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Linear complex training periodization on athletic performance development

Lineer kompleks antrenman periyodizasyonunun atletik performans gelişimine etkisinin incelenmesi

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Abstract

Complex training is a strength and conditioning method that combines high-load resistance exercises with plyometric movements to enhance neuromuscular performance and athletic power output. This study aims to examine the effects of linear complex training periodisation on the development of athletic performance and to evaluate the training parameters that contribute to improvements in strength and power. The training model integrates resistance and plyometric exercises within a single session and manipulates variables such as load intensity, repetition schemes, exercise selection, and rest intervals. The literature indicates that complex training programs implemented over 4–10 weeks can lead to significant improvements in muscular strength, power output, and overall athletic performance. High-load resistance exercises contribute primarily to maximal strength development, while plyometric exercises enhance explosive power and neuromuscular efficiency. In addition, manipulating intra-set and inter-set rest intervals, typically ranging from less than 30 seconds to approximately 5 minutes, plays an important role in optimising neuromuscular adaptations. Findings also suggest that combining multiple exercise modalities within complex training protocols may yield greater improvements in 1RM strength and maximal power output than single-exercise protocols. Furthermore, complex training periodisation supports both strength–power and strength–speed phases of athletic development, allowing athletes to improve muscular performance and sport-specific physical capacities. In conclusion, linear complex training periodisation is an effective method for enhancing athletic performance by improving strength, power, and neuromuscular adaptation. Proper manipulation of training variables, such as load, volume, rest intervals, and exercise combinations, is essential to maximise training outcomes and prevent excessive fatigue. Therefore, complex training can be recommended as an effective strategy within strength and conditioning programs for athletes across various sports disciplines..

Keywords Complex training, linear periodization, strength and power development, athletic performance

Öz

Kompleks antrenman, yüksek yükle uygulanan direnç egzersizleri ile pliyometrik egzersizlerin aynı antrenman oturumu içerisinde birleştirilmesine dayanan bir kuvvet ve kondisyon yöntemidir. Bu çalışmanın amacı, doğrusal kompleks antrenman periyodizasyonunun atletik performans gelişimi üzerindeki etkilerini incelemek ve kuvvet ile güç gelişimine katkı sağlayan antrenman parametrelerini değerlendirmektir. Kompleks antrenman modeli, direnç ve pliyometrik egzersizleri aynı oturumda uygulayarak yük şiddeti, tekrar sayısı, egzersiz seçimi ve dinlenme aralıkları gibi antrenman değişkenlerinin planlı biçimde manipüle edilmesine dayanmaktadır. Literatür bulguları, 4–10 hafta arasında uygulanan kompleks antrenman programlarının kas kuvveti, güç üretimi ve genel atletik performans üzerinde önemli gelişmeler sağlayabileceğini göstermektedir. Yüksek yükle uygulanan direnç egzersizleri maksimal kuvvet gelişimine katkı sağlarken, pliyometrik egzersizler patlayıcı güç ve nöromüsküler verimliliğin artmasına yardımcı olmaktadır. Ayrıca, 30 saniyeden kısa ile yaklaşık 5 dakika arasında değişen dinlenme aralıklarının nöromüsküler adaptasyonların optimize edilmesinde önemli rol oynadığı belirtilmektedir. Çoklu egzersiz protokollerinin kullanıldığı kompleks antrenman uygulamalarının, tekli egzersiz protokollerine kıyasla 1RM kuvveti ve maksimal güç çıktısında daha yüksek gelişim sağlayabileceği bildirilmektedir. Sonuç olarak, doğrusal kompleks antrenman periyodizasyonunun kuvvet, güç ve nöromüsküler adaptasyonları geliştirmede etkili bir yöntem olduğu görülmektedir. Yük, hacim, dinlenme aralıkları ve egzersiz kombinasyonlarının uygun şekilde planlanması, antrenman verimliliğini artırmak ve aşırı yorgunluğu önlemek açısından önem taşımaktadır. Bu nedenle kompleks antrenman, farklı spor branşlarında performans gelişimini desteklemek amacıyla kuvvet ve kondisyon programlarında uygulanabilecek etkili bir antrenman yaklaşımı olarak önerilmektedir..

Anahtar Kelimeler: Kompleks antrenman, doğrusal periyodizasyon, kuvvet ve güç gelişimi, atletik performans

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Introduction

Strength & condition researches are recommended on athletic population, in generally reports determine sport specific strength condition. It that is methods, complex training elicited to strength performance gain as prescribed to periodized model programs. The program level is a set-ups linear weekly including set, load, repetition, rest interval and exercise selection. Weight training is athletic condition, in critically reports noted that positive effect has been training modes, S & C program types find on complex training in as it was high load strength and plyometric exercises (Ebben, 1998). Complex training can be explain weight and plyometric modes, have been viewed to complementing of exercise weeks, for example performed plyometric after weight exercises at 4 and 6 week, complex modes ie., bench press and medicine ball throw can gain initially power (Ebben, 1998). To condition tests include in 1 set - 1-2 trial or 2 set - 1-2 trial as low intensity whereas training volume has detected at 5RM - 60% 1RM for high strength (Ebben, 1998). Chu (1998) complex training method used with multi joint lifts - squat, deadlift, bench press and squat jump, box jump, throw bench press, as Ebben & Blackard (1998) along with high load and number complexes exactly strength and speed combination (Verkhoshansky & Tetyon, 1973). Is a complex modes combined to not traditional performance level, in load and repetition periodization planning, when it modes are using of strength-power phase and strength-speed phase as aimed training development.

Periodization

Complex training changed volume and specified rest intervals follow periodization. Programs, which used implement exercises with preparation training set-ups are weight mode with plyometric mode. The examination, to squat 5 set and 2-8RM by weight mode, exhibited with jump squat 5-15RM by plyometric mode, in generally can be include multi joint exercise selection (Ebben, 1998). Training plan; complex training may be choice specific muscle exercises under taken 1-3 times a week with given to prevent injury and fatigue, in typically set and rest interval perform high load weight followed plyometric exercise; squat followed depth jumps may be all time low intensity 30-40%1RM given 1 min rest interval (Blakey & Southard, 1987). To neuromuscular adaptation can be all time rest intervals < 1 min or 30 s on strength and power gain (Vossen et al., 2000). Weight and plyometric modes in some days found superior vertical jump compared to traditional weight, not optimal training stimulus objectively (Verkhoshansky & Tetyon, 1973). It can important to examine exercise selection, agonist and antagonist muscle, training volume, rest intervals, repetition regimes. Complex training should be strength-power development; as before it condition used terminology on strength and speed in power is velocity (v) of a force (F), is uploading (kg) of movement bias (m) explained mathematically as P=Fv and F=kg;

- Strength-power: Load 70-80%1RM to weight mode
- Strength-speed: Load 30-60%1RM to weight mode, setting 3-5 set: 3-8RM to strength-power, 10-15RM to strength-speed at complex mode intervals; 10 s, 1, 2, 3 and 5 min (May et al., 2010).

Complex training program is multiple periodization to obtain potential aqusition perform strength and condition (Fig 1).

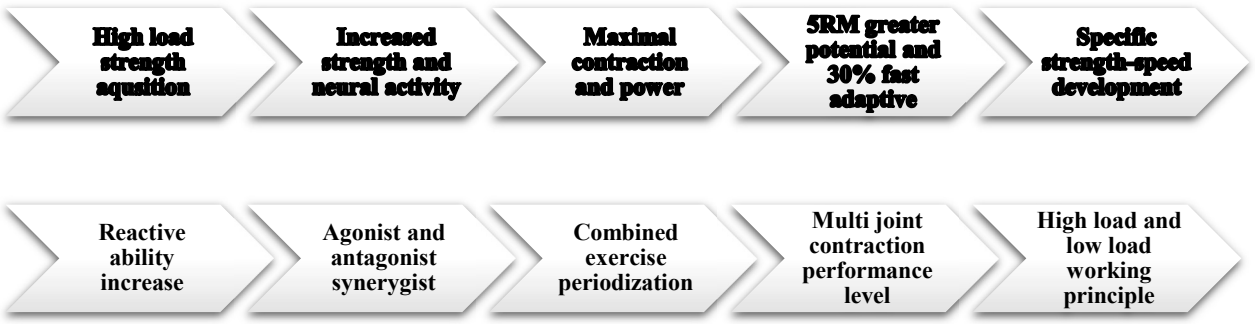

Fig 1. Proposed complex training adaptations

Training manipulation

Training method settings can be manipulated through load, recovery, and exercise selection to improve strength and power output. These manipulations are commonly applied within both strength–power and strength–speed phases. For instance, an intervention strategy combining 6RM bench press (~65% 1RM) with explosive bench press throws (50 kg) has been shown to enhance power development (Daniel Baker, 2003).

Similarly, Steven J. Fleck and Kontor (1986) described complex training protocols involving high loads (>85% 1RM) during traditional resistance exercises such as squats or bench press, followed by low-load explosive movements (30–45% 1RM) including jump squats or medicine ball throws.

Another approach within strength–power phases involves combining heavy resistance exercises (e.g., 3RM back squat) with plyometric movements such as countermovement jumps (CMJ) and squat jumps (SJ). When these exercises are performed using an intracomplex rest interval of approximately five minutes, improvements in muscular performance and power output have been reported (Houlton et al., 2024).

Within this framework, complex training mechanisms are believed to produce greater strength and power gains when sufficient recovery is provided. Although longer rest intervals (~5 min) may maximize potentiation effects, shorter rest periods of approximately three minutes are commonly used in practice to maintain training efficiency (Jones & Lees, 2003).

Training programs combining strength and plyometric exercises may enhance neuromuscular adaptation when appropriate rest intervals are implemented. For example, a program consisting of three sets of 6RM deadlifts (~65% 1RM) combined with three sets of depth jumps over a four-week period has been shown to improve strength–speed characteristics (Mihalik et al., 2008).

Other studies have also reported that complex training protocols incorporating strength–power and strength–speed modalities with different rest intervals can improve explosive strength performance. In general, rest intervals of 3–4 minutes are recommended for explosive strength exercises with intra-set rest periods of less than 1–2 minutes, whereas maximal strength exercises may require approximately five minutes of recovery with intra-set rest periods below three minutes (Santos & Janeira, 2008; Qiao et al., 2022).

Furthermore, Matthews and Comfort (2008) examined protocols involving a 5RM bench press followed by a medicine ball throw for strength–power development, and a 6RM bench press followed by a medicine ball throw for strength–speed training. Their findings suggested that short rest intervals (approximately 30 seconds) between paired exercises may enhance performance when complex training sessions include three to four exercises per week

NOTE: Carter and Greenwood (2014) reported that complex training programs lasting between three and ten weeks are commonly used in strength and conditioning programs. These protocols typically combine high-load resistance exercises (80–90% 1RM) with plyometric movements (~30% 1RM or body weight). In such programs, three to four exercises are often performed with four sets at approximately 6RM.

Training manipulations may include adjustments in repetitions, intensity, and exercise sequencing. For example, antagonist-paired training (e.g., explosive movements performed on a Smith machine) has been shown to improve maximal strength. In contrast, traditional complex training approaches may enhance peak power output when applied within sport-specific training contexts (Macaluso & Nitka, 2010).

Therefore, complex training can be structured to enhance both strength and power adaptations following maximal or near-maximal contractions (see Table 1). Specific exercise selection for complex training protocols is presented in Table 2..

Table 1. 6 week complex training periodization

1	4x5	70-75-75-80
2	4x5	75-80-80-85
3	4x5	80-85-85-90
4	4x3	80-85-85-90
5	4x3	85-90-90-95
6	4x3	90-95-95-100

Table 2. Exercise selection

Deadlift	Box jump
Squat	Depth jump
	Jump squat
	Broad jump
	Countermovement jump shrug
Bench press	Medicine ball throw
Overhead press	Machine throw
Incline bench press	Plyometric push up

Changing week to week load

Complex training programs are typically performed two to three times per week, with short-term interventions lasting approximately 4–6 weeks and longer interventions exceeding 10 weeks to achieve significant improvements in strength and power performance (Stanisaki et al., 2015).

In these programs, strength exercises are generally performed at intensities of 70–90% of one-repetition maximum (1RM), whereas plyometric exercises are performed at approximately 30% of 1RM or body mass resistance. For example, a six-week strength-focused program or a four-week high-load program may induce a transition of muscle fibres from type IIx to type IIa. However, incorporating power-oriented training modes may help preserve a higher proportion of type IIx fibres, which are strongly associated with strength and power adaptations (Stanisaki et al., 2015).

Multiple-exercise complex training protocols have also been described, in which resistance exercises are performed at 60–80% 1RM (6–12RM), followed by plyometric exercises such as vertical jumps, performed for 2–3 sets of 10–12 repetitions. These exercises are typically performed with rest intervals of 60–90 seconds between sets within an eight-week training program (Shen et al., 2025).

Furthermore, complex training has been shown to improve overall athletic performance by optimising strategies that enhance both strength and power. Such training interventions may be repeated weekly as part of a progressive program design (Zhai & Qin, 2024).

A progressive complex training model performed twice per week may include the following phases:

Week 1 – Phase 1: 65% 1RM × 15RM + 3–5RM plyometric exercise – 60 s rest
Week 2 – Phase 2: 70–85% 1RM × 6–12RM + 5–10RM plyometric exercise – 90 s rest
Week 3 – Phase 3: 80–100% 1RM × 1–8RM + 5–10RM plyometric exercise – 240 s rest

Linear periodisation models are commonly used to improve multiple performance outcomes and have been shown to enhance strength, power, and change-of-direction performance (Wang et al., 2024).

Rest Intervals

Rest intervals play an important role in complex training. For moderate loads (60–70% 1RM), plyometric exercises may be performed after approximately 30 seconds of rest, whereas near-maximal loads (~100% 1RM) typically require longer recovery periods of approximately 3–5 minutes (Jensen & Ebben, 2003).

For example, some protocols include a 5RM resistance exercise followed by five countermovement jumps (CMJ), with rest intervals ranging from 1 to 4 minutes. These intervals have been shown to influence performance outcomes, although a four-minute rest interval may not always be considered a true intracomplex rest period in daily training plans.

Previous research suggests that optimal rest intervals for power development occur within the intracomplex training structure (Comyns et al., 2006). When heavy loads exceeding 85% 1RM are used within complex training programs lasting more than six weeks, performance improvements are generally achieved when rest intervals remain below five minutes (Cormier et al., 2020).

Within linear periodisation models, rest intervals of 3–5 minutes between strength and power exercises are considered optimal, whereas shorter rest intervals of 1–3 minutes between sets may also support performance improvements (Shen et al., 2025; Comyns et al., 2006)

Conclusion

Complex training has been widely recognised as an effective strength and conditioning method for enhancing athletic performance by integrating high-load resistance exercises and plyometric movements. The findings presented in this study indicate that properly structured complex training programs can significantly improve muscular strength, explosive power, and neuromuscular performance. In particular, manipulating training variables such as load intensity, repetition schemes, rest intervals, and exercise selection plays a critical role in maximising the effectiveness of complex training protocols.

The results suggest that linear periodisation models provide an appropriate framework for implementing complex training within athletic populations. Gradual progression of training loads combined with plyometric exercises allows athletes to develop both strength–power and strength–speed capacities, which are essential components of sport-specific performance. Additionally, appropriate rest intervals between resistance and plyometric exercises appear to optimise neuromuscular responses and enhance power output.

From a practical perspective, complex training programs implemented over 4–10 weeks may lead to meaningful improvements in athletic performance indicators such as maximal strength, vertical jump performance, and explosive power. The combination of resistance and plyometric exercises within the same training session appears to potentiate subsequent muscular performance. Therefore, complex training can be considered an effective strategy for strength and conditioning specialists aiming to improve athletic performance in various sports disciplines.

Furthermore, the effectiveness of complex training depends on careful program design, including the appropriate manipulation of training volume, intensity, and recovery intervals. Coaches and strength and conditioning practitioners should tailor complex training protocols according to the athlete's training experience, sport-specific demands, and performance goals.

Future research should further investigate the long-term effects of different complex training periodisation models across various sports and athlete populations. In particular, examining the influence of different rest interval durations, load intensities,

and exercise combinations may help optimise complex training strategies to develop athletic performance.

Kısaltmalar / Abbreviations

1RM One Repetition Maximum

RM Repetition Maximum

CMJ Countermovement Jump

SJ Squat Jump

CT Complex Training

LP Linear Periodization

S&C Strength and Conditioning

SD Standard Deviation

$\bar{X}$ Mean

SPSS-Statistical Package for the Social Sciences

p Significance value

t t value

N Number of participants

Min Minimum

Max Maximum

BMI Body Mass Index

kg Kilogram

Beyanlar / Declarations

Etik Onay ve Katılım Onayı / Ethics approval and consent to participate

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During the preparation and writing of this study, scientific, ethical and citation rules were followed in accordance with the 'Higher Education Institutions Scientific Research and Publication Ethics Guidelines'; no alterations were made to the collected data, and this study has not been submitted for evaluation to any other academic publication medium. The author is solely responsible for any violations that may arise in connection with this article. The study was conducted in accordance with the Declaration of Helsinki.

Veri Ve Materyal Erişilebilirliği / Availability of data and material

Bu çalışmanın bulgularını destekleyen veriler, makul talepler üzerine sorumlu yazardan temin edilebilir. Veri seti yalnızca akademik amaçlar için erişilebilir olacak ve verilerin herhangi bir kullanımı, orijinal çalışmayı referans gösterecek ve katılımcıların gizliliğini koruyacaktır.

The data that support the findings of this study are available from the corresponding author upon reasonable request. The dataset will be accessible only for academic purposes, and any use of the data will recognize the original study and maintain the confdentiality of the participants.

Çıkar Çatışması / Competing interests

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Yazar Katkıları / Authors' Contribution Statement

Çalışmanın Çalışmanın tasarımı ve planlanması: A.Ş., H.K.; Veri toplama, analizi ve yorumlanması: A.Ş., H.K.; Makalenin yazımı: A.Ş., H.K.; Veri düzenleme, yöntem belirleme, yazım – özgün taslak, yazım – gözden geçirme ve düzenleme: A.Ş., H.K. Tüm yazarlar (A.Ş., H.K., A.K., S.H., Y.K.) makalenin önemli noktalarını eleştirel olarak gözden geçirmiş ve makalenin son halini onaylamıştır.

Design and planning of the study: A.Ş., H.K.; Data collection, analysis and interpretation: A.Ş., H.K.; Manuscript preparation: A.Ş., H.K.; Data organization, methodology development, writing – original draft, writing – review and editing: A.Ş., H.K. All authors (A.Ş., H.K., A.K., S.H., Y.K.) critically reviewed the manuscript and approved the final version.

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