Traditional Periodization versus Optimum Training Load Applied to Soccer Players: Effects on Neuromuscular Abilities

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Abstract

It is unknown whether traditional periodization of strength-power training involving accumulation, transformation and realization blocks is superior to other simpler and more practical training schemes. The purpose of this study was thus to investigate changes in strength/power/speed characteristics of elite soccer players in response to either classic strength-power periodization (TSP) or optimum power load (OPL). 23 professional soccer players were randomly assigned to TSP or OPL for 6 weeks in-season regular training (3 times per week). TSP involved half squats or jump squats, depending on the respective training block, while OPL involved only jump squats at the optimum power load. Results revealed that both groups presented similar significant ($P<0.05$) improvements in squat one repetition maximum, squat and counter-movement jump heights and change of direction speed. In addition, although both groups reported significant increases in sprinting speed ($P<0.05$); delta change scores demonstrated a superior effect of OPL to improve 10- and 20-m speed. Similarly, OPL presented greater delta change in mean propulsive power in the jump squat. Therefore, training continuously at the optimum power zone resulted in superior performance improvements compared to training under classic strength-power periodization.

Introduction

Owing to the importance of neuromuscular capabilities in influencing specific performance in a wide range of individual and team sports, periodization models of strength and power training have been extensively investigated in the literature [8,20,21,46]. In this regard, the foundation of strength periodization lies in the traditional periodization model proposed by Stone, O’Bryant and Garhammer [45]. This model encompasses an initial “accumulation phase”, with emphasis on muscle hypertrophy followed by a “transformation phase”, with emphasis on maximal strength and, lastly, a “realization phase” (i.e., conversion from maximal strength to power) focusing on muscle power and explosive strength [36,38]. It is assumed that during the “realization phase”, the cumulative muscular adaptations resulting from the 2 previous phases will directly transfer to muscle power due to the volume reduction and load-intensity adjustment (i.e., light to moderate loads, with emphasis on muscle power) [15]. According to the traditional periodization concept, this “conjugated sequencing model” [2] allows for optimized manifestations of the gains obtained during the previous training phases, thus enhancing the subsequent speed-power related adaptations [38,47]. However, although some studies have provided evidence related to the superiority of traditional periodization when compared with a number of planned and unplanned training regimens [12,31,41], findings from other classic investigations appear to contradict the basis of this periodization strategy. For instance, significant decreases in speed/power-related motor tasks (e.g., sprints, agility and peak velocity in vertical jumps) have been reported after periods of heavy strength training, whereas a light-load regimen was capable of producing superior gains in sprinting and agility abilities [28,29]. Although the latter study did not investigate the specific effects of traditional periodization, its data somewhat challenges the role of the earlier accumulation and transformation phases in optimizing neuromuscular adaptations during the subsequent realization phase. In addition, in professional sports, the congested fixture/training schedule hampers the appropriate implementation of each respective
training phase, which calls for the development of novel and simpler training practices. This could enable coaches and sports scientists to properly improve the neuromuscular abilities of their athletes, even in short periods of preparation (usual pre-seasons/inter-seasons lasting from 3–6 weeks).

In this sense, we have shown that non-periodized training using the optimum load for power development (i.e., the load capable of maximizing the muscle power output) elicits similar strength, power and speed improvements to those observed after traditional periodization training in moderately trained participants [25]. In team sports athletes, however, considerably less information is available. In this regard, training at the optimum power zone (half-squats or jump-squats) was able to counteract power and speed decrements that commonly occur in soccer pre-seasons [23], when players are exposed to tactical and technical training, which may induce an interference/concurrent training effect [30, 32, 33]. Importantly, for training at this zone, the athletes only have to determine their “optimum range of loads” (i.e., the load capable of maximizing the muscle power output in a given exercise) [8], by measuring the bar velocities during the movements through the use of portable and cost-effective linear position transducers [9, 21, 23, 27]. Conversely, traditional strength periodization is based on different percentages of one-repetition maximum assessments (1-RMs) [4, 10, 40] and this measurement is not common in professional soccer training routines [23]. In fact, determining 1-RM values for large groups of individuals (i.e., soccer teams) is very time consuming, and it has been suggested that 1-RM testing may expose those being tested to increased risk of injury [3, 5]. Considering the congested fixture in professional sports, more research is warranted regarding the effects of this simpler and more applied training method (i.e., training at the optimum power zone) on high-level athletes during their in-season period (when training loads are reduced compared to the pre-season) [17].

Therefore, the aim of the present study was to compare (during the in-season period) the effects of 2 different strength and power training periodization protocols (i.e., traditional periodization vs. optimum power load) on linear speed, change-of-direction ability, muscle power, and maximum dynamic strength in a group composed of highly trained professional soccer players. Based on our experience with professional soccer teams during in-season phases, we hypothesized that both training regimens would ensue significant gains in both maximum dynamic strength and muscle power but the optimum-power-load regimen would induce greater gains in speed, jumping and agility.

**Methods**

**Participants**

The sample size (n = 5 per group) was determined previously by G*Power software (v.3.0.10), assuming α = 0.05 and β = 0.20, and based on a similar study performed with top-level soccer players [21], using sprinting speed as the main outcome. Hence, 23 professional outfield soccer players (9 midfielders, 8 defenders and 6 attackers) regularly competing in both state and national competitions were pair-matched using the maximum dynamic strength as the criterion and randomly allocated (by tossing a coin) into one of the 2 groups: traditional strength-power periodization (TSP: n = 12; age: 23.1 ± 3.2 years; height: 176 cm ± 6.8 cm, and weight: 75.1 ± 6.9 kg) and optimum power load (OPT: n = 11, age: 23.9 ± 4.4 years, height: 177 ± 5.8 cm, and weight: 75.4 ± 5.3 kg). All players had been engaged in regular soccer training for at least 10 years and competing at a professional level for at least 24 months. Additionally, all players had previous experience of regular strength training (i.e., classic resistance training, using moderate/heavy training loads) and, prior to and throughout the study, no musculoskeletal injuries limiting training participation were registered. Subjects were informed of the experimental risks and signed an informed consent form before taking part in the study. The investigation was approved by an institutional review board for the use of human subjects. The current investigation also adhered to standards of the International Journal of Sports Medicine described by Harriss and Atkinson [13].

**Experimental procedures**

To test the efficacy of OPL in comparison with TSP on neuromuscular adaptations in soccer players, we opted for a parallel-group randomized trial design. The groups were matched by maximum dynamic strength levels (1-RM squat) and were composed of similar numbers of players per player position. The intervention period lasted 6 weeks and took place during the inter-season intermission between the regional (State 1st division) and national (series C National championship) championships. No official matches were scheduled during the first 4 weeks of intervention while players engaged in one friendly match per week during the final 2 weeks of intervention. The typical weekly training program is shown in Table 1. Before the commencement and after the 6-week training period (3 sessions per week for a total of 18 training sessions), lower-limb maximum dynamic strength and power, vertical jump, sprint, and agility abilities were assessed.

**Training regimens**

The TSP training is outlined in Table 2. In brief, TSP encompassed the 3 classic phases as originally proposed with its “classic wave-like pattern” (Fig. 1): a) strength-endurance (1st phase); b) maximal-strength (2nd phase) and; c) power-strength (3rd phase) phases. Athletes performed half squats (1st and 2nd phases) or jump squats (JS) (3rd phase), according to the specific objective of each training block.

As maximum muscle power outputs are always achieved during ballistic exercises, the OPL group performed only jump squats at the optimum power load (6 sets of 6 repetitions) (Fig. 2). Optimum power load determination via assessment of bar-displace-
ment velocity has been previously described [23]. An additional practical advantage of this approach is that it does not require sequential one-repetition-maximum (1-RM) determination in order to properly control training loads. As aforementioned, in professional soccer, multiple in-season 1-RM assessments are considered unfeasible because they are time-consuming and complex, as well as anecdotally associated with an increased risk of injury.

To ensure proper training loads throughout the intervention and to adjust the training intensities according to the changes in the maximum dynamic strength performance (1-RM), players were retested at mid-point (between the 9th and 10th training sessions). Additionally, average training velocities between TSP and OPL were recorded every 3 sessions for training adjustments and further comparisons (via a linear encoder attached to the smith-machine bar).

Prior to each test, a general warm-up (submaximal running for 5 min) was followed by active lower-limb light stretching exercises (5 min) and specific warm-up exercises. Compliance to the training and testing procedures was 100 %.

Maximal dynamic strength (1-RM)
Initially, subjects ran for 5 min on a treadmill at 9 km · h\(^{-1}\), followed by 5 min of lower-limb stretching exercises. The athletes were instructed to execute a knee flexion until the thigh was parallel to the ground (~100° knee angle). Next, they performed 2 back-squat exercise warm-up sets (8 repetitions at 50% of the estimated 1-RM and 3 repetitions at 70% of the estimated 1-RM). A 3-min rest interval was given between sets [3]. 3 min after the warm-up, participants were allowed up to 5 attempts to achieve the squat 1-RM value. A 3-min interval was again given between attempts. Each repetition was performed from full extension up to the point at which the thighs were parallel to the ground. Strong verbal encouragement was provided during all attempts.

Vertical jump testing
Vertical jumping ability was assessed using both squat (SJ) and countermovement (CMJ) jumps. In the SJ, a static position with a 90° knee flexion angle was maintained for 2 s before every jump attempt. No preparatory movement was allowed and an experienced researcher visually checked for proper technique. In the CMJ, athletes were instructed to perform a downward movement followed by a complete extension of the lower limbs and were allowed to freely determine the amplitude of the countermovement in order to avoid changes in their jumping coordination pattern. All jumps were executed with the hands on the hips. 5 attempts interspersed by 15-s intervals were performed for each jump test. Jumps were performed on a contact platform.
(Smart Jump; Fusion Sport, Coopers Plains, Australia) with the obtained flight time (t) being used to estimate the height of the rise of the body's center of gravity (h) during the vertical jump (i.e., \( h = \frac{gt^2}{2} \), where \( g = 9.81 \text{ m/s}^2 \)). A given jump was considered valid for analysis if the take-off and landing positions were visually similar. The best attempt was used for data analysis purposes. Intraclass correlation coefficients (ICCs) were used to indicate the relationship within SJ and CMJ heights. The ICC was 0.97 for the SJ and 0.95 for the CMJ.

**Sprinting speed**

Prior to the execution of the speed tests, 4 pairs of photocells (Smart Speed, Fusion Equipment, ALIS) were positioned at distances of 0, 5, 10 and 20 m along the course. Soccer players sprinted twice, starting from a standing position 0.3-m behind the starting line. In order to avoid weather influences, all sprint tests were performed on an indoor running track. A 5-min rest interval was allowed between the 2 attempts and the fastest time was retained for the analyses.

**Zig-zag change of direction speed (COD speed test)**

The COD course consisted of four 5-m sections marked with cones set at 100° angles. The athletes were required to decelerate and accelerate as fast as possible without losing body stability. 2 maximal attempts were performed with a 5-min rest interval between attempts. Starting from a standing position with the front foot placed 0.3 m behind the first pair of photocells (i.e., starting line), the athletes ran and changed direction as quickly as possible until crossing the second pair of photocells placed 20 m from the starting line [19]. The fastest time out of the 2 attempts was retained for further analysis.

**Maximum mean propulsive power and mean propulsive power with a load corresponding to 40% of body mass in jump-squat exercise**

Mean propulsive power was assessed in the jump-squat exercise (MPPJS) performed on a Smith Machine (Hammer adapted Equipment, USA). The soccer players were instructed to execute 3 repetitions of the jump squat at maximal velocity for each load, starting at 40% of their body mass (BM). Athletes executed a knee flexion until their thigh was parallel to the ground (−100° knee angle) and, after the command, jumped as fast as possible without their shoulder losing contact with the bar. A load of 10% BM was gradually added in each set until a decrease in mean propulsive power was observed. A 5-min interval was provided between sets. To determine MPP, a previously validated linear position transducer [11] (T-Force, Dynamic Measurement System; Ergotests Consulting S.L., Murcia, Spain) was attached to the Smith machine bar. The bar position data were sampled at 1000 Hz using a computer. The finite differentiation technique was used to calculate bar velocity and acceleration, presenting an associated error of <0.25%, while displacement was accurate to ±0.5 mm [11]. Acceleration of the bar was multiplied by the bar mass, determining bar force. Power was calculated by multiplying bar force by bar velocity [27]. MPP in the JS exercise was calculated following the previously described method [22]. We considered the maximum MPP output obtained in all attempts and the higher value of MPP obtained using a load corresponding to 40% of body mass for data analysis purposes. The ICC value observed for MPP in the jump squat exercise was 0.94.

**Statistical analysis**

Data normality was assessed through visual inspection and the Shapiro-Wilk test. A mixed-model for repeated measures was conducted for SJ, CMJ, MPP, 20-m sprint, and COD speed assuming group (OPL and TPL) and time (pre and post) as the fixed factors and subjects as the random factor. In case of significant F-values, a Tukey adjustment was used for multiple comparison purposes. Significance level was set at \( P < 0.05 \). Unpaired t-tests were used to assess possible between-group differences in pre-to-post test changes in scores (delta change analysis calculated as follows: The statistical software SPSS, version 17.0, was used for data analysis. Additionally, the Cohen’s d effect size (ES) [6] was calculated as the mean difference between the baseline and follow-up values divided by the standard deviation of the baseline values. The magnitudes of the ES were interpreted using the thresholds proposed by Rhea [39] for highly trained subjects, as follows: <0.25, 0.25–0.50, 0.50–1, and >1 for trivial, small, moderate, and large, respectively.

**Results**

Mean propulsive bar training-velocity for TSP was (on average) 0.75 m·s⁻¹ throughout the training cycle. All relative TSP training velocities are detailed as follows: (for half squats) 60% 1-RM: 0.67 ± 0.038 m·s⁻¹; 70% 1-RM: 0.58 ± 0.034 m·s⁻¹; 80% 1-RM: 0.46 ± 0.024 m·s⁻¹; 90% 1-RM: 0.40 ± 0.021 m·s⁻¹; and (for jump squats) 30% 1-RM 1.2 ± 0.070 m·s⁻¹. The OPL group always executed jump squats at ~1.0 m·s⁻¹ (the mean propulsive bar-velocity capable of maximizing muscle power outputs in loaded jump squats).

Squat 1-RM was significantly increased in both groups after training (TSP: 8.1 ± 2.8%, 95% confidence interval (CI): 2.5–3.4, \( ES = 2.04, P < 0.0001 \); within-group comparisons). No interaction effect was observed (\( P = 0.99 \)) using the mixed-model for repeated measures. In addition, no differences were detected in delta change scores when comparing the 2 groups (\( P = 0.59 \)) ( Fig. 3 ).

**Fig. 3**

Squat 1-RM: TSP: 13.4 ± 4.7%, 95% CI: 7.86–18.77, \( ES = 2.04, P < 0.0001 \); OPL: 13.8 ± 4.2%, 95% CI: 8.17–19.21, \( ES = 2.03, P < 0.0001 \); within-group comparisons) and CMJ (TSP: 11.4 ± 4.3%, 95% IC: 6.49–17.99, \( ES = 1.41, P < 0.0001 \); OPL: 11.5 ± 4.0%, 95% IC: 4.06–19.04, \( ES = 1.53, P < 0.0001 \); within-group comparisons) were similarly improved in both groups when comparing PRE and POST values. Similarly to 1-RM data, no interaction effect was observed (Sj: \( P = 0.85 \); CMJ: \( P = 0.99 \)) and no differences were detected in delta change scores when comparing the 2 groups (\( P = 0.83; \) CMJ: \( P = 0.97 \)) ( Fig. 4 ).

**Fig. 5** depicts COD speed and 20-m sprint data. Regarding COD speed, within-group comparisons demonstrated similar and significant increases in TSP (6.6±1.8%, 95% IC: 4.39–8.50, \( ES = 2.4, P < 0.0001 \)) and OPL (6.8±2.6%, 95% CI: 3.53–10.00, \( ES = 1.6, P < 0.0001 \)). Neither an interaction effect (\( P = 0.98 \)) nor a between-group difference in delta scores (\( P = 0.83 \)) were observed. 20-m sprint test data analysis revealed that both groups improved speed from PRE to POST in all 3 distances, 5 m (TSP: 7.2±3.3%, 95% IC: 2.0–12.4, \( ES = 1.2, P < 0.0001 \); OPL: 8.0±2.1%, 95% IC: 1.1–15.0, \( ES = 1.1, P < 0.0001 \)), 10 m (TSP: 3.3±2.7%, 95% IC: −0.2–6.9, \( ES = 0.8, P = 0.0002 \); OPL: 7.1±1.5%, 95% IC: 3.9–10.3, \( ES = 2.1, P < 0.0001 \)), and 20 m (TSP: 2.3±2.4%, 95% IC: −1.8–6.8, \( ES = 0.5, P = 0.0013 \); OPL: 5.9±0.9%, 95% IC: 1.5–10.1, \( ES = 1.2, P < 0.0001 \)). Importantly, although no interaction...
Fig. 3 Maximum lower-limb dynamic strength (1-RM squat) for the optimal load and traditional load training groups. Panel a: Absolute values for squat 1-RM (kg) at baseline (PRE) and after the intervention (POST). * Indicates P<0.05 for within-group comparisons. Panel b: Relative change (%) in squat 1-RM.

Fig. 4 Squat jump and countermovement jump heights for the optimal load and traditional load training groups. Panel a: Absolute values for squat jump height (cm) at baseline (PRE) and after the intervention (POST); and relative change (%) in squat jump height. Panel b: Absolute values for countermovement jump height (cm) at baseline (PRE) and after the intervention (POST); and relative change (%) in countermovement jump height. * Indicates P<0.05 for within-group comparisons.

Fig. 5 Change of direction (COD) speed and 20-m sprint speed for the optimal load and traditional load training groups. Panel a: Absolute values for COD speed (m·s⁻¹) at baseline (PRE) and after the intervention (POST). * Indicates P<0.05 for within-group comparisons; and relative change (%) in COD speed. Panel b: Absolute values for 20-m sprint speed (m·s⁻¹) at baseline (PRE) and after the intervention (POST). * Indicates P<0.05 for within-group comparisons; and relative change (%) in 20-m sprint speed, * indicates P<0.05 for between-group comparisons.
effects were observed at any distance (all \(P>0.05\)), delta score analysis revealed greater increases in speed in OPL when compared with TSP at 10- and 20-m (\(P=0.0006\) and \(P=0.0001\), respectively).

MPP increased in TSP (8.3\(\pm\)4.4 %, 95 % IC: 2.86–13.89, ES=1.5, \(P<0.0001\)) and OPL (14.5\(\pm\)3.6 %, 95 % IC: 6.8–22.2, ES=1.7, \(P<0.0001\)) after the training period. However, despite no interaction effect (\(P=0.13\)), delta scores were significantly greater in OPL than TSP (\(P=0.001\)). Within-group analysis for MPP40 revealed a significant increase in OPL (13.0\(\pm\)3.5 %, 95 % IC: 2.8–23.2, ES=1.2, \(P<0.0001\)) but not in TSP (3.0\(\pm\)4.4 %, 95 % IC: –6.18–11.82, ES=0.25, \(P<0.10\)). No significant difference was found in the interaction effect (\(P=0.08\)), however, a significantly greater delta score was observed in OPL when compared with TSP (\(P<0.0001\)) (Fig. 6).

Discussion

This study compared the effects of 2 distinct training programs (i.e., traditional strength-power periodization [TSP] vs. optimum training load regimen [OPL]) on the neuromuscular abilities of elite soccer players. The main findings of this study were: 1) both groups presented similar significant improvements in maximum lower-limb dynamic strength (squat 1-RM), vertical jumping ability (SJ and CMJ), and COD speed; 2) although both groups showed significant increases in sprinting speed, delta change scores demonstrated a superior effect of OPL to improve speed at 10 and 20 m; 3) in spite of the significant increases in muscle power (in both groups), delta change analysis revealed that OPL presented a greater improvement in MPP scores and only OPL were able to significantly increase MPP40.

Both TSP and OPL were equally capable of increasing the maximum lower-limb dynamic strength assessed in squat 1-RM. In agreement, it was recently shown that training at the optimum power zone produced similar improvements in maximum strength to traditional strength training [25]. Additionally, SJs performed using heavy- or light-loads have been shown to produce comparable improvements in squat 1-RM [29]. It is important to emphasize that in both these investigations (as well as in the present study) subjects were instructed to move the bar (in squat and JS exercises) as quickly as possible, thus exerting as much force as possible in each and every repetition. Therefore, it appears that neither the temporal distribution of the training loads (from light- to heavy-loads) nor their absolute magnitude play a crucial role in increasing the maximal strength levels in elite team sport athletes with previous experience in strength training, at least when the exercises are performed as rapidly as possible. From a mechanical perspective, moving higher amounts of mass implies achieving lower rates of acceleration during the course of the movement [21]. Actually, it has already been reported that from 80 % 1-RM onwards, the concentric phase of a given movement is entirely propulsive (portion of the concentric phase during which the acceleration is greater than deceleration due to gravity [i.e., \(a \approx -9.81 \text{ m}\cdot\text{s}^{-2}\)] [43], resulting in a complete absence of a decelerating phase. The absence of deceleration only occurs because the resultant acceleration achieved throughout the whole movement is always very close to zero. Consequently, the force production using these high loads (i.e., \(>80\% \text{ 1-RM}\)) is almost exclusively dependent on the magnitude of the scalar variable of the force equation (i.e., mass). Conversely, when lifting light or moderate loads, the subject can attain higher rates of acceleration, increasing the contribution of this vectorial value in the total amount of applied force. Therefore, if athletes are always required to accelerate the load (i.e., mass) as fast as possible, even using light or moderate loads, they can apply considerable quantities of force. To some extent, these mechanical considerations may explain the similar gains in maximum strength obtained by both TSP and OPL. Nevertheless, it is important to note that these kinematic/kinetic differences are probably interconnected to the adaptations in the ability to produce greater amounts of force at higher velocities (i.e., muscle power) reported by the groups after the experimental period.

In fact, several studies have indicated that adaptations in muscle power (i.e., MPP and MPP40) are directly influenced by the parametric relationship that exists between force and velocity (i.e., the higher the force, the lower the velocity) [1,18,21]. Our data

![Fig. 6](image-url)

**Fig. 6** Maximum mean propulsive power (MPP) and mean propulsive power at 40 % body weight (MPP40) for the optimal load and traditional load training groups. Panel a: Absolute values for MPP (W) at baseline (PRE) and after the intervention (POST), * indicates \(P<0.05\) for within-group comparisons; and relative change (%) in MPP, * indicates \(P<0.05\) for between-group comparisons. Panel b: Absolute values for MPP40 (W) at baseline (PRE) and after the intervention (POST), * indicates \(P<0.05\) for within-group comparisons; and relative change (%) in MPP40, * indicates \(P<0.05\) for between-group comparisons.
are in consistent agreement with these findings, which can be confirmed by analyzing the specific training responses of each experimental group. Although both TSP and OPL presented significant enhancements in muscle power, delta change analysis revealed that OPL demonstrated greater improvements in MPS scores. More importantly, only OPL reported significant increases in the “light-load zone” (MPP40). Possibly, these superior adaptations in muscle power presented by OPL are directly related to the kinematic differences between training regimens. In this regard, while OPL constantly trained at \(-1 \text{ m·s}^{-1}\) [22], TSP executed their exercises at a mean propulsive bar-velocity averaging \(0.75 \text{ m·s}^{-1}\) throughout the training cycle. Therefore, it appears that the possibility of training at higher velocities allowed OPL to enhance its ability to apply greater amounts of force using light and moderate loads. Remarkably, as aforementioned, in spite of the difference between training velocities (and, consequently, training intensities), both TSP and OPL produced significant (and similar) increases in maximum dynamic strength. Taken together, these data indicate that OPL was capable of developing strength and power abilities at both ends of the force-velocity curve (i.e., high-force/low-velocity portion and high-velocity/low-force portion). Although these findings have been previously reported in moderately trained subjects [25], this is the first study to extend this knowledge to high-level athletes (i.e., elite soccer players).

Despite the effectiveness of both training regimens to significantly improve sprinting and COD speed, the comparative advantages reported by the OPL (at longer distances/higher speeds) reinforce the notion that this training mode may be superior to shift the entire force-velocity curve upward. In contrast to the similar increases in 5-m sprint, delta change analysis indicated that OPL presented larger enhancements than TSP in 10- and 20-m sprinting speed. It must be highlighted that, while improvements in sprinting capacity at very-short distances (i.e., 5m) have been commonly related to increases in maximum strength, the ability to sprint faster at longer distances seems to be directly affected by a number of neuromechanical factors, which necessarily require more specific neural (e.g., motoneuronal excitability and nerve conduction velocity) [7, 21, 42] and biomechanical (such as an increase in the ability to apply force vertically against the ground) adaptations [48]. Conceivably, jump squats executed at higher velocities (\(-1 \text{ m·s}^{-1}\)) [22] and under optimum load conditions (i.e., OPL) may have enhanced these specific “high-velocity adaptations” and, consequently, provoked greater gains in the sprinting capacity at longer distances/higher speeds. As a final point of comparison between the speed-related adaptations, the similar improvements in COD ability reported by the 2 groups are consistent with previous research, indicating that this capacity depends directly on the maximum acceleration rate attained by the subjects over very-short distances [16, 34]. Finally, the comparable increases in SJ and CMJ obtained by both TSP and OPL were probably driven by their comparable improvements in squat 1-RM. Importantly, the superiority of OPL in enhancing MPP and MPP40 was not capable of inducing greater adaptations in SJ and CMJ, suggesting that these motor-tasks are not primarily influenced by muscle power (at least when similar gains in 1-RM are observed). Indeed, several studies have identified strong correlations between vertical jumping ability and lower-limb dynamic strength measurements in top-level athletes [35, 44, 49]. Accordingly, maximum strength gains were accompanied by significant increases in vertical jump height after periods of strength-power training under different loading schemes [24–26]. Therefore, it appears that training methods similarly able to improve leg strength qualities in elite athletes are also equally effective at transferring these positive adaptations to vertical jumping ability.

In summary, our data suggest that a “strength foundation phase” [14] seems not to be capable of optimizing specific neuromechanical adaptations (i.e., muscle power), which theoretically should occur in subsequent training phases of a traditional periodization regimen of strength-power training. Analyzing the training outcomes by both TSP and OPL, it seems plausible to challenge the assertion that the accumulation phase found in traditional periodization is able to elicit the transference of maximum strength capacity to the ability to produce force at higher velocities. Actually, the inferior adaptations provided by the traditional periodization regimen brings into question the effectiveness of the speculative “delayed training effects” [37, 50] in boosting neuromuscular responses in soccer players with previous experience in strength training. In effect, the greater gains in muscle power reported by OPL suggest that the accumulation phase performed by TSP may have potentially reduced the increases in MPP and MPP40, possibly due to specific velocity-related neuromuscular adaptations [21, 29].

To conclude, the findings from the present study do not sustain the prevalent idea that maximum strength and muscle power gains must be “compartmentalized” throughout the different phases of the athletes’ general and specific preparation. Even considering that the short period of time (i.e., 6 weeks) used in this study could limit the specific neuromuscular responses provided by the training modes, the findings presented herein might be relevant to coaches and sport scientists, since the restricted time of preparation is a common place in high-level sports with congested calendars. Certainly, the findings reported herein should not be extrapolated to different populations under different training regimens. However, at least for a group composed of strength-trained elite soccer players during their in-season conditioning period, training continuously at the optimum power zone (for a duration of 6-weeks) produces superior performance improvements compared to training under classic strength-power periodization.

**Conclusion**

The current study challenges the concept of classic strength-power training periodization in highly-trained athletes, as compartmentalization of maximum strength and muscle power training was not essential (or superior when compared with OPL) for increasing specific speed-power related abilities in elite soccer players with previous experience in strength-training. Henceforth, there is a clear necessity to create more applied, time-saving, and effective methods for training professional athletes competing under congested fixture schedules. From a practical standpoint, training under optimum load conditions seems to be an efficient alternative for developing specific neuromuscular abilities in elite soccer players during in-season periods. Undoubtedly, it is critical to test the effectiveness of this training regimen (i.e., OPL) in highly-strength-trained subjects (i.e., sprinters and long-distance jumpers) and for longer periods of time (i.e., throughout a year-long periodization cycle). Furthermore, this study is limited by the absence of intermediate assessments (i.e., tests at the end of each different training phase in
To check the variation in maximum muscle strength and its possible transference to speed-power related variables in each specific phase/block of the training period (i.e., whole training cycle). Further studies are necessary to fully describe and compare the specific neuromuscular adaptations provided by both these training regimens.

**Conflict of interest:** The Authors have no conflict of interest to declare.

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