a scientific and continuous process. Anthropometry and body composition are not merely aesthetic issues, but determining factors.



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functional aspects of biomechanical and physiological performance. The modern defensive midfielder is a Athlete honed for efficiency, where every gram of body mass has a specific function in... Execution of the complex motor and tactical tasks required by high-level football.

## 6. Conclusion

The detailed biomechanical and physiological analysis presented in this study confirms, in a way It is unequivocal that the defensive midfielder position is one of the most demanding roles and Complex aspects of modern sport viewed through the lens of movement science. Elite performance in this context. Position is not a matter of chance or simply innate technical talent, but rather the result of adaptation. Refined and systematic biological response to highly specific and controlled training stimuli. harmonious integration between elite aerobic capacity, necessary to withstand the volume of play. ...and intra-effort recovery, and explosive neuromuscular power, vital for defining crucial plays. Winning duels should be the central objective of contemporary physical preparation in football.

The investigation demonstrated that negligence regarding the eccentric demands of Braking and changes of direction are a primary causal factor in the epidemiology of muscle injuries. and ligamentous injuries in flywheels. Therefore, the inclusion of eccentric strength training protocols, Multidirectional plyometrics and core stabilization should not be seen as complementary, but as... The fundamental basis for injury prevention and athletic longevity. The ability to slow down. Efficiency is just as important as the ability to accelerate, both for tactical performance. as well as for the athlete's joint health.

Furthermore, understanding fatigue as a complex neurobiological phenomenon, which It affects decision-making and fine motor coordination, reiterating the need for methodologies of Training that integrates cognitive stress with physical exertion. The modern athlete must be trained To think clearly while operating under metabolic acidosis and mechanical stress. Monitoring The internal and external burden, combined with evidence-based recovery strategies, allows the The coach and physical trainer can modulate the stress imposed on the athlete, maximizing adaptations. positive and minimizing the risk of *overtraining*.

It can be concluded, therefore, that the role of the Physical Education professional in the context of High-performance football must be rigorously based on scientific data and applied physiology. and biomechanics, moving away from empiricism and unfounded tradition. A deep understanding of metabolic pathways, vector mechanics of game actions, and biological markers of fatigue It is essential for building resilient, intelligent, and high-performing athletes. The science of Sport, when applied with academic rigor and practical sensitivity, transforms genetic potential. Raw, sustainable athletic excellence, raising the level of the game and protecting the human being behind it. of the athlete.



## 7. References

BANGSBO, J. **The physiology of soccer--with special reference to intense intermittent exercise.** *Acta Physiologica Scandinavica*, v. 151, suppl. 619, p. 1-155, 1994.

BOMPA, TO; HAFF, GG **Periodization: Theory and Methodology of Training.** 5. ed. Champaign: Human Kinetics, 2009.

BRADLEY, PS et al. **High-intensity running in English FA Premier League soccer matches.** *Journal of Sports Sciences*, vol. 27, no. 2, p. 159-168, 2009.

DI SALVO, V. et al. **Analysis of high intensity activity in Premier League soccer.** *International Journal of Sports Medicine*, vol. 30, no. 3, p. 205-212, 2009.

GABBET, TJ **The training—injury prevention paradox: athletes should be training smarter and harder.** *British Journal of Sports Medicine*, vol. 50, no. 5, p. 273-280, 2016.

MCHUGH, MP et al. **The role of passive muscle stiffness in symptoms of exercise-induced muscle damage.** *American Journal of Sports Medicine*, vol. 27, no. 5, p. 594-599, 1999.

RAMPIRINI, E. et al. **Technical performance during soccer matches of the Italian Serie A league: Effect of fatigue and competitive level.** *Journal of Science and Medicine in Sport*, vol. 12, no. 1, p. 227-233, 2009.

STØLEN, T. et al. **Physiology of soccer: an update.** *Sports Medicine*, vol. 35, no. 6, p. 501-536, 2005.