

Effects of a structured training program on maximal strength levels in amateur powerlifters

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Abstract

Background and Study Aim: Strength-oriented competition requires precise load management and adaptive programming to optimize neuromuscular performance. Although structured planning models are widely recommended, evidence focusing on non-elite practitioners remains limited. This study investigated the effects of an eight-week systematically organized intervention on one-repetition maximum (1RM) performance in recreational male lifters, hypothesizing that a combined strategy of variable load distribution and perceptual intensity adjustment would significantly enhance force production. **Materials and Methods:** Twenty male participants (17–33 years; 1–4 years of experience) completed pre- and post-intervention 1RM assessments in squat, bench press, and deadlift. The intervention consisted of four weekly sessions integrating alternating volume–intensity schemes and daily load modulation through the Rate of Perceived Exertion (RPE). Complementary exercises targeting posterior chain development, joint mobility, and core stabilization were systematically included. Data normality was verified using the Shapiro–Wilk test. Paired-sample t-tests ($\alpha = 0.01$) and Cohen’s d effect sizes were calculated to determine statistical and practical significance. **Results:** Significant improvements were observed in all lifts ($p < .001$). Mean increases were +2.0 kg in squat, +1.68 kg in bench press, and +2.5 kg in deadlift. Effect sizes ranged from 0.894 to 1.842, indicating moderate to very large practical effects, with the greatest magnitude observed in the deadlift. **Conclusion:** The findings indicate that short-term, systematically organized resistance training incorporating daily readiness monitoring can produce meaningful improvements in maximal force expression among recreational lifters. Neural adaptations and improved technical efficiency likely contributed to performance gains. These results support the integration of variable intensity models and subjective load autoregulation to enhance training responsiveness and sustainability in non-elite populations.

Key Words: neuromuscular adaptation; one-repetition maximum; load management; training responsiveness; strength development; recreational athletes

Introduction

Powerlifting is a maximal strength discipline based on the technical and coordinated execution of three fundamental lifts: the squat, bench press, and deadlift (Hernández Ugalde, 2022). Over the last two decades, this discipline has experienced exponential growth, both at the competitive level and among amateur practitioners, driven by the spread of raw powerlifting, the increasing interest in resistance training, and the visibility offered by social media (D’Isanto et al., 2022a; Altavilla et al., 2018). This expansion has led to a substantial rise in scientific output, with studies investigating biomechanical, neuromuscular, preventive, psychological, and methodological aspects of strength training (Ceruso et al., 2019a). However, despite this growth in participation and research, a substantial gap persists between theoretical training models and their practical application in amateur populations. Most experimental studies focus on elite or highly trained athletes, whose physiological characteristics, adaptive potential, and recovery capacities differ markedly from those of recreational lifters (Di Domenico et al., 2022; Esposito & Raiola, 2020).

Consequently, the current level of knowledge does not fully clarify whether programming principles validated in elite contexts are equally effective in amateur settings. This limitation generates uncertainty for coaches and practitioners who seek evidence-based guidelines tailored to non-elite athletes. Despite the common perception that lifting heavy loads may constitute a potentially risky activity, the literature has shown that powerlifting does not present a higher injury rate than other sports (Esposito et al., 2024a, 2024b). On the contrary, when appropriately programmed, it proves safer than sports involving physical contact or unpredictable movements (Esposito et al., 2024c; Esposito et al., 2025a). This safety is attributable not only to the controlled nature of the lifts but also, and especially, to the quality of training planning and to the proper progression of loads (D’Elia et al., 2021a; Huebner & Perperoglou, 2019). In this regard, powerlifting offers a privileged

context for studying neuromuscular adaptation, as performance results from a combination of technical, physiological, and perceptual factors that interact in a complex manner. The central factor determining maximal strength improvement is not merely the magnitude of the load lifted, but rather the way in which that load is distributed over time (Ceruso et al., 2019b). Programming, understood as the rational and periodized organization of volume, intensity, and frequency, represents the structural foundation of powerlifting training (Huebner & Perperoglou, 2019).

Research was therefore needed to investigate how structured programming models operate specifically within amateur populations, who represent the majority of individuals practicing resistance training worldwide. Amateur lifters frequently experience variability in sleep quality, occupational stress, nutritional consistency, and recovery routines (Altavilla et al., 2022; D'Elia et al., 2022). These contextual factors may significantly influence training responsiveness and adaptation, making it necessary to evaluate programming strategies under ecologically valid conditions. Periodization makes it possible to modulate training stimuli according to the different phases of preparation, preventing chronic overload, optimizing recovery processes, and fostering progressive adaptations. Various models of periodization, such as linear, undulating, and block periodization, have been proposed in scientific literature, each with specific characteristics and advantages (Ceruso et al., 2019b). Among these, undulating periodization has demonstrated particular effectiveness for non-professional powerlifters due to its flexibility in managing intensity and volume and its ability to prevent stimulus accommodation (Di Domenico et al., 2023a).

In parallel, autoregulation has gained increasing relevance in strength training methodology in recent years (Esposito et al., 2020; Esposito et al., 2025b). The use of the Rate of Perceived Exertion (RPE) and Repetitions in Reserve (RIR) allows for daily load modulation according to the athlete's readiness, compensating for physiological and psychological fluctuations that characterize day-to-day training (D'Elia et al., 2021b). This is particularly beneficial for amateur powerlifters, who often present greater variability in recovery, personal commitments, and stress, factors that significantly influence performance (van den Hoek et al., 2024). Nevertheless, while both undulating periodization and autoregulatory strategies are independently supported by scientific evidence, there is limited research examining their combined short-term implementation within a controlled experimental design focused specifically on amateur lifters. The absence of such data limits the ability to determine whether integrating variable load distribution with perceptual intensity adjustment can produce statistically significant and practically meaningful improvements in maximal strength over a relatively short training cycle. Alongside programming and autoregulation, another key factor for both performance and athlete safety is movement quality.

The three powerlifting lifts require high technical control, adequate joint mobility, and appropriate muscular balance across body segments (D'Elia et al., 2024). Mobility deficits in the hips, ankles, or thoracic spine, as well as insufficient stability of the core or scapular girdle, may lead to compensations during lift execution, increasing the risk of overuse injuries and limiting strength potential. An effective training program must therefore integrate complementary exercises for strengthening, mobility, and motor control as structural components of preparation and not as marginal additions (Latella et al., 2024). Within this context, the experimental analysis of the effects of specific training protocols on amateur powerlifters is particularly relevant (Raiola et al., 2025). Most existing studies focus on advanced or competitive populations, whereas research involving early-stage or non-competitive practitioners is significantly more limited, even though they represent the majority of individuals approaching powerlifting. Investigating the physiological and technical responses of these subjects provides a broader understanding of how strength adaptations manifest in the early stages of development and how programming can be optimized according to the specific needs of the practitioner (Raiola & Di Tore, 2012).

Purpose

Based on these considerations, the present study aims to analyze the effects of eight weeks of periodized training on a group of amateur powerlifters by evaluating pre-intervention and post-intervention changes in maximal strength levels. The choice of a relatively short intervention period is supported by evidence showing that, in individuals with moderate experience, neural adaptations represent the predominant component of initial improvements, making it possible to observe significant changes even within time frames shorter than three months. The study seeks to contribute empirical evidence clarifying whether structured, autoregulated load organization can effectively enhance maximal strength in amateur powerlifters, while also offering practical implications for coaches and practitioners operating in real-world training environments.

Material & methods

Study Participants

The study sample consisted of 20 male athletes aged between 17 and 33 years, all practicing raw powerlifting and with barbell training experience ranging from one to four years. This composition accurately reflects the profile of the average amateur practitioner, who has already developed sufficient technical competence to perform the three fundamental lifts safely, yet remains in a developmental phase regarding neuromuscular capacities and motor control. All athletes were registered with the same sports center and had

been following a structured training program for at least six months. The study was conducted between September and November 2025 at a certified strength training facility in Naples, Italy. All testing and training sessions were performed in the same facility, using the same equipment and under standardized environmental conditions. Before the start of the study, participants completed an anamnesis questionnaire to verify the absence of medical contraindications and to identify any previous musculoskeletal issues. None of the subjects presented acute injuries or clinical conditions that could interfere with their participation in the study. Athletes who had reported minor injuries in the preceding months were still included, since such conditions did not affect their ability to perform the tests or follow the established protocol and are typical of the population under consideration. Inclusion criteria were: male sex; age between 17 and 35 years; minimum of one year of continuous barbell training experience; ability to correctly perform squat, bench press, and deadlift according to International Powerlifting Federation standards; absence of acute injury at the time of enrollment. Exclusion criteria included: recent surgery (< 6 months), cardiovascular or neurological conditions contraindicating maximal exertion, and inability to complete at least 90% of the scheduled training sessions.

The anthropometric characteristics, baseline strength values, and level of sporting experience highlighted a heterogeneous but methodologically representative group of amateur athletes. Morphological differences, varied performance levels, and variability in motor background realistically reflect the training environment of non-competitive powerlifting. This aspect, far from being a limitation, is functionally relevant to the study because it allows for the examination of the protocol's effectiveness across subjects with different profiles, thereby increasing the generalizability of the results. Before the intervention began, all athletes were informed about the aims of the research, the structure of the program, and the monitoring procedures, and voluntary informed consent was obtained. All subjects gave their informed consent for inclusion before participating in the study. The present study is part of the research project entitled "Psychophysical perception and body awareness in school and sports contexts through observational and non-invasive tools", approved by the Ethics Committee of Pegaso University (Prot./E 004726, dated 15/07/2025).

Study Design

The study employed a pre-post experimental design, in which the maximal strength values collected before and after the intervention served as the comparative basis for evaluating the effects of the training program. Each athlete acted as his own internal control, which reduced the influence of interindividual variables that could have affected the interpretation of the results, such as age, body morphology, technical ability, or previous training history. Maximal strength values were collected at two distinct time points. The initial assessment represented the baseline condition from which the effects of training could be observed, while the final assessment, conducted at the end of the eight-week program, allowed for the determination of training-induced changes. Baseline testing was performed during Week 0, and post-intervention testing was conducted within seven days after completion of Week 8, maintaining identical testing procedures. To ensure the most stable conditions possible, athletes were asked to maintain an unchanged lifestyle, including nutrition, sleep duration, and weekly recovery routines.

This helped to limit the influence of external factors not directly attributable to the training program. The entire process was carried out under controlled conditions, with supervision from qualified coaches and continuous monitoring of lift execution quality. The decision not to include a control group was based on the need to evaluate the real response of athletes in a naturalistic context, keeping training loads as similar as possible to their habitual practice. This condition was essential for ensuring adherence to the program and the quality of execution. All training sessions were supervised by certified strength and conditioning coaches to ensure technical consistency and standardized load progression. Attendance was recorded, and adherence to the protocol was monitored throughout the intervention period.

Training Protocol

The training protocol was carried out over an eight-week period and integrated the main principles of strength training methodology, with reference to undulating periodization, autoregulation, and complementary work aimed at injury prevention and movement quality (Raiola, 2015; Ceruso et al., 2024). The athletes trained four times per week, alternating sessions oriented toward volume with sessions oriented toward intensity, in order to achieve systematic progression of the training stimulus. During the first four weeks, the priority was the development of work capacity and technical consolidation. Loads were adjusted to maintain a moderate intensity, compatible with high movement quality, while the number of repetitions allowed for sufficient volume to stimulate the desired technical and muscular adaptations.

During this phase, intensity ranged approximately between 65–80% of the estimated 1RM, with repetition ranges between 5 and 8 per set. The following weeks were dedicated to the progressive intensification of loads, with a gradual approach to the level's characteristic of the 1RM test. The objective was to enhance neural adaptations through higher loads while maintaining strict control of fatigue. In the intensification phase (Weeks 5–8), intensity ranged approximately between 75–92% of estimated 1RM, with repetition ranges between 2 and 5 per set, and rest intervals between 3 and 5 minutes for main lifts. Autoregulation through the

RPE scale was a central element of the protocol. It enabled daily adjustment of training intensity according to the athlete's readiness, assessed on the basis of subjective perception of effort. The Borg CR-10 adapted RPE scale was used, and load adjustments of 2.5–5 kg were made when the perceived exertion deviated from the target range (Raiola et al., 2020; Sannicandro et al., 2024a, 2024b). Alongside the specific work on the three lifts, the program included complementary exercises targeting core stabilization, improvement of joint mobility, and compensation of eventual asymmetries. These exercises played a crucial role in supporting technical efficiency, reducing compensatory patterns, and ensuring optimal distribution of mechanical stress. Complementary training included activities aimed at strengthening the posterior chain, developing scapular control, and maintaining mobility of the hips, ankles, and thoracic spine, which are areas particularly prone to limitations among strength sport practitioners.

Assessment tests

Maximal strength was assessed through 1RM testing in the squat, bench press, and deadlift. All tests were conducted according to the execution criteria established by the International Powerlifting Federation, without any variation in the way validity and correctness of the movement were evaluated.

Testing was performed using Olympic barbells (20 kg) and calibrated weight plates, and all loads were recorded to the nearest 0.5 kg. To reduce the influence of residual fatigue, the tests were distributed over two consecutive days. On the first day, squat and bench press were performed, while on the second day the deadlift test was completed. Each evaluation session included a general warm-up focused on joint mobility and activation of the main muscle groups involved, followed by a specific warm-up composed of progressive sets with controlled load increases. Specific warm-up sets consisted of approximately 8 repetitions at 50% estimated 1RM, 5 repetitions at 60%, 3 repetitions at 75%, and 1–2 repetitions at 85%, followed by progressive single attempts with 2.5–10 kg increments until the maximal valid lift was achieved.

Rest intervals between maximal attempts ranged from 3 to 5 minutes. Attempts were performed with gradual increments until the valid maximal load was identified. Standardization of the procedure ensured the reliability of the collected data and the comparability of measurements between the two assessments. The highest successfully completed lift was recorded as the 1RM value and used for subsequent statistical analysis.

Statistical Analysis

For each lift, mean values and standard deviations were calculated for both testing phases, along with the percentage increase recorded by each athlete. Individual absolute differences (Post – Pre) were calculated for each participant before computing group statistics. Before carrying out inferential tests, the distribution of the differences (post–pre) was examined using the Shapiro-Wilk normality test. A paired-sample t-test was then applied, with the significance level set at 0.01, in order to determine whether the observed variations could plausibly be attributed to the training program.

This analysis provided a clear overview of the protocol's effectiveness, considering the natural variability of the sample and individual responses to training. In addition to statistical significance, effect sizes were calculated using Cohen's *d* with the corresponding 95 percent confidence interval, in order to estimate the practical relevance of the changes independently of test significance. Statistical analyses were performed using JASP software, version 0.95.4.0.

Results

The means and standard deviations (SD) of the 1RM values for the squat, bench press, deadlift, and total are reported in Table 1. All results derive from the recorded one-repetition maximum (1RM) values obtained during standardized pre-intervention (Week 0) and post-intervention (Week 9) testing sessions. Group statistics were calculated from individual raw data (*n* = 20 participants).

Table 1. Mean values ($\pm$ SD) of 1RM pre and post intervention (kg).

	Squat Pre	Squat Post	Bench Press Pre	Bench Press Post	Deadlift Pre	Deadlift Post
Mean	145.6	147.6	87.70	89.38	169.0	171.5
SD	43.70	44.61	31.92	31.38	46.36	45.87
Minimum	80.00	82.00	42.00	43.00	100.0	105.0
Maximum	230.0	241.0	150.0	150.9	260.0	261.0

After verifying the normality of the distribution of differences (post-pre) for each variable using the Shapiro-Wilk test, a paired t-test was applied to compare strength values before and after the intervention. The results of the statistical comparison are shown in Table 2. The Shapiro-Wilk test confirmed normal distribution of the difference scores for squat ($p > .05$), bench press ($p > .05$), and deadlift ($p > .05$), allowing the use of parametric testing.

Table 2. Pre-post statistical comparison.

Measure 1	Measure 2	t	df	p	Cohen's d	SE Cohen's d	95% CI for Cohen's d	
							Lower	Upper
Squat Pre	- Squat Post	-3.999	19	< .001	-0.894	0.012	-1.407	-0.364
Bench Press Pre	- Bench Press Post	-5.395	19	< .001	-1.206	0.012	-1.778	-0.617
Deadlift Pre	- Deadlift Post	-8.238	19	< .001	-1.842	0.010	-2.561	-1.105

Note. Student's t-test.

The paired-sample t-test revealed statistically significant differences between pre- and post-intervention values for all three lifts ($p < .001$). The paired-sample t-test revealed statistically significant differences between pre- and post-intervention values for all three lifts ($p < .001$).

Figures 1–3 graphically represent individual pre- and post-intervention 1RM values and corresponding group means, illustrating the direction and magnitude of change for each exercise.

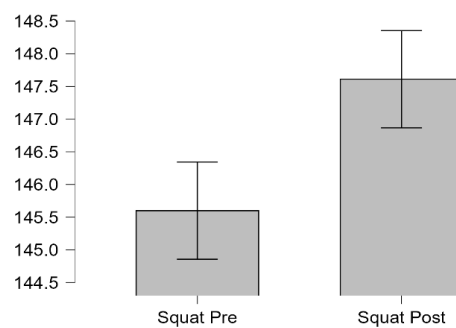


Fig. 1. Squat Pre - Squat Post

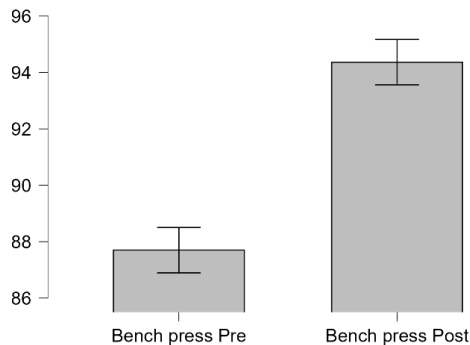


Fig.2. Bench press pre - Bench Press pre post

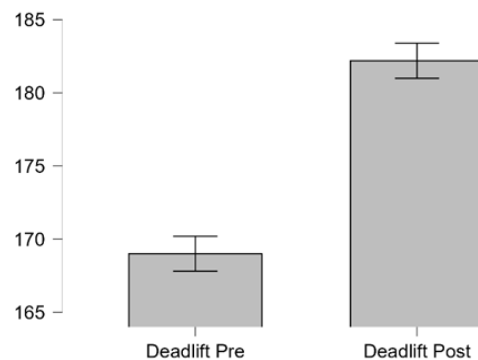


Fig.3. Deadlift pre - Deadlift post

Discussion

The present study showed that an eight-week structured program based on undulating periodization and load autoregulation is capable of producing significant increases in maximal strength in a group of amateur powerlifters. These findings directly address the original objective of the study, which was to determine whether a short-term, systematically organized intervention integrating undulating load distribution and autoregulatory strategies could produce measurable improvements in maximal strength in non-elite athletes. The results confirm the initial hypothesis advanced in the Introduction, namely that combining structured variation of volume and intensity with perceptual load adjustment would enhance strength performance even within a relatively brief intervention period. The improvements observed in the squat, bench press, and deadlift are consistent with the literature, which indicates that individuals with moderate training experience can quickly benefit from the neural and coordinative adaptations induced by exposure to progressive loading.

In relation to recent reviews on strength development and periodization models (D'Elia et al., 2020; 2023), the present findings support the growing consensus that flexible programming strategies may be particularly advantageous for intermediate-level athletes, whose adaptation potential remains high, but whose recovery capacity may fluctuate due to non-training stressors. Unlike highly controlled elite environments, amateur settings require adaptable solutions capable of maintaining stimulus quality while preventing excessive fatigue accumulation. The large effect size observed in the deadlift may be attributed to two possible factors. On one hand, this lift involves a less complex technical component compared to the squat and relies more heavily on the ability to express pure force, elements that may facilitate more rapid improvements. On the other hand, the complementary work targeting the posterior kinetic chain may have substantially contributed to stability and force-generating capacity in the muscle groups involved (Sanseviero et al., 2019). As shown in Tables 1 and 2 and illustrated in Figures 1–3, performance improvements were consistent across participants, with effect sizes indicating meaningful practical relevance.

The graphical representation of pre–post changes demonstrates a uniform upward shift in individual values rather than isolated extreme responses, suggesting that the intervention effect was systematic rather than incidental. The role of autoregulation, introduced through the RPE scale, appears to have supported an effective adaptation to the training stimulus, allowing athletes to modulate daily loads based on their readiness and to avoid unplanned fatigue accumulation. This aspect is particularly relevant for amateur powerlifters, whose recovery levels may vary due to external commitments, irregular daily routines, and stressors unrelated to training (D'Isanto et al., 2022b, 2022c; D'Isanto et al., 2017). A significant and original contribution of this study lies in the integrated application of undulating periodization and RPE-based autoregulation within a controlled yet ecologically valid amateur context.

While previous research has examined these strategies independently (D'Isanto et al., 2022d), fewer investigations have empirically tested their combined short-term effectiveness in recreational strength athletes. Therefore, even though the direction of the results aligns with established theoretical principles, the contextual validation provided here contributes practical evidence supporting their real-world applicability. Despite the positive outcomes, the present study has some methodological limitations. First, the absence of a control group limits the ability to attribute the observed improvements exclusively to the training program, although the pre–post design and standardized conditions help mitigate this risk. Second, the sample, although representative of amateur powerlifters, consists of a relatively small number of participants. A larger sample size would have allowed more in-depth analyses of interindividual variability and differences related to training experience. Another limitation concerns the duration of the intervention.

Eight weeks are sufficient to observe neural and technical adaptations but do not allow for a comprehensive assessment of long-term morpho-functional adaptations. Nevertheless, within these constraints, the consistency of statistical significance, effect magnitude, and direction of change strengthens the internal validity of the findings. Future studies could expand the sample by including athletes of different levels and comparing responses among novices, intermediate practitioners, and advanced lifters. It would also be beneficial to introduce control groups following alternative programming models, such as linear or block periodization, in order to determine more precisely the comparative effectiveness of different load-organization strategies. Another research avenue involves integrating additional measures beyond the 1RM test, such as neuromuscular variables (lifting velocity, daily readiness via jump testing, heart rate variability) or biomechanical parameters of the lifts (Di Domenico et al., 2023b; Di Domenico et al., 2024). These tools would allow for a deeper understanding of the mechanisms underlying adaptation and help identify which components of the program contribute most to the observed improvements. Finally, evaluating longer-term interventions, including multiple preparatory cycles, would allow researchers to analyze the evolution of adaptations and their long-term stability, a particularly relevant aspect in real-world powerlifting practice. From a practical standpoint, coaches working with amateur strength athletes may consider implementing structured load variation combined with daily perceptual monitoring as a sustainable strategy to optimize performance. The results suggest that even in non-elite contexts, systematic planning rather than random load progression is a key determinant of measurable improvement.

Conclusions

The present study demonstrated that a structured training program based on undulating periodization and autoregulation can produce significant improvements in maximal strength among amateur powerlifters, even within a relatively short time frame. Beyond confirming statistical significance, the findings provide practical and theoretical contributions to the field of strength training methodology. First, the study substantiates the applicability of variable load organization in recreational contexts, demonstrating that carefully structured alternation of volume and intensity can enhance neuromuscular performance without requiring long intervention periods. Second, the integration of RPE-based autoregulation highlights the importance of individualized daily load adjustment in populations characterized by fluctuating recovery capacity. The most important takeaway from this research is that strength development in amateur athletes does not depend solely on increasing load magnitude, but rather on the strategic distribution of training stress combined with continuous monitoring of perceived exertion. This integrated approach represents a credible and applicable solution capable of improving performance while maintaining sustainability and reducing unnecessary fatigue accumulation. From a theoretical perspective, the study contributes to the body of knowledge by providing empirical evidence supporting the combined implementation of undulating programming and autoregulatory principles in non-elite strength athletes. From a practical perspective, the findings offer coaches and practitioners an efficient and replicable framework that can be adapted to real-world training environments.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors didn't use of AI in the writing of the article.

Conflicts of interest The authors declare no conflicts of interest.

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