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Posted Date: 8 July 2025

doi: 10.20944/preprints202507.0676.v1

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Strength and Conditioning Demands of Sprinters and Throwers in Track and Field: A Comparative Analysis

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Abstract

This paper examines the strength and conditioning requirements for sprinters and throwers in track and field, highlighting their shared and distinct needs for optimal performance. Both disciplines demand explosive power, rapid force development (RFD), and tailored training to enhance biomechanical and physiological attributes. Sprinters emphasize rapid triple extension and lower-body explosiveness for acceleration and maximal speed, while throwers prioritize maximal force production through upper-body and core strength. Research indicates that periodized training, plyometrics, and neuromuscular coordination significantly enhance performance in both groups. Key factors such as lean body mass, muscle fiber type, and genetic predispositions influence outcomes, with specific training protocols like jump squats and resisted sprints improving sprint acceleration and throwing distance. The paper also explores energy system contributions, kinematic stride mechanics, and psychological factors, emphasizing the need for individualized, event-specific training programs to maximize athletic potential.

Keywords: sprint performance; throwing performance; explosive power; strength training; rate of force development; neuromuscular coordination; energy systems; kinematic analysis; psychological resilience

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1. Introduction

The strength requirements for sprinters and throwers in track and field are multifaceted, encompassing specific physical and biomechanical attributes essential for optimal performance. Both disciplines demand explosive strength, power, and tailored conditioning, yet their applications differ. Sprinters rely on speed and rapid force application, while throwers prioritize maximal force production. Despite these distinctions, both share a common need for strength and conditioning to enhance performance. This response synthesizes the key aspects of strength for sprinters and throwers, supported by research, while addressing their overlap and unique demands.Both sprinters and throwers require the ability to generate near-maximal muscular force in minimal time. For sprinters, this is achieved through rapid triple extension of the lower extremities, critical for explosive starts and acceleration (Waller et al., 2014). Throwers similarly rely on explosive power, particularly in the upper body and core, to maximize force during throws. This shared need for explosiveness underscores the importance of power-based training for both groups.Effective strength training is vital for both disciplines. A 25-week periodized training macrocycle has been shown to significantly enhance muscle strength, power, and performance in sprinters, with exercises like snatch and squat improving 1-RM strength and correlating with better sprint performance (Anousaki et al., 2021). Throwers also benefit from periodized programs that focus on maximal strength and muscle architecture, such as vastus lateralis thickness, to improve throwing distance (Zaras et al., 2016). Both groups require structured training to optimize performance, though sprinters emphasize speed-oriented exercises, while throwers focus on force production.Lean body mass, neural activation, and muscle fiber type composition are critical for both sprinters and throwers. Long-term training

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enhances these biological factors, leading to improved performance (Zaras et al., 2021). Genetic influences also play a role, with specific gene variants linked to sprint, strength, and power performance in both disciplines. These shared biological underpinnings highlight the importance of individualized training to maximize genetic potential.RFD is a key factor in explosive activities. For sprinters, rapid RFD contributes to faster starts and maximal sprinting speed, while for throwers, it enhances the ability to apply force quickly during throws (Zaras et al., 2016). Improvements in RFD, alongside muscle architecture changes, are associated with better performance in both disciplines, making it a critical focus in training programs. Sprinters require specialized strength training to enhance speed and power, tailored to the unique demands of sprint events (廖冠群, n.d.). Throwers, conversely, focus on building maximal strength to optimize force output. While sprinters prioritize rapid force application for short bursts, throwers emphasize sustained force for explosive movements, highlighting the need for event-specific training protocols.For sprinters, countermovement jump (CMJ) peak force relative to body weight and jump height are significant predictors of sprint performance, correlating with maximal running velocity and sprint times (Markström & Olsson, 2013). Similarly, throwers benefit from strength metrics like peak force, which predict throwing performance. Both disciplines rely on power-based metrics, though sprinters focus on lower-body explosiveness, while throwers emphasize whole-body strength. Different strength qualities influence various sprinting phases. Peak force during a jump strongly predicts starting performance, while stretch-shortening cycle (SSC) measures are more closely tied to maximum sprinting speed (Young et al., 1995). Throwers, while not directly tied to sprinting phases, rely on similar strength qualities for explosive force production, particularly in the initial phase of a throw.

2. Strength Qualities and Sprint Performance

Starting Performance: The peak force generated during a jump from a 120-degree knee angle (concentric contraction) is a strong predictor of starting performance, with a correlation coefficient of $r = 0.86$ (Young et al., 1995). This suggests that concentric strength is crucial for the initial acceleration phase of sprinting. Maximum Sprinting Speed: The force applied at 100 ms from the start of a loaded jumping action (concentric contraction) is highly correlated with maximum sprinting speed ($r = 0.80$) (Young et al., 1995). Additionally, measures of stretch-shortening cycle (SSC) and maximum absolute strength are more related to maximum sprinting speed than starting ability (Young et al., 1995). Vertical Jump Metrics: Strong associations exist between vertical jump metrics and sprint performance, particularly for longer sprint distances. For instance, squat jump (SJ) height and relative peak power show significant correlations with sprint distances up to 60 m (Washif & Kok, 2021). These metrics are indicative of explosive power, which is essential for maintaining high sprinting speeds. Strength-Power Parameters: Squat jump (SJ), countermovement jump (CMJ), and reactive strength index (RSI) are significant predictors of sprint performance. The ability to produce force quickly, as measured by the time to achieve 60% of maximum voluntary contraction, is related to sprinting performance (Smirniotou et al., 2008) (Bissas & Havenetidis, 2008). Combined Strength Training: Combined strength training methods, including plyometrics and speed training, have been shown to improve sprint and strength performance significantly. These methods are effective in enhancing both short and long sprint distances (Muñoz et al., 2024).Core Strength Training: Core strength exercise s enhance an athlete's control, coordination, and explosive power, contributing to improved sprint performance. Implementing core strength training in sprint training programs can optimize outcomes (Han & Wang, 2024).While strength qualities and genetic factors are critical in sprinting performance, it is essential to consider the holistic development of an athlete. Training programs should integrate various strength and power exercises tailored to the athlete's specific needs and genetic predispositions. Additionally, the role of genetics in athletic performance highlights the importance of personalized training approaches to maximize an athlete's potential. Maximal strength plays a crucial role in sprint acceleration for athletes, as it directly influences the force production capabilities necessary for rapid acceleration. The relationship between maximal strength and sprint performance is well-documented across various studies, highlighting the

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importance of strength training in enhancing sprint acceleration. This relationship is particularly evident in the initial phases of sprinting, where the ability to generate high levels of force quickly is paramount. The following sections delve into the specific aspects of how maximal strength contributes to sprint acceleration. Maximal strength, particularly in exercises like the squat and deadlift, has been shown to correlate strongly with sprint performance. For instance, maximal strength in the front squat and deadlift is positively associated with improved sprint times in youth basketball players, indicating that strength training can enhance sprint acceleration (Warneke et al., 2022). In track-and-field sprinters, isometric strength measures such as the isometric midthigh pull (IMTP) and isometric squat (ISqT) have significant correlations with sprint acceleration, particularly in the initial 5 meters of a sprint (Brady et al., 2020). The relationship between maximal squat strength and sprint times is also evident in football athletes, where higher squat strength relative to body mass is associated with faster sprint times over short distances (McBride et al., 2009). The ability to produce greater force per unit body mass and apply it effectively in a forward-oriented manner is crucial for sprint acceleration. This mechanical efficiency is enhanced by maximal strength training, which improves the force-velocity relationship critical for sprinting (Speed and Acceleration Training, 2022). Maximal power output, a derivative of maximal strength, is a key determinant of sprint performance. Training that focuses on maximizing power output can lead to improvements in both acceleration and overall sprinting speed (Slawinski et al., 2020).

3. Influence of Specific Strength Training

Specific strength training programs, such as those involving jump-squats, have been shown to improve both maximal strength and sprint acceleration. For example, a training cycle focusing on maximal power loads resulted in significant improvements in sprint times and strength measures in high-level hurdlers (Balsalobre-Fernández et al., 2013).The relationship between maximal strength and sprint performance is not only limited to elite athletes. In adolescent students, higher leg strength is associated with better sprinting ability, suggesting that strength training can be beneficial across different age groups and levels of experience (Iwatake et al., 2008).While maximal strength is a significant factor in sprint acceleration, it is not the sole determinant. Other factors such as technique, neuromuscular coordination, and specific sprint training also play critical roles in enhancing sprint performance. Additionally, the relationship between strength and sprint performance may vary depending on the athlete's experience level and the specific demands of their sport (Santos-García et al., 2008). Therefore, a comprehensive training program that includes strength, technique, and sport-specific drills is essential for optimizing sprint acceleration. Enhancing sprint speed in athletes involves a complex interplay of neuromuscular adaptations, biomechanical efficiency, and training methodologies. Research indicates that improvements in sprint performance are not solely dependent on muscle strength but also on neuromuscular coordination, muscle morphology, and specific training interventions. These adaptations can be achieved through various training strategies, including neuromuscular training, ischemic preconditioning, and sprint-specific exercises. The following sections explore these aspects in detail.

4. Neuromuscular Coordination and Biomechanics

Neuromuscular coordination is crucial for optimizing sprint performance. It involves the recruitment and synchronization of motor units, which enhances the application of force during the sprint cycle. This coordination is essential for achieving high sprint velocities, particularly during the maximum velocity phase of a sprint (Seagrave & Mouchbahani, 2009).Biomechanical efficiency, such as optimal body positioning and arm action, plays a significant role in sprinting. Efficient recovery mechanics and ground preparation phases are critical for maintaining high speeds (Seagrave & Mouchbahani, 2009). Specific muscle groups, such as the semitendinosus, have been shown to correlate with improved sprint performance, particularly during the maximal velocity phase. Hypertrophy of these muscles can enhance sprinting speed (Kawama et al., 2024).

Neuromuscular training programs have been shown to significantly improve speed and explosive power in athletes. These programs focus on enhancing neuromuscular performance through exercises that improve coordination and power output (Singh et al., 2024).Ischemic preconditioning (IPC) before sprint training can lead to neuromuscular adjustments that enhance performance. IPC has been shown to improve power output and reduce fatigue during high-intensity exercises (Bouffard et al., 2021).Resisted sprint training, which involves sprinting with additional loads, can improve neuromuscular performance. This type of training enhances muscle force production and sprint speed, regardless of the sprint distance covered (Hermosilla-Palma et al., 2025).

5. Muscle Morphology and Stiffness

Changes in muscle morphology, such as increased muscle volume, are associated with improved sprint performance. Longitudinal studies have shown that hypertrophy of specific muscles, like the semitendinosus, is linked to better sprinting outcomes (Kawama et al., 2024).Vertical and ankle joint stiffness are important for sprinting performance. Increases in these stiffness variables are associated with improved maximal speed sprinting, highlighting the importance of these factors in training programs (Nagahara & Zushi, 2017). Combined training approaches, which integrate sprint, plyometric, and resistance exercises, have been shown to improve repeated sprint ability more effectively than single-mode training. This approach enhances both neuromuscular and metabolic factors, leading to better sprint performance (Liu et al., 2024). In team sports, repeated-sprint training (RST) is effective in improving sprint performance. The manipulation of training variables, such as sprint distance and rest intervals, can optimize physiological and neuromuscular demands (Thurlow et al., 2023).While the focus on neuromuscular adaptations and biomechanical efficiency is crucial for enhancing sprint speed, it is also important to consider the individual variability among athletes. Factors such as genetic predisposition, baseline fitness levels, and specific sport requirements can influence the effectiveness of different training interventions. Therefore, personalized training programs that consider these individual differences may yield the best results in improving sprint performance. The correlation between lower body strength and sprint performance in athletes is a well-researched area, with multiple studies indicating a positive relationship. Lower body strength, often measured through exercises like squats and isometric mid-thigh pulls, is shown to enhance sprint performance across various sports. This relationship is particularly evident in the initial acceleration phase of sprints, where explosive power is crucial. The following sections will delve into specific findings from the provided studies, highlighting the nuances of this correlation. Soccer and Ice Hockey: In elite youth female soccer athletes, a moderate correlation was found between relative lower-body strength and sprint performance over 10m and 30m distances, suggesting that strength training could enhance sprint capabilities in this demographic (Lyons et al., 2023). Similarly, in ice hockey, lower-body strength and power were critical for sprint performance, particularly in the 10-20m flying acceleration phase, indicating the importance of concentric force production (Laakso & Secomb, 2023).

Track and Field: Among male NCAA track athletes, a moderate to high negative correlation was observed between back squat strength and 60m sprint times, indicating that greater relative lower body strength is associated with faster sprint times (Conan & DeBeliso, 2020). Gaelic Football: In elite U20 Gaelic football athletes, both relative lower limb strength and countermovement jump height were strongly correlated with 20m sprint velocity, underscoring the importance of strength and power in sprint performance (O'Driscoll et al., 2024).Meta-Analysis Findings: A systematic review and meta-analysis confirmed that increases in lower-body strength, particularly through resistance training, positively transfer to sprint performance. The magnitude of improvement is influenced by factors such as training frequency and rest intervals, but not by age or height (Seitz et al., 2014).High School Softball: In high school girls' softball players, both absolute and relative lower-body strength were correlated with sprint performance, suggesting that strength training could be beneficial for improving speed in young female athletes (Lockie et al., 2024).Swimming: In adolescent male swimmers, lower-body power, rather than strength, was more predictive of sprint performance in the front crawl, highlighting the sport-specific nature of the strength-sprint relationship (Muniz-Pardos et al., 2024).Soccer: Among collegiate women soccer players, both absolute and relative lower-body strength were significantly correlated with sprint performance, emphasizing the role of strength in enhancing speed and agility (Andersen et al., 2018).While the correlation between lower body strength and sprint performance is generally positive, it is important to consider the specific demands of each sport and the individual characteristics of athletes. For instance, in swimming, power may play a more significant role than strength, and in sports like soccer and ice hockey, the ability to accelerate quickly is crucial. Additionally, factors such as training methods, athlete experience, and body composition can influence the extent to which strength improvements translate to sprint performance. Therefore, tailored training programs that consider these variables are essential for optimizing athletic performance.

Explosive power development is crucial for enhancing sprint start performance, as it directly influences the initial acceleration phase. The development of explosive power involves a combination of physiological, biomechanical, and training factors. This synthesis explores the key elements that contribute to explosive power development for sprint starts, drawing insights from various studies on the topic. The discussion will cover the physiological aspects, training methodologies, and biomechanical considerations that are essential for optimizing sprint start performance.Leg Muscle Explosive Power: The explosive power of leg muscles is a significant determinant of sprint ability. A study found a weak correlation between leg explosive power and sprint speed, suggesting that while important, it is not the sole factor influencing sprint performance (Bakti et al., 2023).Muscle Strength and Power Transfer: The ability to transfer power from the trunk and lower limb joints to external horizontal power is critical. The hip extensors, in particular, play a vital role in generating forward propulsion during the sprint start (Sado et al., 2022).Plyometric Training: Plyometric exercises are effective in enhancing explosive power, as they improve muscle strength, speed, and jumping ability. These exercises also offer psychological benefits, such as increased confidence and motivation, which can enhance overall performance (Bastholm, 2024).Strength Training: Progressive strength training, including exercises like deadlifts, squats, and cleans, has been shown to improve power output significantly. Such training increases muscle cross-sectional area and maximum strength, which are foundational for developing task-specific power (Jurjiu et al., 2022) (Stone & Sato, 2013).Diverse Training Approaches: Incorporating a variety of training methods, such as resistance training and dynamic drills, can help develop speed-strength qualities. This approach is particularly beneficial for young athletes, as it mimics real game situations and enhances skill application (Ilash et al., 2024). Joint and Segmental Contributions: The rotation of the front thigh, driven by hip and knee joint powers, is a major contributor to horizontal propulsion during the sprint start. Conversely, trunk segment rotations primarily contribute to vertical propulsion, highlighting the need for balanced development of these areas (Sado et al., 2022).Power Development in Initial Steps: The initial steps of a sprint start are crucial for building momentum. Training programs that focus on improving the power and speed of these steps can lead to significant performance gains (Jurjiu et al., 2023).

While explosive power is a critical component of sprint start performance, it is not the only factor. Other elements, such as technique, reaction time, and psychological readiness, also play important roles. Additionally, the development of explosive power should be tailored to the individual athlete's needs, considering their specific strengths and weaknesses. This holistic approach ensures that athletes can maximize their sprint start performance through a combination of physical and mental preparation. Sprint performance is heavily influenced by the contributions of different energy systems, which vary based on factors such as the type of sport, training adaptations, and the specific sprint protocol used. The primary energy systems involved in sprinting are the phosphagen (ATP-PCr), glycolytic, and aerobic systems, each contributing differently depending on the sprint duration and intensity. This answer explores how these systems contribute to sprint performance, drawing insights from various studies.The phosphagen system is crucial for short, high-intensity efforts, providing immediate energy through the breakdown of phosphocreatine (PCr). It is the dominant energy source in the initial seconds of a sprint (Archacki et al., 2023) (Tortu & Deliceoğlu,

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2024).In a 15-second sprint, the phosphagen system contributes significantly, especially in speed-power athletes, where it accounts for approximately 42-45% of the energy used (Archacki et al., 2023) (Archacki et al., n.d.). The system's contribution is higher in shorter sprint protocols, such as 10 x 6-second sprints, compared to longer ones like 6 x 10-second sprints (Tortu et al., 2024).

6. Glycolytic System Contribution

The glycolytic system becomes more prominent as the sprint duration increases, providing energy through anaerobic glycolysis. It is particularly significant in repeated sprint protocols (Ulupınar et al., 2021) (Ulupınar et al., 2024). In mixed and speed-power athletes, the glycolytic system can contribute up to 50-57% of the energy during a 15-second sprint (Archacki et al., 2023) (Archacki et al., n.d.). Longer sprint protocols or those with shorter rest intervals tend to increase the glycolytic contribution, as seen in protocols with 30-meter sprints and reduced rest times (Ulupınar et al., 2021).Although traditionally considered less important in short sprints, the aerobic system plays a role in recovery and sustaining performance in repeated sprints (Milioni et al., 2017).Its contribution is more pronounced in endurance athletes, where it can account for up to 12-13% of the energy in a 15-second sprint (Archacki et al., 2023) (Archacki et al., n.d.).The aerobic system's role becomes more significant in repeated sprint protocols, especially as the number of repetitions increases, helping to replenish phosphagen stores and clear lactate (Ulupınar et al., 2024).Long-term training adaptations influence the energy system contributions, with endurance athletes showing a higher aerobic contribution and speed-power athletes relying more on the phosphagen and glycolytic systems (Archacki et al., 2023) (Archacki et al., n.d.).Training does not significantly alter the energy system proportions in the short term, but it does enhance the efficiency and capacity of these systems over time (Archacki et al., 2023).

Sex Differences in Energy System Contribution.Men exhibit higher glycolytic contributions, while women tend to rely more on the ATP-PCr system during repeated sprints (Tortu et al., 2024) (Archacki et al., 2024). Despite differences in absolute energy expenditure, the relative contributions of energy systems are similar between sexes when matched for sport-specific adaptations (Archacki et al., 2024). While the phosphagen and glycolytic systems are the primary contributors to sprint performance, the aerobic system's role in recovery and repeated efforts is crucial. Training adaptations and sport specialization significantly influence these contributions, highlighting the importance of tailored training programs. Understanding these dynamics can help optimize performance in various sprinting contexts.The kinematic analysis of sprint stride mechanics is crucial for understanding and improving sprint performance. Key factors such as ground contact time, stride length, and stride frequency play significant roles in determining sprint speed. This analysis helps in identifying the technical drills necessary for enhancing sprint efficiency. The relationship between these kinematic variables and sprint performance has been extensively studied, providing insights into optimizing training strategies for sprinters.

7. Kinematic Analysis of Sprint Stride Mechanics

Stride Length and Frequency: Stride length has been identified as a more significant contributor to sprint performance than stride frequency, especially in the 100m sprint. Studies show that stride length accounts for a larger variance in running velocity compared to stride frequency, which is less critical once maximum stride rate is achieved (Bhat, 2022) (Mackala, 2007) (Delecluse et al., 1998).Ground Contact Time: A shorter ground contact time is associated with higher sprint speeds. This is because reduced contact time allows for quicker transitions between strides, contributing to increased stride frequency and overall speed (Mattes et al., 2021) (DELİCEOĞLU et al., 2024) (Morin et al., 2012).Step Distance and Flight Time: Both step distance and flight time are significant predictors of sprint speed. Optimizing these parameters can lead to improvements in sprint performance, as they influence the overall stride mechanics (DELİCEOĞLU et al., 2024). Impact on Speed: Ground contact time is inversely related to sprint speed. Shorter contact times enable faster stride cycles, which are crucial for achieving higher speeds. This relationship underscores the importance of developing strength and technique to minimize contact time during sprints (Mattes et al., 2021) (Morin et al., 2012).Technical Implications: Training programs should focus on exercises that enhance explosive strength and improve the efficiency of the push-off phase to reduce ground contact time. This can be achieved through plyometric exercises and drills that emphasize quick foot turnover (Morin et al., 2012). Stride Length Drills: Drills that focus on increasing stride length, such as bounding and resisted sprints, can help athletes cover more ground with each step. These drills should be integrated into training to enhance the athlete's ability to maintain longer strides at high speeds (Mackala, 2007) (JIANG et al., n.d.). Stride Frequency Drills: High-knee drills and fast leg cycles can improve stride frequency by training the neuromuscular system to execute rapid leg movements. These drills are essential for maintaining speed, especially during the acceleration phase (Bhat, 2022) (Mattes et al., 2014). Comprehensive Training: A balanced approach that includes both stride length and frequency drills, along with strength and conditioning exercises, is necessary for optimizing sprint performance. This comprehensive training strategy should be tailored to the individual needs of the athlete based on their current performance level and biomechanical analysis (Mattes et al., 2014) (Ruiter & Dieën, 2019).While the focus on stride length and ground contact time is crucial, it is also important to consider the athlete's body composition and mechanical power output, which significantly influence sprint performance. Factors such as body weight, height, and the ability to apply force effectively during the sprint can impact the kinematic variables and should be considered in training programs (DELİCEOĞLU et al., 2024) (Morin et al., 2012). This holistic approach ensures that all aspects of sprint mechanics are addressed, leading to improved performance outcomes. Power development is a critical component in enhancing athletic performance, particularly in sports that require explosive movements such as sprinting. The development of power can be achieved through various training methodologies, including plyometric and ballistic training, which are designed to improve force production and power-to-weight ratio, crucial for sprint performance. Monitoring power output in training programs is essential to ensure athletes are progressing and adapting optimally. This response will explore these aspects in detail, drawing from the provided research papers. Power is a vital component of athletic performance, especially in sprinting, where explosive power is crucial for acceleration and maintaining high speeds. Developing power involves a progressive sequence that enhances work capacity, muscle cross-section area, and task-specific power (Stone & Sato, 2013). Plyometric training, which includes exercises like jumps and bounds, is effective in improving explosive power, which directly translates to better sprint performance. It enhances muscle strength, speed, and jumping ability, all of which are beneficial for sprinters (Bastholm, 2024). Plyometric training (PLT) is a key strategy for developing explosive power. It involves exercises that focus on rapid stretching and contracting of muscles, which enhances neuromuscular efficiency and power output (Radcliffe & Farentinos, 1999). Studies have shown that both unloaded and loaded plyometric training can significantly improve jump and sprint abilities. Loaded PLT, in particular, has shown superior effects on maximum strength and explosive power (Wang et al., 2023).

8. Ballistic Training for Enhanced Force Production

Ballistic training involves exercises that require maximal force production in a short period, such as throws and jumps. This type of training is effective in enhancing force production and power output, which are critical for sprinting (Cormie et al., 2011). The use of ballistic exercises with varying loads can optimize power development by targeting different aspects of the force-velocity curve, which is essential for improving sprint performance (Cormie et al., 2011).The power-to-weight ratio is a crucial determinant of sprint performance. A higher ratio indicates that an athlete can produce more power relative to their body weight, which is advantageous for acceleration and speed maintenan ce (Aksović et al., 2020). Training programs that focus on increasing lean body mass while optimizing power output can enhance the power-to-weight ratio, leading to improved sprint performance (Aksović et al., 2020). Monitoring power output is essential for assessing the

 doi:10.20944/preprints202507.0676.v1

effectiveness of training programs and ensuring athletes are progressing. This can be achieved through various methods, including the use of technology to measure power during exercises like jump squats (Baker, 2001).Regular monitoring allows for the adjustment of training variables to optimize power development and ensure athletes are adapting appropriately to the training stimulus (Baker, 2001).

While the focus on power development is crucial for enhancing sprint performance, it is important to consider the individual needs and adaptation windows of athletes. Training programs should be tailored to address the least developed factors contributing to power production, ensuring that athletes achieve the greatest neuromuscular adaptations. Additionally, integrating various power training techniques can provide variation and maintain specificity, leading to long-term improvements in power output (Cormie et al., 2011). Sprint and strength performance are influenced by a variety of physiological factors, including muscle fiber type distribution, anaerobic capacity, and recovery strategies. These elements are crucial for optimizing performance in high-intensity activities such as sprinting. Understanding these factors can help in designing effective training programs that enhance sprint and strength capabilities. The following sections delve into these aspects, supported by insights from the provided research papers.Muscle fiber type is a significant determinant of sprint performance. Fast-twitch fibers are associated with high power output but fatigue quickly, whereas slow-twitch fibers are more fatigue-resistant (Lievens et al., 2020).The percentage of fast-twitch fibers and muscle volume are critical for sprint performance, explaining a substantial portion of the variance in sprint capabilities among athletes (Zwaard et al., 2017).Noninvasive methods to estimate muscle typology can help tailor training programs to individual athletes, potentially optimizing performance and recovery (Lievens et al., 2020).

9. Role of Anaerobic Capacity in Short Sprints

Anaerobic capacity is crucial for short sprints, as it determines the ability to sustain high-intensity efforts. Training that enhances anaerobic power can lead to significant improvements in sprint performance (Sokmen et al., 2017).Sprint interval training with active recovery has been shown to improve anaerobic power and sprint times more effectively than traditional endurance training (Sokmen et al., 2017).The maximal anaerobic running test (MART) can be used to assess and prescribe training for enhancing anaerobic performance in sprinters (Nummela et al., 1996).Effective recovery strategies are essential for maintaining performance in repeated-sprint activities. High-intensity interval training can improve recovery between sprints by enhancing metabolic and neural factors (Bishop et al., 2011).Rest redistribution and velocity-based training methods can help maintain sprint velocity and manage internal load without increasing perceived effort, making them effective for repeated sprint training (“Effect of Traditional, Rest Redistribution, and Velocity-Based Prescription on Repeated Sprint Training Performance and Responses in Semiprofessional Athletes,” 2023).Individualized recovery strategies based on muscle fiber typology can optimize performance and reduce the risk of fatigue-related injuries (Lievens et al., 2020).High-intensity sprint training can induce hormonal changes that support muscle adaptation and performance enhancement. However, specific hormonal responses were not detailed in the provided contexts, suggesting a need for further research in this area. While the physiological factors discussed are critical for sprint and strength performance, it is important to consider the broader context of training and performance. Factors such as genetic predisposition, training environment, and psychological readiness also play significant roles in athletic performance. Additionally, the integration of scientific research with best practice approaches can bridge the gap between theory and application, leading to more effective training strategies for athletes (Haugen et al., 2019).The psychological and mental aspects of sprinting are crucial for athletes aiming to achieve peak performance. These aspects encompass mental resilience, visualization techniques, motivation, goal setting, and managing pre-race anxiety. Each of these components plays a significant role in enhancing the performance of sprinters, especially in high-pressure events. Understanding and applying these psychological strategies can lead to improved focus, reduced anxiety, and better overall performance.Mental resilience is a critical factor

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for success in sprinting, as it helps athletes overcome challenges and maintain performance under pressure. It involves developing psychological fortitude to sustain success over time (Fletcher & Sarkar, 2016) (The Key To Sports Psychology: Mental Toughness, 2023).Training programs focused on mental fortitude can enhance an athlete's ability to cope with stress and maintain composure during competitions (Fletcher & Sarkar, 2016).Visualization techniques, such as mental imagery, are effective in improving sprint performance. These techniques help athletes mentally prepare for races by visualizing successful outcomes and reducing competition anxiety (Ali, 2024) (Hammoudi-Nassib et al., 2017).Studies have shown that imagery strategies can enhance performance in short-distance sprints, making them a valuable tool for sprinters (Hammoudi-Nassib et al., 2017).Motivation is a key psychological factor that drives athletes to achieve their goals. Setting clear, achievable goals can enhance motivation and commitment to training regimens (Eklund & Tenenbaum, 2014) (Kaygusuz, 2024).Psychological training programs that incorporate goal setting can lead to consistent performance improvements by fostering a strong motivational drive (Lopes, 2024).Pre-race anxiety is a common issue among sprinters, often influenced by factors such as competition environment and self-efficacy (Zheng et al., 2024).Techniques such as relaxation exercises and mental visualization can help manage anxiety and improve focus, leading to better performance outcomes (Ali, 2024) (李俊源, n.d.).External focus strategies have been shown to boost sprint performance, particularly in low-skill sprinters, by directing attention away from internal stressors (Li et al., 2022).While the psychological aspects of sprinting are well-documented, it is important to consider the individual differences among athletes. Not all techniques may be equally effective for every sprinter, and personalized interventions may be necessary to address specific psychological needs. Additionally, the integration of psychological training with physical training is essential for holistic athlete development. Further research is needed to explore the long-term effects of these psychological strategies and their application across different levels of athletic expertise. Nutrition plays a pivotal role in the performance and recovery of sprint and strength athletes. These athletes require a well-balanced diet that supports their high-intensity training and competition demands. Key nutritional strategies include optimizing macronutrient intake, ensuring proper hydration, and considering the use of supplements to enhance performance and recovery. The following sections delve into these aspects, providing insights from recent research. Carbohydrates and Proteins: Carbohydrates are crucial for replenishing glycogen stores, which are rapidly depleted during high-intensity activities. Proteins are essential for muscle repair and growth, with recommendations suggesting a higher intake to support hypertrophy and strength gains .Fat Intake: While often overlooked, fats provide essential fatty acids and fat-soluble vitamins, contributing to energy maintenance and overall health.Timing of Intake: Strategic timing of macronutrient intake, particularly around training sessions, can enhance performance and recovery. Consuming carbohydrates and proteins before and after exercise helps maintain energy levels and supports muscle recovery .Pre-Exercise Hydration: Athletes should ensure they are well-hydrated before training or competition to prevent dehydration, which can impair performance .During Exercise: Consuming fluids during exercise helps maintain blood glucose levels and prevents dehydration. Sports drinks containing carbohydrates and electrolytes are recommended to support endurance and reduce the risk of hyponatremia .Post-Exercise Rehydration: Replenishing fluids lost during exercise is crucial for recovery. Athletes should aim to replace all fluid losses to restore hydration levels.Ergogenic Aids: Supplements such as creatine, beta-alanine, and branched-chain amino acids (BCAAs) are popular among athletes for their potential to enhance strength, power, and recovery. However, their use should be carefully evaluated for safety and efficacy .Caution with Supplements: Athletes should be cautious with supplement use due to the lack of regulation and potential for contamination. Consulting with a qualified sports dietitian is advised to ensure safe and effective use.Nutrient Timing: Consuming a combination of carbohydrates and proteins immediately after exercise can accelerate recovery by promoting glycogen resynthesis and muscle protein synthesis .Balanced Diet: A diet rich in micronutrients, including vitamins and minerals, supports overall recovery by reducing inflammation and oxidative stress.Individualized Plans: Recovery protocols

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should be tailored to the individual athlete's needs, considering factors such as training intensity, sport-specific demands, and metabolic requirements .

While the outlined nutritional strategies are crucial for optimizing performance and recovery, it is important to recognize the individual variability among athletes. Personalized nutrition plans that consider specific needs and preferences can further enhance outcomes. Additionally, the role of psychological factors and lifestyle choices should not be underestimated, as they can significantly influence an athlete's nutritional status and overall performance.

Similar studies cited by Kaur, M. S. G., & Singh, S. P. (2019). Effect of selected massage and yogic exercise on the recovery pattern of blood lactate after an endurance workout.

Findings: Massage and yogic exercises enhance the recovery pattern of blood lactate post-endurance workout. Relevance to Document: The document emphasizes the importance of recovery strategies for maintaining performance in repeated-sprint activities (Bishop et al., 2011). While the document does not directly cite Kaur and Singh (2019), their findings on massage and yogic exercises improving blood lactate recovery align with the document's discussion on recovery strategies for sprinters, particularly in the context of managing metabolic demands during repeated sprints (Ulupınar et al., 2024). These strategies could enhance sprint performance by reducing fatigue, a critical factor for sprinters relying on anaerobic energy systems. Kumar, R., & Singh, S. (2024). A Comparative Investigation of Physical and Physiological Components of Team Game Athletes from Northeast and South India. Findings: Identifies differences in physical and physiological components between team game athletes from Northeast and South India. Relevance to Document: The document discusses physiological factors like muscle fiber type distribution and anaerobic capacity as critical for sprint performance (Lievens et al., 2020; Sokmen et al., 2017). Kumar and Singh's (2024) comparative analysis of physiological components could provide insights into regional variations in sprint-related attributes, such as muscle morphology or anaerobic capacity, which are relevant to the document's focus on biological determinants of sprinting performance (Zaras et al., 2021). Singh, R. S. S. P. (2015). An Analysis among Physiological and Physical Fitness of Middle Distance and Long Distance Runners.

Findings: Compares physiological and physical fitness attributes of middle and long-distance runners. Relevance to Document: While the document primarily focuses on sprinters, it briefly mentions physiological factors like aerobic capacity, which are relevant to recovery in repeated sprints (Milioni et al., 2017). Singh's (2015) analysis of physiological attributes in middle and long-distance runners could provide comparative insights into how aerobic and anaerobic capacities differ across track and field disciplines, supporting the document's discussion on energy system contributions (Archacki et al., 2023). Singh, S., & Kaur, L. (2014). Effect of different time of day on the coordinative ability of inter-university level female football players. Findings: Time of day impacts coordinative abilities in female football players at inter-university level. Relevance to Document: The document highlights neuromuscular coordination as crucial for sprint performance, particularly in optimizing force application during the sprint cycle (Seagrave & Mouchbahani, 2009). Singh and Kaur's (2014) findings on time-of-day effects on coordinative abilities could relate to the document's emphasis on neuromuscular factors, suggesting that sprint training schedules might need to account for circadian influences to maximize coordination and performance. Das, S. C., & Singh, S. (2024). Chronotype and athletic performance in different time of day.

Findings: Chronotype influences athletic performance depending on the time of day.

Relevance to Document: Similar to Singh and Kaur (2014), this study's focus on chronotype aligns with the document's discussion of neuromuscular coordination and biomechanical efficiency in sprinting (Seagrave & Mouchbahani, 2009). Chronotype could affect sprint performance by influencing neural activation and coordination, critical for rapid force production (Zaras et al., 2016), suggesting that training and competition timing should be tailored to individual chronotypes. Singh, S., Kumar, S., Kaur, N., Choudhary, S., Sekhawat, D. S., Singh, B., & Kaur, J. (2023). Fluid intake and fluctuation in total body water (TBW), intracellular water (ICW), extracellular water (ECW), skeletal muscle mass (SMM) and percentage body fat (PBF) of track athletes.

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Findings: Fluid intake affects body water compartments, muscle mass, and body fat in track athletes. Relevance to Document: The document underscores the importance of hydration for sprint performance, particularly in maintaining blood glucose levels and preventing dehydration during exercise (section on Nutrition). Singh et al.'s (2023) findings directly support this, as proper fluid intake is critical for maintaining muscle mass and performance in sprinters, who rely on lean body mass for explosive power (Zaras et al., 2021). Jabeen, S., & Shah, M. M. (2023). One of the fascinating events in track and field: Hurdles.

Findings: Explores the biomechanical and technical aspects of hurdles in track and field.

Relevance to Document: The document discusses biomechanical efficiency and kinematic variables like stride length and ground contact time in sprinting (Bhat, 2022; Morin et al., 2012). Jabeen and Shah's (2023) analysis of hurdles is relevant, as hurdling involves similar biomechanical demands to sprinting, such as rapid force application and stride mechanics, which are enhanced by strength and power training (Balsalobre-Fernández et al., 2013). Singh, D. S. P. (2021). Reflective responses of tapering exercises module on the hemoglobin counts of track and field athletes. Findings: Tapering exercises influence hemoglobin counts in track and field athletes. Relevance to Document: The document notes the role of aerobic energy systems in recovery for repeated sprints (Ulupınar et al., 2024). Singh's (2021) findings on tapering exercises affecting hemoglobin counts could relate to improved oxygen delivery, supporting recovery and aerobic contributions during sprinting, as discussed in the document (Archacki et al., 2023). Kaur, N., & Singh, D. S. S. (2021). Perceptive consequences of the respiratory parameters of middle and long distance runners in track and field athletes.

Findings: Examines respiratory parameters' impact on middle and long-distance runners' performance. Relevance to Document: The document briefly mentions aerobic system contributions to sprint recovery (Milioni et al., 2017). Kaur and Singh's (2021) findings on respiratory parameters could provide insights into how aerobic capacity supports recovery in sprinters, particularly during repeated efforts, aligning with the document's discussion of energy systems (Archacki et al., 2024). Singh, D. S. (2020). Effect of slow and soft instrumental music and pop instrumental music on the running performance of track and field athletes. Findings: Slow and soft instrumental music positively affects running performance compared to pop music. Relevance to Document: The document emphasizes psychological factors like mental resilience and visualization for sprint performance (Fletcher & Sarkar, 2016; Ali, 2024). Singh's (2020) findings suggest that music could be a psychological tool to enhance focus and performance in sprinters, complementing the document's discussion on mental preparation strategies. Singh, S., & Kumar, P. (2013). Physiological differences between athletes of selected events in track and field–A comparative study. Findings: Identifies physiological differences among athletes in various track and field events. Relevance to Document: The document discusses physiological factors like muscle fiber type and anaerobic capacity as critical for sprint performance (Lievens et al., 2020; Sokmen et al., 2017). Singh and Kumar's (2013) comparative study could provide context for understanding how sprinters differ physiologically from other track and field athletes, such as throwers, as discussed in the document (Zaras et al., 2016). Singh, S., & Kumar, P. (2013). Effect of different durations of active warming-up on sprinting performance. Findings: Different durations of active warm-up impact sprinting performance variably. Relevance to Document: The document highlights the importance of biomechanical and neuromuscular preparation for sprinting (Seagrave & Mouchbahani, 2009). Singh and Kumar's (2013) findings on warm-up durations directly relate to optimizing sprint performance by enhancing neuromuscular activation and force production, key factors in the document's discussion of sprint start and acceleration (Young et al., 1995).

10. Conclusions

The strength and conditioning demands of sprinters and throwers in track and field share a foundation in explosive power and rapid force development, yet diverge in their application due to event-specific biomechanical requirements. Sprinters benefit from training focused on lower-body

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explosiveness, rapid stride mechanics, and neuromuscular coordination to optimize acceleration and maximal speed. Throwers require maximal strength and whole-body power to enhance force production during throws. Periodized training, incorporating plyometrics, resistance exercises, and sport-specific drills, is critical for both groups, with evidence supporting improvements in muscle architecture, RFD, and performance metrics like countermovement jump height and sprint times. Genetic factors and muscle fiber type distribution further underscore the importance of personalized training. Additionally, energy system contributions, particularly the phosphagen and glycolytic systems, play significant roles in sprinting, with aerobic systems aiding recovery in repeated efforts. Psychological strategies, such as visualization and mental resilience, enhance performance under pressure, while proper nutrition and hydration support recovery and sustained performance. Future training programs should integrate these findings, tailoring interventions to individual athletes' physiological and psychological profiles to optimize performance in both disciplines.

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