

Research article

Long-Term Effects of NASM-OPT Periodized Training on Lower-Limb Strength, Explosive Power, and Stretch-Shortening Cycle Function in Adolescent Athletes

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Abstract

Strength training plays an essential role in improving performance and lowering injury incidence among adolescent athletes. However, current training practices often involve premature specialization, insufficient load management, and adult-oriented programming. The periodized National Academy of Sports Medicine's Optimum Performance Training (NASM-OPT) model develops stability, strength, and lower-limb power in a progressive manner, but its long-term effects in adolescents remain unclear. This randomized controlled trial compared NASM-OPT with traditional periodized training to examine the effects on maximal lower-limb strength and explosive power among 42 adolescent athletes randomly allocated to the OPT and CON groups (n = 21 per group). A 26-week intervention was completed in both groups. Squat one-repetition maximum (1RM), countermovement jump (CMJ), squat jump (SJ), pre-stretch augmentation percentage (PSAP), and eccentric utilization ratio (EUR) were assessed at baseline and post-intervention. Repeated-measures ANOVA was used to analyze group×time interactions ($\alpha = 0.05$). Compared with the CON group, the OPT group demonstrated greater post-intervention values in 1RM (133.1 ± 21.4 vs 119.2 ± 18.0 kg), CMJ (47.4 ± 5.8 vs 39.8 ± 4.0 cm), PSAP (10.63% vs 6.07%), and EUR (1.11 vs 1.06) post-intervention ($p < 0.05$). The OPT group maintained these improvements throughout the intervention, whereas the CON group showed plateaued values, potentially suggesting enhanced stretch-shortening cycle (SSC) function. Periodized NASM-OPT training efficiently promotes lower-limb strength, explosive power, and SSC function in adolescent athletes. These findings indicate that systematic and progressive programming can optimize performance while minimizing injury risk.

Key words: Stretch-shortening cycle, PSAP, EUR, vertical jump, youth resistance training.

Introduction

Adolescence is a critical stage for athletic development, typically defined as the period spanning 10 to 19 years of age (WHO, 2023), though in competitive youth sports, it frequently focuses on the developmental window of 12 to 18 years. During this stage, strength training substantially contributes to improved physical fitness and overall sports performance. According to the Long-Term Athlete Development (LTAD) model, this stage is essential for acquiring motor skills and establishing a strength foundation. Appropriate strength training enhances competitiveness while also providing meaningful protection against injury (Granaicher et al., 2016; Lloyd et al., 2016; Lloyd et al., 2015a;

Varghese et al., 2022).

Despite these benefits, adolescent athletes commonly face issues such as early sport specialization, excessive training load, and adult-oriented training. In an effort to accelerate progression, disproportionate emphasis is placed on training intensity, overall volume increases indiscriminately, and athletes are pushed prematurely toward physiological limits (MI, 2016). These practices heighten the likelihood of injury and may even shorten athletic careers (Lloyd et al., 2015b; Matos et al., 2011). Accordingly, designing strength training interventions that simultaneously support performance improvements and mitigate injury risk in adolescents remains a substantial challenge.

Periodization offers a structured approach that divides training into progressive phases, each deliberately manipulating key variables such as intensity, frequency, and volume to optimize performance at specific time points (Afonso et al., 2019; Kataoka et al., 2021; Williams et al., 2017). By sequencing load management, fatigue control, and recovery strategies in a planned manner, athletes can achieve an optimal training stimulus, reduce the probability of overtraining and injury, and sustain long-term adaptations (Cunanan et al., 2018; Kataoka et al., 2021). However, different models of periodization may vary not only in their efficacy for developing strength but also in their impact on load management and injury risk (Williams et al., 2017).

The Optimum Performance Training (OPT) model, developed by the National Academy of Sports Medicine (NASM, USA), organizes training into three levels: stability, strength, and power. Each level incorporates distinct phases that target stability, muscular endurance, hypertrophy, maximal strength, and power. The OPT model incorporates elements of linear progressive training while systematically emphasizing movement quality and neuromuscular control. Compared with traditional periodization models, whether linear models that progressively increase training volume or intensity, or strength periodization models structured around muscular physiological adaptations (hypertrophy, maximal strength, and power) (Bompa and Buzzichelli, 2019; Buford et al., 2007; Cunanan et al., 2018; Turner, 2011), the OPT model places greater emphasis on postural stability, joint control, and movement efficiency, upon which load and velocity are progressively increased. This framework provides clear guidance for the design of training content and loading parameters at each phase. Such a structured progression is intended to sequen-

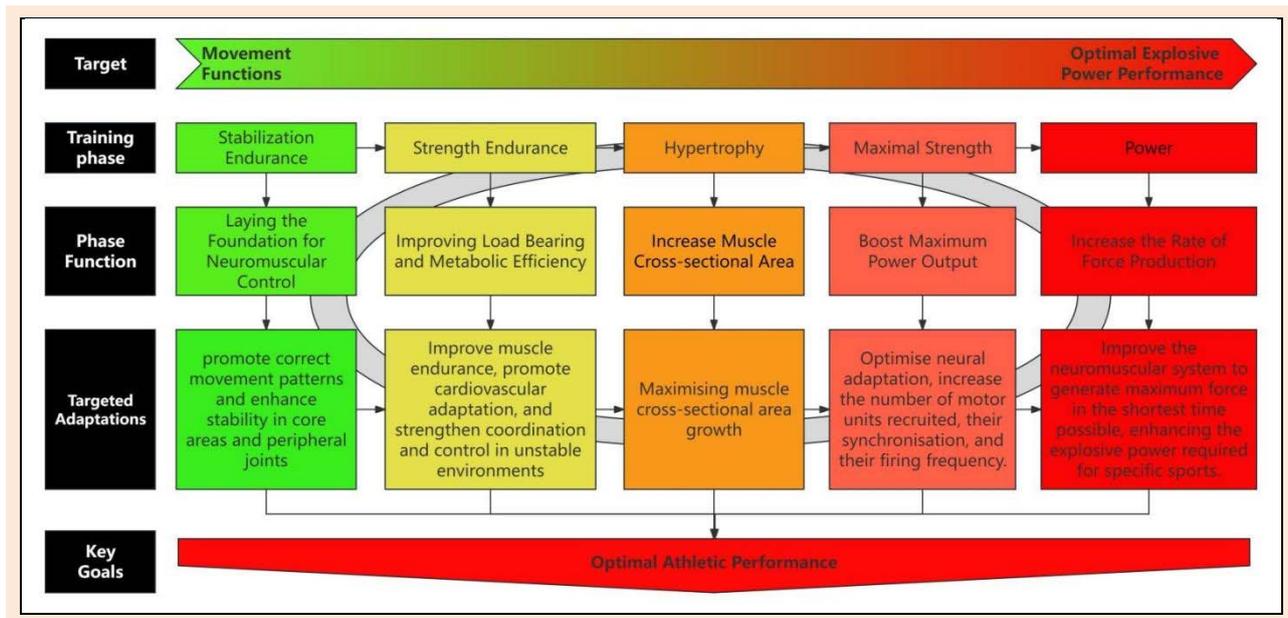


Figure 1. Logical relationship diagram of the NASM-OPT training model.

tially enhance neuromuscular stability, strength, and power, thereby improving overall athletic performance. The sequential progression and interrelationships among these levels constitute the conceptual framework of the present study and are summarized in Figure 1.

This approach may be particularly suitable for adolescents because it prioritizes movement quality and neuromuscular control before introducing high external loads—a strategy that aligns with youth development principles and may reduce injury risk during periods of rapid growth (Faigenbaum and Myer, 2010; Lloyd and Oliver, 2012; Myer et al., 2013). In contrast, traditional linear models often emphasize progressive load increases without systematic stabilization phases, potentially exposing young athletes to premature physiological stress.

Despite the theoretical robustness of the NASM-OPT model in systematic athletic development, its long-term efficacy and specific physiological adaptations within the adolescent population remain insufficiently explored. Most existing studies have focused on short-term interventions or adult cohorts, leaving a gap in understanding how this progressive structure influences the complex neuromuscular development unique to youth athletes. Therefore, the purpose of this study was to investigate the longitudinal effects of a 26-week NASM-OPT periodized training program on maximal lower-limb strength, power, and SSC efficiency in adolescent athletes, and to compare these adaptations with those resulting from a traditional linear periodized training model. We hypothesized that the NASM-OPT model would produce greater improvements in lower-limb strength, power, and SSC efficiency than traditional linear periodization, with the largest between-group differences emerging during the later phases of the macrocycle.

Methods

Subjects

42 adolescent athletes (20 males and 22 females; age: 14.4 ± 1.2 years) were recruited from a Youth Competitive

Sports School in Guangdong Province. Eligible participants met all of the following criteria: (1) no history of lower-limb injury; (2) full participation in every scheduled training session and assessment; and (3) ≥ 2 -year resistance training experience with proficiency in strength training techniques.

Maturity Status Assessment: While Peak Height Velocity (PHV) and Peak Weight Velocity (PWV) were not explicitly measured, all participants underwent bone age assessment using hand radiography with the Greulich-Pyle atlas at baseline. The mean bone age was 14.50 ± 1.10 years (range: 12.8 - 16.2 years). We acknowledge that bone age alone does not fully characterize maturity status, as chronological age, skeletal maturity, and biological maturity may not be perfectly aligned. Therefore, the lack of direct PHV/PWV measurement represents a limitation of this study (see Limitations section).

Informed Consent: Before enrollment, all participants and their parents or legal guardians were informed of the study objectives, procedures, and potential risks. Written informed consent was obtained from both the athletes and their parents/guardians prior to participation. All athletes were based at the same school and maintained similar dietary and rest habits, which ensured uniformity of experimental conditions. Additionally, participants were instructed to refrain from caffeinated beverages and nutritional supplements throughout the study to minimize confounding factors.

Experimental design

A randomized controlled design was adopted to compare the NASM-OPT periodization model with a traditional periodized strength regimen over a 26-week macrocycle. Participants ($n = 42$) were randomly assigned to either the OPT group ($n = 21$) or the CON group ($n = 21$) using computer-generated random numbers, with allocation stratified by sex and sport type, and bone age quartile to ensure balanced distribution across groups (Table 1). Male and female athletes, as well as badminton and wrestling

Table 1. Basic information of participants.

Group	Sex	n	Bone Age(y)	Range(y)	Height(cm)	Weight(kg)
OPT	male	10	14.70 ± 1.06	12.9~16.1	171.90 ± 4.79	55.80 ± 4.61
	female	11	14.55 ± 0.82	12.8~16.2	161.18 ± 5.47	58.97 ± 5.26
	Total	21	14.60 ± 1.00	12.8~16.2	166.25 ± 7.45	57.48 ± 5.08
CON	male	10	14.80 ± 0.63	12.9~16.0	171.60 ± 5.52	54.70 ± 4.52
	female	11	14.18 ± 0.60	13.1~16.1	160.45 ± 5.32	57.28 ± 2.96
	Total	21	14.10 ± 1.20	12.9~16.1	165.74 ± 7.78	56.05 ± 3.91

Between-group comparison: $p > 0.05$ (independent-samples t-test).

players, were evenly distributed between the two groups (OPT: badminton $n = 10$, wrestling $n = 11$; CON: badminton $n = 10$, wrestling $n = 11$). Bone age distribution was also balanced between groups (OPT: mean bone age 14.6 ± 1.0 years; CON: mean bone age 14.4 ± 1.2 years; $p = 0.52$).

In the NASM-OPT model, training across the macrocycle was organized into three sequential phases: a stability phase (weeks 1 - 4), a strength phase (weeks 5 - 22), and a power phase (weeks 23 - 26). The strength phase was further divided into strength endurance, hypertrophy, and maximal strength sub-phases. Thus, stability, strength, and power were not trained concurrently in each phase, but were emphasized in a planned sequence.

The CON group followed a traditional linear periodization model in which training volume was gradually reduced, and intensity was progressively increased across successive mesocycles. The control program included general preparatory, basic strength, and pre-competition phases that were time-matched to the stabilization, strength, and power phases of the OPT model, respectively; however, it did not incorporate the structured stabilization–strength–power sequencing or phase-specific neuromuscular emphasis characteristic of NASM-OPT (Table 2).

Complex Training Protocol: During the power phase, the OPT group performed complex training sequences, in which each set of heavy resistance exercises (e.g., barbell squat at 75% 1RM) was immediately followed by a plyometric exercise (e.g., squat jump) performed for 5 repetitions. This pairing was intended to

leverage post-activation potentiation (PAP) to enhance the neuromuscular response to the explosive movement. Rest intervals of 30 seconds were provided between the resistance exercise and plyometric exercise, and 3-4 minutes between complex training sets to allow adequate recovery for PAP effects.

Training program structure

Training was conducted twice weekly (Mondays and Thursdays), with at least 48 h of rest between sessions. Certified coaches supervised all sessions to ensure adherence and safety. Participants were instructed not to engage in additional physical training besides the assigned program.

Training Volume Equivalence: While both groups completed training for 26 weeks at the same frequency (2 sessions per week) and duration (each session approximately 60-75 minutes), the total training volume (load \times reps) differed between groups due to different programming philosophies. Specifically, the OPT model employed lower loads with higher repetitions in early phases, while the traditional linear model used relatively higher loads and lower repetitions overall, particularly in the later mesocycles. This difference reflects the distinct periodization approaches and was intentional to preserve the fidelity of each model.

Importantly, this difference allows us to examine whether superior performance outcomes in the OPT group were achieved with lower overall training volume, suggesting greater training efficiency.

Table 2. Lower-limb strength training protocols for OPT and CON groups.

Tier	Phase	OPT		CON	
		Content	Load	Content	Load
Stabilization	Endurance (4 wks)	Single-leg balance extension		Barbell back squat	
		Single-leg deadlift	BW, 3×30s	Barbell deadlift	30%, 3×15
		Single-leg calf raise	15%, 3×10	Barbell high pull	
Strength	Endurance (6 wks)	Dumbbell Lunge		Barbell back squat	
		Dumbbell Squat	30%, 3×15	Barbell deadlift	60%, 3×15
		Dumbbell Single-leg deadlift		Barbell power clean	
	Hypertrophy (6 wks)	Barbell Squat		Barbell back squat	
		Seated Leg Extension	60%, TF×2	Barbell deadlift	80%, 5×10
		Seated Leg Curl		Barbell power clean	
Maximal Strength (6 wks)	Barbell Squat	100%/95%/90%	Barbell back squat		
	Barbell Deadlift	3×1/2/3	Barbell deadlift	90%, 3×6	
	Barbell Hip Thrust		Barbell power clean		
Power	Power (4 wks)	Squat Jump		Barbell back squat	
		(5 Vertical Jumps*)		(5 Vertical jumps*)	
		Lunge Jump	75%, 3×6	Barbell deadlift	80%, 3×10
		(5 Vertical Jumps*)		(5 Vertical jumps*)	
		Barbell Power Clean		Barbell power clean	
(5 Vertical Jumps*)		(5 Vertical jumps*)			

BW = Body weight; TF = to failure. Complex training: Each set of heavy resistance exercise was immediately followed by 5 plyometric repetitions with 30-second rest interval between exercises.

Test program

Key performance indicators were evaluated at baseline, and in the 4th, 10th, 16th, 22nd, and final weeks. All testing was conducted during a standardized time window to reduce diurnal variation. No additional physical training was permitted beyond the intervention.

Maximal dynamic strength (1RM Squat): Maximal dynamic strength was assessed using a 1RM back squat test, which measures the maximum load that can be lifted in a single repetition of the back squat exercise. A standardized warm-up was first conducted at ~50% estimated 1RM for 6 - 10 repetitions, followed by ~80% 1RM for three repetitions. Load was then increased by 10 - 20% incrementally until maximal dynamic strength was reached (3 - 7 attempts), with 3 - 5 min of rest between attempts. Squat depth was considered valid when the proximal femoral head was aligned horizontally with the superior border of the patella, as determined by visual inspection by two experienced strength and conditioning coaches observing from the sagittal plane; only lifts meeting this depth criterion and executed with proper technique were recorded as successful attempts(Strength and Association, 2021).

Vertical jump tests: Lower-limb power was assessed via lower-limb power with SSC (CMJ) and concentric-only power (SJ) using Smart Jump devices. For the SJ, participants descended to the prescribed squat depth and held this position for 2-s before jumping to eliminate any CMJ (i.e., concentric-only action). To minimize the influence of an unintended “dip” (unweighting) before the propulsive phase, participants were instructed not to perform any additional countermovement once the squat position was reached, and the tester visually monitored every attempt for signs of downward motion. Any trial in which a visible dip occurred after the 2-s hold was immediately repeated. For the CMJ, participants performed a self-selected CMJ before jumping. All jumps were performed with maximal intent, and the best height from three attempts was recorded for each condition.

Pre-Stretch Augmentation Percentage (PSAP) and Eccentric Utilization Ratio (EUR) were calculated as follows:

CMJ and SJ performances and were determined below:

$$PSAP = (CMJ - SJ) \times SJ^{-1} \times 100\%$$

$$EUR = CMJ \times SJ^{-1}$$

Where CMJ and SJ represent the optimal jump height (cm) achieved in each respective test.

Interpretation Framework: Based on established athletic research(McGuigan et al., 2006; Schmarzo and Dyke, 2017; Suchomel et al., 2016), a PSAP of approximately 10% (range: 8 - 12%) and an EUR of approximately 1.1 were adopted as reference thresholds. These values

represent a balanced contribution between SSC-mediated and concentric-only power. Values exceeding these thresholds indicate a greater reliance on elastic energy storage, while lower values suggest potential for further SSC development. These indices were treated as indirect markers of neuromuscular efficiency(Bobbert et al., 1996; James et al., 2023).

Volume Load: Record the athlete's training intensity and repetition count for each session to calculate the volume of load. The cumulative training load for each phase was calculated as: Volume Load = 1RM × %1RM × repetitions.

Data analysis

Participant characteristics and performance outcomes (1RM, CMJ, SJ, PSAP, EUR) were reported as mean ± SD for normally distributed variables, and median (range) for non-normal distributions. Shapiro–Wilk tests were employed to examine normality. When data were non-parametric, Mann–Whitney U and Wilcoxon signed-rank tests were used.

Sex differences in outcomes were evaluated using analysis of covariance(ANCOVA) (group as the independent variable, intervention effects as the dependent variable, and sex as the covariate) to determine whether training effects were moderated by sex. As no significant group × sex interactions were observed, subsequent analyses were conducted on data pooled across sex.

Training effects for outcome metric (1RM, CMJ, SJ) were examined using two-way repeated-measures ANOVA (2 groups × 6 time points) with Bonferroni post-hoc correction. Mauchly’s test assessed sphericity, and Greenhouse - Geisser adjustments were applied if this assumption violated. Within-group changes were analyzed using paired-samples t-tests.

Effect sizes (ES) were interpreted according to Cohen’s criteria (0.2 = small, 0.5 = medium, and 0.8 = large). Statistical significance was set at p < 0.05. All analyses were completed in SPSS 26.0 and Jamovi 2.3.0.

Results

Sex difference in outcome

No statistically significant interaction effect of sex was found on intervention outcomes (1RM, CMJ, SJ, PSAP, EUR) across any training phase in either the OPT or CON group (p > 0.05). These findings indicate that sex did not contribute to meaningful differences in training responses.

Baseline characteristics

As presented in Table 3, there were no significant pre-intervention differences between the OPT group (M: 10; F: 11) and the CON group (M: 10; F: 11) in any measured parameter at baseline.

Table 3. Between-group differences in pre-intervention test items. Values are presented as mean ± SD.

Outcome	OPT	CON	p
1RM(kg)	99.05 ±20.37	94.00 ±17.68	0.63
CMJ(cm)	33.50 ±5.06	32.79 ±5.56	0.66
SJ(cm)	31.28 ±4.65	30.54 ±5.13	0.40
PSAP(%)	6.21 ±2.56	7.40 ±3.58	0.22
EUR	1.07 ±0.03	1.07 ±0.03	0.73

CMJ = countermovement jump; SJ = squat jump; PSAP = pre-stretch augmentation percentage; EUR = eccentric utilization ratio.

Table 4. Comparison of volume load between OPT and CON groups across different training phases (Kg).

	Stabilization Endurance	Strength Endurance	Hypertrophy	Maximal Strength
OPT Group	74880	339228	661871	218515
CON Group	213192	647676	1068960	463644

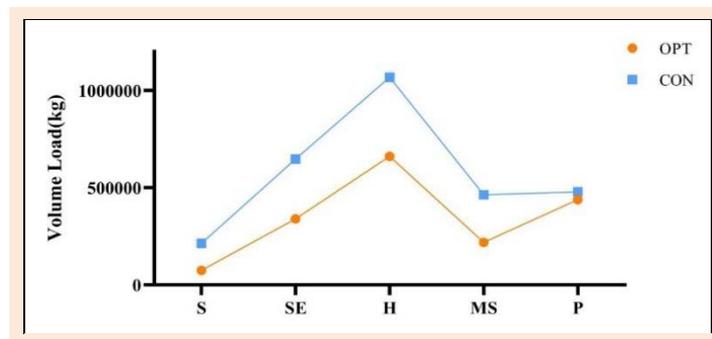


Figure 2. Changes in volume load during the experimental process. Volume Load = 1RM × %1RM × repetitions; S = Stabilization Endurance phase; SE = Strength Endurance phase; H = Hypertrophy phase; MS = Maximal Strength phase; P = Power phase.

Table 5. Comparison of evaluation indicators between opt and con groups before and after the experiment.

Group	Outcome	Baseline	Post	p	ES
OPT	Back squat(kg)	99.0 ±20.4	133.1 ±21.4	< 0.01**	4.04
	CMJ(cm)	33.5 ±5.06	47.4 ±5.76	< 0.01**	3.55
	SJ(cm)	31.3 ±4.65	42.9 ±5.17	< 0.01**	3.17
	PSAP(%)	6.21 ±2.56	10.63 ±0.94	< 0.01**	1.62
	EUR	1.07 ±0.03	1.11 ±0.01	< 0.01**	1.11
CON	Back squat(kg)	94.0 ±17.7	119.2 ±18.0	< 0.01**	4.39
	CMJ(cm)	32.8 ±5.56	39.8 ±3.99	< 0.01**	2.42
	SJ(cm)	30.5 ±5.13	37.8 ±4.03	< 0.01**	2.97
	PSAP(%)	7.40 ±3.58	6.07 ±2.36	0.12	0.36
	EUR	1.07 ±0.03	1.06 ±0.03	0.08	0.40

* indicates p < 0.05; ** indicates p < 0.01.

Changes in volume load during the experimental process

Volume load for each phase is presented in Table 4. The CON group accumulated substantially higher training volume than the OPT group across all phases (Figure 2).

Despite the CON group accumulating nearly 1.85 times greater total training volume than the OPT group (2,393,472 kg vs. 1,294,494 kg), the OPT group achieved greater improvements in 1RM, CMJ, SJ, PSAP, and EUR. This suggests that the OPT model may promote superior training efficiency, achieving greater performance gains per unit of training volume.

Changes in Outcome Measures Before and After the Experimental Intervention 1RM

Both groups demonstrated significant post-intervention improvements in squat 1RM (p < 0.01; Table 5). In the OPT group, there were significant increases in 1RM from the stabilization endurance phase (4 weeks) to the strength endurance phase (10 weeks), from the strength endurance phase to the hypertrophy phase (16 weeks), from the hypertrophy phase to the maximal strength phase (22 weeks), and from the maximal strength phase to the power phase (post) (p < 0.01; Table 6).

In the CON group, significant improvements were observed between the stabilization endurance phase (4 weeks) and the strength endurance phase (10 weeks), and between the strength endurance phase (10 weeks) and the

hypertrophy phase (16 weeks) (p < 0.01). A modest but significant increase was also detected between baseline and the stabilization endurance phase (p < 0.05). Inter-group comparisons confirmed significant differences between OPT and CON during the maximal strength and power phases (p < 0.05).

CMJ

CMJ performance improved significantly from pre- to post-intervention in both groups (p < 0.01; Table 5). In the OPT group, multiple comparisons (Table 6) revealed significant increases from the strength endurance phase to the hypertrophy phase, from the hypertrophy phase to the maximal strength phase, and from the maximal strength phase to the power phase (post) (p < 0.01). A significant between-group difference was also identified during the power phase (post) (p < 0.01).

SJ

Significant increases in SJ height were observed in both groups from pre- to post-intervention (p < 0.01; Table 5). Within the OPT group, there was a significant improvement from the strength endurance phase to the hypertrophy phase (p < 0.05), and significant increases from the hypertrophy phase to the maximal strength phase, and from the maximal strength phase to the power phase (post) (p < 0.01). Between-group comparisons showed significant differences after the hypertrophy and power phases (p < 0.01).

Table 6. Multiple comparisons of various parameters between OPT and CON groups across different training phases.

	Time	OPT	CON	p
Back squat 1-RM (Kg)	Baseline	99.05 ±20.37	94.00 ±17.68	0.39
	4 weeks	99.71 ±20.24	95.19 ±17.65*	0.45
	10 weeks	103.95 ±19.76**	107.24 ±18.45**	0.58
	16 weeks	113.19 ±20.37**	116.43 ±19.02**	0.60
	22 weeks	132.76 ±21.07**	118.71 ±17.96	0.02†
	Post	133.14 ±21.43	119.20 ±18.02	0.03†
CMJ (cm)	Baseline	33.50 ±5.06	32.79 ±5.56	0.66
	4 weeks	33.53 ±4.93	32.97 ±6.08	0.74
	10 weeks	34.00 ±4.79	35.33 ±5.82**	0.42
	16 weeks	37.42 ±4.76**	40.12 ±4.05**	0.05
	22 weeks	41.23 ±6.14**	39.65 ±4.04	0.33
	Post	47.45 ±5.76**	39.85 ±3.99	0.00††
SJ (cm)	Baseline	31.28 ±4.65	30.53 ±5.13	0.63
	4 weeks	31.27 ±4.83	30.61 ±5.13	0.67
	10 weeks	31.57 ±4.59	33.33 ±5.65**	0.27
	16 weeks	32.94 ±4.87*	38.21 ±4.17**	0.00††
	22 weeks	38.90 ±6.03**	37.71 ±4.03	0.46
	Post	42.92 ±5.17**	37.77 ±4.03	0.00††

* indicates a significant difference between this training phase and the previous training phase within the OPT or CON group; ** indicates a highly significant difference between this training phase and the previous training phase within the OPT or CON group; † indicates a significant difference between the OPT and CON groups within the same training phase; †† suggests a highly significant difference between the OPT and CON groups within the same training phase; * indicates a significant difference between this training phase and the previous training phase within the OPT or CON group; ** indicates a highly significant difference between this training phase and the previous training phase within the OPT or CON group; † indicates a significant difference between the OPT and CON groups within the same training phase; †† suggests a highly significant difference between the OPT and CON groups within the same training phase.

PSAP and EUR

Significant increases in PSAP and EUR were observed in the OPT group from baseline to post-intervention ($p < 0.01$), whereas the CON group showed no significant changes ($p > 0.05$; Table 5). Specifically, the OPT group's PSAP increased from $6.21 \pm 2.56\%$ at baseline to $10.63 \pm 0.94\%$ post-intervention, reaching the approximate reference threshold of 10% that has been associated with balanced SSC and concentric-only contributions to jump performance. In contrast, the CON group's PSAP decreased slightly from $7.55 \pm 3.29\%$ at baseline to $6.07 \pm 2.36\%$

post-intervention, remaining below the 10% reference threshold throughout the intervention.

Similarly, EUR increased in the OPT group from 1.07 ± 0.03 at baseline to 1.11 ± 0.01 post-intervention, approaching the approximate reference value of 1.1 associated with optimal SSC utilization. The CON group's EUR remained essentially unchanged at approximately 1.07 throughout the intervention. Figure 3-D and Figure 3-E illustrate the progressive changes in PSAP and EUR across the training phases for both groups.

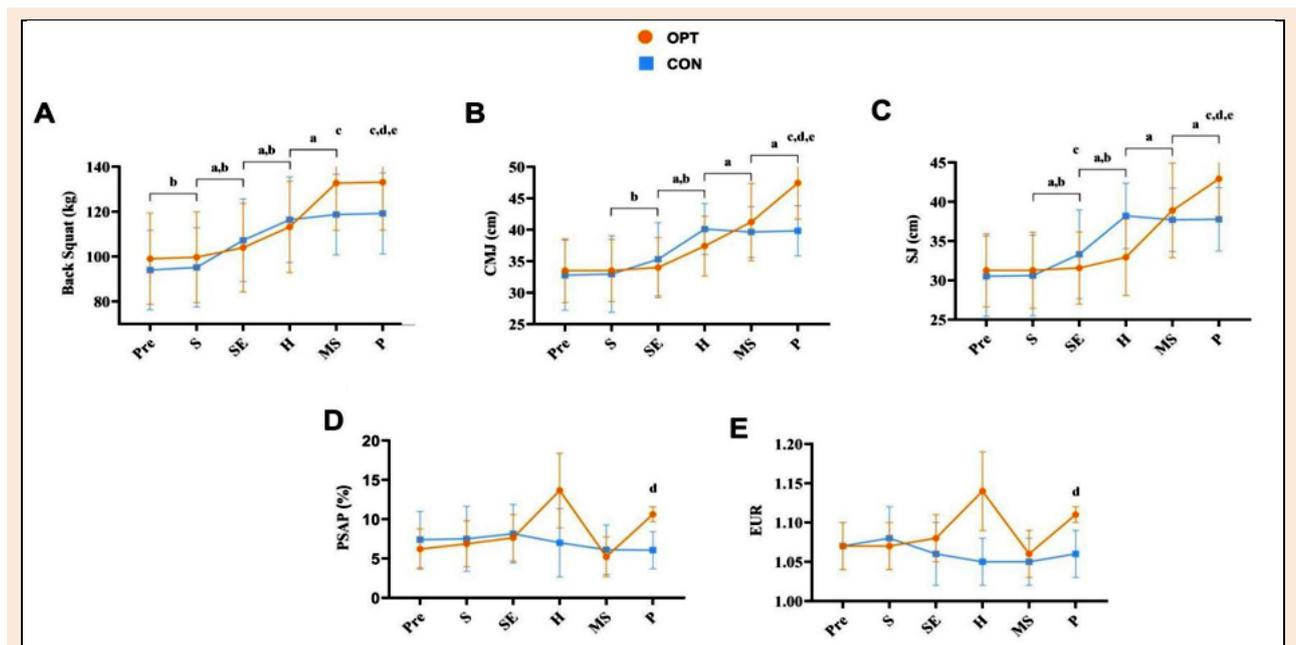


Figure 3. Changes in 1RM (A), CMJ (B), SJ (C), PSAP (D), and EUR (E) across training phases. OPT (n = 21) and CON (n = 21). Data are mean ± SD; pre = pre-intervention; S = Stabilization phase; SE = Strength Endurance phase; H = Hypertrophy phase; MS = Maximal Strength phase; P = Power phase. (a) indicates a significant difference relative to the previous phase within the OPT group; (b) indicates a significant difference relative to the previous phase within the CON group; (c) indicates a significant difference between OPT and CON; (d) indicates a significant pre-post difference within the OPT group; (e) indicates a significant pre-post difference within the CON group.

Discussion

In this study, the NASM-OPT periodization model was compared with a traditional periodized strength training model over a 26-week macrocycle to examine their effects on lower-limb maximal dynamic strength and vertical jump performance in adolescent athletes. The findings showed that the NASM-OPT program produced greater improvements in lower-limb maximal dynamic strength and vertical jump performance than traditional periodized training.

The OPT group demonstrated a progressive increase in PSAP from baseline ($6.21 \pm 2.56\%$) to post-intervention ($10.63 \pm 0.94\%$), reaching the approximate reference threshold of 10% that has been established in previous research as associated with balanced SSC and concentric-only contributions to jump performance (McGuigan et al., 2006; Suchomel et al., 2016). This increase suggests that the OPT model may have enhanced the athletes' capacity to utilize pre-stretch augmentation during dynamic jumping tasks.

These changes in PSAP and EUR may reflect differences in how the two training models affected SSC-related performance capacity. Higher PSAP and EUR values suggest an enhanced ability to utilize elastic energy and to exhibit reflexive responses during fast stretch-shortening actions (Bobbert et al., 1996; Harrison et al., 2004). The concurrent improvements in 1RM strength and CMJ height in the OPT group are consistent with the principle that increased strength provides a stronger foundation for expressing power through SSC mechanisms (Suchomel et al., 2016).

However, because PSAP and EUR are indirect indices calculated from jump height measurements, they do not directly reveal the underlying neuromuscular mechanisms (e.g., motor unit recruitment patterns, elastic energy storage capacity, or reflex potentiation). Direct measurements using electromyography or force plate kinetics would be required to confirm the specific adaptations responsible for the observed improvements.

Notably, the OPT group achieved greater improvements in strength and jump performance despite accumulating substantially less total training volume than the CON group (approximately 1.85-fold lower). This suggests that the structured progression of the OPT model - with its emphasis on movement quality, phase-specific variation, and sequential development of stability, strength, and power—may promote more efficient training adaptations than traditional linear periodization.

Our findings align with previous work showing that periodized models emphasizing progressive development from stabilization to strength and power phases can enhance SSC function and jump performance in youth athletes (Lloyd and Oliver, 2012; Myer et al., 2013). By systematically targeting movement quality, force production, and high-velocity expression, the NASM-OPT framework appears to optimize both force generation and neuromuscular adaptation in adolescents.

These results indicate that the NASM-OPT framework not only improves key performance outcomes but also supports a more efficient long-term training process,

potentially reducing excessive fatigue and mitigating overtraining risks.

The development of maximal dynamic strength differed significantly between the two training models (Figure 3-A). Both groups experienced increases by the 10th week; however, outcomes diverged during later phases. The OPT group continued to improve through the 22th week, whereas the CON group plateaued by the 16th week. This divergence likely reflects differences in the systematic manipulation of intensity, frequency, and volume. By strategically adjusting these variables, OPT-based training appeared to provide new stimuli that sustained neuromuscular adaptation.

According to the general adaptation syndrome theory, overly linear loading or repeated training exposure without novel stimuli may reduce neuromuscular responsiveness and lead to plateaued or excessive fatigue states (Haff and Triplett, 2016; Selye, 1976; Stone et al., 2007). In contrast, the OPT program applied planned, phase-specific variation in exercise type, volume and intensity (stabilization - strength - power), which periodically shifted the primary neuromuscular demand (e.g., from movement control, to heavy force production, to high-velocity SSC actions). This structured variation likely limited accommodation to a single stimulus and provided repeated novel overloads, helping to explain the greater and more sustained performance improvements observed in the OPT group.

Although the CON group carried a higher cumulative load, it generated smaller strength adaptations. During weeks 4 - 16, increases in total load were positively correlated with strength adaptations in both groups; however, from weeks 16 - 22, the OPT group continued to improve strength despite a moderated reduction in volume, whereas the CON group remained stable. This aligns with evidence suggesting that elevating intensity alongside reducing volume can improve neuromuscular adaptations (Rhea et al., 2003; Rhea et al., 2002) and is consistent with previous findings (Williams et al., 2017).

Overall, the OPT model is structured to gradually overload training load within a long-term framework, in a manner that differs from the traditional model. By progressively varying the type, volume, and intensity of exercise, it helps avoid inadequate stimulus exposure, excessive fatigue, and performance plateaus, thereby enabling sustained adaptation and continued strength development.

Both models improved jump height in the SJ and CMJ; however, the OPT model showed greater adaptations (Figure 3 B and 3C). This aligns with previous research showing that increases in lower-limb maximal dynamic strength are a key determinant of improvements in vertical jump performance (Helgerud et al., 2011) and that resistance training (Chelly et al., 2009; Christou et al., 2006; Gorostiaga et al., 2004), plyometric training (King and Cipriani, 2010; Lloyd et al., 2012; Meylan and Malatesta, 2009; Thomas et al., 2009), and complex training (Maio Alves et al., 2010; Wong et al., 2010) can all enhance jump ability in youth, largely via adaptation in lower-limb maximal dynamic strength. In the present study, the larger improvements observed in the OPT group may therefore reflect greater increases in maximal dynamic strength of the

lower limbs, providing a more effective foundation for jump performance than the traditional model. This interpretation is supported by the continued strength adaptation from weeks 16 - 22 and the sustained increases in jump height and SSC indices observed only in the OPT group.

Recent research has emphasized the role of velocity loss monitoring in optimizing training outcomes (Pareja-Blanco et al., 2016). While the OPT model in this study did not include explicit velocity-loss monitoring, future iterations could incorporate this approach to further enhance the precision of training load management.

Complex training combines resistance exercises with plyometrics, leveraging post-activation potentiation (PAP) to concurrently develop strength and power (Verkhoshansky, 1986). Plyometric training further promotes neuromuscular efficiency by increasing motor unit recruitment, pre-activation, contraction velocity, and short-latency stretch reflex contribution (Argus et al., 2012; Kritpet, 1988).

The OPT model integrates these elements in the power phase, refining the force-power curve and improving SSC function. This stage is critical, as it converts the strength foundation built in earlier phases into sport-specific explosive performance.

The two groups exhibited different temporal patterns of improvement. In the OPT group, lower-limb power improvements steadily progressed from weeks 10 - 22; in contrast, improvements in the CON group were concentrated in weeks 4 - 10 and plateaued thereafter. The earlier improvements in the CON group likely reflected higher cumulative loads during the initial phases, but this also appeared to accelerate neuromuscular adaptation saturation (Santos et al., 2023). By contrast, gradual loading, structured phase integration, and optimized progression in the OPT model promoted sustained development. Consequently, at the end of the macrocycle, the OPT group achieved superior maximal dynamic strength and lower-limb power.

Across the macrocycle, PSAP and EUR exhibited phase-dependent fluctuations in the OPT group, whereas the CON group remained comparatively stable (see Figure 3D, Figure 3E and Table 6). These patterns suggest that the OPT structure may facilitate time-varying adaptations in SSC-related performance indices. However, PSAP/EUR are indirect indices derived from jump heights and should be interpreted as performance proxies rather than direct neuromuscular mechanisms. Future studies incorporating force-time variables and EMG are needed to verify the underlying mechanisms.

Limitations of the Study

This was a single-center investigation involving athletes from a single sports school specializing in wrestling and badminton. Consequently, it remains unclear whether the NASM-OPT model yields similar outcomes in other sports or athletic populations. The limited sample size prevented the detection of potential sex-based differences within either model.

Although skeletal maturity was assessed via hand-wrist radiography and Greulich-Pyle bone age, we did not directly quantify somatic maturation using PHV or PWV.

As a result, inter-individual differences in biological maturation status may not have been fully captured, which could have influenced training responses and jump performance outcomes.

In addition, squat jump compliance with the “no countermovement” instruction was verified only via standardized verbal cues and visual observation, so small, sub-visual unweighting phases ($\leq 2\%$ of body mass) may still have occurred. However, recent work suggests that squat jump unweighting amplitudes $\leq 2\%$ of body mass do not meaningfully increase jump height, whereas larger amplitudes do (Agar-Newman et al., 2025), making it unlikely that any residual undetected dip substantially affected our PSAP and EUR estimates.

PSAP and EUR are indirect performance ratios derived from jump height measurements. While they may reflect SSC utilization, they do not directly measure neuromuscular mechanisms such as motor unit recruitment, firing frequency, or muscle fiber type activation. Therefore, mechanistic interpretations based on these indices should be made cautiously. Future studies should employ direct physiological assessments such as electromyography (EMG), ultrasound imaging, or force plate analysis to clarify the underlying neuromuscular adaptations. Future studies should expand the sample size and incorporate broader athletic demographics to evaluate the applicability of different periodization models across sex-specific and sport-specific contexts.

Implications for Practice and Recommendations

The selection of a periodization model should adopt a dialectical perspective, as each model offers distinct strengths and limitations. The NASM-OPT framework is advantageous for long-term development of lower-limb power and comprehensive athletic performance; however, it requires a relatively extended training duration for full effect. Traditional models may yield faster maximal dynamic strength adaptations over shorter timeframes.

A flexible, athlete-centered approach is therefore recommended, taking into account individual training history, sport-specific characteristics, and competition schedules. Training should be aligned with the principle of “adapting methods to the athlete and conditions.” Future research should further investigate individual response variability across different cyclical training frameworks to advance personalized periodization strategies.

Monitoring and evaluation metrics are essential for optimizing training outcomes. EUR and PSAP not only validate training efficacy but also provide dynamic feedback for timely program adjustment. By tracking neuromuscular function and SSC development, coaches can determine the appropriate timing to prioritize maximal dynamic strength versus lower-limb power. These metrics allow both qualitative and quantitative assessments of athlete progression and are therefore indispensable for refining periodization strategies and individualizing training prescriptions. In addition, EUR and PSAP offer indirect indications of neuromuscular adaptations. Further studies should incorporate direct physiological assessments such as ultrasound imaging or electromyography (EMG) to clarify the mechanisms underlying morphological and neural

changes.

Recommendations for Implementation

Physiological and biomechanical monitoring tools, such as EUR and PSAP, should be used in combination to continuously evaluate strength profiles and SSC efficiency. Regular assessments should be performed throughout the training cycle, and program variables (intensity, volume, and exercise selection) should be adjusted based on real-time athlete responses. Flexibility is especially important during phase transitions, and the progression of maximal dynamic strength development should be balanced with lower-limb power training according to performance indicators, individual adaptation trends, and competition demands. Through structured periodization combined with adaptive monitoring, coaches can enhance performance potential, promote cumulative long-term adaptations, and reduce the likelihood of injury or excessive fatigue.

Conclusion

This 26-week randomized controlled trial shows that the NASM-OPT periodization model produces greater improvements in lower-limb maximal strength, vertical jump performance, and SSC-related indices (PSAP and EUR) than a traditional linear strength program in adolescent athletes. Consistent with the study findings, the OPT group achieved significantly larger gains in squat 1RM, CMJ, and SJ ($p < 0.05$) and progressed from suboptimal to near-reference PSAP and EUR values, despite performing approximately 1.85-fold lower total training volume, indicating more efficient and sustained neuromuscular adaptation—this also supports that NASM-OPT is a systematic and progressive training strategy suitable for long-term youth strength and power development. Nonetheless, the single-center, sport-specific sample, modest sample size ($n=42$), absence of direct PHV/PWV assessment, and reliance on indirect SSC indices (PSAP, EUR) limit generalizability and mechanistic inference. Future studies should involve more diverse cohorts and direct physiological and biomechanical measures to further refine youth periodization models, which will also provide more comprehensive empirical evidence for optimizing adolescent strength training programs and minimizing injury risk.

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References

- Afonso, J., Rocha, T., Nikolaidis, P. T., Clemente, F. M., Rosemann, T. and Knechtle, B. (2019) A systematic review of meta-analyses comparing periodized and non-periodized exercise programs: Why we should go back to original research. *Frontiers in Physiology* **10**. <https://doi.org/10.3389/fphys.2019.01023>
- Agar-Newman, D. J., Funk, S., Cavin, E., Geneau, M. C., Tsai, M. C. and Klimstra, M. (2025) Determining the threshold of unweighting in squat jumps: A study on jump height and unweighting amplitude. *Journal of Strength and Conditioning Research* **39**, 295-299. <https://doi.org/10.1519/JSC.0000000000005019>
- Argus, C. K., Gill, N. D., Keogh, J. W. L., McGuigan, M. R. and Hopkins, W. G. (2012) Effects of two contrast training programs on jump performance in rugby union players during a competition phase. *International Journal of Sports Physiology and Performance* **7**, 68-75. <https://doi.org/10.1123/ijspp.7.1.68>
- Bobbert, M. F., Gerritsen, K. G. M., Litjens, M. C. A. and Van Soest, A. J. (1996) Why is countermovement jump height greater than squat jump height? *Medicine and Science in Sports and Exercise* **28**, 1402-1412. <https://doi.org/10.1097/00005768-199611000-00009>
- Bompa, T. O. and Buzzichelli, C. (2019) *Periodization: Theory and methodology of training*. Human Kinetics. <https://doi.org/10.5040/9781718225435>
- Buford, T. W., Rossi, S. J., Smith, D. B. and Warren, A. J. (2007) A comparison of periodization models during nine weeks with equated volume and intensity for strength. *Journal of Strength and Conditioning Research* **21**, 1245-1250. <https://doi.org/10.1519/R-20446.1>
- Chelly, M. S., Fathloun, M., Cherif, N., Ben Amar, M., Tabka, Z. and Van Praagh, E. (2009) Effects of a back squat training program on leg power, jump, and sprint performances in junior soccer players. *Journal of Strength and Conditioning Research* **23**, 2241-2249. <https://doi.org/10.1519/JSC.0b013e3181b86c40>
- Christou, M., Smilios, I., Sotiropoulos, K., Volaklis, K., Piliandis, T. and Tokmakidis, S. P. (2006) Effects of resistance training on the physical capacities of adolescent soccer players. *Journal of Strength and Conditioning Research* **20**, 783-791. <https://doi.org/10.1519/R-17254.1>
- Cunanan, A. J., DeWeese, B. H., Wagle, J. P., Carroll, K. M., Sausaman, R., Hornsby, W. G., Haff, G. G., Triplett, N. T. and Stone, M. H. (2018) The general adaptation syndrome: A foundation for the concept of periodization. *Sports Medicine* **48**, 787-797. <https://doi.org/10.1007/s40279-017-0855-3>
- Faigenbaum, A. D. and Myer, G. D. (2010) Resistance training among young athletes: Safety, efficacy and injury prevention effects. *British Journal of Sports Medicine* **44**, 56-63. <https://doi.org/10.1136/bjism.2009.068098>
- Gorostiaga, E. M., Izquierdo, M., Ruesta, M., Iribarren, J., Gonzalez-Badillo, J. J. and Ibanez, J. (2004) Strength training effects on physical performance and serum hormones in young soccer players. *European Journal of Applied Physiology* **91**, 698-707. <https://doi.org/10.1007/s00421-003-1032-y>
- Granacher, U., Lesinski, M., Busch, D., Muehlbauer, T., Prieske, O., Puta, C., Gollhofer, A. and Behm, D. G. (2016) Effects of resistance training in youth athletes on muscular fitness and athletic performance: A conceptual model for long-term athlete development. *Frontiers in Physiology* **7**, 164. <https://doi.org/10.3389/fphys.2016.00164>
- Haff, G. G. and Triplett, N. T. (2016) *Essentials of strength training and conditioning*. Human Kinetics.
- Harrison, A. J., Keane, S. P. and Cogan, J. (2004) Force-velocity relationship and stretch-shortening cycle function in sprint and endurance athletes. *Journal of Strength and Conditioning Research* **18**, 473-479. <https://doi.org/10.1519/13163.1>
- Helgerud, J., Rodas, G., Kemi, O. J. and Hoff, J. (2011) Strength and endurance in elite football players. *International Journal of Sports Medicine* **32**, 677-682. <https://doi.org/10.1055/s-0031-1275742>
- James, L. P., Talpey, S. W., Young, W. B., Geneau, M. C., Newton, R. U. and Gustin, P. B. (2023) Strength classification and diagnosis: Not all strength is created equal. *Strength and Conditioning Journal* **45**, 333-341. <https://doi.org/10.1519/SSC.0000000000000744>
- Kataoka, R., Vasenina, E., Loenneke, J. and Buckner, S. L. (2021) Periodization: Variation in the definition and discrepancies in study design. *Sports Medicine* **51**, 625-651. <https://doi.org/10.1007/s40279-020-01414-5>
- King, J. A. and Cipriani, D. J. (2010) Comparing preseason frontal and sagittal plane plyometric programs on vertical jump height in high-school basketball players. *Journal of Strength and Conditioning Research* **24**, 2109-2114. <https://doi.org/10.1519/JSC.0b013e3181e347d1>
- Kritpet, T. T. (1988) The effects of six weeks of squat and plyometric training on power production. Doctoral thesis, Oregon state University, Oregon state. 1244.

- Lloyd, R. S., Cronin, J. B., Faigenbaum, A. D., Haff, G. G., Howard, R., Kraemer, W. J., Micheli, L. J., Myer, G. D. and Oliver, J. L. (2016) National Strength and Conditioning Association position statement on long-term athletic development. *Journal of Strength and Conditioning Research* **30**, 1491-1509. <https://doi.org/10.1519/JSC.0000000000001387>
- Lloyd, R. S. and Oliver, J. L. (2012) The youth physical development model: A new approach to long-term athletic development. *Strength and Conditioning Journal* **34**, 61-72. <https://doi.org/10.1519/SSC.0b013e31825760ea>
- Lloyd, R. S., Oliver, J. L., Faigenbaum, A. D., Howard, R., De Ste Croix, M. B., Williams, C. A., Best, T. M., Alvar, B. A., Micheli, L. J., Thomas, D. P., Hatfield, D. L., Cronin, J. B. and Myer, G. D. (2015a) Long-term athletic development, part 1: A pathway for all youth. *Journal of Strength and Conditioning Research* **29**, 1439-1450. <https://doi.org/10.1519/JSC.0000000000000756>
- Lloyd, R. S., Oliver, J. L., Faigenbaum, A. D., Howard, R., De Ste Croix, M. B. A., Williams, C. A., Best, T. M., Alvar, B. A., Micheli, L. J., Thomas, D. P., Hatfield, D. L., Cronin, J. B. and Myer, G. D. (2015b) Long-term athletic development, part 2: Barriers to success and potential solutions. *Journal of Strength and Conditioning Research* **29**, 1451-1464. <https://doi.org/10.1519/01.JSC.0000465424.75389.56>
- Lloyd, R. S., Oliver, J. L., Hughes, M. G. and Williams, C. A. (2012) The effects of 4 weeks of plyometric training on reactive strength index and leg stiffness in male youths. *Journal of Strength and Conditioning Research* **26**, 2812-2819. <https://doi.org/10.1519/JSC.0b013e318242d2ec>
- Maio Alves, J. M. V., Rebelo, A. N., Abrantes, C. and Sampaio, J. (2010) Short-term effects of complex and contrast training in soccer players' vertical jump, sprint, and agility abilities. *Journal of Strength and Conditioning Research* **24**, 936-941. <https://doi.org/10.1519/JSC.0b013e3181c7c5fd>
- Matos, N. F., Winsley, R. J. and Williams, C. A. (2011) Prevalence of nonfunctional overreaching/overtraining in young English athletes. *Medicine and Science in Sports and Exercise* **43**, 1287-1294. <https://doi.org/10.1249/MSS.0b013e318207f87b>
- McGuigan, M. R., Doyle, T. L. A., Newton, M., Edwards, D. J., Nimphius, S. and Newton, R. U. (2006) Eccentric utilization ratio: Effect of sport and phase of training. *Journal of Strength and Conditioning Research* **20**, 992-995. <https://doi.org/10.1519/R-19165.1>
- Meylan, C. and Malatesta, D. (2009) Effects of in-season plyometric training within soccer practice on explosive actions of young players. *Journal of Strength and Conditioning Research* **23**, 2605-2613. <https://doi.org/10.1519/JSC.0b013e3181b1f330>
- Mi, J. (2016) Problems and solutions of youth training in China. *Journal of Chengdu Sport University* **42**, 77-82.
- Myer, G. D., Sugimoto, D., Thomas, S. and Hewett, T. E. (2013) The influence of age on the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes. *American Journal of Sports Medicine* **41**, 203-215. <https://doi.org/10.1177/0363546512460637>
- Pareja-Blanco, F., Rodríguez-Rosell, D., Sánchez-Medina, L., Sanchis-Moysi, J., Dorado, C., Mora-Custodio, R., Yáñez-García, J. M., Morales-Alamo, D., Pérez-Suárez, I., Calbet, J. A. L. and González-Badillo, J. J. (2016) Effects of velocity loss during resistance training on athletic performance, strength gains and muscle adaptations. *Scandinavian Journal of Medicine and Science in Sports* **27**, 724-735. <https://doi.org/10.1111/sms.12678>
- Rhea, M. R., Alvar, B. A., Burkett, L. N. and Ball, S. D. (2003) A meta-analysis to determine the dose response for strength development. *Medicine and Science in Sports and Exercise* **35**, 456-464. <https://doi.org/10.1249/01.MSS.0000053727.63505.D4>
- Rhea, M. R., Ball, S. D., Phillips, W. T. and Burkett, L. N. (2002) A comparison of linear and daily undulating periodized programs with equated volume and intensity for strength. *Journal of Strength and Conditioning Research* **16**, 250-255. <https://doi.org/10.1519/00124278-200205000-00013>
- Santos, P. D. G., Vaz, J. R., Correia, J., Neto, T. and Pezarat-Correia, P. (2023) Long-term neurophysiological adaptations to strength training: A systematic review with cross-sectional studies. *Journal of Strength and Conditioning Research* **37**, 2091-2105. <https://doi.org/10.1519/JSC.0000000000004543>
- Schmarzo, M. and Dyke, M. V. (2017) *Isometrics for performance*. Van Dyke Strength.
- Selye, H. (1976) Stress without distress. *Bruxelles Medical* **56**, 205-210. https://doi.org/10.1007/978-1-4684-2238-2_9
- Stone, M. H., Stone, M. E. and Sands, W. A. (2007) *Principles and practice of resistance training*. Human Kinetics. <https://doi.org/10.5040/9781492596875>
- National Strength and Conditioning Association. (2021) *Essentials of strength training and conditioning*. Human Kinetics.
- Suchomel, T. J., Sole, C. J. and Stone, M. H. (2016) Comparison of methods that assess lower-body stretch-shortening cycle utilization. *Journal of Strength and Conditioning Research* **30**, 547-554. <https://doi.org/10.1519/JSC.0000000000001100>
- Thomas, K., French, D. and Hayes, P. R. (2009) The effect of two plyometric training techniques on muscular power and agility in youth soccer players. *Journal of Strength and Conditioning Research* **23**, 332-335. <https://doi.org/10.1519/JSC.0b013e318183a01a>
- Turner, A. (2011) The science and practice of periodization: A brief review. *Strength and Conditioning Journal* **33**, 34-46. <https://doi.org/10.1519/SSC.0b013e3182079cdf>
- Varghese, M., Ruparell, S. and LaBella, C. (2022) Youth athlete development models: A narrative review. *Sports Health* **14**, 20-29. <https://doi.org/10.1177/19417381211055396>
- Verkhoshansky, Y. V. (1986) Speed-strength preparation and development of strength endurance of athletes in various specializations.
- World Health Organization. (2023) Adolescent health. Retrieved from <https://www.who.int/health-topics/adolescent-health>
- Williams, T. D., Tolusso, D. V., Fedewa, M. V. and Esco, M. R. (2017) Comparison of periodized and non-periodized resistance training on maximal strength: A meta-analysis. *Sports Medicine* **47**, 2083-2100. <https://doi.org/10.1007/s40279-017-0734-y>
- Wong, P. L., Chamari, K. and Wisloff, U. (2010) Effects of 12-week on-field combined strength and power training on physical performance among U-14 young soccer players. *Journal of Strength and Conditioning Research* **24**, 644-652. <https://doi.org/10.1519/JSC.0b013e3181ad3349>

Key points

- This randomized controlled trial compared the effects of two periodized training approaches—the NASM-OPT model versus traditional periodization—on maximal lower-limb strength and explosive power in adolescent athletes. The study specifically addresses the current evidence gap regarding long-term macrocycle strength programming for this population.
- Forty-two youth athletes were randomly assigned to the NASM-OPT or control group. Both groups completed a 26-week intervention. Post-intervention, the OPT group demonstrated significantly greater improvements in squat 1RM, CMJ, PSAP, and EUR compared with the control group.
- Periodized NASM-OPT training effectively enhances lower-limb strength, explosive power, and stretch-shortening cycle (SSC) function in adolescent athletes, providing empirical evidence for optimizing adolescent strength training programs to improve athletic performance and minimize injury risk.

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