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The Relationship Between Somatotype and Energy Utilization Efficiency During High and Low-Intensity Exercise in Athletes

Bouaita Toufik*[1]

[1] Institute of Science and Techniques of Physical and Sports Activities, University Abdelhamid Mehri of Constantine 2, Algeria, E-Mail bouaita.toufik@univ-constantine2.dz

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Abstract:

This study focuses on the relationship between somatotypes and energy efficiency in athletes, analyzing differences in anaerobic and aerobic efficiency across various somatotypes and exercise intensities. Using a descriptive-analytical approach, results confirmed a clear link between somatotype and metabolic efficiency. Ectomorphs excel in aerobic endurance, mesomorphs demonstrate overall superior energy efficiency, while endomorphs face challenges. This understanding enables coaches and nutritionists to design personalized programs for maximizing performance and minimizing risks.

KEY WORDS : Somatotype ; Energy Efficiency ; High-Intensity Exercise ; Low-Intensity Exercise ; Athletic Performance

الملخص:

تركز هذه الدراسة على العلاقة بين الأنماط الجسمانية وكفاءة استخدام الطاقة لدى الرياضيين، وتحلل الاختلافات في الكفاءة اللاهوائية والهوائية باختلاف الأنماط وشدات التمرين. باستخدام المنهج الوصفي التحليلي، أكدت النتائج وجود رابط واضح بين النمط الجسماني والكفاءة الأيضية. يتفوق النحفاء (الإكتومورف) في التحمل الهوائي، وذوو البنية العضلية (الميزومورف) يظهرون كفاءة طاقة شاملة، بينما يواجه ذوو البنية الممتلئة (الإندومورف) تحديات. هذا الفهم يمكّن المدربين وخبراء التغذية من تصميم برامج مخصصة لتعظيم الأداء وتقليل المخاطر.

الكلمات المفتاحية: النمط الجسدي ؛ كفاءة استخدام الطاقة ؛ التمارين عالية الشدة ؛ التمارين منخفضة الشدة ؛ الأداء الرياضي.

* *Corresponding author.*

1-Introduction:

Optimal athletic performance stems from genetic predispositions (like somatotype), rigorous training, and tailored nutrition. Somatotype, classified by Sheldon in the 1940s into primary (endomorph, mesomorph, ectomorph) and mixed types, significantly influences an athlete's capabilities.

This study highlights that body structure variations inherently impact physiological responses and energy efficiency. However, generic training and nutrition programs often overlook these differences, limiting athletes' potential, leading to suboptimal performance and increased injury risk. This research aims to address this gap by exploring the fundamental relationship between somatotypes and energy extraction/utilization efficiency during high and low-intensity exercise in athletes.

Accordingly, the general question that this study seeks to answer is: How does energy utilization efficiency (anaerobic and aerobic) differ among various somatotypes during exercises of varying intensities (high and low)?

To answer this general question, the study proposes the following main hypotheses:

- Hypothesis 1: There is an expected analytical relationship between an athlete's Somatotype and the most efficient metabolic systems for energy utilization during high-intensity exercises.
- Hypothesis 2: There is an expected analytical relationship between an athlete's Somatotype and the most efficient metabolic systems for energy utilization during low-intensity exercises.

This study is significant because it offers a scientific foundation for coaches, trainers, and athletes to design personalized training and nutrition programs. By understanding the physiological predispositions linked to each somatotype, training can be optimized for better metabolic efficiency, peak performance, and reduced risks associated with generic approaches, ultimately helping athletes reach their full potential.

2- General objective of the study:

The general objective of this study is to provide a comprehensive analytical framework that elucidates how energy utilization efficiency (anaerobic and aerobic) differs among various somatotypes across varying exercise intensities.

1. Describe and analyze the relationship between an athlete's somatotype and the efficiency of metabolic systems in energy utilization during high-intensity exercise.
2. Describe and analyze the relationship between an athlete's somatotype and the efficiency of metabolic systems in energy utilization during low-intensity exercise.
3. Provide a scientific framework for designing personalized training and nutrition programs based on somatotype-specific energy utilization efficiency.

3- Procedural definition of the concepts mentioned in the research:

- **The first concept**: Somatotypes

Somatotyping serves as a fundamental analytical tool in the fields of sports science and anthropometry, enabling the description and classification of individuals based on the proportions of three primary body components: roundness/fatness (Endomorphy), muscularity (Mesomorphy), and linearity/slenderness (Ectomorphy) (Norton & Olds, 1996). This classification offers a profound understanding of each athlete's physical constitution, which impacts their metabolic efficiency and training response across various sports disciplines (Cichy et al., 2021). The main and mixed somatotypes can be detailed as follows:

- Ectomorph: Characterized by a slender build, delicate bones, long limbs, and a minimal percentage of fat and muscle. Individuals of this somatotype typically find it challenging to gain weight and usually possess a high metabolic rate (Caruso et al., 2023).
- Mesomorph: Naturally athletic and strong in build, featuring broad shoulders, a defined waist, and well-developed muscles. They

exhibit a remarkable ability to build muscle and lose fat with ease, showing an excellent response to training (Smith et al., 2021).

- Endomorph: Characterized by a fuller body with an inherent tendency to store fat, particularly in the abdominal and hip areas. They often possess a larger bone structure and a slower metabolic rate, which makes weight management more challenging, yet they enjoy considerable natural physical strength (Cichy et al., 2021).

Beyond these pure somatotypes, the vast majority of athletes exhibit mixed characteristics combining traits from two or more types, and these mixed somatotypes play a vital role in determining specialized athletic performance:

- Ecto-Mesomorph: Combines the leanness of the ectomorph with good muscle-building capability, making it suitable for sports requiring agility and relative strength.
- Meso-Ectomorph: Tends towards a clear muscular build with a relative lean tendency, making it an effective somatotype in endurance sports that demand repetitive strength.
- Meso-Endomorph: Possesses good muscle mass with a tendency to store some fat, often being strong and having muscular endurance capabilities.
- Endo-Mesomorph: Combines the tendency to store fat with inherent muscular strength, and can excel in pure strength sports that do not require rapid movement or significant aerobic endurance (Norton & Olds, 1996; Smith et al., 2021).

Understanding these multiple somatotypes significantly enhances coaches' ability to design optimized training and nutrition programs that align with an athlete's individual constitution.

The researcher concludes that somatotypes, particularly mixed types, are crucial for comprehensive assessment and personalized training design.

The second concept: Energy Utilization Efficiency

Energy utilization efficiency is a pivotal factor in determining athletic performance and an athlete's endurance capacity. It is defined

as the body's ability to convert available energy sources (carbohydrates, fats, and even proteins) into kinetic energy with minimal waste, coupled with the ability to rapidly regenerate this energy to sustain continuous physical effort and delay the onset of fatigue (Powers et al., 2021). This efficiency relies on complex mechanisms involving several metabolic systems that produce energy, working in varying harmony depending on the intensity and duration of the activity.

In the Anaerobic System, which is essential for high-intensity, short-duration exercises, two primary mechanisms stand out: First, the ATP-PCr System, which relies on high-energy phosphate stores of ATP and PCr to produce immediate and very rapid energy, ideal for short bursts of power (e.g., throwing and jumping). Second, Anaerobic Glycolysis, which breaks down glycogen (stored in muscles and the liver) to rapidly produce energy in the absence of oxygen, supporting medium-duration high-intensity exercises. However, it produces lactic acid as a byproduct, leading to fatigue (McArdle et al., 2015).

Conversely, the Aerobic System is relied upon for energy production during low-intensity, long-duration exercises, where it efficiently uses oxygen to burn carbohydrates and fats over the long term, providing a sustained energy supply and delaying exhaustion (Brooks et al., 2020). Based on these systems, exercises are classified as High-Intensity Exercise, characterized by very high energy demands and heavy reliance on anaerobic systems for maximal power and speed production, and Low-Intensity Exercise, which primarily depends on the aerobic system to sustain effort for prolonged periods with efficient fat utilization to preserve glycogen stores (Powers et al., 2021).

The researcher concludes that energy utilization efficiency is a dynamic process governed by complex metabolic pathways, which are fundamentally influenced by the type and intensity of physical activity.

4- **The methodological procedures used in the study:**

4-1 Method and tools: The study adopted a descriptive-analytical approach, focusing on the conceptual framework of somatotypes and energy utilization efficiency. This study is theoretical and analytical in nature and does not involve a direct sample of participants. Instead, it relies on a comprehensive review and synthesis of existing scientific literature and established conceptual frameworks related to somatotypes and human energy systems. The "sample" in this context refers to the body of knowledge, scientific theories, and empirical findings drawn from various scholarly sources, which form the basis for the analysis and conclusions.

The primary "tools" for this research are scientific literature review and analytical synthesis. This includes:

- Academic Databases: Utilizing databases such as PubMed, Google Scholar, ResearchGate, and university library resources to identify relevant peer-reviewed articles, reviews, books, and theses.
- Key Textbooks and Encyclopedias: Consulting foundational texts in exercise physiology, sports science, human anatomy, and nutrition to establish a robust theoretical understanding of somatotypes and energy metabolism.
- Conceptual Models: Employing established models of energy systems (e.g., ATP-PC system, anaerobic glycolysis, aerobic oxidation) and somatotyping methodologies (e.g., Sheldon's somatotype components) as analytical frameworks.
- Data Analysis (Conceptual): Interpreting and correlating the information gathered from various sources to identify patterns, relationships, and implications regarding somatotype-specific energy efficiency.

- The scientific foundations of the tool: This theoretical study's analytical methodology is founded on established scientific principles from exercise physiology, anthropometry, and sports nutrition. It utilizes widely accepted models (e.g., Heath-Carter Somatotype Method, energy system pathways) as its "scientific foundations." Since no new primary data was collected, "tools" refer to the analytical framework applied to existing literature. Similarly, "statistical tools" denote the qualitative synthesis and comparative

analysis of reported findings from other studies, focusing on logical inference from comprehensive evidence, not new computation.

4-2 Presentation and Analysis of Results:

Table N°1: Energy System Efficiency and High-Intensity Exercise Performance for Each Somatotype

Somatotype	Key Characteristics	Anaerobic System Efficiency	High-Intensity Exercise Performance
Mesomorph	Muscular, athletic build; high capacity for muscle/endurance.	Very High (Creatine Phosphate & Anaerobic Glycolysis)	Superior explosive power and speed (jumping, sprinting, weightlifting) due to large glycogen stores and rapid ATP generation
Meso-Ectomorph	Strong, muscular, relatively lean; high strength/speed.	Very High	Combines strength and speed for intense, short-duration efforts.
Meso-Endomorph	Muscular, mass with tendency to store fat; tremendous natural strength.	Good	Natural absolute strength in high-intensity, non-rapid movements (e.g., shot put, maximal weightlifting) Efficiency in repeated explosive movements may be limited.
Ectomorph	Slim frame, low muscle/fat; fast	Struggles	Challenges in sustaining anaerobic power

	metabolism.		due to lower muscle mass and fewer fast-twitch fibers, leading to rapid fatigue
Ecto-Mesomorph	Muscular with low body fat; balanced athletic build; combines fast metabolism and muscular capacity.	Good	Better than pure Ectomorphs, but still faces challenges in prolonged anaerobic power compared to mesomorphic types.
Endomorph	Solid build, tendency to store fat; natural strength, slow metabolism.	Struggles	Faces challenges across all energy systems, including anaerobic, due to slow metabolism and fat storage, limiting explosive and endurance performance.
Endo-Mesomorph	Muscular with mass, tendency to store fat.	Good (for absolute strength)	Natural absolute strength, but repeated explosive movements may be limited.

Source: Prepared by the Researcher Based on: (Cichy et al., 2021; Haff & Triplett, 2016; Kenney et al., 2024)

This text illustrates a clear link between body structure and physiological capacity for high-intensity exercise. Mesomorphic somatotypes (including Ecto-Mesomorph and Meso-Endomorph) show high anaerobic efficiency, enabling explosive power for activities like sprinting, due to superior glycogen stores and ATP generation. Conversely, Ectomorphs (and Ecto-Mesomorphs) struggle with sustained anaerobic power due to less muscle mass and quick

glycogen depletion. Endomorphs (and their mixed types like Endo-Mesomorph and Meso-Endomorph), despite slower metabolisms and fat storage, can generate absolute strength in non-agile, high-intensity tasks (e.g., shot put), though their efficiency in repeated explosive movements is limited.

Table N°2: Specific Metabolic Characteristics of Each Somatotype

Somatotype	Metabolic Characteristics	Anaerobic System Efficiency (Phosphagen & Glycolysis)	Aerobic System Efficiency
Ectomorph	High metabolic rate; struggles with weight gain and muscle building.	Low; challenges in high-intensity efforts due to limited muscle mass and rapid glycogen depletion.	Moderate to good; natural tendency for endurance due to lighter body weight, efficient fat utilization.
Mesomorph	Efficient muscle metabolism; easily builds muscle and loses fat; excellent response to training.	Superior; larger muscle glycogen stores and rapid ATP generation support high-power, short-duration activities.	Good; supports diverse athletic performance, highly adaptable.
Endomorph	Fuller body, tendency to store fat; slower metabolic rate; large natural physical strength.	Moderate; can generate absolute strength in non-rapid high-intensity tasks; lower efficiency in explosive movements.	Low; faces challenges in sustained aerobic performance due to body's tendency to store fat and slower metabolic rate.

Ecto-Mesomorph	Combines fast metabolism and muscular capacity; balanced athletic build with low body fat.	Good to Excellent; better than pure Ectomorphs in anaerobic power.	Excellent; benefits from aerobic endurance for overall performance improvement.
Meso-Ectomorph	Strong muscular, relatively lean; high strength/speed, good endurance capacity.	Very Excellent; highly efficient in generating power and speed.	Excellent; highly adaptable and efficient for endurance efforts.
Endo-Mesomorph	Muscular with mass, tendency to store fat; tremendous natural strength.	Good (for absolute strength); effective in heavy lifting but may struggle with repeated explosive movements.	Good (with focus on fat burning); needs integrated aerobic training for fat loss and metabolic improvement.
Meso-Endomorph	Strong and muscular build, higher fat percentage; high endurance and strength capacity.	Good to Excellent; effective in combining strength and some explosive power.	Good to Excellent; benefits from improving metabolic efficiency, adaptable to various endurance activities (e.g., team sports).

Source: Prepared by the Researcher Based on: (Cichy et al., 2021; Haff & Triplett, 2016; Kenney et al., 2024)

This analysis details how each somatotype utilizes energy across anaerobic and aerobic systems. Ectomorphs are aerobically

efficient for endurance but struggle anaerobically due to low muscle mass. Mesomorphs excel in both systems, demonstrating superior anaerobic power and adaptable aerobic capacity. Endomorphs possess natural strength but face challenges in sustained aerobic performance due to slower metabolism and fat storage, with moderate explosive efficiency. Mixed types blend these traits: Ecto-Mesomorphs show balanced efficiency; Meso-Ectomorphs are highly efficient in power and speed; Endo-Mesomorphs excel in strength but need aerobic support for fat management; and Meso-Endomorphs combine strength with good overall efficiency. This understanding of inherent metabolic predispositions is vital for tailored exercise and nutrition strategies.

Table N°3: The Relationship Between the Seven Somatotypes and Energy Utilization Efficiency in Low-Intensity Training and Competitive Activities Within the Aerobic System.

Somatotype	Somatotype Characteristics	Aerobic Efficiency	Strength, speed, and general endurance activities.	% HR max	Volume (Duration)	Density (Pace/ Rest)
Ectomorph	- Slim frame, little muscle and fat- Fast metabolism; struggles to build muscle	Moderate to Good (after adaptation) Benefits from larger training volume	Strength Endurance: Bodyweight exercises. Speed Endurance: Steady-pace running. General Endurance: Walking, swimming.	60-70%	45-90 minutes (3-5 times/ week)	Steady and continuous; very short rest for strength exercises
Mesomorph	Muscular, proportioned, athletic build-	Excellent Adapts quickly to fat burning	Strength Endurance: Weight circuit training. Speed	65-75%	30-60 minutes (4-6 times/ week)	Good pace; very short/no rest periods

	High capacity for muscle building and endurance		Endurance: Fast running, cycling. General Endurance: HIIT, football, rowing.			
Endomorph	- Solid build, tendency to store fat - Natural strength, slower metabolism	Very Good (with regular training) Requires higher training volume and consistency	Strength Endurance: Resistance, loaded uphill walking. Speed Endurance: Brisk walking, steady aerobics. General Endurance: Long walks, rowing, swimming.	55-65%	60-120 minutes (4-6 times/ week)	Steady and low pace; continuous
Ecto-Mesomorph	Lean, muscular, balanced build with fast metabolism.	Excellent Benefits from aerobic endurance to improve overall performance	Strength Endurance: Circuit/body weight. Speed Endurance: Running, swimming. General Endurance: Triathlon, running.	65-75%	45-75 minutes (4-5 times/ week)	Fairly steady; short rest periods
Meso-Ectomorph	- Strong muscular, relatively lean - High	Very Excellent Adapts quickly, high efficiency	Strength Endurance: Short-rest resistance. Speed Endurance:	70-80%	30-50 minutes (5-6 times/ week)	Relatively high pace; continuous

	strength/ speed, good endurance capacity		Fast/Fartlek running. General Endurance: Middle-distance, swimming**.**			
Endo-Mesomorph	- Muscular with mass, with a tendency to store fat - Tremendous natural strength	Good (with a focus on fat burning) Needs to integrate aerobic training for fat loss	Strength Endurance: High-rep resistance/circuit. Speed Endurance: Fast walking, light jogging. General Endurance: Rowing, integrated strength endurance.	60-70%	45-75 minutes (3-4 times/ week)	Moderate pace; very short rest
Meso-Endomorph	- Strong and muscular build, higher fat percentage- High endurance and strength capacity	Good to ExcellentBenefits from improving metabolic efficiency	Strength: High-rep bodyweight/functional. Speed: Short shuttle runs. General: Team sports (basketball, rugby, handball).	65-75%	40-70 minutes (4-5 times/ week)	Moderate; very short rest periods

Source: Prepared by the Researcher Based on: (Bini et al., 2024; Physiopedia, n.d.; The Sustainable Training Method, 2021)

This table serves as a powerful analytical tool for coaches and athletes to understand how to adapt low-intensity aerobic training to suit the individual characteristics of each somatotype. By focusing on appropriate intensity, volume, and density, and selecting activities that aerobically enhance strength endurance, speed endurance, and general

endurance, energy utilization efficiency can be improved, and overall athletic performance boosted. This approach considers each individual's physiological strengths and weaknesses, ensuring more effective and efficient training while reducing the risks of overexertion or injury.

Table N°4: Summary of Energy System Characteristics by Somatotype

Somatotype	Endomorphy	Mesomorphy	Ectomorphy	Anaerobic Efficiency	Aerobic Efficiency	Metabolic Rate	Ideal Sport/ Exercise.
Ectomorph	Low	Low	High	Low	Moderate to Good (with adaptation)	High	Light-body endurance (running, cycling); low explosive power; requires calorie surplus for muscle.
Mesomorph	Moderate	High	Moderate	Very High	Excellent	Balanced	Excels in power/strength/speed sports (sprinting, weightlifting, team sports); highly adaptable.
Endomorph	High	Moderate	Low	Moderate (for absolu	Low to Moderate (with focus	Slow	Suited for static strength sports

				te strength)	on fat burning)		(shot put, sumo wrestling); requires consistent aerobic training and calorie/fat control.
Ecto-Mesomorph	Low	High	Moderate	Good to Excellent	Excellent	High	Balanced athlete for agility/strength/endurance (gymnastics, mid-distance running); benefits from varied training.
Meso-Ectomorph	Low	High	Moderate	Very High	Excellent	High	Leaner Mesomorph, excels in strength-to-weight and endurance sports (rock climbing, combat).
Endo-Mesomorph	High	High	Low	Good to Excellent (absolute strengt	Good (with consistent training)	Moderate to Slow	Excels in power/throwing/heavy lifting; strong with mass

				h)			tendency; requires aerobic training for fat management.
Meso-Endomorph	Moderate	High	Moderate	Good to Excellent	Good to Excellent	Moderate	Excels in strength-endurance sports (rugby, wrestling, team sports); builds muscle while maintaining endurance

Source: Prepared by the Researcher Based on: (Bini et al., 2024; Physiopedia, n.d.; PureGym, 2024; The Sustainable Training Method, 2021)

This comprehensive table summarizes the core energy system characteristics for each of the seven somatotypes, including pure and mixed types. It provides a quick reference for understanding the metabolic strengths and weaknesses associated with different body compositions, directly correlating somatotype to the efficiency of anaerobic (ATP-PCr and Glycolysis) and aerobic (Oxidative) pathways. The table also indicates the typical metabolic rate and suggests ideal exercise or sport tendencies, offering a foundational guide for personalized training and performance optimization based on physiological predispositions.

4-3 Discussion and interpretation of the results:

- The conclusion reached.

The study conclusively demonstrates a profound and analytical relationship between an athlete's somatotype and their body's efficiency in utilizing various energy systems during both high-intensity and low-intensity physical activity. This confirms that morphological characteristics are not merely superficial but are critical determinants of an individual's physiological capacity and optimal performance in specific exercise types.

-Explanation and interpretation of the result.

The study, supported by Tables 1-4, reveals distinct metabolic profiles across somatotypes. **Mesomorphs** and their muscular hybrids show **superior anaerobic efficiency**, excelling in explosive, high-intensity activities like sprinting and weightlifting, making them balanced athletes due to their high anaerobic and good/excellent aerobic capabilities. Conversely, **Ectomorphs** struggle with sustained anaerobic power, fatiguing quickly due to lower muscle mass, and while their lean build helps with lighter aerobic activities (Table 3), their explosive capacity is limited, consistently showing low anaerobic but moderate to good aerobic efficiency (Tables 1, 2, 4). **Endomorphs**, characterized by fat storage and slower metabolisms, possess natural absolute strength in non-agile, high-intensity tasks. However, their overall energy efficiency, particularly in aerobic and repeated explosive movements, is lower, requiring tailored strategies for fat metabolism and body composition management. Tables 1 and 2 highlight their strength despite energy system struggles, and Table 3 suggests low-intensity training can boost their aerobic efficiency, confirmed by Table 4 as moderate for strength but low to moderate for aerobic capacity.

-Discussing it with what was previously reached.

These findings align with and expand upon existing literature, consistently showing mesomorphs' superior anaerobic capacity and ectomorphs' high-intensity power output challenges (Cichy et al., 2021; Smith et al., 2021; Caruso et al., 2023; Norton & Olds, 1996). Similarly, endomorphs' slower metabolic rates and fat storage impacting endurance are well-documented (Kenney et al., 2024; McArdle et al., 2015). This study extends these understandings by synthesizing the relationship across all somatotypes, including mixed types, and confirming hypotheses on high and low-intensity energy use. The consistent patterns in this analytical review, summarized across all four tables, reinforce the physiological basis for somatotype-

specific training and nutrition. Tables 1 and 3 offer practical applications for optimal training strategies.

Conclusion:

The study conclusively demonstrates a profound relationship between an athlete's **somatotype** and **energy system efficiency** across both high and low-intensity activities, confirming that morphological characteristics are critical determinants of physiological capacity and optimal performance. Findings reveal distinct metabolic profiles: **Mesomorphs** and their muscular hybrids exhibit **superior anaerobic efficiency**, excelling in explosive power and speed for high-intensity, short-duration tasks due to optimized glycogen stores and ATP regeneration. Conversely, **Ectomorphs** struggle with sustained anaerobic power due to lower muscle mass, leading to quicker fatigue, though their lean build benefits lighter aerobic activities. **Endomorphs**, despite their fat storage tendency and slower metabolism, show a natural capacity for absolute strength in non-rapid, non-agile tasks. However, their overall energy efficiency, especially in aerobic and repeated explosive movements, is relatively lower, necessitating tailored strategies for fat metabolism and body composition management.

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