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Optimizing Powerlifting Bench Press Technique Using Contextual Interference via Antagonist Task Selection

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Featured Application

Integrating contextual interference strategies, such as alternating primary tasks with antagonist overload exercises, offers a practical method within resistance training programs to optimize motor skill acquisition. For example, in the bench press exercise, powerlifters and coaches can directly apply this approach to enhance the overall technical execution of the bench press, while fully maintaining maximal strength gains throughout the training cycle.

Abstract

Background: Contextual interference (CI), defined as interleaved practice, improves motor skill learning in powerlifters. However, previous protocols lacked ecological validity. This study evaluated an alternative, highly specific CI exercise (the seal row) to provide a more practical approach for powerlifting routines. *Methods:* Fifteen powerlifters (10 males and 5 females, age: 23 ± 2 years, 1RM: 78 ± 32 kg) were randomized in high CI group (HCI) and low CI group (LCI) undergoing a 6-week training intervention. Powerlifters were tested on their bench press exercise strength and technical execution. Technical execution was assessed using a 13-item Likert scale. *Results:* Strength significantly increased in both groups ($F(3.42, 46.5) = 9.553$, $p < 0.05$). Global technique analysis showed a group × time interaction ($F(4,952) = 2.547$, $p = 0.038$, pes = 0.01). A significant group × time interaction occurred for scapular adduction ($F(2.98, 38.76) = 4.118$, $p = 0.013$), with the HCI group showing greater improvement. *Conclusions:* Alternating a primary task (bench press) with antagonist overloads (seal row) improves technical execution over six weeks without hindering strength gains. These findings support practical CI strategies in resistance training to optimize skill acquisition.

Keywords: random practice; powerlifting; strength training; motor skill pattern

1. Introduction

The introduction should briefly place the study in a broad context and highlight why it is important. It should define the purpose of the work and its significance. The current state of the research field should be carefully reviewed and key publications cited. Please highlight controversial and diverging hypotheses when necessary. Finally, briefly mention the main aim of the work and highlight the principal conclusions. As far as possible, please keep the introduction comprehensible to scientists outside your particular field of research. References should be numbered in order of appearance and indicated by a numeral or numerals in square brackets—e.g., [1] or [2,3], or [4–6]. See the end of the document for further details on references. Practice organization refers to the structured arrangement of exercises within one or more training sessions. This encompasses the execution of multiple motor programs as well as variations in the performance of a single motor skill [1]. In the realm of motor skill acquisition and sports training, practice organization is pivotal for the

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development and refinement of technical motor skills [1]. A particularly significant concept in this field is contextual interference (CI), a cognitive and motor phenomenon that describes the impact of variability in the sequencing of exercises during motor skill acquisition. Specifically, CI refers to the difficulty level induced by alternating different motor tasks within the same training session [2–4]. Contextual interference arises primarily through two forms of practice organization: blocked practice, where a specific skill is repeated multiple times before moving on to the next, and random practice, which involves performing different exercises in either a predetermined or unpredictable sequence. While blocked practice can facilitate the initial learning phases through constant repetition, random practice (characterized by a high degree of CI) enhances adaptability and skill retention, ultimately improving the transfer of acquired competencies to competitive environments [3,5,6]. Several studies have shown that increasing CI, although initially more challenging for the athlete, leads to more effective and long-lasting learning [2–4,7]. This is attributed to the engagement of more complex cognitive processes during random practice, resulting in improved adaptability to the dynamic conditions of competition [7]. Research across various sports has demonstrated that practice variability and its organization can enhance long-term learning when CI is promoted [3,7]. However, this effect has not always been consistently confirmed through experimental research [8]. [5] investigated the effect of CI in powerlifting, specifically focusing on the bench press exercise. Powerlifting is a strength discipline where execution technique, alongside conditional capacities, plays a crucial role. The learning-teaching process is fundamental for developing proper lifting techniques, and current theoretical knowledge suggests various organizational strategies for training sessions and cycles to optimize skill acquisition [3]. To our knowledge, this remains the only study on CI in powerlifting. The researchers found that participants in the high-CI group showed significantly greater improvements in both one-repetition maximum (1RM) strength and execution technique compared to those in the low-CI group. Notably, participants engaged in dart throwing to induce CI. Although this finding supports the role of CI in learning execution techniques in powerlifting, its practical applicability remains limited [8].

Resistance training is characterized by a high degree of flexibility in combining training session elements, such as exercise sequence, number of repetitions and sets, and execution speed. Some training modalities specifically incorporate the alternation of antagonist muscle groups between sets [9]. This approach is often used to enhance recovery between sets by applying a lower load on the antagonist muscle group than on the primary muscle being trained, based on the premise that this may activate reciprocal inhibition reflexes. Based on this theoretical foundation, we decided to address the applicability issue raised by [5], by inducing CI with a specific antagonist exercise. We used the seal row to enhance recovery by working on the antagonist muscle, thereby inducing CI simultaneously. The seal row exercise was selected due to its specific execution technique, which is specular to the bench press and emphasizes scapular adduction, a crucial element of the pushing movement pattern.

Transitioning between different tasks induces a condition of high CI, which could positively impact the acquisition of technical motor skills. Therefore, the aim of the current study was to compare a low-contextual-interference group (LCI) and a high-contextual-interference group (HCI) participating in a six-week powerlifting training program. Contextual interference was introduced by incorporating the seal row exercise between sets of bench presses, engaging antagonist muscles. We hypothesized that the HCI group would achieve greater improvements in technique retention compared to the LCI group.

2. Materials and Methods

2.1. Participants

A priori sample size calculation based on 1RM (2way mixed ANOVA) effect-size found in Naimo et al. (2013) equal to 0.19, setting alpha to 0.05 and power to 0.90 returned a sample size of 12 subjects, which we increased by 20% to account for drop out, leading to a final figure of 15 subjects.

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Fifteen participants (10 males and 5 females) aged 20–30 years (mean age 23 ± 2 years) were enrolled in the study. They were informed that their participation was voluntary and that they could withdraw from the study at any time without providing a reason. Participants were also notified that the study complied with the Declaration of Helsinki and the European General Data Protection Regulation (GDPR). After being fully informed, participants were asked to sign an informed consent form to confirm their participation. The inclusion criteria for this study were: i. experience in performing all three powerlifting movements (bench press, deadlift, and squat). ii. absence of injuries that could compromise participation. iii. sufficient physical conditioning to complete the designed training program. The exclusion criteria were: i. lack of experience in powerlifting movements (bench press, deadlift, and squat). ii. presence of injuries. iii. insufficient physical conditioning to complete the designed training program.

2.2. Procedure

To test our research hypothesis, we employed a randomized controlled longitudinal trial design. Participants were randomly assigned to one of two groups: LCI and HCI. Participants attended the laboratory at the University of Chieti-Pescara in the afternoon, ensuring they had rested for at least 48 hours prior to testing. During the initial assessment session, participants performed a 1RM test on the bench press, which was the primary exercise under investigation. The training sessions commenced the following week and continued for six weeks, with three sessions per week.

2.3. Training Protocol

The training program was structured into two phases: an initial adaptation phase to acclimate participants to the training volume, followed by an intensification phase that culminated in peak intensity levels during the final stages. The regimen adhered to a powerlifting-style strength training protocol, focusing on the three main lifts: barbell bench press, squat, and deadlift. The program was divided into fundamental exercises and technical variations. For instance, the bench press was performed as a fundamental exercise, whereas slow-tempo bench press sets (3 seconds for the eccentric phase and 3 seconds for the concentric phase) were considered technical variations. Alternating between these exercise modalities allowed for multiple weekly sessions targeting the same muscle groups while mitigating excessive overload. Fundamental exercises were executed at an intensity of up to 83% of 1RM. Exercises with technical variations were prescribed at different intensities as follows: a maximum of 70% of 1RM for the slow-tempo bench press (due to the increased difficulty requiring a lighter load), up to 89% of 1RM for deficit deadlifts (which are mechanically facilitated). Given that the bench press was the study's focal point, particular attention was devoted to its integration with the other two lifts. The weekly training schedule was as follows: Monday: Squat and bench press; Wednesday: Deadlift, bench press (technical variation), and squat; Friday: Squat, bench press, and deadlift (technical variation). All exercises were performed in accordance with official powerlifting competition regulations. The Bench press technique was standardized for both groups, with three minutes of rest between sets for all participants. For the remaining lifts, rest intervals were self-selected, with participants instructed to ensure full recovery.

To induce CI the bench press was paired with the seal row. This is a horizontal pulling exercise employing a motor pattern similar to the bench press but targeting the antagonist muscles. The seal row was incorporated into the Monday and Friday sessions and performed with at least three repetitions in reserve (RIR) to maintain moderate intensity. In the HCI group, CI was introduced by performing the seal row during the three-minute rest periods between bench press sets. In contrast, the LCI group executed the seal row after completing all bench press sets, ensuring sufficient rest to minimize muscular fatigue maintaining an equivalent training volume. Every other Friday, a maximum velocity lift (MVL) test was conducted on the bench press without any contextual interference. At the conclusion of the six-week training period, a follow-up test was administered two weeks after the final training session to further evaluate the effects of the intervention (Figure 1).

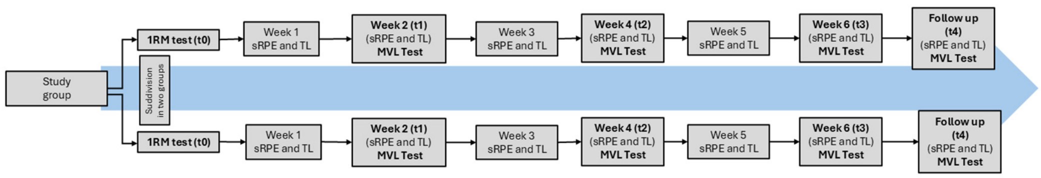

Figure 1. Study flow diagram. 1RM= one repetition maximum; TL= Training Load; MVL= maximum velocity lift.

2.4. Maximal Repetition and MVL Testing

To estimate the 1RM, we used a conversion table that relates the number of repetitions to the percentage of 1RM [10]. The 1RM test was preceded by a general warm-up, joint mobilization exercises, and technical drills with an unloaded barbell. Progressive loading was then implemented using an incremental strategy to approach the estimated maximal load, with a maximum of five sets. As the load increased, the number of repetitions decreased until only single repetitions were performed. Video recordings were captured during all 1RM attempts until all potential attempts for each participant were exhausted. A total of 34 recordings were obtained, all employing three-quarter angle shots to ensure adherence to international powerlifting criteria and to assess technical proficiency. During a separate session, a similar procedure was used for evaluating the MVLs. Maximum velocity lift, also known in Italian strength training as the “Miglior Alzata Veloce”, refers to the highest weight lifted at the highest maximal execution velocity, provided that the lifting technique remains unaltered. For each attempt, participants were informed of the prescribed load percentage relative to their initial 1RM (e.g., 80% of 1RM). If a rapid lifting execution attempt was successful, the load was progressively increased. If the lift failed, participants had a total of three attempts for a given load. The best MVL attempt—evaluated in terms of both technical execution and total lifted weight—was selected for analysis.

2.5. Technical Evaluation and RPE Scale

Lifting technique was assessed using a scoring table (Table 1) designed to quantify the quality and validity of each bench press repetition, based on the criteria established by Naimo et al. (2013).

Table 1. Evaluation criteria for bench press exercise.

Bench press technical execution criteria
Dorsal arch
Scapular retraction
Gluteal contact
Shoulder contact
Head contact
Feet placement
Leg drive
Chest pause
Elbow lockout
Symmetrical arm extension
Pressing trajectory
Adherence to commands
Correct placement of the little finger on the barbell

The evaluation criteria comprised: The 1RM and each MVL were evaluated by two independent powerlifting competition judges, who were external to the study and free from potential biases. Each judge meticulously analyzed every recorded lift and assigned a score based on a Likert scale [11,12] ranging from 1 (very poor) to 4 (excellent).The two judges showed perfect agreement. Additionally, subjective effort perception was recorded for each training session using the CR10 scale modified by [13] to obtain the Rating of Perceived Exertion (RPE). Foster's method was then applied to calculate the session RPE (sRPE) for each session using the formula:

$$sRPE = RPE \times \text{session duration (minutes)}.$$

Fatigue was mitigated in both groups by asking participants to maintain 3 repetitions in reserve. This was checked a posteriori by 2-way mixed ANOVA on session RPE scores, which showed no significant interactions nor main effects.

2.6. Statistical Analysis

All data were analyzed using R software in RStudio (version 2024.12.0+467). Assumptions for ANOVA were verified, and a Greenhouse-Geisser correction was applied to address any violations of sphericity. Baseline differences were assessed using independent t-tests. A Two-Way Repeated Measures ANOVA (TWRM ANOVA) was conducted to analyze the interaction between a within-subject factor of time (with five levels: 1RM [t0], MVL1 [t1], MVL2 [t2], MVL3 [t3], MVL4 [t4]) and a between-subject factor of group (with two levels: LCI, HCI). Additionally, a 4 × 2 TWRM ANOVA [time (MVL1, MVL2, MVL3, MVL4) × group] was performed to evaluate the significance of values normalized as a percentage of their initial 1RM. In cases where a significant main effect of time was found, a Wilcoxon post hoc test with Bonferroni correction was used to identify differences between groups. Technical execution was evaluated using non-parametric Aligned Rank Transform Test (Joshi et al., 2015; Norman, 2010). The alpha level was set at 0.05 for all analyses, including those involving Likert scale points (Joshi et al., 2015).

3. Results

3.1. Participant Characteristics

Table 2 presents the general characteristics of the sample, shown as mean ± standard deviation. There were no significant differences in age, weight, and BMI, nor were there differences in performance capacity, as assessed by 1RM (kg).

Table 2. Participants characteristics.

Variable	LCI (n=7)	HCI (n=8)
Males/Females	5/2	5/3
BMI	22.9 ± 3.2	24.5 ± 4.2
Age	22.4 ± 2.9	22.6 ± 1.8
1RM (Kg)	77.8 ± 29.7	78.8 ± 36.7

All the data are presented as mean ± standard deviation. LCI= low contextual interference group, HCI= high contextual interference group.

3.2. Strength Capacity

No baseline differences were observed between the two groups in 1RM, as detected with a Two Sample T-Test ($p = 0.9571$). There was no group × time interaction ($F (3.48, 45.28) = 1.407$, $p = 0.250$), nor a main effect of group in strength capacity ($F (1, 13) = 0.057$, $p = 0.816$). However, there was a statistically significant main effect of time with Greenhouse-Geisser correction ($F (3.32, 46.5) = 9.553$, $p < 0.05$, pes = 0.420). Strength significantly increased in both groups without significant between-group differences, although post hoc analyses revealed that the increase was not always statistically significant across all measurement points. Specifically, a Wilcoxon Test with Bonferroni corrections showed significant comparisons at: t0–t3 ($p = 0.025$), t0–t4 ($p = 0.047$), t1–t3 ($p = 0.015$), and t1–t4 ($p = 0.035$) (Figure 2).

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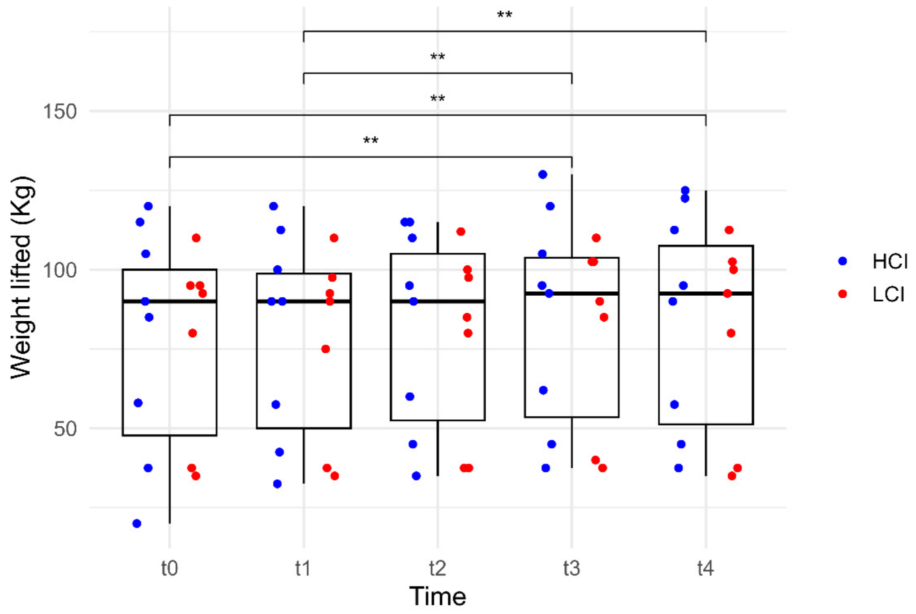

Figure 2. Comparisons between time conditions in bench press MVLs with significant differences. HCI= high contextual interference group, LCI= low contextual interference group; t0= 1RM, t1= MVL1, t2= MVL2, t3= MVL3 and t4= MVL4.

3.3. Scores of the Technical Components Checklist

No baseline differences were observed between the two groups in all 13 technical elements, as detected with a Two Sample T-Test ($p > 0.05$). Global technique analysis of all 13 items showed an interaction effect between group and time ($F_{(4,952)} = 2.547$, $p = 0.038$, pes = 0.01) no main effect of group ($F_{(1,13)} = 4.518$, $p = 0.053$, pes = 0.26) (Figure 3). Moreover, there was a statistically significant main effect for time ($F_{(4,952)} = 19.961$, $p < 0.001$, pes = 0.08). Analyzing the individual technical components, seven out of thirteen showed a significant time effect and four of group. The only significant group × time interaction effect was found for Item 2 (scapular adduction) ($F_{(4,52)} = 3.753$, $p = 0.009$, pes = 0.22) (Figure 4), with participants in the HCI group showing greater improvement over time. Item 2 had also a significant main effect of time ($F_{(4,52)} = 4.164$, $p = 0.005$, pes = 0.24).

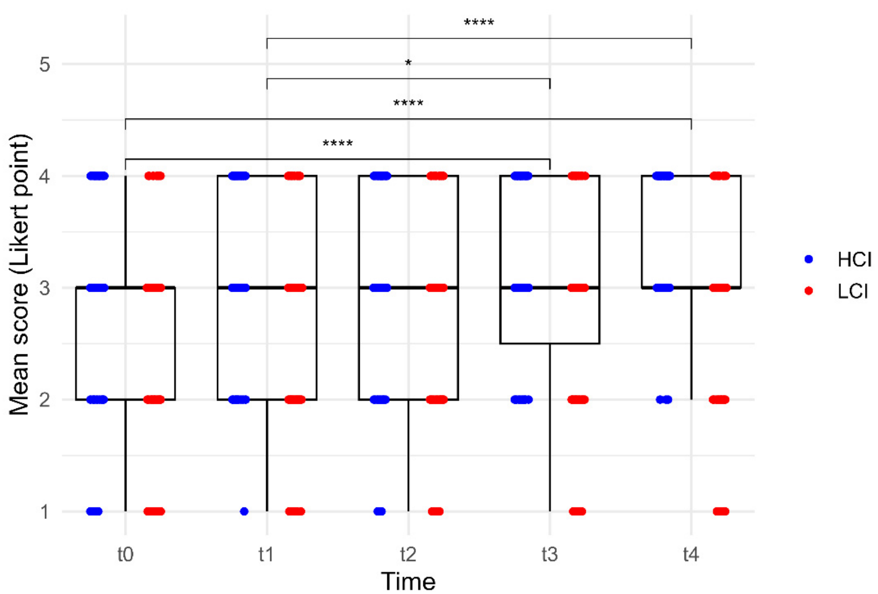

Figure 3. Group × time interaction for global techinique during bench press. HCI= high contextual interference group, LCI= ow contextual interference group; t0= 1RM, t1= MVL1, t2= MVL2, t3= MVL3 and t4= MVL4.

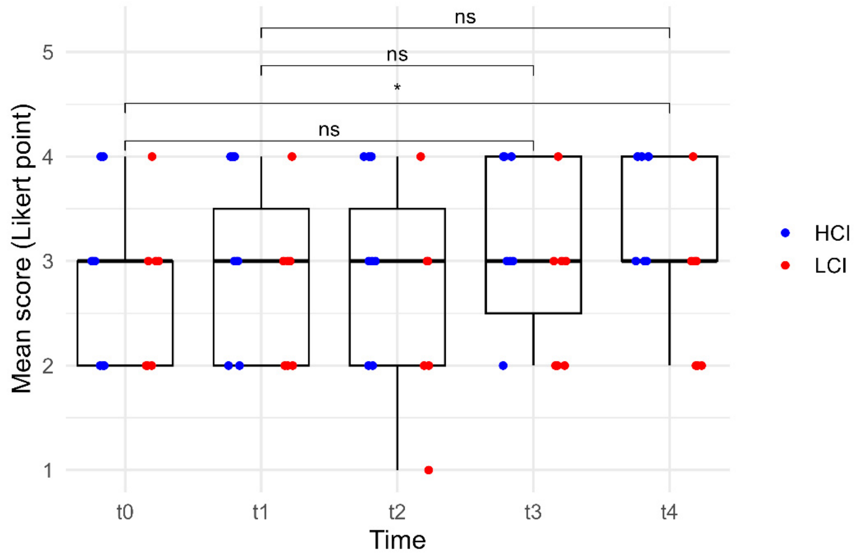

Figure 4. Group × time interaction for item 2 (scapula adduction) during bench press. HCI= high contextual interference group, LCI= ow contextual interference group; t0= 1RM, t1= MVL1, t2= MVL2, t3= MVL3 and t4= MVL4.

4. Discussion

The results of our study showed that the HCI Powerlifters group improved technical execution, with the same maximal force improvement as recorded in the LCI group. The effectiveness of high CI in the acquisition of technical skills is well established in the literature [2,4,7,8]. Although there is overall consensus about the positive effect of alternating motor programs on long-term learning, a recent study investigating the effectiveness of alternating practice (through serial practice) in learning a complex task did not find an advantage of CI over blocked practice [6]. Specifically, while blocked practice reduced the number of errors in the short term, serial practice led to an increase in errors during the initial sessions. In the medium term, however, error frequency was comparable between the two conditions. This study suggests that when motor tasks are particularly complex, alternating practice may initially lead to greater execution difficulties. Over time, the gap between the two groups closed, indicating that these difficulties can be overcome in the long term. Due to the complexity of the task, the authors divided it into multiple parts (five) before integrating global practice [6]. Furthermore, the alternation was achieved by switching between the right and left sides, rather than a true alternation of motor programs [6].

The motor task selected in our study was relatively simple (i.e., bench press), yet it was not devoid of technical elements. In fact, we used 13 technical exercise execution items commonly employed in official powerlifting competitions. The technical elements evaluated play a key role in the execution of the bench press exercise. Many of them have a purely educational role (e.g., gluteal contact, shoulder contact, head contact, feet placement, chest pause, adherence to commands, and correct placement of the little fingers on the barbell), while other items represent variables that can be improved through training and have a central role (e.g., scapula adduction [item 2]). Correct placement, also known as setting, during the bench press exercise must be done with scapula adduction. Maintaining scapula adduction allows for correct activation of the pectoral muscles, prevents shoulder injuries, and ensures a good pressing trajectory. Based on the statistical analysis

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results, we observed an overall improvement technical execution and in particular in scapular adduction in the HCI group. This enhancement could be related to the exercise used to create CI, the seal row. In the seal row exercise, the subject lies prone on a raised bench with a barbell positioned beneath it, performing a horizontal pull that primarily emphasizes scapular adduction. Given the critical involvement of scapular control in both the bench press and the seal row, the latter was selected as the CI exercise within the protocol. It is interesting to note that this technical aspect gradually improved over time, reaching significance after 6 weeks. This suggests that CI interventions may need time to induce an effect and it is thereafter maintained [2].

Motor adaptations induced by CI are generally characterized by an initial phase of transient performance perturbation, followed by a subsequent recovery [14]. However, the optimal timing for assessing transfer and retention effects remains a topic of ongoing debate. For example, a controlled laboratory study on motor control demonstrated that although random practice in a force field task required a longer adaptation period, it resulted in superior short-term retention and transfer compared to blocked practice. Notably, these advantages diminished after 24 hours [15]. Our study may have benefited from a build-up of retention and transfer over time.

Our hypothesis suggested that using an antagonist exercise could have increased conscious processing and the reconstruction of action plans by participants, thereby increasing cognitive load and, in the long term, learning. Moreover, from an empirical perspective, motor schemes involving antagonist muscles are often used to enhance recovery between sets. The underlying idea of this method is reciprocal inhibition, which facilitates the relaxation of the agonist when the antagonist is engaged in a task [9]. In addition to the level of experience, attentional focus may also influence weightlifting performance. It has been shown that adopting an external focus of attention enhances muscular efficiency of weightlifters [16]. A noteworthy link between CI and external focus was identified in a study on golf motor learning, where the most effective strategy combined external focus of attention, CI, distributed practice, and exercises aimed at reducing the number of errors [17]. In our study no particular instructions were given regarding attention focus.

This study introduces novel insights into contextual interference research. Firstly, only one previous study in the literature has investigated contextual interference in powerlifting. Indeed, Naimo et al. (2013) used a completely unrelated interference task (e.g., target shooting) producing positive effects. Secondly, our study examined two tasks belonging to the same family of exercises, thereby adopting a more ecologically valid design compared to previous research. Although, our study is based on sample size in line with the study of Naimo et al. (2013), future research is needed to confirm our findings on a larger sample. Furthermore, further studies could focus on the effect of CI on other aspects of powerlifting, such as squat and deadlift. Moreover, as a combined strategy of CI and external focus may lead to more evident improvements this should be researched further.

5. Conclusions

In conclusion, alternating exercises with antagonist overloads (e.g., seal row) relative to the primary task (bench press) effectively enhance technical execution in powerlifters over six weeks, with particular improvements in scapular adduction, while maintaining maximal strength gains. These results highlight the practical value of integrating contextual interference strategies into resistance training programs to optimize skill acquisition. Further research could investigate the application of this approach to other powerlifting movements and larger athlete populations to confirm and extend these findings.

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Institutional Review Board Statement: The study was approved on the (21.06.2024) by the Institutional Review Board of the Department of Human Sciences, and Health of the University of Cassino and Lazio Meridionale (approval Number 16259).

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the participants to publish this paper.

Data Availability Statement: Data can be reached only upon request to the corresponding author and exclusively for the purpose specified in the objectives of the study.

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Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CI	Contextual Interference
1RM	One Repetition Maximum
HCI	High Contextual Interference
LCI	Low Contextual Interference
GDPR	General Data Protection Regulation
RIR	Repetitions In Reserve
MVL	Maximum Velocity Lift
RPE	Rating of Perceived Exertion
sRPE	session Rating of Perceived Exertion
TWRM	Two Way Repeated Measure
BMI	Body Mass Index

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