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Analytical study of certain models for developing explosive strength (Complex training – plyometric - contrast training) A Theoretical approach to the effectiveness of the three methods.

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Abstract:

Explosive strength is a critical determinant of athletic performance across various sports, influencing key movements such as sprinting, jumping, and tackling. This study investigates the efficacy of three prominent training methods: complex training, contrast training, and plyometric training in enhancing explosive strength. Complex training combines heavy resistance exercises with explosive movements to leverage post-activation potentiation (PAP), while contrast training alternates between heavy and light loads to exploit neuromuscular adaptations. Plyometric training utilizes the stretch-shortening cycle (SSC) to improve power output through rapid, high-intensity movements. Despite extensive research, the superiority of one method over others remains unclear, with studies showing mixed results. This research aims to clarify the appropriate method for developing explosive strength across different sports. By examining the mechanisms of effectiveness, practical applications, and optimal timing within annual periodization, the study seeks to provide evidence-based recommendations for athletes and coaches to optimize training programs and enhance explosive performance.

Keywords: **Complex training – Plyometric - Contrast training.**

Article info

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1. Problematic:

Explosive strength is recognized as one of the most crucial physical qualities in all sports disciplines. Whether in team sports, or individual competitions, the ability to generate rapid force is directly tied to performance outcomes. In football (soccer) for instance, many players possess strength or speed. By combining strength and power training, players will increase their ability to generate force in basic movements like sprinting, jumping, tackling, and shooting, which plays a key role in an athlete's overall performance (Greg Gatz, 2009, p. 5). In basketball. Powerful players who can generate maximum force in a short time, such as jump, rebounds, sprint, and defensive reactions, can significantly influence their success on the court (Gregg Popovish, 2007, p. 127). Similarly, understanding the best methods to enhance explosive strength becomes essential for athletes and coaches seeking to optimize their training.

Several training methods have been proposed to develop explosive strength, including complex training, contrast training, and plyometric, which are among the most widely researched approaches. First, Complex training, which combines heavy strength exercises with explosive movements, aims to improve muscular power. (G. Gregory Haff, N. Travis Tripplet, 2016, p.480). Second, Contrast training, which alternates between heavy loads in conjunction with lighter explosive movements, is designed to exploit the contrast in muscle activation to enhance explosive power (Felipe García-Pinillos, Antonio Martínez-Amat, Fidel Hita-Contreras, Emilio J. Martínez- López, and Pedro A. Latorre, 2014, p.2453). Lastly, plyometric exercises have been described as activities that involve maximal effort, such as high-intensity depth jumps. Plyometric training uses the stretch-shortening cycle to increase muscle power through exercises such as jumps, bounds, and sprints (Donald A. Chu, Gregory D. Myer,2013, p. 13). These methods are often implemented in various combinations, with the assumption that they will lead to improvements in both strength and power.

However, while these methods have been extensively researched, the question remains: Which of these training methods is most effective for improving explosive strength across different sports? Although some insights are provided by existing literature, studies show mixed results regarding the superiority of one approach over another. For instance, studies by Sébastien Lagrange, Pierre-Marc Ferland, Mario Leone, Alain Steve Comtois (2020): suggest that Contrast training generates post-activation potentiation and improves repeated sprint capacity in elite ice hockey players, while other research has argued that plyometric training provides the most efficient and immediate gains in explosive performance and velocity (Francesco Fischetti, Alessio Vilardi, Stefania Cataldi, Gianpiero Greco 2018) This divergence of findings highlights the need for further investigation into the most effective training protocols for explosive strength. In addition, Braulio Cavaco, Nelson Sousa, Victor Machado dos Reis, Nuno Garrido, Francisco Saavedra, Romeu Mendes, José Vilaça-Alves. (2014) shows that The Complex Training (CXT) program proved to be effective for improving motor skills and abilities in youth soccer players, particularly shooting effectiveness.

A review of previous studies in this area consistently focuses on the positive impact of plyometric training for improving vertical jump height, and sprint times, key measures of explosive power. However, despite these promising findings, the comparison between complex and contrast training on these variables remains less clear. Some studies suggest that contrast training may offer more nuanced improvements by targeting both strength and speed simultaneously, while others find that complex training better prepares

athletes for explosive tasks. These contrasting viewpoints leave the issue open for debate, with no single method being universally recognized as superior, which is why we decided to undertake this investigation.

This study aims to address this gap in literature by investigating the effects of complex, contrast, and plyometric training on explosive strength for athletes. Despite the ample body of research, the optimal training protocol remains a controversial issue. The question that guides this investigation is: Which method; complex, contrast, or plyometric training produces the greatest improvement in explosive strength for athletes across different sports disciplines? By exploring this question, the study seeks to provide valuable insights into the development of more effective training programs tailored to enhancing explosive performance in sports.

In our research, we used a descriptive analytical approach, which relies on the bibliographic method to collect data by reviewing research findings, literature, and previous studies published on the topic of our current research.

2. Literature Review:

2.1. Complex training:

Complex training is a highly effective method for developing explosive strength. It combines heavy resistance exercises with explosive movements in the same workout session (Donald A. Chu, Gregory D. Myer,2013, p.189). This method is grounded in the principle of post-activation potentiation (PAP), a physiological phenomenon where a heavy resistance exercise temporarily boosts muscle force output. PAP is driven by increased neural activation and improved motor unit recruitment, enabling athletes to produce greater power in the following explosive movements (Robbins, 2005, p. 453).

2.1.1. Mechanisms of Effectiveness Post activation potentiation:

heavy resistance exercises, such as squats or deadlifts, prepare the nervous system by enhancing the sensitivity of myosin light chains to calcium, a process referred to as myosin light chain phosphorylation. This mechanism boosts the muscle's ability to generate force during subsequent explosive actions, such as jumps or sprints. When a heavy load is lifted, the nervous system activates high-threshold motor units. This brief phase of increased neural readiness enables athletes to produce more force and power in subsequent explosive movements. For example, a 2.39% improvement in vertical jump was observed after participants performed five sets of half squats at progressively increasing loads from 20% to 90% of 1RM, and a 4.5% increase in power output after performing a 6RM bench press at 65% 1RM, with power measured through bench press throws at 50 kg (Robbins, 2005, p. 454**).**

This theory further elaborates on this concept, stating that increasing the load used in a power movement stimulates or excites the central nervous system, leading to an increase in the overall output of the working muscles. By capitalizing on this effect and performing a speed-based exercise immediately afterward, athletes can achieve greater speed and power because the targeted muscles are more productive (Hancen, 2014, p. 119).

2.1.2. Neuromuscular Adaptation:

After performing a heavy load, the strength and power characteristics of subsequent muscle actions can be temporarily enhanced due to increased central nervous system (CNS) excitability, a phenomenon known as post-activation potentiation (PAP). This acute physiological change is widely recognized in the strength and fitness literature, with the hypothesis that a prior heavy load increases peak muscle activity by inducing high neuronal firing rates, leading to greater motor unit recruitment and enhanced high-frequency firing (Robbins, 2005, p. 453). The underlying mechanisms include the phosphorylation of regulatory myosin light chains, which increases the sensitivity of contractile proteins (actin and myosin) to calcium, a key regulator of muscle contraction (Haff & Nimphius, 2012, p. 5). Additionally, the recruitment of larger, fast-twitch motor units contributes to greater force and power output (Robbins, 2005, p. 454). These mechanisms enhance explosive performance by increasing CNS excitability, improving motor unit recruitment, and optimizing muscle contraction efficiency. PAP forms the basis of advanced training methods like complex training, where heavy resistance exercises are paired with explosive movements to maximize power output. This approach is particularly valuable for athletes in sports requiring explosive actions, such as sprinting, jumping, and weightlifting, as it leverages temporary but significant improvements in strength and power.

2.1.3. Practical Example of Complex Training in Action:

A typical complex training session might include the following paired exercises:

1. Heavy Resistance Exercise: Back squats at 90% of 1RM (3-5 reps).
    - The heavy squats activate high-threshold motor units and induce post-activation potentiation (PAP), priming the nervous system for enhanced force production.
2. Explosive Movement: weighted jumps (6-8 reps).
    - The weighted jumps capitalize on the heightened neural state created by the heavy squats, translating the increased neural drive into greater power output.
3. Allow 3-5 minutes of rest between the heavy resistance exercise and the explosive movement to optimize the PAP effect (Robbins, 2005, p. 456).

This combination of heavy resistance and explosive movements leverages the PAP effect, allowing athletes to generate more force and power in the explosive task. Research has demonstrated that such paired exercises can lead to a 5-10% improvement in explosive performance when implemented correctly (Robbins, 2005, p. 456). For example, a basketball player performing heavy squats followed by vertical jumps may experience a noticeable increase in jump height, while a sprinter pairing heavy deadlifts with sprint drills could see improvements in acceleration and top speed.

2.1.4. Recommendations:

Complex Training, though not extensively researched, offers significant benefits when integrated into a well-structured program. It should be periodized, starting with a foundation of functional strength before incorporating low-intensity plyometrics and progressing to sport-specific compound pairings during pre-competition phases. High intensity is essential for both weight training (2-8 reps) and plyometric exercises (5-15 reps), with low volume (2-5 sets) to avoid fatigue and maintain quality. Exercises should be biomechanically similar, such as pairing squats with squat jumps or bench presses with medicine ball throws, and tailored to the athlete's sport. Training frequency should range from 1-3 sessions per week, with 48-96 hours of recovery between sessions targeting the same muscle group. During pre-competition and competitive phases, complex training can be used 2-3 times weekly as a time-efficient, high-intensity method. complex training can enhance strength, power, and sport-specific performance by adhering to periodization, intensity, exercise specificity, and recovery while minimizing injury risk. (Ebben, W. P., & Watts, P. B. 1998, P. 23,24).

2.2. Plyometrics:

In 1966, Zatsiorski demonstrated that when an athlete pushes against a fixed bar from a squat position, they generate a specific level of force known as the maximum isometric force (Cometti G & Cometti D, 2007, p.34). However, during a drop jump, also categorized as a plyometric exercise, the same athlete can generate up to 1.5 to 2 times their maximum isometric force.

Plyometric exercises leverage the stretch-shortening cycle (SSC), which involves eccentric, isometric, and concentric contractions working together. Before executing a powerful movement like a jump, the body instinctively undergoes a rapid eccentric phase—a controlled lowering motion—which creates a cushioning effect that increases the time available for force application. Additionally, this quick stretch activates the myotatic (stretch) reflex, enhancing force production when followed by an explosive concentric phase (Reiss & Prévost, 2013, p.317).

2.2.1. Mechanisms of Effectiveness:

The effectiveness of plyometric training is rooted in the stretch-shortening cycle (SSC). The SSC is a natural physiological process that occurs when a muscle lengthens (eccentric phase) and immediately shortens (concentric phase). This rapid sequence generates a powerful force that enhances athletic performance. Plyometrics take advantage of the SSC, thereby improving neuromuscular efficiency and increasing the power of subsequent movements. (Ramp Physio and Fitness, 13/03/2025).

2.2.3. The Two Key Muscle Function Curves:

a. Force-Velocity Relationship:

According to Cometti (2007), muscle force production is inversely related to movement speed as velocity increases, and force output decreases. This is because at higher speeds, muscle fibers have less time to form strong cross-bridges between actin and myosin filaments, which are responsible for generating force. Lieber (2002), as cited by Cometti, explains that force output largely depends on the number of actin-myosin bridges. Since forming these bridges takes time, faster movements result in fewer active cross-bridges, reducing overall force output (Cometti G & Cometti D, 2007, p.17).

b. Sarcomere Force-Length Relationship:

This relationship describes how the length of a sarcomere (the functional unit of a muscle fiber) influences force production. When sarcomere length is too short, excessive overlap of filaments reduces force output under isometric conditions. Conversely, when actin and myosin filaments are positioned at an optimal intermediate length, maximum cross-bridge formation occurs, allowing for peak force production. If the sarcomere stretches beyond this ideal range, the contact area between filaments decreases, leading to reduced force generation.

These principles are fundamental in understanding how plyometric training enhances explosive power, making it a valuable method for athletes in sports that demand rapid, high-intensity movements such as sprinting, jumping, and agility-based activities. (COMETTI, G and COMETTI, D, 2007, p.20,21).

2.2.4 The Sliding Filament Theory (Muscle Contraction):

When a muscle contracts, its muscle fibers shorten. This phenomenon is explained by the sliding filament theory. When a myosin head attaches to an actin filament, it forms an actin-myosin cross-bridge, allowing the two filaments to slide past each other. As soon as the myosin heads bind to the active sites on the actin filaments, they exert a strong molecular attraction, causing the myosin head to pivot toward the center of the sarcomere. This movement generates the force necessary for muscle contraction. (NASM, 2004, P46).

2.2.5 Practical Example of Plyometrics in Action:

Box Jumps (4 sets of 6 reps):

- Objective: Improve vertical jump height and explosive power.
- Execution: Stand in front of a box (30-50 cm height). Jump onto the box with both feet, landing softly with knees slightly bent. Step down and repeat.
- Rest: 1-2 minutes between sets.

2.2.6 Recommendations:

To implement a plyometric training program, start by evaluating the athlete, including their sport, training history, and physical readiness. Next, establish sport-, position-, and athlete-specific goals to tailor the program to their needs. Assign appropriate program design variables, such as intensity, frequency, recovery, volume, and program length, to ensure safety and effectiveness. Teach the athlete proper jumping, landing, and throwing techniques to minimize injury risk and maximize performance. Finally, progress the program systematically, gradually increasing intensity and complexity as the athlete's strength, technique, and conditioning improve. (G. Gregory Haff, N. Travis Tripplet, 2016,p.478).

2.3. Contrast training:

Contrast training utilizes post-activation potentiation (PAP) to enhance muscle force output by alternating heavy and light loads within a single session. This method engages different muscle contraction regimens and is highly effective for power development. By combining heavy resistance exercises (≥80% 1RM) with lighter, ballistic movements, contrast training stimulates neuromuscular adaptations that improve various performance variables (Felipe García-Pinillos et al., 2014, pp. 2452–2453). Additionally, contrast training pairs high-resistance exercises with explosive movements that follow the same biomechanical pattern, such as squats followed by vertical jumps, to develop both strength and power. (Carley Gould, 2021, p. 30).

2.3.1. Mechanisms of Effectiveness:

Post-Activation Potentiation (PAP), as described by Robbins (2005), is a physiological mechanism in which a muscle's ability to generate force is temporarily enhanced following a high-intensity contraction. This occurs due to increased central nervous system (CNS) excitability and improved muscle contractile properties, particularly through the phosphorylation of myosin light chains, which makes actin-myosin interactions more efficient. (Pedro Ángel Latorre Román and All, 2017, p 2).

Contrast Training (CT) capitalizes on this phenomenon by pairing heavy resistance exercises with lighter, high-velocity movements of a similar biomechanical pattern, such as squats followed by vertical jumps. The heavy resistance primes the neuromuscular system, increasing motor unit recruitment and firing frequency, thereby enhancing subsequent explosive movements. This training method effectively improves power output, rate of force development (RFD), and athletic performance, making it particularly beneficial for sports requiring rapid and forceful movements like sprinting, jumping, and Olympic lifting (Robbins, 2005, p. 453; Haff & Nimphius, 2012, p. 6).

2.3.2. Practical Example of contrast training in Action:

A contrast training session might include the following paired exercises:

1. Heavy Resistance Exercise: Back squats at 85% of 1RM (3-5 reps).
    - The heavy squats activate high-threshold motor units and induce post-activation potentiation (PAP), priming the nervous system for enhanced force production.
2. Fast Explosive Movement: vertical jumps (8 to 10 reps).
    - The vertical jumps capitalize on the heightened neural state created by the heavy squats, translating the increased neural drive into greater power output.
3. Allow 30 to 60 seconds of rest between the heavy resistance exercise and the explosive movement.

2.3.3. Recommendations:

For effective contrast training, it’s very important to alternate heavy resistance exercises (80-90% 1RM) with lighter, explosive movements that share the same biomechanical pattern, such as squats followed by vertical jumps. Contrast training is more transient and requires less rest than complex training.

Rest intervals between intense resistance training and lighter, faster explosive movement range from 30 to 60 seconds. Volume should include 3 to 5 sets per exercise, performed 2 to 3 times per week, to ensure adequate stimulation and allow for optimal recovery. Proper technique during resistance and plyometric exercises is essential to prevent injury and improve force production. Progressive overload should be applied, gradually increasing the intensity of intense resistance and plyometric exercises. Contrast training should be incorporated into a periodic training plan. (Carley Gould, 2021, p. 32).

3. Theoretical Analysis:

The initial question of this research was: Which method; complex, contrast, or plyometric training produces the greatest improvement in explosive strength in athletes from different sports disciplines?

To answer the initial question, it is essential to highlight the importance of structuring an annual strength training program throughout the mesocycles and micro cycles phases of the sports season, adapted to the training method chosen from the three options presented. This analysis will be based on the results of relevant research, existing literature, and previous studies presented in the following sections.

Periodization is a key concept in strength and conditioning, allowing athletes to maximize performance gains while minimizing fatigue and injury risks. The integration of complex training, contrast training, and plyometric training should be strategically planned across different phases of the annual training cycle to optimize explosive strength development. Each method has unique benefits and is best applied during specific stages of periodization to align with the athlete's goals, fitness level, and competition schedule. Below is a discussion of the best times to use these methods within the macrocycle

In the annual planning for athletes, the periodization of training is crucial to optimize performance and minimize injury risk. Complex training, contrast training, and plyometric exercises are highly effective for enhancing explosive power, speed, and neuromuscular coordination (Bompa & Haff, 2009, p. 145). These methods are best utilized during the pre-competitive phase and the early competitive phase of an annual training plan. During the pre-competitive phase, athletes transition from general preparation to sport-specific preparation, making it an ideal time to introduce high-intensity training modalities (Issurin, 2008, p. 81). This phase allows athletes to build on foundational strength and endurance while developing explosive power and sport-specific skills.

The early competitive phase is another suitable period for incorporating complex, contrast, and plyometric training. During this phase, athletes are fresh enough to handle high-intensity work, and the focus shifts to maintaining and refining explosive power (Ebben & Watts, 1998, p. 18). Combined training program, which alternates between heavy resistance exercises and explosive movements, is particularly effective for enhancing the transfer of strength gains into dynamic actions (Cormie et al., 2011, p. 137). Plyometric exercises, such as box jumps or depth jumps, can also be used to maintain neuromuscular efficiency and power output (Markovic & Mikulic, 2010, p. 866). However, the volume and intensity of these exercises should be carefully managed to avoid excessive fatigue.

In contrast, the peak competitive phase and the transition phase are less suitable for heavy use of these training methods. During the peak competitive phase, the focus shifts to maintaining performance and managing fatigue, as athletes are often exposed to high competition loads (Issurin, 2008, p. 93). High-

intensity training methods should be reduced or replaced with lower-intensity maintenance exercises to avoid overtraining and injury. Similarly, during the transition phase (off-season), the emphasis is on recovery and regeneration, making high-intensity training inappropriate (Bompa & Haff, 2009, p. 210). By strategically timing the use of complex, contrast, and plyometric training during the pre-competitive and early competitive phases, athletes can maximize their explosive power and performance while minimizing the risk of injury and burnout.

4. Conclusion:

Explosive strength development remains a fundamental goal for athletes and coaches seeking to optimize performance. Complex, contrast, and plyometric training each provide unique physiological benefits, with their effectiveness depending on factors such as sport specificity, training phase, and individual athlete needs. While:

- complex training maximizes PAP (post-activation potentiation) for immediate power gains,
- contrast training efficiently integrates strength and speed,
- Plyometric training enhances neuromuscular efficiency through rapid SSC engagement (stretch-shortening cycle).

The optimal training approach likely involves a strategic combination of these methods, periodized to align with competition demands.

Further research is needed to establish definitive guidelines on their integration for different athletic populations, ensuring athletes receive the most effective and sport-specific explosive strength training.

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