

# COMPARISON OF PERIODIZATION MODELS: A CRITICAL REVIEW WITH PRACTICAL APPLICATIONS

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## ABSTRACT

*Periodization has been used for years in the sports domain as a method of controlling and planning training to reach the highest performance and decrease injury risk. Several periodization models have been developed, such as traditional, block, and undulating. Those models are theoretical training structures designed to facilitate understanding, study, and organization of training. Based on studies, certain models have shown to be superior to others. For instance, block periodization seemed to be more efficient for advanced athletes than traditional and undulating models. While for novice athletes, the chosen model has not seemed to affect their development. Although periodization has been largely studied, the experiments have several limitations, such as considering only training variation as periodization, using short-term investigations, and disregarding the technical and tactical components. Therefore, this critical review aimed to describe and discuss the contents related to traditional, block, and undulating periodization models and to provide coaches with a practical application of each of those models to develop strength, power, and endurance for novice and advanced athletes.*

**Keywords:** Periodization; Sports Training; Strength; Power; Endurance; Athlete development

## INTRODUCTION

Periodization is a method to plan and organize the preparation for athletes, consisting of subdivisions of the training program into long, medium, and short periods with well-defined characteristics to maximize training adaptations and reach peak performance at the desired competition (Issurin, 2014). Programming is embedded in periodization and consequently represents different components. While periodization represents the macro management of the training, such as determining the length of the periods and fitness components to be developed, programming is related to the micro-management of the training variables, such as exercise selection, intensity, volume, and the number of exercises (Cunanan *et al.*, 2018). Although a clear distinction exists between pe-

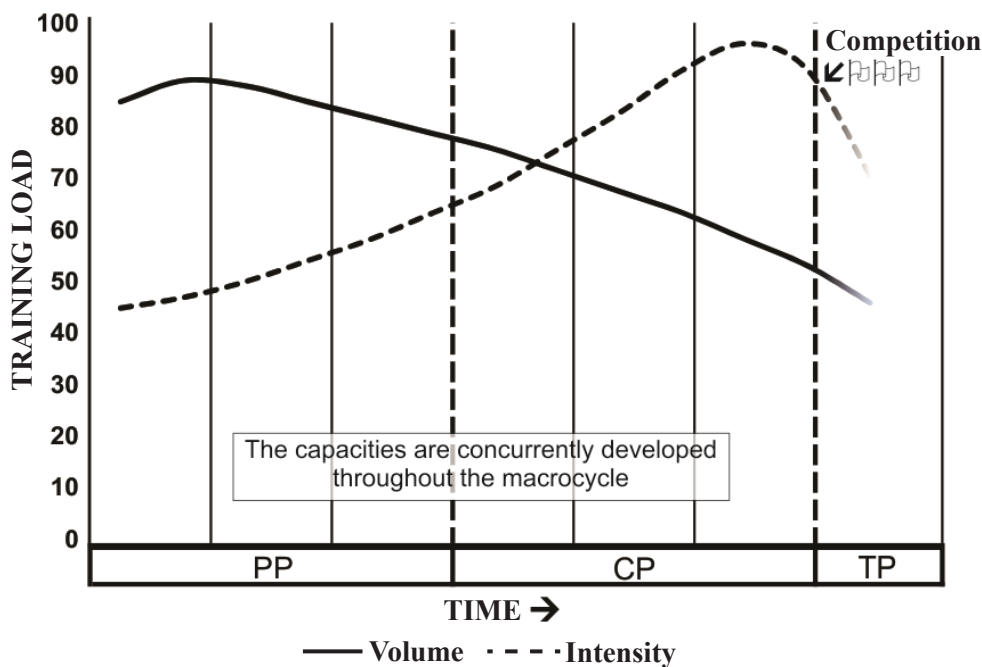
riodization and programming, previous studies investigating periodization have used the terms interchangeably, considering the simple manipulation of programming variables as periodization (Kiely, 2012, 2018). In addition, the predominance of experimental studies is in one-dimensional models, focusing only on the physical components and, consequently, disregarding other aspects of training, such as technique and tactics (Afonso *et al.*, 2019).

Despite the aforementioned limitations in the periodization literature, several periodization models have been developed. Those models are theoretical training structures designed to facilitate understanding, study, and organization of training. The models can promote more or less variation in the training components, such as intensity, volume, and density, in which those

could be manipulated within the session, week, or month (Issurin, 2014). Overall, periodization models have three main divisions, progressing from less specific loads to more specific ones, followed by a transitory period. The first phase is the preparatory period, with two main subdivisions (general and specific). While the second phase is the competitive period, containing two subdivisions (pre and competitive), and finally, finishing the periodization with a transitory period to allow recovery and, possibly, preparation for the following cycle. Some periodization models have been largely investigated, such as the classic or traditional (TP), block (BP), and undulating (UP) periodization.

The TP model was proposed by Russian professor Matveev in the 50s. This model's workload goes from high volume and low intensity to low volume and high intensity throughout the macrocycle (Figure 1). This relationship between volume and intensity also occurs within the mesocycles (Matveev & Zdornyj, 1981). Currently, this model is recommended for beginners or low-level athletes.

Therefore, its effectiveness is low for high-level athletes, who already have the general capacities well developed and highly adapted to specific sports needs (Issurin, 2016; Kiely, 2012). Alternatively, a sub-type of TP is the reverse periodization (RP), which adopts the same load dynamics but in a reverse manner. Initially, the intensity starts high and, throughout the season, decreases reversely compared to the linear periodization (Clemente-Suárez & Ramos-Campo, 2019). The classic model has been criticized for several reasons, (a) it allows only one or two performance peaks, which is not appropriate with the current competition system in most sports, (b) it does not improve each capacity to its full potential because multiple capacities are developed at the same time, (c) general exercises might negatively interact with each other due to lack of energy, fatigue, the complexity of technique, among others (Afonso *et al.*, 2016). Consequently, other models have been developed based on the deficiencies of the classic model, such as BP and UP models.

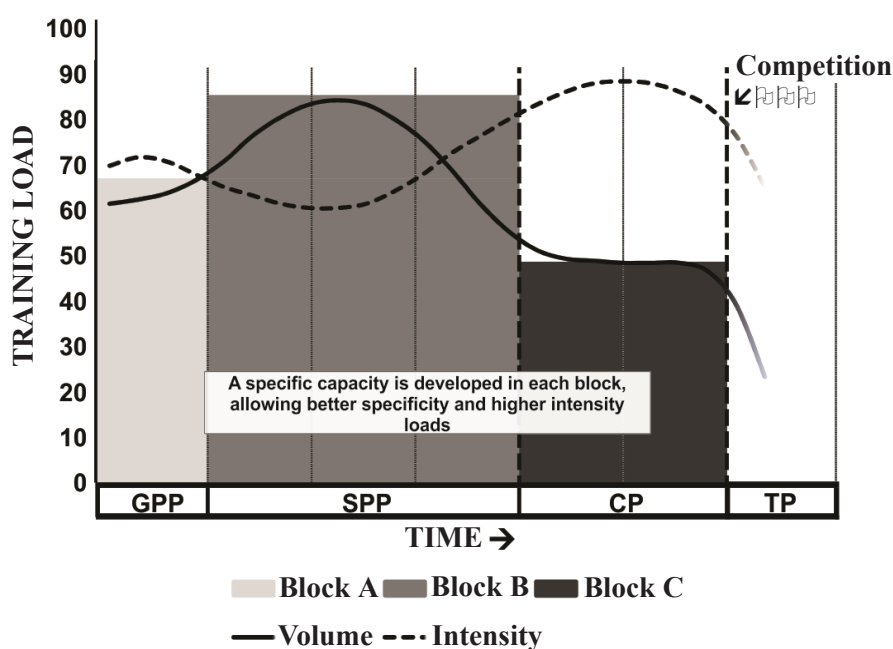


PP= Preparatory Period, CP= Competitive Period, TP=Transitory Period.

**Figure 1.** An example of Traditional Periodization Model. The volume starts relatively high and decreases throughout the season, whereas the intensity increases progressively

Training in blocks was a term widely used among high-performance coaches in the early 80's, then later becoming denominated Block Periodization (Issurin, 2010). In fact, BP is referred to as a training cycle of highly concentrated specialized workloads and was proposed and developed in the early 80s. There are divergences in the studies about who was the first proponent of the BP model. However, authors such as Verkhoshansky and Bondarchuk have been attributed as pioneers of this model. BP resembles the idea from the conjugate

sequence system, which involves a sequential coupling of training means to create conditions for a more substantial cumulative effect, resulting in increased performance (Siff, Verkhoshansky); in other words, linking capacities that progressively induce a higher effect in the final result (e.g., strength, strength-speed, strength endurance). The goal is to allow the athlete to transfer the acquired capacities in the previous phases into the skills related to the sport (Issurin, 2014). Figure 2 is used to illustrate the concept of a BP model.

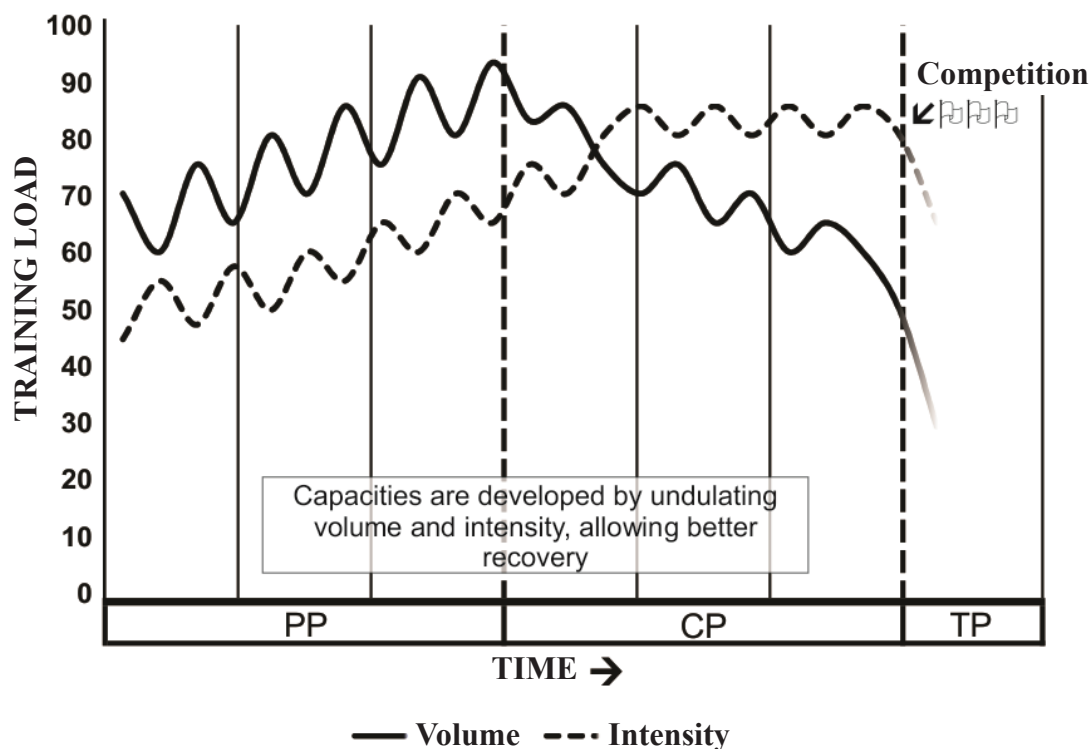


GPP= General Preparatory Period, SPP= Special Preparatory Period,  
CP= Competitive Period, TP= Transitory Period.

**Figure 2.** An example of Block Periodization Model. Each Block consists of a concentrated training load for a determined capacity. The intensity is emphasized throughout the program

Finally, the undulating or nonlinear model has been studied in the literature as a periodization model. Although undulation is a component in most periodization models, several authors tried to compare undulation-based programs with other types of periodization. The nonlinear model is characterized by frequent fluctuations in volume and intensity that could occur daily, weekly, or biweekly (Fleck, 2011), as can be seen in Figure 3. The constant

alterations provide the neuromuscular system with more recuperation periods (Buford *et al.*, 2007) and promote more variation in the aimed capacity (Zourdos, Jo, *et al.*, 2016). More recently, models that take into account other factors have been created, such as the tactical periodization proposed by Vitor Frade (1989) for soccer (Borges, 2015) and the skill acquisition periodization developed by Farrow and Robertson (2016).



PP= Preparatory Period, CP= Competitive Period, TP= Transitory Period.

**Figure 3.** *Undulating Model – Volume and Intensity have constant variation alternating between higher and lower training loads, thus allowing recovery and adaptation on a short-term basis*

Most studies have been dedicated to answering questions involving the traditional, undulating, and block models, generally in a short-term manner. However, the studies present only variation or manipulation of one or two variables (volume and/or intensity), which does not make a training program periodized and, therefore, not investigating the whole periodization process, such as the division of general, special, and competitive periods. Moreover, the duration of the programs could be considered inadequate when considering the recommendations from the authors' models (Issurin, 2010), interrupting the potential outcomes from a full periodization process. Due to those limitations, studies should be carefully analyzed because their applicability depends on particular aspects, such as the conditions in which the studies were performed (duration, population, studied

capacity, and training protocol). In addition, despite the relatively large body of research on this topic, there are few to no investigations providing clear application examples on how effectively those models apply in practical situations in a way that coaches might get overwhelmed and commonly lost with the amount of information about periodization, leading to difficulty in making sense and applying the results.

Therefore, the objectives of this study were to critically review in the literature the effects and benefits of the block, undulating, and traditional periodization models on capacities related to strength, power, and endurance between untrained and trained individuals. Secondly, analyze whether the models are superior and provide coaches with a practical application for periodization for novices and advanced athletes.

## METHODS

### *Inclusion Criteria*

In this review, we included studies that compared at least two of the periodization models of interest, Traditional, Block and Undulating. In addition, we also included the Reverse model, which is a variation from the Traditional model, and similarly for the Undulating model, we included variations, such as Weekly and Daily periodizations. The following motor capacities were included for this review: strength, power, and endurance, as well as specific-sport performance. Since periodization has been used in various contexts, studies for any sports in a broad sample of subjects (trained and untrained) were selected.

### *Data Sources*

Forty-five articles were selected from Pubmed and Google Scholar. The chosen period for the search process was set to be between 2000 and 2021. We used the following keywords: “Block,” “Traditional,” “Linear,” “Classic,” “Classical,” “Undulating,” “Undulating,” “Non-Linear,” “Reverse,” combined with the boolean operator “AND” to “Periodization” and “Comparison.”

### *Exclusion Criteria*

Since this review aimed to elucidate the differences between periodization models in sport-related performance outcomes, we excluded studies including variables related to particular care subjects (e.g., elderly, injured, and obese people). Also, studies that investigated periodization models to improve health-related aspects, such as pain tolerance, disease conditions, lipidic profiles, and wellness, were also excluded.

## RESULTS

Forty-five articles were included in this review. Those articles investigated the periodization models in relation to changes in strength, power, endurance, or sports performance.

Thirty papers investigated TP vs. UP, in which TP was better in six investigations (20%), whereas in nine articles (30%), UP was significantly better. Finally, no differences were found in 15 investigations (50%). Also, fifteen articles were found comparing BP to TP or UP. Twelve investigations (80%) yielded a better result using BP, one (6.7%) using UP, and two (13.3%) did not find any differences. The summary of the results can be found in Table 1.

**Table 1.** Summary of reviewed studies comparing Periodization Models

Author/Year	Weeks	Subjects (n)	Age (Mean or Range)	Level/Time of Practice	Sex	Periodization Model	Assessment (Main Outcome)	Statistical Superiority? If Yes, which one?
Abt <i>et al.</i> , 2016	12	85 (BP: 46 ; UP: 39)	BP (29.4 ± 5.5), NP (29 ± 6)	Naval Special Warfare Operators		BP and UP	Overall Strength (Maximal Dynamic, Isokinetic and Muscular Endurance), Power (Med Ball Throw, Standing Long Jump), Aerobic Performance, Flexibility, Body Composition, Postural Stability	Yes. BP
Alvar, Wener, Dodd, 2010	6	20 (TP:10 ; DUP:10)		Collegiate Athletes		TP and DUP	Dynamic Strength (Bench Press 1RM)	No
Apel, Lacey, Kell, 2011	12	42 (TP:14 ; WUP:14 ; C:14)	C(22±2.3), TP(23±2.8), WUP(22±1.9)	Recreationally trained subjects with 6 to 11 months of resistance training experience	M	TP and WUP	Dynamic Strength	Yes. TP (Back Squat, Lat Pulldown and Bench Press)
Arroyo-Toledo <i>et al.</i> , 2013	14	26 (TP:13 ; RP:13)	16.02±0.6	5 year experienced swimming Athletes	M/F	TP and RP	Sport-Specific Performance (Swimming Sprint 100m, Specific Swim Power, Maximum Drag Charge)	Yes. RP - However more HIIT volume for RP
Bartolomei <i>et al.</i> , 2015	10	17 (BP: 9 ; WUD:8)	BP (24.7 ± 4.2), WUD (23.2 ± 2.2)	Recreationally trained subjects (at least 2 years of resistance training experience [Kg/bw in Squat: BP ~1,37; WUP ~1,59])	F	BP and WUP	Isometric and Dynamic (1RM) Strength and Power and Counter-movement Jump	Yes. WUP
Bartolomei, Hoffman, Merni, 2014	15	24 (BP: 12; TP:12)	BP (24.2 ± 3.1), TP(26.2 ± 6)	Strength and Power Athletes - Track and Field, Rugby and American Football (at least 3 years of resistance training experience)	M	BP and TP	Isometric and Dynamic Strength (1RM) and Power and Jump Performance	Yes. BP
Bradbury <i>et al.</i> , 2018	14	30 (NP:10 ; TP:10 ; RP:10)	25.2 ± 7.4	More than 2 year experienced recreational runners	M/F	NP, TP and RP	Aerobic Performance, Energy Economy, Training Load and Monotony	Yes. TP and RP > NP and TP similar to RP
Buford <i>et al.</i> , 2007	9	28 (LP:9; DUP 10; WUP:9)	LP(22.67±3.61), DUP (23.9±5.11), WUP (20.11±1.54)	Recreationally Trained with previous strength training experience	M/F	TP, WUP and DUP	Dynamic Strength (Bench and Leg Press 1RM) and Body Composition	No

**Table 1.** Summary of reviewed studies comparing Periodization Models (Continued)

Author/Year	Weeks	Subjects (n)	Age (Mean or Range)	Level/Time of Practice	Sex	Periodization Model	Assessment (Main Outcome)	Statistical Superiority? If Yes, which one?
Clemente-Suarez et al. 2016	10	17 (TP:7 ; RP:10)	TP F(18.5±1.9), TP M (17.3±0.6), RP F(15.8±2.6), RP M(19.3±3.0)	National Level Swimming Athletes (6,5+4,9 years of training)	M/F	TP and RP	Swimming Velocity at Anaerobic and Aerobic Threshold, Energy Expenditure and Cost, Aerobic Capacity	Yes. TP
Clemente-Suarez et al. 2019	10	31 (RP:11 ; TP:13 ; CG:8)	RP(25.6±6.8), TP(28.2±9.6), CG(25.9±3.4)	Triathlon Amateur Athletes, at least 1 year of experience, national-level competitors	M/F (Only CG)	TP, RP and NP(CG)	Aerobic, Anaerobic (Running and Swimming Tests) and Neuromuscular (Horizontal Jump) Performance. Body Composition and Heart Rate Variability.	No. Overall without differences, only RP is better for Horizontal Jump
Colquhoun et al. 2016	9	25 (Cross-over Study)	18 - 46	Trained subjects with at least 6 months of resistance training (3.1 ± 1.6 years; 1.25x bw squat; 1x bw bench press; 1.5x bw deadlift.)	M	DUP and Flexible DUP	Dynamic Strength (Squat, Bench Press and Deadlift 1RM) and Body Composition	No
de Lima et al. 2012	12	28 (LP: 10; DUP: 10; CON:8)	LP (25.20 ± 4.35), DUP (27.40 ± 2.80), CON (23.40 ± 1.29)	Sedentary	F	TP and DUP	Body composition, Dynamic Strength (1RM and Muscular Endurance) and Aerobic Performance	Yes. TP for 1RM. DUP for Muscular Endurance
Eifler, 2016	6	200 (CL:50 ; IL:50 ; DL:50 ; DCL:50)	CL (36.06 ± 10.91), IL(29.90 ± 9.55), DL(31.74 ± 10.77), DCL(33.92 ± 11.58)	Recreationally trained with at least 12 months of experience in resistance training (CL[5.66 ± 3.36], IL[5.08±2.87], DL[5.00±2.96], DCL[5.12±2.80])	M/F	NP(CL), TP(IL), RP(DL) AND DUP(DCL)	Dynamic Strength	Yes. DUP
Franchini et al. 2015	8	13 (TP:6; UP:7)	18 - 35 (No means, SD)	Judo athletes with at least 6 months of resistance training experience (Brown and Black Belt)	M	TP and UP	Isometric (handgrip) and Dynamic (bench press, squat and row 1RM) Strength, Standing Long Jump (Broad Jump), Specific Dynamic and Isometric Muscle Endurance Handgrip Test, Specific Judo Fitness Test and Body Composition	No

**Table 1.** Summary of reviewed studies comparing Periodization Models (Continued)

Author/Year	Weeks	Subjects (n)	Age (Mean or Range)	Level/Time of Practice	Sex	Periodization Model	Assessment (Main Outcome)	Statistical Superiority? If Yes, which one?
García-Pallarés et al. 2010	12(BP) and 22(TP)	10 (Cross-over Study)	25.6 ± 2.2	World Level Kayak Athletes (11.2 ± 2.7 training experience)	M	BP and TP	Aerobic Performance and Sport-Specific Performance (Stroke Rate and Paddling Speed and Power)	Yes. BP: BP program achieved similar results with half the endurance training volume used in the TP model. Better Paddling Speed and Power for BP
Gavanda et al. 2018	12	28 (BP: 14; DUP: 14)	BP (17.14 ± 0.86), DUP (16.86 ± 0.66)	German's First Division Football Athletes (0.93±0.99 years of resistance training experience)	M	BP and DUP	Dynamic Strength (Squat and Bench Press 1RM), Power (Vertical Jump, MB Throw and Sprint), Jump Height	No
Hartmann et al. 2009	14	40 (SPP/TP:13; DUP:14; C: 13)	SPP(24.31±3.17), DUP(25.14±3.98), C(24.77±3.09)	Subjects with Strength Training Experience (SPP/TP: 1.15x bw, DUP 1.21x bw in bench press)	M	TP(SPP) and DUP	Isometric and Dynamic Strength and Power in Bench Press	No
Hoffman et al. 2009	15	51	NP (19.9±1.3), TP (19.5±1.1) UP(19.6±0.9)	NCAA Third Division Football Athletes	M	NP, TP and UP	Dynamic Strength (Bench Press and Squat 1RM), Vertical Jump (Height and Power) and Medball Throw	No
Kraemer et al. 2003	32	27 (DUP:9; NP:10; C:8)	DUP(19.2±1.1); NP(18.6±1.3); C(19.3±1.6)	College Tennis Players	F	NP and DUP	4Isometric and Dynamic Strength, Sprint and Agility Speed, Ball Velocity, Anaerobic Cycling Power, Aerobic Capacity, Body Composition and Resting Hormonal Concentrations	Yes. DUP
Manchado et al. 2018	17	11 (Cross-over Study)	18 - 27 (no means, SD)	Spain's First Division Handball Athletes (at least 4 years of resistance training experience)	F	BP and TP	Isometric and Dynamic Strength (1RM), Jump and Sprint Performance, Sport-Specific Performance (Throwing Velocity), Aerobic Performance.	Yes. BP
Marques et al. 2011	8	12 (LP:6; NLP:6)	17.1 ± 0.5	Volleyball Players	M	TP and UP	Dynamic Strength, Jump Performance and Medball Throw	Yes. UP just for 5kg med ball throw , no difference for jump performance, strength or 3kg med ball throw
Monteiro et al. 2009	12	27(NP:9; LP:9; NLP:9)	NP (26.6±2.2 years), LP (27.6±2.7), NLP (28.1±2.9)	Trained subjects with at least 2 years of resistance training	M	NP, TP and UP	Dynamic Strength (Bench Press and Leg Press 1RM) and Body Composition	Yes. UP

**Table 1.** Summary of reviewed studies comparing Periodization Models (Continued)

Author/Year	Weeks	Subjects (n)	Age (Mean or Range)	Level/Time of Practice	Sex	Periodization Model	Assessment (Main Outcome)	Statistical Superiority? If Yes, which one?
Moraes et al. 2013	12	38 (NP:14; DNLP:14; CG:10)	NP(15.5±0.9), DNLP(15.4±1.1), CG(15.6±0.9)	Untrained young individuals		NP and DUP	Dynamic Strength, Jump (Vertical and Broad) and Flexibility	Yes. DUP (Effect Size and Percentage Change)
Painter et al. 2018	10	19 (BP: 10; DUP: 9)	BP (20.1 ±1.3), DUP (19.2 ± 0.7)	NCAA First Division Track and Field Athletes	M/F	BP and DUP	Isometric Strength, Squat 1RM, Testosterone-Cortisol Ratio, Training Volume and Injury Incidence	Yes. BP: More efficient for BP (less training volume), less monotony, strain and minor injury incidence (40%BP vs 100%DUP)
Painter, McBride, 2012	10	26 (BP: 14 ; DUP: 12)	BP (19.9 ± 1.2), DUP (19.4 ± 0.8)	NCAA First Division Track and Field Athletes (~1.4xBW in squat)	M/F	BP and DUP	Isometric Strength, Squat 1RM, Training Volume	Yes. BP: More efficient for BP (Lesser training volume). Rate of force development and Squat 1RM
Pelzer et al. 2017	6	19 (Crossover Study)	22±1.8	Subjects with 27.9 ± 4.4 months of strength training experience on average	F	TP and DUP	Isometric, Isokinetic and Dynamic Strength (Leg Extensor) and Muscle Architecture and Activity	No
Pelzer et al. 2018	6	20 (TP:10 ; DUP:10)	24.2 ± 2.6 years	Team Sports Amateur Athletes with at least 5 years of resistance/strength training experience	M/F	TP and DUP	Loaded Countermovement Jump Performance (Height, Power and Take-off velocity)	No
Pliauga et al. 2018	8	10	not by groups 21.5 ± 1.7	Basketball Athletes (7.6 ± 1.1 training experience)	M	BP and TP	Countermovement Jump and 20 meters Sprint Time	Yes. BP for Countermovement Jump
Prestes et al. 2009a	12	20 (LP:10 ; RP:10)	LP (27.6±1.15), RP (26.2±0.92)	Trained subjects with at least 6 months of resistance training (LP[1,4±0,68]; RP [1,6±0,45])	F	TP(LP) and RP	Dynamic Strength (1RM and Muscular Endurance) and Body Composition	Yes. TP (Body Composition and 1RM [Higher Percentage Change])
Prestes et al. 2009b	12	40 (LP:20 ; DUP:20)	LP (22.3±7.5), DUP (21.2±9.2)	Trained subjects with at least 1 year of resistance training (LP[1,8±0.63]; DUP [1,6±0,57])	M	TP(LP) and DUP	Dynamic Strength (1RM)	No

**Table 1.** Summary of reviewed studies comparing Periodization Models (Continued)

Author/Year	Weeks	Subjects (n)	Age (Mean or Range)	Level/Time of Practice	Sex	Periodization Model	Assessment (Main Outcome)	Statistical Superiority? If Yes, which one?
Rhea et al. 2002	12	20 (TP:10; DUP:10)	21±2.3	Trained subjects with at least 2 years of resistance training	M	TP(LP) and DUP	Dynamic Strength (Bench Press and Leg Press IRM) and Body Composition	Yes. DUP (Only Leg Press) - Subjects already had experienced a TP
Rhea et al. 2003	15	60 (LP:20; DUP:20; RLP:20)	LP(21±2.4), DUP(21±1.9), RLP (22±1.6)	At least 1 year and maximum 5 years of strength training experience	M/F	TP, RP and DUP	Dynamic Strength (IRM and Muscular Endurance) and Tight Circumference	Yes. RP for Muscular Endurance; LP and DUP for Muscular Strength
Rønnestad et al., 2012	4	19 (BP:10; TP:9)	BP (30 ± 7), TP (32 ± 6)	Well Trained Cyclists (3-5 years of training)	M	BP and TP	Aerobic Performance	Yes. BP
Rønnestad et al., 2014	12	15 (BP:8; TP:7)	BP (32 ± 7), TP (34 ± 6)	Well Trained Cyclists (3-5 years of training)	M	BP and TP	Aerobic Performance	Yes. BP
Rønnestad et al. 2015	5	19 (BP:10; TP:9)	BP (23 ± 5), TP (22 ± 5)	Cross Country Ski Athletes	M/F	BP and TP	Aerobic Performance	Yes. BP
Rønnestad et al., 2018	6	16 (BP:8; TP:8)	BP (17.5 ± 0.5), TP (17.3 ± 0.5)	National Level U18 and U20 Ice Hockey Players	-	BP and TP	Muscle Torque, Squat Jump and Aerobic Performance	Yes. BP: Muscle Torque and Aerobic Capacity. Overall, BP exhibited a moderate to large effect size for all these variables compared to TP
Solli et al. 2019	1 Year Each (Comparison between models in two distinct periods)	1	Not Reported	Cross Country Ski Olympic Champion - Marit Bjørgen	F	BP and TP	Total Training Volume and Intensity Distribution	No. Although, BP had less total volume, with more HIT sessions
Souza, et al. 2014	6	31 (NP 9, TP, 9 DUP 8 CG 5)	CG(25.4 ±3.5); NP(25.0±7.7); TP(26.2±7.3); UP(23.8±4.3)	Recreationally active and engaged in team sports activities	M	NP, TP and DUP and CG	Dynamic Strength and Muscle Hypertrophy	No
Spinetti et al. 2013	12	29 (UP:10; LP: 13; CG:9)	UP (30.5 ± 1.7), LP (29.1 ± 2.9), CG (25.9 ± 3.5)	Brazilian Marine Corps sergeant's course students. Aerobic and Calisthenics experience. No experience in strength- or weight-training	M	LP and UP	Isometric and Dynamic Strength and Hypertrophy	Yes. UP (Higher Effect Size in comparison with LP)
Stone et al., 2000	12	21 (NP:5; TP: 9; UP: 7)	Not Reported	Moderately trained (1.3xBW in squat)	M	NP, TP and UP	Squat IRM, Body Composition	TP and UP > NP: TP similar to UP
Tammam, Hashem, 2015	13	11 (Cross-over Study)	24.18±2.23	Volleyball athletes, at least 1 year strength training experience	-	WUP and DUP	Dynamic Strength	Yes. WUP

**Table 1.** Summary of reviewed studies comparing Periodization Models (Continued)

Author/ Year	Weeks	Subjects (n)	Age (Mean or Range)	Level/Time of Practice	Sex	Periodization Model	Assessment (Main Outcome)	Statistical Superiority? If Yes, which one?
Tammam, Hashem, 2016	12	16 (LP:8; WUP:8)	LP(24.75±2.49), WUP(25.13±3.27)	Volleyball athletes, at least 1 year strength training experience	-	TP and WUP	Dynamic Strength, Jump Performance	Yes. WUP
Ullrich et al. 2015	14	10 (Cross- over Study)	24.4 ± 3.2	No strength training experience, recreationally active in social physical activity	F	TP and DUP	Isometric and Dynamic Strength and Mus- cle Architecture and Activity	No
Ullrich et al. 2016	4	11 (Cross- over)	14.8 ± 0.6	Elite and Regional level judo athletes with 5 to 8 years of sport experience and 2.7 ± 1.1 years of strength training experience	M/F	TP and UP	Isometric, Isokinetic and Dynamic Strength and Muscle Architec- ture and Activity	No
Ullrich et al. 2018	6	22 (11:TP; 11:DUP)	24.3 ± 2.6	Team Sports Amateur Athletes with 5.1 ± 2.2 years of resistance/ strength training experience	M/F	TP and DUP	Isometric Strength, Loaded Countermove- ment Jump Perform- ance and Muscle Ar- chitecture and Activity	No

NP: Non-periodized; UP: Undulatory Periodization; DUP: Daily Undulatory Periodization; WUP: Weekly Undulatory Periodization; BP: Block Periodization; NLP: Non-linear Periodization; DNLP: Daily Non-linear Periodization; TP: Traditional Periodization; LP: Linear Periodization; RP: Reverse Periodization; CG: Control Group; OPL: Optimum Power Load Scheme; CL: Constant Load; IL: Increasing Load; DL: Decreasing Load; DCL: Daily Changing Load; IRM: One Repetition Maximum; M: Men; W: Women; RTE: Resistance Training Experience.

### *Studies investigating the traditional periodization*

The TP might be more efficient than non-periodized programs in strength development for both trained and untrained people, as demonstrated by Williams et al. (2017), who conducted a meta-analysis comparing periodized and non-periodized programs on resistance training plans and found that the periodized programs were overall superior. Although both trained and untrained participants showed more improvements under periodized programs, untrained subjects had significantly more improvements than trained people. This can be explained due to the trainability level. As a person gets accustomed to training, more complex programs are needed to promote adaptations, such as by including more variation (Turner, 2011). Evans (2019), in his review, also found a superiority for periodized programs for strength in trained and untrained people, but the same statement was not confirmed for hypertrophy development. According to the author, most studies investigating hypertrophy were conducted with untrained people, who would need more time than the length of the experiment (about 12 weeks) to show improvements in hypertrophy (Schoenfeld, 2020). Strohacker et al. (2015) conducted a review of studies for inactive adults. In their review, they investigated resistance and endurance training. The studies varied across different activities and populations, and evidence showing the superiority of periodized models was not found. Therefore, both periodized and non-periodized programs could efficiently improve the physical capacities of inactive people.

Merely adopting a periodization model is not enough to potentialize the development of physical capacities. Consequently, the manipulation of the training variables seems to be more important than the periodization model

(Afonso et al., 2017). For example, specificity should be considered when designing the periodization. Each organism responds differently throughout the training, and the variation in the response from the training could vary by more than 30% among individuals (Ahtiainen et al., 2016). Thus, using only time as a parameter to adjust the loads (e.g., increasing the weight every month), either varying intensity or volume, might not be optimal (Loturco et al., 2016). Coaches should consider the differences among the athletes, making individual adjustments based on control measurements such as the rating of perceived exertion (RPE) (Helms et al., 2016; McLaren et al., 2017).

Furthermore, the TP model might be as efficient as the reverse model. Suarez et al. (2017) applied a traditional and reversed linear periodization to competitive swimmers; the goal was to increase endurance measurements. At the final of the study, both approaches led to similar results, but the reverse periodization was more time-efficient, attaining the same results with less training volume. For recreative triathlon athletes, the findings were similar, for both traditional and reverse models, except for lower limb power, with reverse periodization being more efficient on increasing horizontal jump (Clemente-Suárez & Ramos-Campo, 2019). Rhea et al. (2003) found that reverse periodization was more efficient in increasing local muscular endurance.

Conversely, for strength and body composition, linear periodization showed to be more efficient than reverse periodization, as showed by Prestes et al. (2009) investigating strength-trained individuals. Strong evidence favoring the utilization of either reverse or traditional periodization was not found. Therefore, the order in which intensity increases or decreases throughout the season (beginning or ending) may not be a determinant factor for effectiveness in periodization models. However, more stud-

ies are needed to comprehend that model comparison fully. Indeed, according to the model, the capacities should develop in different time frames (Mujika *et al.*, 2018), and, unfortunately, most of the experimental studies measure the target capacity only pre- and post-intervention, and consequently, it is difficult to understand how the capacities change over the periodization program. For example, we could expect the largest adaptations to occur after the highest intensities due to the general syndrome adaptation (Verkhoshansky & Siff, 2009).

When the TP was compared with the BP and UP models, no differences were found among individuals with less than two years of experience in strength, power, and endurance (Buford *et al.*, 2007; Hartmann *et al.*, 2009; Pelzer *et al.*, 2017; Prestes *et al.*, 2009). Likewise, studies with recreationally-trained individuals showed improvements in strength capacities, regardless of the periodization model (Apel *et al.*, 2011; Buford *et al.*, 2007; Evans, 2019; Souza *et al.*, 2014). Therefore, for recreational individuals, models with few variations might be sufficient to improve performance. As the athletes improve their level of conditioning, the trainability decreases, and thus more advanced strategies are needed, which should incorporate higher variability and a greater volume of training loads (Issurin, 2010). According to Turner (2011), in the periodization models for novice athletes, progression in the biomotor aspects must be emphasized. Since these subjects are naive to exercise, they require some time for basic adaptations at a neural level, joint-muscular, and cardiovascular. Consequently, their organisms are not ready for higher training intensities. If the intensities are high for an extended period, it might increase the injury risk and hinder or slow down the improvements in the capacities (Bompa & Buzzichelli, 2019).

Finally, using the term linear or traditional periodization brings the concept that the pro-

gram occurs linearly and progressively. However, the TP model (linear) has fluctuations between sessions, microcycles, and mesocycles. This model does not restrain the range of these variations, which seems to be crucial, preventing overtraining and allowing the organism to adapt (Brown *et al.*, 2001; Issurin, 2010). Therefore, the definitions of Matveev's model as "linear" are not in total agreement since the tenet of periodization is to integrate variation to remove linearity. One possible reason for that seems to be related to the Western countries having named this model linear and, therefore, not being a universal concept (Bartolomei *et al.*, 2014).

### ***Studies investigating the Block Periodization***

Block periodization has been shown to elicit greater performance outcomes for many endurance and strength/power sports. Mølmen *et al.* (2019) conducted a meta-analysis that revealed evidence for the beneficial effects of BP compared to TP regarding VO<sub>2</sub>max and W<sub>max</sub> in trained endurance athletes, emphasizing that BP is an alternative and adequate strategy with potentially greater training effects than TP for experienced athletes. Similarly, DeWeese *et al.* (2015a) presented a review showing that BP is a superior strategy to other periodization models for strength and power development.

Some studies pointed out reasons for more significant improvements in performance than other models. For endurance athletes, studies with BP have shown superiority against TP in sports like cycling (Rønnestad *et al.*, 2014), cross-country skiing (Rønnestad *et al.*, 2016; Solli *et al.*, 2019), ice hockey (Rønnestad *et al.*, 2018) and kayaking (García-Pallarés *et al.*, 2010). In general, studies demonstrated similar performance results with the BP model using less training volume but with higher intensity sessions. The utilization of BP models might be a better strategy to maintain resid-

ual training effects, as well as achieve better improvements in certain variables related to endurance performance. It could be explained due to better training efficiency and optimized distribution of high-intensity loads.

Additionally, for athletes, BP was also superior in strength and power assessments in sports such as track and field (Painter *et al.*, 2018; Painter *et al.*, 2012), ice hockey (Rønnestad *et al.*, 2018), basketball (Pliauga *et al.*, 2018), handball (Manchado *et al.*, 2018), and other strength/power-related sports (Bartolomei *et al.*, 2014). Likewise, BP models showed that less volume was required to increase strength and power performance, providing less monotony and strain, minor injury incidence, and better fatigue handling than daily undulating models (DUP) (Painter *et al.*, 2018, 2012). Additionally, studies have shown that strength (Bartolomei *et al.*, 2014; Rønnestad *et al.*, 2018), jump and sprint performance (Pliauga *et al.*, 2018), and throwing velocity (Manchado *et al.*, 2018) could be improved in BP compared to TP or UP models. However, in our analysis, one study found BP was not superior to weekly undulating periodization (WUP) when assessing the strength and hypertrophy components in recreationally trained women. It could be explained by the different distribution of high-volume training that may have elicited more significant improvements in lower body strength and hypertrophy in the WUP group compared with the BP group (Bartolomei *et al.*, 2015).

Furthermore, performance during matches or competitions is one variable that should be measured, as it is one of the main goals of periodization (Issurin, 2014). Still, most studies investigating periodization have not measured competition performance. One exception is the study by Mallo (2011), who found that using a BP focused on the physical components positively affected the match results for adult soccer players.

### *Studies investigating the Undulating Periodization*

Some studies concluded that undulating periodization models (UP) might be superior in developing strength and power for trained and untrained participants in relation to non-periodized and linear models (Alvar *et al.*, 2010; Franchini *et al.*, 2015; Gavanda *et al.*, 2019; Hoffman *et al.*, 2009; Marques *et al.*, 2011; Pelzer *et al.*, 2018; Ullrich *et al.*, 2016, 2018). However, the amount of athletes' experience could be a determinant factor, and the results could be considered ambiguous or controversial. For example, in individuals with more than two years of experience in strength and power training, UP did not show superiority to TP, BP, or non-periodized models when assessing these variables (Alvar *et al.*, 2010; Franchini *et al.*, 2015; Gavanda *et al.*, 2019; Hoffman *et al.*, 2009; Marques *et al.*, 2011; Pelzer *et al.*, 2018, 2018; Ullrich *et al.*, 2016, 2018). Conversely, for trained individuals with less than two years of resistance training experience, UP seems to be more effective in producing increased outcomes (Bartolomei *et al.*, 2015; Monteiro *et al.*, 2009; Rhea *et al.*, 2003). Similarly, for individuals with at least one year or less of resistance training experience, the results are superior to TP and non-periodized (Hassan Tammam and Mohamed Hashem, 2016; Kraemer *et al.*, 2003; Tammam and Hashem, 2015). However, the athlete's level must be considered since most of the studies here have demonstrated a lack of systematization for individuals considered "trained," ranging from 6 months to more than five years of experience in strength/resistance training.

For instance, Caldas *et al.* (2016) conducted a meta-analysis comparing undulating and traditional models in muscular strength and hypertrophy, and according to the review, regardless of the level (trained or untrained), UP is superior to traditional periodization for maximum strength,

but not for power, muscular endurance, isometric strength, and muscle hypertrophy. Although the studies did not provide an in-depth explanation about the reasoning for the superiority of UP for maximum strength, it is hypothesized that the morphological changes in the muscle, such as hypertrophy, are not the determinant factor because UP did not promote more hypertrophy. Thus, neural adaptations could explain the advantages of UP for maximum strength, such as promoting higher excitability and increasing central motor drive (Colquhoun *et al.*, 2018; Grgic *et al.*, 2018). However, that hypothesis still has not been tested. It poses some problems, such as why those mechanisms (excitability and motor drive) could be directly related only to maximum strength when actually those neural mechanisms are also associated with improvements in other muscle components such as power (Colquhoun *et al.*, 2018; Grgic *et al.*, 2018).

It is well known that the volume of training affects maximum strength (Colquhoun *et al.*, 2018; Grgic *et al.*, 2018; Zourdos Jo, *et al.*, 2016), and then, when that variable is not controlled, the results should not have been attributed only to the periodization model. The length of the studies is also another essential factor to be considered. For instance, experiments comparing the periodization models in a short-term period could yield relevant results only for the short term. This is different from the actual conditions, where the coach plans the training considering the whole season (Rhea *et al.*, 2003). Finally, the specificity of the stimuli could also affect the results. Although Monteiro *et al.* (2009) and Rhea *et al.* (2003) concluded that the UP model was superior to the TP, in both experimental designs, there was a prevalence of stimuli closer to 1RM in undulating/nonlinear groups, leading to adaptations more related maximum strength components. The prolonged exposure to related maximum-strength stimuli may have led the undulating group to

a better strength adaptation than the traditional group. When special training loads (in this case, maximum strength) are frequently stimulated over time, it is possible to retain and prevent the loss of the acquired level of the specific capacity (Zatsiorsky *et al.*, 2020).

### ***Applying Periodization***

In the paragraphs below, we guide coaches and practitioners on how to apply the discussed models and their concepts to develop strength, power, and endurance for novices (6 months to 2 years of training) and experienced (more than two years of training) athletes. It is essential to highlight those general suggestions and variations that may be applied to maximize the periodization of physical capacities in different sports effectively. For instance, some sports are more dependent on strength than endurance, and consequently, more time should be dedicated to developing strength. Also, strength-power athletes need better organization of the training loads for further performance improvement, dividing exercises between force-related or power-related, whereas for individuals with low experience in strength training, a more basic organization already promotes benefits for strength and power (DeWeese *et al.*, 2015b).

Another concern is about how to monitor each exercise performance. A common way to monitor performance is using validated scales, and despite that, it is possible to use the same scale for all capacities; some scales are more reliable and indicated to measure physical capacities or tasks in a given context (Helms *et al.*, 2016). Therefore, in our recommendation, we adopted the use of repetition in reserve (RIR) for strength monitoring (Zourdos *et al.*, 2016), percentage of velocity loss (VL) for power (González-Badillo *et al.*, 2017; Pérez-Castilla *et al.*, 2018; Sánchez-Medina and González-Badillo, 2011), and RPE for endurance (Foster *et al.*, 2021), since evidence has shown significant

positive effects of monitoring the cited capacities by those scales. Since measuring velocity loss percentage is more objective than the others, it also requires some type of device, which might be expensive to acquire. However, there are low-cost means to monitor such data via reliable smartphone apps, such as *MyLift* (Cetin and Isik, 2021). If equipment is unavailable, a validated perceived velocity loss scale could be used to monitor velocity reliably (Bautista *et al.*, 2016).

For novice athletes, as we reviewed here, it is better to use TP to develop strength, power, and endurance properly. Regarding strength and power, the training should be designed, firstly, to establish optimal neuropathways to execute the exercises. This process can be optimized by providing those athletes with enough repetitions per exercise at early phases. It is an important aspect because strength will increase due to neuromuscular factors associated with coordination mechanisms. After early neural and morphological adaptations, which in resistance exercises could be from two to three months, intensity and volume manipulations should be increased to develop further changes in muscular strength, such as decreasing the number of repetitions per set and increasing weight (Fleck & Kraemer, 2014). Training frequency should initiate with two to three interspersed sessions per week, where the volume could progress from one to three sets, and the repetition range could vary based on the relative load desired to be developed in training. Although intensity can vary from 30% to 80% of 1RM for increases in strength performance, the higher range loads (60%-80%) seem to be more beneficial (Schoenfeld *et al.*, 2017). Also, rest intervals should vary from one to three minutes, depending on the training load and goal (Fleck & Kraemer, 2014).

In terms of endurance, capacities could be classified according to physiological markers,

such as lactate or heart rate. Usually, athletes adopt three zones of training, zone 1, which is below 65% of  $VO_2$ max (lactate concentrations  $<2$ mM, high-volume, low-intensity exercise); zone 2, which is near to 90% of  $VO_2$ max (lactate threshold at about  $\sim 4$ mM); and zone 3, when the  $VO_2$ max is higher than 90% (high-intensity interval exercises, anaerobic exercises) (Seiler, 2010). For novice athletes, the development of aerobic capacity should be prioritized with three to six sessions a week, and the training load must be increased moderately so that the power characteristics of the exercise also increase towards the end of the periodization. There is no consensus about minimum volume thresholds to develop endurance for low-level trained individuals, but based on results from previous studies (Muñoz *et al.*, 2014; Neal *et al.*, 2013), it is possible to determine potential optimal training volumes for each week. As the volume and/or intensity increases, the frequency of high-intensity sessions (zone 3) must be taken carefully and interspersed with lower-intensity sessions (zone 1) in a way to permit a better recovery from stressful training loads because high loads of aerobic training induces increased muscle damage, neural and peripheral fatigue (Finsterer, 2012). It is worth noting that, for endurance athletes, strength and power training are key factors for injury prevention and performance enhancement. Specialized sessions should find a balance with aerobic development, where strength and power training should not decrease muscle function for subsequent training sessions (Doma *et al.*, 2019).

Table 2 presents a suggestion for a TP model for the development of strength-power and endurance for novice athletes. Some capacities might also be practiced in technical/tactical contexts, especially for the endurance capacity, in which the coach can control the physiological intensity (e.g., heart rate) during technical or tactical training in a given sport to

ensure the improvement of aerobic capacity. It is important to highlight that the volume set for these individuals is substantially less than for trained athletes due to the fact that their organisms are not prepared to support higher training loads like trained athletes. Also, the training frequency may be equally lesser. Overall, for strength and power, a relatively higher number of repetitions per set are performed, movement velocity is not a primary concern in the exercises, and intensity should increase progressively and not necessarily reach failure over sets because the goal is to learn the movements by improving coordination.

In addition, intensity dictates the number of repetitions performed. For instance, more repetitions are allowed for exercises with low load and with more reactive characteristics, e.g., low plyometrics or velocity coordination exercises. In contrast, higher-intensity exercises should be executed using fewer repetitions,

such as squat jump and weightlifting exercises. Once the exercise technique is mastered, higher intentional movement velocity is required to develop power, and higher intensities should be used to increase strength. The general preparatory period (GPP) is relatively more extended for these individuals to learn movements and techniques and generate basic physiological adaptations. In the special preparatory period (SPP), volume decreases substantially, and intensity levels are increased by larger relative intensities or exercise complexity in a manner that more effort is required. The competitive period (CP) has the least volume and moderate to high intensity related to the specific task performance, where the emphasis on competitive tasks is demanded. Decreasing volume allows the athletes to improve technique quality at the intensity required in competitions, and tapering is necessary to achieve the highest performance (See Zatsiorsky et al., 2020).

**Table 2.** Suggestion of a traditional periodization for novice athletes considering the development of strength-power and endurance capacities

Period	Variable	Strength and Power			Endurance				
GPP	Intensity	Low to Moderate	3-4 RIR / <20% VL	<75% 1RM	Low	<5 RPE	Zone 1	Zone 2	Zone 3
	Volume	Moderate to High	26-30 sets/week	8 to 15+ repetitions/ set	Moderate to High	6-8 hr/ week	85%	10%	5%
	Objective	To improve coordination and quality of movement execution.			To develop basic cardiovascular adaptations from aerobic exercises.				
SPP	Intensity	Moderate	2-4 RIR / <15% VL	<85% 1RM	Moderate	5-7 RPE	Zone 1	Zone 2	Zone 3
	Volume	Moderate	20-25 sets/week	6 to 12 repetitions/ set	Moderate	5-7 hr/ week	80%	12,50%	7,50%
	Objective	To gradually increase the movement complexity, requiring higher effort and faster movements with a relatively higher load.			To promote specific endurance by using exercises that are similar to the target sport.				

<b>CP</b>	<b>Intensity</b>	Moderate to High	1-3 RIR / <10% VL	50-90% 1RM	Moderate to High	6-9 RPE	Zone 1	Zone 2	Zone 3
	<b>Volume</b>	Low	12-16 sets/week	2 to 8 repetitions/ set	Low to Moderate	4-6 hr/ week	75%	15%	10%
	<b>Objective</b>	To increase the force and power output with higher movement complexity and moderate to heavy loads.			To develop task-specific endurance using competitive loads.				

GPP, general preparatory period; SPP, special preparatory period; CP, competitive period; RIR, repetitions in reserve; RM, repetition maximum; RPE, rating of perceived exertion; MHR, maximum heart rate.; hr, Hours. The volume of sets is described as sets by major muscle groups.

It is well-documented that advanced athletes require more complex training structures with higher volumes and specific exercises to develop physical capacities (Rasmussen *et al.*, 2013; Schoenfeld, 2020). As we reviewed here, BP seems to be more efficient in enhancing physical capacities in advanced athletes compared to TP and UP. Although the trained capacity might dictate how the training should be structured, BP allows the application of common principles, such as emphasizing one capacity at a time. Thus, for advanced athletes, the training process should be planned so that a target capacity is prioritized according to blocks of preparation (mesocycle, 4 to 10 weeks). While a target capacity is being developed, the other capacities will be stimulated only to decrease their losses within that mesocycle. Also, coaches should be aware that some capacities are concurrent. For example, suppose the athlete practices first exercises related to hypertrophy, then after, exercises for maximum strength. In that case, the second group of exercises will not be well developed because the muscle fibers will be fatigued from the previous exercises. The training variables, such as repetitions, load, and density, should vary according to the capacity throughout the mesocycle, and the microcycles could have different characteristics.

Table 3 shows a BP suggestion for strength/power athletes, where the target capacity is either power or strength. At the same time, endurance is complementary. Consequently, more

sessions should be dedicated to strength-power, with four to six sessions per week (or even more if high-level athlete training twice a day) than endurance, with only two sessions per week. Endurance training should be performed with a minimum volume threshold not to affect the development of the target capacity. It is important to note that some sports could be more strength or power-oriented even if the competition environment is defined by open skills, such as rugby, football, or hockey. However, endurance development is also essential for these sports, in which specific field/court training might contribute to aerobic capacity.

These endurance recommendations presented do not necessarily need further improvement with aerobic-specific exercises (e.g., running). The recommended volume for each phase is related to major exercises for the sport; for example, for jumping or sprinting athletes, more time is dedicated to lowering limb training, whereas, most of the time, a lower volume is employed for upper limb training. However, the number of sets largely varies in the literature, ranging from 8 sets/week (Peterson *et al.*, 2004) to more than 40 sets/week (González-Badillo *et al.*, 2005); likewise, the level of effort, proximity to muscular failure as well as exercise characteristics (e.g., ballistic, dynamic, isometric) will influence the total number of sets to be performed. Although isometric exercises are not presented in the recommendations, they can be included in the development of strength variables (See Lum

& Barbosa, 2019; Oranchuk et al., 2019). In the general preparatory phase (GPP), the goal is to promote the basic strength-related morphological adaptations or the stretch-shortening cycle by neuromuscular adaptations.

Thus, strength, hypertrophy, and strength endurance are emphasized with more repetitions per set and higher proximity to muscular failure. Whereas for power development, exercises with less mechanical impact are utilized, and movement velocity is increased progressively, allowing higher movement quality for the subsequent phase. Endurance training should not deteriorate the development of the main capacities over time. Therefore, volume is slightly higher to promote better general conditioning and cardiovascular adaptations only in the first phase, up to twice a week. In the special preparatory period (SPP), the volume and intensity are increased for strength to promote more stress and, consequently, more adaptation from each session.

In contrast, maximal strength development is concerned with increasing force production, then work should be done with more repetitions in reserve to allow better performance with higher loads (Davies et al., 2016; Grgic et al., 2021; Rodríguez-Rosell et al., 2020). Power should maintain similar volumes but with increased intensity where repetitions drop,

and less velocity loss is permitted. Endurance is reduced not to hinder the development of strength and power. Finally, in the competitive period, for strength, the volume is reduced to promote recuperation, and the intensities could be increased to reach optimal performance. It is possible to use near-maximal intensities (e.g., eccentric training) to induce higher activation. Still, the practitioner must have caution and apply this at a lower frequency because fatigue and stress will enormously decrease performance levels (Hody et al., 2019).

Although total volume is reduced, volume for power is increased to yield a more specific adaptation; as it has been seen in this review, the performance is achieved with a higher specific volume for the desired capacity. Since quality should be emphasized, the loss in velocity (quality/fatigue) should be maintained as low as possible. Intensity should be adequate to the force-velocity profile specificity of the competition. Thus, force-related athletes must increase the intensity to achieve strength-speed outcomes, whereas velocity-related ones must decrease to achieve higher velocity outcomes. For sports where force-velocity profile could vary, both profiles should be used. The exercises in this phase should be specific to the target task, resembling the physiological and mechanical characteristics of the actual sport.

**Table 3.** Suggestion of a block periodization for advanced strength/power athletes considering the development of strength-power and endurance capacities

Period	Variable	Strength	Power	Endurance		
GPP	Intensity	Moderate	Moderate	Moderate	Zone 1,2	Zone 3
		0-2 RIR	<20% VL	5-7 RPE		
		55%-75% 1RM	55%-70% 1RM			
	Volume	Moderate to High	Moderate	Moderate to High	80%	20%
		18-22 sets/week	14-18 sets/week	3-4 hr/week		
		6-15 repetitions/set	6-12 repetitions/set			
Objective	To promote basic physiologic adaptations regarding hypertrophy and strength endurance. Technical development for power exercises.		To develop aerobic power and capacity.			

SPP	Intensity	Moderate to High	Moderate to High	Low to Moderate	Zone 1,2	Zone 3
		0-3 RIR	<10% VL	4-6 RPE		
		70%-85% 1RM	70%-85% 1RM			
	Volume	High	Moderate	Low to Moderate	70%	30%
		22+ sets/week	14-18 sets/week	1-2 hr/week		
		4-8 repetitions/ set	3-6 repetitions/set			
Objective	To increase the utilization of special exercises similar to those found in target sports with more demand in power output.		Aerobic power maintenance and sprint development. Some light aerobic sessions for active recovery.			
CP	Intensity	High	Low / High	Low	Zone 1,2	Zone 3
		0-4 RIR	<5% VL	<5 RPE		
		85-100% 1RM	<45%1RM / 85-100% 1RM			
	Volume	Low to Moderate	Moderate to High	Low	60%	40%
		10-14 sets/week	18-22 sets/week	<1 hr/week		
		1-4 repetitions/ set	6-12 / 1-3 repetitions/set			
Objective	To attain the highest specific performance by utilizing competition loads and allowing enough recovery.		To allow organism's recovery by using light intensity aerobic training. High-intensity short duration sprints, to increase acceleration.			

GPP, general preparatory period; SPP, special preparatory period; CP, competitive period; RIR, repetitions in reserve; RM, repetition maximum; RPE, rating of perceived exertion; MHR, maximum heart rate; hr, Hours. The volume of sets is described as total sets per week (not divided by muscle group).

Regarding advanced endurance athletes, training could be optimized by utilizing block periodization. For instance, athletes can emphasize one zone/capacity by mesocycle, potentializing the development by designing exercises and recuperation that target that zone. As in other physical components, the other zones or capacities should be stimulated to decrease their losses and maintain a better sports form. Consequently, strength-power training should comprise a minimum of two sessions per week. In comparison, endurance training must have five to eight sessions per week (if training twice a day) to meet the recommended volume (Seiler & Tønnessen, 2009). Table 4 provides a BP suggestion for endurance athletes, considering the development of endurance, power, and strength. The target capacity is endurance, while the other capacities are supplementary and, consequently, with less training load.

The general preparatory phase (GPP) aims to promote basic physiological adaptations to prepare the organism for the following more in-

tense phases. Since the intensity of endurance in the first period is lower, this is an appropriate moment to develop strength and power without deteriorating endurance. During the Special Preparatory Period (SPP), the training's goal is to increase endurance loads, stressing the capacity more and promoting more adaptations. The interval training (zone 3) is also increased so that the athlete will sprint at a high intensity to develop the muscle power required for endurance training to increase the lactate threshold (Dolci *et al.*, 2020). The intensity for strength-power is increased to potentialize an appropriate development of those capacities; repetitions in reserve are also increased not to generate fatigue, whereas the training volume is reduced to allow optimal development of the endurance capacity. The competitive period (CP) is when specific loads should be optimized to situations similar to the actual sport. The session duration is approximated to meet, in general, the different sports and events. There are variations, and the number of ses-

sions per week can be different.

Regarding strength-power training, intensity should not decrease to maintain the previ-

ously developed muscular capacity. However, the volume should be low. Also, an additional tapering microcycle is recommended.

**Table 4.** Suggestion of a block periodization for advanced endurance athletes considering the development of endurance and strength-power and capacities

Period	Variable	Endurance					Strength and Power		
GPP	Intensity	Low to Moderate	4-6 RPE	Zone 1	Zone 2	Zone 3	Moderate		
							1-3 RIR / <20% VL		
							50%-70% 1RM		
	Volume	Moderate to High	12-16 hr/ week	80%	5%	15%	Moderate to High	26-30 sets/ week	6-14 repetitions/ set
	Objective	To optimize aerobic capacity by improving the basic cardiovascular/respiratory.					To optimize the muscle contraction mechanisms by using resistance training.		
SPP	Intensity	Moderate to High	6-9 RPE	Zone 1	Zone 2	Zone 3	Moderate to High		
							2-4 RIR/ <15% VL		
							60%-85% 1RM		
	Volume	High	14-18 hr/ week	75%	10%	15%	Moderate	20-25 sets/ week	4-12 repetitions/ set
	Objective	To increase VO <sub>2</sub> max and lactate threshold.					To increase strength through higher relative intensities and focus more on power and velocity development.		
CP	Intensity	High	8-10 RPE	Zone 1	Zone 2	Zone 3	Low/High		
							3-5 RIR/ <10% VL		
							30%-85% 1RM		
	Volume	Moderate	10-14 hr/ week	75%	5%	20%	Low	12-16 sets/ week	2-10 repetitions/ set
	Objective	To increase sports performance by improving speed endurance and utilizing sessions with similar intensities of the target sport's capacity/characteristics.					To maintain previously developed muscular capacity.		

GPP, general preparatory period; SPP, special preparatory period; CP, competitive period; RIR, repetitions in reserve; RM, repetition maximum; RPE, rating of perceived exertion; MHR, maximum heart rate; hr, Hours. The volume of sets is described as total sets per week (not divided by muscle group).

**CONCLUDING REMARKS**

Studies sought to demonstrate the superiority of certain models over others. Although the results often differ, it is possible to draw a couple of conclusions based on most of the results. For novice athletes with little or no experience, the type of model does not seem to influence

their physical capacities' development, and the characteristics of the exercise would be one of the main factors for the improvement in performance (Ullrich *et al.*, 2016). Conversely, for trained athletes, the BP model may be more efficient. Although BP produced similar results in the studies, it attained the same results with

less applied volume. Undulating programs seemed to be effective for novices or recreationally-trained individuals for strength and power development. Consequently, for more advanced athletes, only varying the training seems insufficient for optimal development. More advanced training structures should be applied, such as monitoring the athlete's daily state (McGuigan, 2017), including more specific exercises equivalent to competition (Verkhohansky, 1998) and tasks with increased complexity (La Scala Teixeira *et al.*, 2019).

Several factors could bias the interpretation of the results. Often, studies that the physical capacities were trained in the final phase of the program or more stimulated throughout the program also showed the most significant improvement between groups. It does not necessarily mean that one type of model is superior to the other one, but that the specificity of the training dictates the improvements instead. The absence and differences in the equalization of training loads can mislead the results among studies, making it difficult to compare the different outcomes. Additionally, the studies did not present information on how the training loads were controlled and adjusted. For example, strength is tested pre and post-intervention, but it is unknown whether that result represented the best performance throughout the whole cycle. Perhaps, that capacity could have had its peak performance earlier or later. Thus, when models are tested, evaluations that monitor the performance evolution/involution according to the training phases are needed.

Periodization is strongly inserted in the competitive sports environment. However, there is no ideal model that fits all sports. In the case of sports where technical-tactical components have significant influence, just periodizing training, emphasizing the physical capacities, is not ideal. More recently, specific periodization models that consider these com-

ponents have been developed. For some examples, the tactical periodization was by Vitor Frade (1989) for team sports, with an emphasis on soccer (Borges, 2015), and periodization for technical development by Otte *et al.* (2019). In addition, other strategies have been concerned about accurately adjusting the loads throughout the program, like auto-regulatory training (Mann *et al.*, 2010) and velocity-based training (Pareja-Blanco *et al.*, 2017). Those approaches have shown better improvements in strength and power in a more efficient way than previous models. For instance, Riscart-López *et al.* (2021) found that regardless of the training program, when adjusting relative intensity based on day-to-day variations, there is no statistical difference for linear, reverse, undulating or constant training programs. Consequently, the coach must daily monitor the aspects related to training and use the sports science to assess the athletes' potential and current state, also to verify how the athlete is responding to the training program, and consequently, to measure the progress that will be translated into sports performance (Foster *et al.*, 2017).

Finally, to effectively apply a periodization model, coaches and practitioners should take into account the athlete's experience, total time available for training, and temporal organization of the loads; also, monitoring and adjusting the variables throughout the program because each organism has a different response to exercise. Thus, the type of utilized periodization is just one of the many variables that dictate the training.

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