Articles	**Question**: Is there one best periodization approach while resistance training for improving strength in athletes?				**Abbreviations:** 1RM = 1-repetition max NP = non-periodized LP = linear periodization UP = undulating periodization DUP = daily undulating periodization WUP = weekly undulating periodization BP = block periodization EF = effect size RT = resistance training SPP = strength-power periodization CMJ = counter movement jump RFD = rate of force development	
Author/Year	**Purpose**	**Design/Subjects**	**Intervention and Procedures**	**Measurements**	**Outcomes/Results**	**Conclusions/Limitations**
Moesgaard et al, 2022[1]	Determine the effects of periodization in relation to muscle strength and hypertrophy within the current literature when volume is equated and how intensity and volume can properly be dosed to produce the most changes in strength and hypertrophy.	Systematic Review and Meta-analysis 35 included studies 13 studies included non-resistance training groups that were not included in the study 1022 participants - 129 adolescents 791 adults, and 102 older adults -	-NP versus periodized resistance training -LP versus UP Comparisons were included for the following but lacked enough studies to determine appropriate conclusions for strength and hypertrophy changes: -BP versus UP -DUP to WUP	Maximal strength was assessed by a 1RM (squat, bench, deadlift, leg press, leg ext, biceps curl, row, shoulder press, leg curl, triceps ext) dependent on study Muscle hypertrophy was assessed by various means - BIA, skinfold measurements, circumference measurements, DEXA, and BOD POD dependent on study	NP versus periodized resistance training effects on: -Maximal strength: increase of 1.77% +/- 1.06% per week for NP and 2.13% +/- 1.32% per week for periodization. Within group ES 0.98+/-0.70 for NP and 1.30+/- 1.11 for periodization -Hypertrophy: 0.27%+/-0.31% per week for NP and 0.34%+/-0.34% per week for	When comparing various program types with a volume-equated resistance training there are greater improvements in overall strength between NP and periodization programs. There were also greater improvements in strength noted in UP versus LP. There were no significant differences noted in muscle hypertrophy between any of the models utilized. The increase in muscular strength was not limited due to training status; either trained and untrained reinforcing that

		were included within the percent change and effect size calculations 19 studies included only male participants, 7 studies included only female participants, and 9 studies included both	-DUP to RLP -LP to RLP -LP to BP Duration of studies ranged from 6 to 36 weeks with a mean of 13.7+/-6.0 weeks Frequency ranged from 2 to 4 days/week with a mean of 2.9+/-0.7 days/week Volume ranged from 1 to 7 sets of 1-30 repetitions Intensity ranged from 30-105% 1RM		periodization. ES 0.22+/-0.30 for NP and 0.34+/-0.28 for periodization LP versus UP effects on: -Maximal strength: 1.71%+/-1.29% per week for LP and 2.20%+/-1.43% per week for UP. ES within-group mean was 0.81+/-0.35 for LP and 1.26+/-1.12 for UP. -Hypertrophy: 0.37%+/-0.29% per week for LP and 0.46%+/-0.39% per week for UP. Within-group mean EF was 0.34+/-0.26 for LP and 0.38+/-0.25 for UP.	a periodization model is more beneficial than NP resistance training. The improvements in UP compared to LP was only noted in trained individuals and this should be a consideration when developing programs. There may be need for further investigation into neuromuscular adaptations due to periodization models due to only resulting increases in strength and not in hypertrophy.
Harries et al, 2015[2]	To compare linear and undulating periodization resistance training program and their effect on muscular strength.	Systematic Review and Meta-analysis Search was performed in July 2014, no year	Participants were either part of a LP or UP resistance training program Mean duration was 12.6 +/- 4.1 weeks	Maximal strength including 1RM bench press for UE strength and 1RM squat for LE strength dependent on the study	16 studies compared muscular strength for UE and determined there was no significant difference between LP and UP; $p<0.37$.	There were significant improvements in muscular strength as determined by a 1RM following completion of a periodization program. However there were no significant differences noted between LP and UP.

		restriction on search 17 studies were included in the meta-analysis There were 510 participants with a average age of 24 years (ranging 19-39 yo) -untrained (less than 1 year of RT) and trained individuals (greater than 1 year of RT) were included	Frequency of training was 3.2 +/- 0.7 sessions per week RT included single joint and multi joint movements, free weight and machine weight exercises		7 studies compared muscular strength for LE and determined no significant difference between LP and UP; p=0.07	The program interventions were short in duration; around 12 weeks in length and the patient population was mostly younger males. There was no specific criteria looking at athletic populations.
Hartmann et al, 2015[4]	Compare various short-term periodization training models and their effects on strength and strength-power in athletes during off-season, in-season and preseason training. Determine appropriate programming	Systematic Review Search criteria included studies up to February 2015 Inclusion criteria included athletes of various sports (tennis, track and field, throwers, football and rugby) who	Compare mesocycle length for UP (daily and weekly), BP, and NP in relation to strength and strength-power gains Compare the effects of periodization short term models on	Comparisons of training cycles including type of training, frequency, training zones and rest of various periodization models Power: assessed through various movements including mid-thigh pull, leg press, jump squats, CMJ, squat jump, loaded vertical	The utilization of DUP for untrained individuals is typically associated with strength endurance based sessions (12-15 rep range) in a linear model to produce greater hypertrophic results. There were greater improvements in maximal strength and vertical jump	The inability to properly determine a constant micro/mesocycle length, frequency, and duration within various program types suggest the ability to add variety within training sessions with the main focus on overall load and volume to combat fatigue while optimizing performance. It can be difficult to compare studies utilizing different periodization approaches due to the variation in volume,

	frequency with various models and training emphasis to appropriately load an athlete for different phases of competition.	participated in any form of periodization during their competitive season	strength and strength-power during in-season training Determine strength and strength-power changes in athletes following long-term periodization	jump, clean, ball throw dependent on study Strength: assessed by 1RM squat or 1RM box squat, 1RM bench dependent on study	performance when compared to NP however there are similar results noted in strength and strength-power when comparing DUP and BP. There is no significant support for one specific training time, mesocycle length and duration of periodization within the various program types. Power output is directly related to maximal strength; training intensities >/=80% are necessary to improve maximal strength, peak power, impulse and explosive strength. This had positive results on performance pre-season and in-season training as	mesocycle length, intensity and other factors contributing to program details. However, it can be determined that improvements in strength and strength-power can be produced with both an UP and BP. Depending on the type of athlete, either trained or untrained, it will be important to change the type of programming used as UP seems to produce greater improvements for a trained athlete. However, there may be a need for pre-season changes with a BP focus dependent on length of cycle.

					reduction in intensity showed reduction in ultimate power. A 7 week program of BP, DUP and NP all produced gains in strength and power but a transition to a 5-week plyometric focus did not produce further improvements. Comparison from BP to DUP noted increased RFD but the last 3 weeks there were continued improvement, 15%, in BP but a loss, -22%, in UDP. There were also greater improvements in 1RM squat in BP compared to DUP.	
Campos et al, 2002[3]	Determine various physiological adaptations including intra-muscular	RCT 32 untrained (not participating in an exercise program for at	Each participant completed a pre and post assessment for each of the test	Anthropometric measures: total body mass, fat-free mass, percentage body fat	Anthropometric: no significant differences between groups	All strength training programs produced improvements in maximal strength but the low rep with higher percentage program produced the most significant improvements in

	adaptations following three different training models including emphasis on muscular strength and muscular endurance.	least 6 months) male participants; average age of 22.5 years 27 participants randomly divided into three training groups (low, intermediate and high intensity) 6 participants were part of the non-exercising control group; one began an endurance program and was not included in final tests	and measures utilized Trained individuals participated in an 8-week training program for the lower extremities. Training session began and ended with 10-15 minute calisthenics, stretching and low-intensity cycling. All participants completed the same three exercises; leg press, squat and knee extension in order for each training day. Frequency: 2 days/week for 4 weeks and progressed to 3 days/week for 4 weeks	Maximal oxygen consumption (Vo2 max) Maximal strength:leg press, squat, knee extension for 1RM Muscular endurance: maximum repetitions until failure at 60% of 1RM for leg press, squat and knee extension Muscle biopsy from vastus lateralis for fiber type and cross sectional area, myosin heavy chain analysis and capillary assessment	Vo2 Max: the high rep group was the only one to show significant increases in maximal aerobic power; statistical difference of 41, and time to exhaustion; statistical difference of 1.3 No significant differences noted in volume and cardiorespiratory stress according to total work All training groups showed increase in 1RM testing; the low rep group had greater increase in strength in squat and leg press when compared to the intermediate and high rep group All training groups showed improvements in muscular endurance; the high rep group	overall strength production which supports most strength and conditioning principles. The greatest improvements in muscular endurance were noted from the higher repetition and lower percentage group which again supports the principles found within NSCA and ACSM. At a local muscular level there were changes in all three groups from Type IIB to Type IIAB which is a more fast-fiber or power related muscle fiber type. THe biggest difference from the cross sectional biopsy was noted in hypertrophy or cross-sectional area. The biggest changes in hypertrophy were noted in the low repetition group. This may be contraindicated because perception of cross-sectional area gains is typically associated with higher repetitions. The increased hypertrophy parallels changes in fiber types as these types are stimulated from power and heavy resistance training.

			Low: 3-5 repetitions max for 4 sets with 3 min rest between sets and exercises Intermediate: 9-11 repetitions max for 3 sets with a 2 minute rest between sets and exercises High: 20-28 repetition max for 2 sets with 1 minute rest between sets and exercises Weight was progressively increased to maintain appropriate rep range		showed the greatest improvements between groups Fiber type changes in all three groups noted a decrease in type IIB and increase in type IIAB. There was a significant decrease in MHCIIb and increase in MHCIIa Increase in cross sectional area was noted for the low and intermediate groups; 12.5% for type I, 19.5% for type IIa and 26% for type IIb No significant changes noted in capillary density or number of capillaries per fiber type	

Synthesis: Programming for athletes has many components including microcycle/mesocycle length, intensity, overall volume, sport demands and intensity utilized within each program. There is very strong support for either a blocked periodization, linear periodization or undulating periodization when compared to a non-periodization program for improving strength, hypertrophy and power. There is a general consensus that a linear periodization has greater improvements for an untrained individual whereas an undulating periodization, either daily or weekly, will

demonstrate greater improvements for a trained athlete. Additionally, it is important to consider preseason, off-season, and in-season demands. There is support for UP and BP for both in-season and pre-season and specific athlete goals, sport and training status should be considered.

Improvements in strength and power are directly related. Strength is a necessary foundational component to build power. Improvements in maximal strength as noted from 1RM testing continue to show improvements in rate of force development as well as ultimate power output. At a cellular level we see changes in fiber types when resistance training at all levels of intensity resulting in the ability for greater force and power output. Due to increases in hypertrophy, fiber type and overall strength a higher intensity with lower repetition may be the most beneficial for improving strength and power. There are still limitations to consider and adjustments to programs may be needed to optimize performance due to volume and potential of overtraining.

Reference List:

1. Moesgaard L, Beck MM, Christiansen L, Aagaard P, Lundbye-Jensen J. Effects of Periodization on Strength and Muscle Hypertrophy in Volume-Equated Resistance Training Programs: A Systematic Review and Meta-analysis. *Sports Med*. 2022;52(7):1647-1666. doi:10.1007/s40279-021-01636-1
2. Harries SK, Lubans DR, Callister R. Systematic review and meta-analysis of linear and undulating periodized resistance training programs on muscular strength. *J Strength Cond Res*. 2015;29(4):1113-1125. doi:10.1519/JSC.0000000000000712
3. Campos GE, Luecke TJ, Wendeln HK, et al. Muscular adaptations in response to three different resistance-training regimens: specificity of repetition maximum training zones. *Eur J Appl Physiol*. 2002;88(1-2):50-60. doi:10.1007/s00421-002-0681-6
4. Hartmann H, Wirth K, Keiner M, Mickel C, Sander A, Szilvas E. Short-term Periodization Models: Effects on Strength and Speed-strength Performance. *Sports Med*. 2015;45(10):1373-1386. doi:10.1007/s40279-015-0355-2