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Strategies for Modifying Athletes' Somatometabolic Profiles in Individual and Team Sports (Sports Nutrition, Training Load)

استراتيجيات تغيير الأنماط الأيضية الجسدية لدى الرياضيين في الرياضات الفردية والجماعية (التغذية الرياضية, حمولة التدريب)

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Abstract : This analytical study investigated how nutritional and training interventions influence athletes' transformation towards an optimal mesomorphic somatotype. It reviewed metabolism's role in performance, classified somatotypes, and analyzed influencing factors including genetics, nutrition, and training. Results confirm that significant physical transformations are achievable through specific programs, highlighting the muscular component's vitality in boosting metabolism, enhancing performance, and secreting anabolic hormones. The study supports the effectiveness of these strategies in maximizing athletic performance.

Keywords: Metabolic-Somatic Profiles, Metabolism, Somatotype, Athletes, Individual Sports, Team Sports, Sports Nutrition, Training Load, Transformation, Athletic Performance

الملخص : هدفت هذه الدراسة التحليلية إلى استكشاف تأثير التدخلات الغذائية والتدريبية على تحويل الأنماط الجسدية والأيضية للرياضيين نحو النمط الميزومورفي الأمثل (العضلي المتوازن), حيث استعرضت الدراسة أهمية الأيض ودوره في الأداء، وصنفت الأنماط الجسدية وعوامل تأثيرها كالجينات والتغذية والتدريب. أظهرت النتائج أن التحولات الجسدية ممكنة ببرامج محددة، وأن المكون العضلي حيوي لرفع الأيض وتحسين الأداء البدني والمهاري والخططي وإفراز الهرمونات البنائية و يؤكد البحث توافق التحليل النظري مع الفرضيات، مما يدعم فعالية هذه الاستراتيجيات في تعظيم الأداء الرياضي.

- **الكلمات المفتاحية :** الأنماط الأيضية الجسدية, الأيض, النمط الجسدي, الرياضيون, الرياضات الفردية, الرياضات الجماعية, التغذية الرياضية, حمولة التدريب, التحول, الأداء الرياضي.

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1. Introduction and problematic of the study:

Optimizing athletes' somatometabolic profiles is crucial for peak performance, as the muscular component directly impacts anabolic hormone secretion, boosting performance and delaying fatigue. This is a significant challenge for athletes and coaches across all sports and categories.While athletes fall into five main somatotypes, the pure mesomorph (or balanced muscular) physique is ideal for high performance, offering delayed fatigue, high endurance, and significant strength and power. Achieving this physiological shift is essential throughout all training phases (GPP, SPP, competitive, and transitional) to ensure optimal performance and prevent health issues. Therefore, coaches, alongside strength and conditioning specialists and sports nutritionists, must guide athletes towards a balanced mesomorphic build. This requires identifying effective transformation strategies based on each athlete's unique somatometabolic data to achieve elite competitive performance. The core challenge then becomes: How can sports nutrition and training loads be effectively used to transform athletes' metabolic and physical profiles towards the optimal mesomorphic (balanced muscular) type, and to what extent does this transformation maximize athletic performance efficiency across various individual and team sports, given that the mesomorphic somatotype is strongly linked to high efficiency due to its balance of strength, speed, and endurance?

To fully address the aspects of this study, we will attempt to answer the following sub-questions:

1. What specific nutritional principles and protocols (in terms of macronutrient and micronutrient quality and quantity, and meal timing) should be applied to induce metabolic and physiological changes in athletes of different somatometabolic profiles (ectomorph, endomorph, mixed types) towards the balanced mesomorphic somatotype?

2. How can training loads (in terms of intensity, volume, frequency, and specific exercise types) be designed and adapted to achieve maximal physiological and metabolic transformation towards the mesomorphic somatotype, and what is the impact of this transformation on physical, technical, and tactical performance indicators in individual and team sports?

2. Research Hypotheses:

Hypothesis 1: Specific nutritional principles and protocols (such as increased protein and carbohydrates for ectomorphs, and calorie adjustment and fat control for endomorphs), tailored to each somatometabolic profile, can stimulate positive metabolic and physiological changes, thereby moving athletes closer to a balanced mesomorphic somatotype.

Hypothesis 2: Applying adapted training loads (combining high-intensity strength training with endurance exercises and appropriate recovery periods) leads to a physiological and metabolic transformation towards a balanced mesomorphic somatotype, which positively impacts the improvement of athletes' physical, technical, and tactical performance indicators in individual and team sports.

3. **Study Objectives:** This research aims to identify effective nutritional and training strategies to transform athletes' somatometabolic profiles toward an optimal mesomorphic type. It will explore precise macronutrient protocols and adapted training loads (intensity, volume, frequency) to induce physiological and metabolic changes. The study will also evaluate how this transformation impacts athletic performance in areas like endurance,

strength, power, and fatigue. Ultimately, it seeks to confirm that systematic application of these strategies maximizes performance by enhancing ATP generation, delaying fatigue, and boosting strength and endurance.

a. **Research Methodology:** In this research, we adopt both the descriptive and analytical approaches to achieve the study objectives and verify the proposed hypotheses.
b. **Study Divisions:** To address the research problem and objectives, this study is divided into two sections: the first covers the theoretical aspects of somatometabolic profiles and athletic performance, while the second presents strategies for metabolic and physical transformation and their impact on performance.

4.Section One: Theoretical Aspects of Somatometabolic Profiles and Their Relationship to Athletic Performance

First. Metabolism and Energy Production Pathways in Athletic Performance: Metabolism is the core biochemical engine generating ATP, the body's energy currency, which fuels all life functions and physical activity. For athletes, efficient ATP production is vital for sustained performance, delaying fatigue, and powering muscle movement. Metabolism converts food into ATP, utilized by three harmonious systems to power diverse athletic activities (Nelson & Cox, 2017; McArdle, Katch, & Katch, 2014) :

Phosphagen System (ATP-PCr System): The phosphagen system is the body's fastest and most immediate energy pathway, relying on muscle-bound adenosine triphosphate (ATP) and phosphocreatine (PCr). When rapid energy is needed, ATP is directly broken down. PCr then quickly regenerates ATP by donating a phosphate group to adenosine diphosphate (ADP). This system provides very limited, but high-intensity and immediate energy, making it ideal for activities requiring maximal strength and speed for very short durations (under 10-15 seconds). Examples include heavy weightlifting (1-3 repetitions), vertical and horizontal jumps, 100-meter sprints, javelin or shot put throws, powerful tennis serves/strokes, and explosive jumps in sports like basketball, volleyball, handball, and football..

Anaerobic Glycolysis: When high-intensity physical activity continues beyond a few seconds and oxygen is limited, the body utilizes the anaerobic glycolytic system. This system breaks down glucose (from muscle and liver glycogen) to produce ATP without oxygen, with lactic acid as a byproduct, leading to muscle fatigue. It provides energy faster than aerobic metabolism, in larger quantities, and for longer durations than the phosphagen system, but is associated with lactate-induced fatigue. This system is suitable for high-intensity activities lasting from 30 seconds to approximately 2-3 minutes, including sprinting events (200m, 400m), fast swimming (50m, 100m), repeated high-speed bursts in team sports (football, basketball, handball), and High-Intensity Interval Training (HIIT).

Aerobic Metabolism: The aerobic system is the most efficient pathway for energy production, utilizing oxygen to break down carbohydrates (glucose/glycogen), fats (fatty acids), and rarely proteins, to generate large quantities of ATP primarily within cellular mitochondria. Characterized by providing vast energy for very long durations, it is the slowest to initiate and does not result in significant lactic acid accumulation. This system dominates low-to-moderate intensity, extended activities such as marathons, long-distance cycling and swimming, continuous play in sports like football, basketball, and handball, brisk walking, and sustained aerobic exercises.

Metabolic efficiency directly impacts athletic performance and recovery by optimizing energy. It delays fatigue through efficient fuel (ATP) use and byproduct removal, enhances endurance via improved fat usage, and supports strength and power through rapid ATP/PCr regeneration. This efficiency also promotes muscle mass by aiding protein synthesis and accelerates recovery by replenishing glycogen, repairing tissues, and removing waste (McArdle et al., 2015).

Second. Somatometabolic Profiles and Their Classification: Somatometabolic profiles link body shape (somatotype) with metabolic efficiency, classifying individuals by how they process energy and store nutrients. This framework differentiates between ectomorphs (fast metabolism, lean) and endomorphs (slow metabolism, store fat easily). Beyond genetics, metabolism is influenced by muscle mass, age, gender, hormones, and activity. These profiles, based on William H. Sheldon's 1940s classifications, reveal individual variations in body structure, metabolism, muscle building, fat storage, and their implications for athletic performance (Sheldon, Tucker, & Stevens, 1940) :

Ectomorph: Ectomorphs are characterized by a lean, long build with thin bones, low muscle mass, and very low body fat. They have a fast metabolism, making weight gain (muscle or fat) extremely challenging despite high caloric intake. Athletically, ectomorphs excel in endurance and agility sports like long-distance running or gymnastics, but struggle in strength and power-based activities.

Mesomorph: Mesomorphs naturally have an athletic, muscular build with a medium bone structure, broad shoulders, and a high muscle-to-fat ratio. Their efficient metabolism allows them to easily gain muscle and lose fat, showing quick results from training. This makes them the ideal "athletic type," excelling in sports requiring strength, speed, power, and endurance like weightlifting, sprinting, and various team sports.

Endomorph: Endomorphs typically have a fuller, stronger build with a natural tendency to store fat, often around the abdomen, hips, and thighs. They possess a slower metabolism, making weight loss challenging and weight gain easier. Despite this, endomorphs often exhibit significant natural strength, particularly in the lower body, allowing them to excel in sports requiring absolute strength and mass, such as heavy weightlifting or sumo wrestling (Kenney, Wilmore, & Costill, 2024).

Few individuals perfectly fit a single pure somatotype. Most people, including athletes, display mixed somatotypes, blending characteristics from two or all three types, with one or two dominant (Norton & Olds, 1996) :

Meso-Ectomorph: The Meso-Ectomorph combines mesomorphic athleticism with ectomorphic leanness, resulting in a muscular yet slender build with low body fat. Characterized by broad shoulders and a narrow waist, often with longer, agile limbs, they excel in sports requiring a blend of strength, speed, and agility, such as martial arts or dynamic roles in basketball and football.

Meso-Endomorph: The Meso-Endomorph blends mesomorphic strength with endomorphic fullness, resulting in a powerful, muscular build with a greater tendency to store fat than a pure mesomorph. Though they build muscle easily, maintaining low body fat requires more effort. Their immense strength and muscle mass make them ideal for strength-based sports like American football (linemen), weightlifting, and powerlifting.

The mesomorphic somatotype is highly conducive to athletic performance, characterized by exceptional muscle mass and a robust bone structure for generating power in activities like lifting, jumping, and pushing. Mesomorphs also show an incredibly effective training response due to their efficient metabolism, readily gaining muscle and losing fat. This balanced metabolism provides both explosive power for movements like sprinting and jumping, and good aerobic endurance for sustained high-efficiency performance, allowing them to excel in critical competitive moments (Kenney et al., 2024).

Ideal Physique for Adaptation: The mesomorphic body shape, with broad shoulders and a narrow waist, optimizes weight and muscle distribution, enhancing movement efficiency, agility, quickness, stability, and strength. This build provides a clear athletic advantage, enabling excellence in diverse sports through a combination of strength, speed, and endurance, along with delayed fatigue and rapid recovery.

Third. Factors Influencing the Determination and Modification of Somatometabolic Profiles: While genetics establish the foundation, an athlete's somatometabolic profile (body type and metabolic characteristics) is significantly shaped and evolves through various other factors in both individual and team sports.(McArdle et al., 2015):

1. **Genetic and Hereditary Factors:** Genetics primarily shape an individual's initial somatotype and metabolic profile. They influence BMR, muscle fiber distribution, and training response, impacting muscle gain and aerobic capacity. Hereditary factors also dictate body fat distribution and fundamental structural characteristics like bone size and limb length.

2. **Sports Training (Type, Intensity, Volume, Density):** Training is the primary driver for changing athletes' somatometabolic profiles. The method and application of training directly influence these changes (Kenney et al., 2024):

- **Strength and Resistance Training:** Strength and resistance training profoundly transforms somatotypes and metabolic profiles. It significantly increases muscle mass (hypertrophy) and reduces body fat, especially with proper diet. This shifts ectomorphs towards a more mesomorphic profile and enhances existing mesomorphic/endomorphic traits. Metabolically, it permanently boosts basal metabolic rate due to increased muscle mass and improves insulin sensitivity, leading to more efficient glucose utilization. These effects are clearly visible in strength athletes like bodybuilders and weightlifters. (Haff & Triplett, 2016).
- **Aerobic endurance training** Aerobic endurance training directly impacts an athlete's somatotype and metabolic profile. While it primarily reduces body fat and enhances muscle efficiency rather than significant hypertrophy, it reinforces or maintains ectomorphic traits. Metabolically, it improves fat metabolism for ATP production and increases mitochondrial density, boosting overall aerobic capacity. These adaptations are evident in endurance athletes like marathon runners and long-distance swimmers. (Haff & Triplett, 2016).
- **Explosive/speed training (anaerobic)** Anaerobic training primarily develops fast-twitch muscle fibers, enhancing explosive power, increasing muscle mass, and maintaining agility, directly impacting an athlete's somatotype. Metabolically, it improves rapid energy production via the phosphagen and anaerobic glycolysis systems, boosting repeated high-intensity effort capacity. These adaptations, crucial for sports demanding explosive, agile movements like sprinting, jumping, and team sports (soccer,

basketball, handball, volleyball), are evident in top athletes.(Kenney et al., 2024).

- **The type of sport itself** Sport-specific training drives somatometabolic adaptation towards an optimal profile. Basketball players, for instance, lean ectomorphic-mesomorphic, while rugby players are more endomorphic-mesomorphic. This study, observing such influences, aims to standardize athletes' somatotypes towards a moderate-to-high muscular composition due to the proven benefits of a balanced mesomorphic build for enhanced performance across diverse sports.

3. **Nutrition** is a crucial factor that complements the impact of training in shaping athletes' metabolic and somatotype profiles (Jeukendrup & Gleeson, 2018):
4. **Caloric intake** Nutrition is critical for an athlete's somatotype modification. Caloric balance dictates weight changes: surplus for muscle gain (mesomorphs/endomorphs) and deficit for fat loss (ectomorphs/endomorphs). Macronutrient ratios are vital: protein for muscle repair, carbohydrates for energy and glycogen stores, and fats for hormonal health and sustained energy. Nutrient timing (pre-, intra-, post-exercise) further impacts energy recovery, muscle repair, and physiological adaptations, maximizing athletic performance.
5. **Hormones and Hormonal Balance:** Hormones are pivotal for regulating metabolism and body composition. Thyroid hormones directly affect basal metabolic rate, while insulin controls blood sugar and energy storage. Growth Hormone (GH) and IGF-1 are crucial for muscle growth and repair. Testosterone and estrogen influence muscle mass and fat distribution. Conversely, high cortisol (a stress hormone) can impede muscle building and

increase fat storage. Thus, hormonal balance is essential for metabolic efficiency and optimal training response. (Haff & Triplett, 2016).

6. **Age and gender** significantly influence metabolic rate and body composition. As individuals age, their metabolic rate tends to slow down, partly due to sarcopenia, the natural loss of muscle mass, and the body's training response also changes over time. Gender is another pivotal factor: men typically have greater muscle mass and lower body fat percentages than women on average, directly impacting their basal metabolic rate and overall body composition. These differences are largely attributed to hormonal variations between the sexes (McArdle et al., 2015).
7. **Sleep and Recovery:** Adequate sleep is crucial for muscle repair, hormone regulation (including growth and hunger hormones), and energy restoration. Insufficient sleep severely disrupts metabolism, negatively impacting body composition and athletic performance. Similarly, sufficient rest is vital for adaptation; without it, overtraining can lead to chronic fatigue and elevated cortisol, hindering performance and positive somatometabolic changes. (Doherty, Madigan, Nevill, Warrington, & Ellis, 2021).

- **Possibility of Transformation Among Common Somatotypes:** Athletes' somatotypes and metabolic profiles are not fixed; they are significantly influenced by genetics and targeted interventions like sports nutrition and training load. This enables athletes to achieve remarkable body transformations to meet specific athletic goals through carefully designed programs.

1. **From Lean (Ectomorph) to Lean Muscular (Meso-Ectomorph) Type:** Ectomorphs, with their fast metabolism, face challenges gaining weight and muscle. To counteract this, sports nutrition must include a significant caloric

surplus, prioritizing complex carbohydrates and high-quality protein through frequent, substantial meals. Training load should focus on high-effort strength and resistance exercises with moderate-to-low repetitions, ensuring ample rest for muscle recovery and growth. Excessive aerobic training should be avoided to prevent further calorie expenditure. The goal is to build muscle while maintaining a lean physique, moving towards a Meso-Ectomorph profile. (Jeukendrup & Gleeson, 2018).

2. **From Lean Muscular (Meso-Ectomorph) to Balanced Muscular (Mesomorph) Type:** Individuals with a Meso-Ectomorph somatotype have good muscle-building capacity but require more focus on overall muscle mass and maximal strength. Sports nutrition should support muscle growth with precise calorie and micronutrient adjustments to avoid excess fat. Training load should emphasize advanced strength training with progressive increases in load and volume, combining maximal strength and hypertrophy programs. Crucial attention to recovery prevents overtraining. The aim is to develop a more balanced, stronger, and agile physique, approaching the ideal Mesomorph model. (Haff and Triplett, 2016).
3. **From Adipose (Endomorph) to Muscular-Adipose (Meso-Endomorph) Type:** Individuals with an Endomorphic somatotype face challenges due to their slow metabolism and tendency to store fat. To address this, sports nutrition requires a strict caloric-controlled diet, prioritizing protein for satiety and muscle preservation, while reducing refined carbohydrates and unhealthy fats to achieve a caloric deficit. Training load should combine intense strength training to build muscle and increase basal metabolic rate, with aerobic endurance training (e.g., HIIT or moderate cardio) for effective calorie and fat burning. The goal is to reduce body fat while developing good

muscle mass, moving the athlete towards a Meso-Endomorph somatotype. (Jeukendrup & Gleeson, 2018).

4. **From Muscular-Adipose (Meso-Endomorph) to Balanced Muscular (Mesomorph) Type:** Meso-Endomorphs, possessing strength and muscle, must address their tendency to store fat. Sports **nutrition** demands precise calorie and nutrient adjustments to reduce fat while preserving muscle, often requiring caloric reduction and increased protein. Training load should combine intense strength training with regular aerobic or explosive training to boost fat-burning and metabolic rate, possibly including high-intensity circuit training. The goal is a balanced Mesomorph physique: prominent muscle, low body fat, and excellent strength and endurance. (Haff and Triplett, 2016).

Achieving desired somatotype and metabolic transformations relies on continuous adaptation via targeted interventions. Sports nutrition provides flexible fuel adjusted to individual responses and training phases, while training load acts as the progressive stimulus. Regular monitoring and evaluation are crucial for effectiveness and necessary adjustments.

Fourth. Muscle Component and Its Impact on Performance and Anabolic Hormones: This study links metabolism, energy production, and somatotypes to improved athletic performance and delayed fatigue. It identifies the mesomorphic body type as ideal for high performance due to its muscularity and balanced energy/endurance. Genetics and environmental factors (training, nutrition, hormones, recovery) influence these profiles. The research emphasizes muscle tissue's vital role in basal metabolism, energy production, and anabolic hormone secretion (e.g., Testosterone, GH, IGF-1), which are crucial for growth, recovery, and overall athletic performance. Effective training and significant muscle mass synergistically promote hypertrophy, accelerated recovery, and enhanced strength and power (Haff and Triplett, 2016; McArdle et al., 2015). This framework will guide optimizing athletes' body composition and metabolic profiles.

Section Two: Strategies for Metabolic and Somatotype Change and Their Impact on Athletic Performance

First. Targeted Sports Nutrition Strategies for Modifying Metabolic and Somatotype Profiles:

Specific Nutritional Principles and Protocols for Each Somatometabolic Profile (Aimed at Mesomorph Transformation):

For the Ectomorph Somatotype: For individuals with an extremely fast metabolism struggling to gain weight and muscle, the dietary protocol requires a continuous caloric surplus (250-1000+ daily) on both training and rest days to support muscle building and prevent catabolism. Complex carbohydrates (50-60% of daily calories) from low glycemic index sources like brown rice and oats are crucial for sustained energy. A high protein intake (1.6-2.2 g/kg body weight) from quality sources is essential for muscle protein synthesis, while moderate healthy fats (20-30% of calories, ~1.1 g/kg body weight) support hormonal health and provide additional energy. Frequent meals (5-7 daily) are fundamental to ensure a continuous nutrient supply and prevent muscle breakdown (Sutton, 2021).

For the Endomorph somatotype, For individuals with slower metabolisms and a tendency to store fat, the nutritional protocol prioritizes strict caloric control and a deficit (300-500 calories below maintenance) to achieve fat loss while preserving muscle. This requires a high protein intake (1.8-2.5 g/kg daily) from lean sources for satiety and muscle protection. Carbohydrates are kept moderate to low (25-40% of calories), focusing on complex, fiber-rich options. Moderate healthy fats (20-30% of calories, ~0.8 g/kg daily) support vital functions and satiety. Regular, controlled meals (3-5 small to medium-sized) help manage hunger and energy levels effectively (Sutton, 2021).

For Mixed Somatotypes (Meso-Ectomorph & Meso-Endomorph) and Transition Towards a Pure Mesomorph: According to Payne (n.d.), Meso-Ectomorphs build muscle well but need more volume, while Meso-Endomorphs are strong but easily store fat. To balance muscle and fat for improved body composition, the nutritional protocol requires precise calorie adjustments based on individual response and goals (slight surplus for muscle, slight deficit for fat). Protein intake should be high (1.8-2.2 g/kg) for muscle support. Carbohydrate quantity varies with activity, high on training days, lower on rest days. Fats are moderate (25-35% of total calories; ~1 g/kg for lean types, ~0.8 g/kg for muscular-adipose types) from healthy sources. Meal frequency and timing should be flexible, with continuous monitoring of fat and muscle percentages for adjustments.

Vitamins and minerals are crucial for metabolic processes, energy, immunity, and bone health, often requiring dietary diversity or supplements for deficiencies. Adequate hydration is also vital for metabolism and preventing fatigue. **Nutrient timing** is paramount for performance and recovery: **Pre-exercise:** Carbs and protein for energy and muscle protection. **During prolonged activity:** Carb and electrolyte drinks for sustained energy and hydration. **Post-workout** (within the "metabolic window"): Fast-digesting carbs and quality protein for glycogen replenishment and muscle repair. **Frequent meals:** Maintain stable energy and support muscle protein synthesis. Certain **nutritional supplements** further enhance adaptations: **Whey protein** (recovery/growth), **creatine** (strength/energy), **caffeine** (focus/fatigue reduction), **BCAAs** (muscle breakdown reduction), and **multivitamins/minerals** (nutritional gaps/metabolic optimization) (Burke & Deakin, 2021).

Second. Designing and Adapting Training Loads to Achieve Mesomorphic Transformation: Designing and adapting training loads aims to achieve mesomorphic transformation by targeting the muscle component, improving metabolism, and reducing body fat percentage. This requires a precise understanding of how the body responds to different types of training, while considering individual somatotypes and the importance of recovery.

1. **Review of Training Types (Strength, Endurance, Speed) and How to Design Them to Suit Different Somatotypes for Enhanced Muscle Component:**

Strength and Resistance Training: Strength and resistance training is crucial for increasing muscle mass (hypertrophy) and absolute strength, particularly for those targeting a mesomorphic body type. This involves high intensity (6-12 reps/set, 3-6 sets/exercise, 3-5 exercises/group) with 60-180 second rest periods for ATP replenishment (Golden, 2022; Schoenfeld et al., 2021). For ectomorphs, focus on lower volume, higher intensity, and fundamental compound exercises (Squats, Deadlifts, Bench Presses, Rows) with ample rest to prevent overtraining. Endomorphs benefit from slightly higher training volume and the integration of intense cardio like HIIT. Mesomorphs and mixed somatotypes thrive on a blend of intensity and volume (3-5 sessions/week), combining compound and isolation exercises, and respond well to both HIIT and steady-state cardio (American Sports & Fitness Association, n.d.; PureGym, n.d.).

Endurance Training (Aerobic): Aerobic endurance training enhances metabolic efficiency, boosts endurance, and reduces body fat, typically at low to moderate intensity (60-80% max heart rate) for 30-60+ minutes, 3-5 times weekly, to favor fat as an energy source (Mayo Clinic, n.d.).For ectomorphs, cardio should be limited to avoid hindering muscle gain, focusing on cardiovascular health and warm-ups/cool-downs (O'Brien, 2022). Endomorphs benefit greatly from regular, intense endurance training (2-3 sessions, 30-60 minutes weekly) for maximum calorie and fat reduction (Mehta, n.d.). Mesomorphs and mixed somatotypes can effectively combine endurance with strength training (2-3 cardio sessions/week, 15-30 minutes) to maintain low body fat and aid active recovery (PureGym, 2024).

Speed and explosive strength training (anaerobic) Training to develop fast-twitch muscle fibers aims to increase rapid force generation and improve repeated performance. This involves maximal intensity and very short durations (<30 seconds/rep) with long rest periods (1:5 to 1:10 work-to-rest ratio) for complete phosphagen system recovery (e.g., sprinting, jumping, Olympic lifts, HIIT). All body types benefit from this for explosive strength, a key mesomorphic trait. The ACSM (2018) emphasizes high intensity and longer rest for maximal strength/power, while Payne (n.d.) stresses integrating anaerobic training (plyometrics, speed work) for all somatotypes to boost overall athletic performance.

The Role of High-Intensity Resistance Training in Muscle Building and Boosting Basal Metabolism: High-intensity resistance training is crucial for muscle hypertrophy by causing microscopic damage, triggering repair, and boosting force generation. This is supported by an anabolic hormonal response (testosterone, growth hormone) and increased muscle protein synthesis. This training also significantly improves Basal Metabolic Rate (BMR), as muscle tissue is metabolically active and burns more calories, even at rest. This elevated calorie expenditure continues post-exercise via Excess Post-exercise Oxygen Consumption (EPOC), aiding muscle repair and energy replenishment (NSCA, 2016).

2. **Integrating endurance exercises is crucial for enhancing aerobic metabolic efficiency and reducing body fat percentage**. The American College of Sports Medicine (ACSM, 2018) identifies aerobic endurance exercises as crucial for improving metabolic efficiency by boosting oxygen utilization, particularly fat metabolism, which enhances mitochondrial function and enzyme activity. These exercises effectively reduce body fat by increasing calorie expenditure and improving fat utilization, thereby preserving muscle glycogen and boosting long-term endurance. For optimal mesomorphic transformation, a balanced combination of strength and endurance training is recommended. This can be achieved through High-Intensity Interval Training (HIIT), which blends short bursts of maximal effort with brief recovery periods (e.g., 10 seconds work - 10 seconds rest, 15 seconds work - 10 seconds rest), stimulating both aerobic and anaerobic metabolism and significantly increasing post-exercise calorie burning.
3. **The Importance of Recovery Periods in Achieving Desired Somatic and Metabolic Adaptations:** Recovery periods are indispensable for achieving

desired physical and metabolic adaptations. Muscle growth and repair, along with energy replenishment (glycogen stores), occur during these times, preparing the body for subsequent training. Adequate recovery also maintains hormonal balance, preventing elevated stress hormones like cortisol, and regenerates the neuromuscular system, thus preventing overtraining, maintaining performance quality, and reducing injury risk.

Third. Impact of Somatic and Metabolic Transformation on Athletic Performance Indicators: Transforming towards an optimal **mesomorphic somatotype** significantly improves diverse athletic performance indicators (physical, skill, tactical). Data analysis reveals specific correlations :

❖ **Physical Indicators:** The National Strength and Conditioning Association (NSCA, 2016) points to the following:

Maximal Strength: As muscle mass increases and muscles adapt to training loads, maximal strength directly improves. This can be measured by increases in the maximum weight an athlete can lift in fundamental resistance exercises (e.g., 1RM in squats, deadlifts, or bench presses). The mesomorphic somatotype, with its ideal muscular composition, often demonstrates high levels of maximal strength.

Explosive Power and Speed: Mesomorphic transformation, which involves developing fast-twitch muscle fibers and enhancing neuromuscular efficiency, leads to a significant increase in explosive power and speed. This can be measured by improved sprint times, increased vertical jump height, or the ability to generate maximal force in a short period. These indicators are closely linked to athletic activities requiring quick reactions and immediate power.

Muscular Endurance: With improved local muscle metabolism and increased mitochondrial density, along with the efficient use of glycogen and fats, muscular endurance significantly improves. This is evident in the ability to perform more repetitions with a given weight or maintain a specific performance intensity for longer durations. The mesomorphic somatotype possesses a strong muscular foundation that supports this endurance.

Cardiorespiratory Endurance: Integrating aerobic endurance training, which enhances the efficiency of the heart and lungs in transporting oxygen to muscles, leads to improved cardiorespiratory endurance. This is reflected in an increased VO2max (maximal oxygen consumption), a reduced resting and exercise heart rate, and an increased ability to sustain high effort for prolonged periods. This improvement allows athletes to continue performing at a higher efficiency for longer durations and delay fatigue.

- ❖ **Skill-Based and Tactical Indicators:** The ACSM (2018) emphasizes that good physical fitness contributes to better decision-making under pressure, which aligns with the NSCA (2016) regarding the importance of endurance for effective repeated performance. This has an impact on skill-based and tactical aspects as follows:

Efficiency of Motor Skill Performance: Somatic and metabolic transformation is linked to improved efficiency in motor skill performance. Increased strength, speed, and physical endurance translate into a better ability to execute athletic movements with higher technique and greater precision. For instance, a mesomorphic athlete often exhibits better muscular control and greater balance, making them more agile and adaptable to the demands of complex skills.

Decision-Making Under Pressure: When an athlete is in optimal physical and metabolic condition, physical and mental fatigue are reduced. This enhances the ability to make sound and rapid decisions under competitive pressure. Transforming towards a mesomorphic somatotype lessens the physical burden on the body, allowing the mind to focus better on strategic and tactical aspects.

Ability to Repeat Performance Effectively: Improved muscular and cardiorespiratory endurance, coupled with efficient recovery, grants the athlete the capacity to effectively repeat high-intensity performance throughout a game or training session. The mesomorphic somatotype supports this ability by providing sufficient energy stores and a rapid capacity to clear metabolic waste.

4. **Connecting These Changes to the Mesomorphic Transformation:** This study's core chapter focuses on how targeted nutrition and training cultivate the ideal mesomorphic somatotype for athletes, enhancing muscle strength, endurance, and low body fat. By optimizing somatometabolic profiles, these methods boost metabolic efficiency (carbohydrate/fat utilization) and muscular capacity (strength, speed, endurance), improving overall athletic performance. The chapter details specific nutritional protocols, including calorie/nutrient adjustments, meal timing, and the role of vitamins, minerals, hydration, and supplementation. It also outlines effective training load design, emphasizing high-intensity resistance and aerobic endurance, along with critical recovery periods. Ultimately, these somatic and metabolic transformations lead to tangible gains in athletic performance, providing evidence for the research hypotheses and actionable insights for maximizing performance through targeted somatometabolic changes.

Results: Based on all the above, we arrived at the following results:

1. **Metabolism and Its Importance for Athletic Performance:** Metabolism fuels all athletic activity by producing ATP, which delays fatigue, enhances endurance and strength, and accelerates recovery through optimized fuel use. Its three systems (phosphagen, anaerobic glycolysis, and aerobic) power everything from explosive bursts to sustained endurance.
2. **Somatotypes and Their Metabolic Impact:** Somatotypes classify body types as ectomorphs (lean), endomorphs (fuller), and mesomorphs (athletic). While mixed types are common, the mesomorphic somatotype is ideal for high athletic performance due to its muscularity, strong training response, and balanced power/endurance.
3. **Factors Influencing Metabolic and Somatic Profiles:** These profiles are shaped by genetics, training, nutrition, hormones, age, gender, sleep, and recovery.
4. **Potential for Somatotype Transformation:** Somatotype transformations (e.g., aiming for a balanced mesomorph) are achievable through targeted training and nutrition, requiring consistent monitoring.
5. **Impact of Muscle Component on Performance and Anabolic Hormones:** Muscle mass boosts BMR and stores glycogen. Resistance training stimulates anabolic hormones (testosterone, GH, IGF-1), promoting muscle growth, faster recovery, and enhanced athletic performance.
6. **Theoretical Alignment:** The theoretical analysis strongly supports the hypotheses.

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