The Effectiveness of Contrast Training on Improving Clean and Jerk Lifts in Adolescent Weightlifters

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ABSTRACT

This study aimed to examine the effectiveness of contrast training in improving clean and jerk performance among adolescent weightlifters. The research employed a quantitative approach using a quasi-experimental one-group pretest–posttest design. Participants consisted of 10 junior high school weightlifting athletes aged 13–15 years with prior training experience. The intervention involved a structured four-week contrast training program conducted three times per week, integrating 70% one repetition maximum (1RM) loads to stimulate maximal strength and 30% 1RM loads to enhance explosive power. This loading configuration is theoretically grounded in post-activation performance enhancement (PAPE), which facilitates increased motor unit recruitment, neuromuscular activation, and rate of force development. Performance was assessed using the 1RM clean and jerk test before and after the intervention. Descriptive analysis indicated a consistent improvement in lifting performance across participants. Inferential analysis using the Wilcoxon Signed-Rank Test revealed a statistically significant difference between pretest and posttest results ($p < 0.05$). The findings suggest that contrast training effectively enhances maximal strength and explosive capacity in adolescent athletes, primarily through neural adaptation mechanisms. These results provide empirical support for incorporating contrast training into youth weightlifting programs as an evidence-based strategy to overcome performance stagnation and optimize neuromuscular development during critical growth phases.
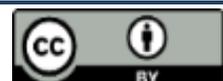
AUTHORS' CONTRIBUTION

A. Conception and design of the study;
B. Acquisition of data;
C. Analysis and interpretation of data;
D. Manuscript preparation;
E. Obtaining funding

Cites this Article	:	Mentari, M.Putri.; Suyoko, A.; Subagio, I.; Kusuma, I.D.M.A.W. (2026). The Effectiveness of Contrast Training on Improving Clean and Jerk Lifts in Adolescent Weightlifters. **Competitor: Jurnal Pendidikan Kepelatihan Olahraga**. 18 (1), p.1362-1373

INTRODUCTION

Weightlifting is a competitive sport characterized by the integration of maximal strength, explosive power, intermuscular coordination, and high technical precision, particularly in the clean and jerk movement, which represents one of the most complex lifts in Olympic weightlifting. Performance in the clean and jerk depends on the athlete's capacity to generate high force within a short time frame while maintaining

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biomechanical efficiency and neuromuscular coordination (Comfort et al., 2019; Suchomel et al., 2018). In adolescent athletes, the developmental stage is marked by rapid neuromuscular adaptation; however, performance progression often stagnates due to suboptimal training stimulus, limited program variation, and insufficient application of evidence-based strength development models (Lloyd et al., 2016; Granacher et al., 2020).

Empirical observations in the weightlifting extracurricular program at SMPN 2 Tuban indicate that several adolescent athletes experienced stagnation in clean and jerk performance over the past training cycle. The training program was predominantly linear, repetitive, and lacked structured variation in load intensity and neuromuscular stimulation. Such monotony may reduce adaptive responses due to inadequate overload progression and insufficient stimulation of fast-twitch motor units (Bompa & Buzzichelli, 2021; Soriano et al., 2019). In youth populations, inappropriate programming not only limits performance enhancement but may also compromise long-term athletic development (Faigenbaum et al., 2016; Lesinski et al., 2020).

Training in sports science is defined as a systematic and periodized process designed to induce physiological adaptation through progressive overload, specificity, and recovery management (Zafar, 2019; Suchomel et al., 2018). Contemporary evidence emphasizes that structured physical conditioning enhances neuromuscular efficiency, rate of force development (RFD), and motor unit synchronization—key determinants in Olympic lifting performance (Cormie et al., 2016; Comfort et al., 2019). Therefore, identifying training methods capable of effectively stimulating neuromuscular potentiation in adolescents becomes essential to overcome stagnation in clean and jerk outcomes.Weightlifting is a competitive sport characterized by the integration of maximal strength, explosive power, intermuscular coordination, and high technical precision, particularly in the clean and jerk movement, which represents one of the most complex lifts in Olympic weightlifting. Performance in the clean and jerk depends on the athlete's capacity to generate high force within a short time frame while maintaining biomechanical efficiency and neuromuscular coordination (Comfort et al., 2019; Suchomel et al., 2018). In adolescent athletes, the developmental stage is marked by rapid neuromuscular adaptation; however, performance progression often stagnates due to suboptimal training stimulus, limited program variation, and insufficient application of evidence-based strength development models (Lloyd et al., 2016; Granacher et al., 2020).

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Recent developments in strength and conditioning science highlight contrast training as an effective strategy to simultaneously develop maximal strength and explosive power. Contrast training involves alternating heavy resistance exercises with biomechanically similar lighter or explosive movements within the same set or session (Gould, 2021; Seitz & Haff, 2016). The theoretical foundation of this method is closely linked to the post-activation potentiation (PAP) phenomenon—more recently conceptualized as post-activation performance enhancement (PAPE)—whereby prior high-intensity muscular contractions enhance subsequent explosive performance (Blazevich & Babault, 2019; Smilios et al., 2017).

Physiologically, PAP mechanisms involve increased phosphorylation of myosin regulatory light chains, heightened motor neuron excitability, and improved motor unit recruitment efficiency (Boullosa et al., 2020; Tillin & Bishop, 2009). Empirical evidence demonstrates that contrast training protocols can significantly enhance jump performance, sprint speed, and maximal strength in trained populations (Seitz & Haff, 2016; Dobbs et al., 2019). In Olympic weightlifting contexts, integrating heavy squats followed by explosive lifts has been shown to improve power output and bar velocity (Comfort et al., 2019; Suchomel et al., 2018).

Furthermore, adolescent athletes may benefit from appropriately structured neuromuscular training due to their heightened neural plasticity and sensitivity to strength stimuli (Lloyd et al., 2016; Moran et al., 2017). Studies in youth populations report that resistance training, when properly supervised, enhances strength, coordination, and injury resilience (Faigenbaum et al., 2016; Granacher et al., 2020). However, adaptations in youth differ from adults, with neural factors playing a more dominant role compared to hypertrophic responses (Lesinski et al., 2020).

Although several studies confirm the positive impact of contrast training on explosive tasks such as vertical jump and sprinting (Dobbs et al., 2019; Boullosa et al., 2020), its direct application to Olympic weightlifting performance—particularly clean and jerk—in adolescent school-based athletes remains underexplored. Most available evidence derives from adult or elite samples, limiting its generalizability to developmental-stage athletes (Seitz & Haff, 2016; Blazevich & Babault, 2019). Therefore, translating PAP theory into youth weightlifting training contexts requires empirical validation.

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Despite robust theoretical support for contrast training and PAP mechanisms, several limitations remain evident in current literature. First, the majority of empirical studies have been conducted on adult or elite athletes with advanced training backgrounds (Seitz & Haff, 2016; Dobbs et al., 2019). The neuromuscular responses of adolescent athletes whose endocrine systems and motor control patterns are still developing may differ significantly (Lloyd et al., 2016; Moran et al., 2017).

Second, prior research has predominantly examined surrogate performance indicators such as vertical jump height, sprint performance, or squat power output (Boullosa et al., 2020; Comfort et al., 2019), rather than complex Olympic lifts that integrate multiple technical phases like the clean and jerk. The clean and jerk requires synchronized triple extension, precise bar trajectory control, and stabilization under load, making it biomechanically distinct from simpler explosive tasks (Suchomel et al., 2018).

Third, there is limited evidence addressing the implementation of contrast training within school-based extracurricular programs, where training frequency, supervision quality, and recovery management may differ from elite training environments. Contextual constraints such as limited facilities and time allocation may influence adaptation outcomes (Granacher et al., 2020).

Thus, a clear gap exists between (1) theoretical assertions that contrast training enhances neuromuscular power through PAP mechanisms, and (2) empirical validation of its effectiveness in improving clean and jerk performance among adolescent weightlifters in school settings. Addressing this gap is essential not only for advancing sports science knowledge but also for providing practical solutions to coaching stagnation issues observed in youth athletes.

Based on the identified theoretical and empirical gaps, this study aims to examine the effectiveness of the contrast training method in improving clean and jerk performance among adolescent weightlifters participating in a school based extracurricular program. Specifically, the study seeks to determine whether integrating heavy load resistance exercises followed by explosive movements within a structured training protocol can produce significant improvements in lifting performance.

The novelty of this research lies in three primary contributions. First, it empirically tests the application of contrast training within a developmental-stage population, thereby extending PAP theory into adolescent sports contexts. Second, it focuses directly on clean and jerk performance rather than indirect power indicators providing sport-specific evidence relevant to Olympic weightlifting coaching. Third, it situates the intervention within a real-world school training environment, enhancing ecological validity and practical applicability.

By bridging the gap between theory and applied youth coaching practice, this study contributes to the advancement of evidence-based training models for adolescent weightlifters. The findings are expected to provide scientific justification for implementing contrast training as a structured strategy to overcome performance stagnation and optimize neuromuscular adaptation during critical developmental phases.

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METHODS

Research Design

This study employed a quasi-experimental design using a one-group pretest–posttest approach to examine the effectiveness of contrast training on clean and jerk performance in adolescent weightlifters. Experimental designs are widely used in sports science to determine causal relationships between training interventions and performance outcomes (Thomas, Nelson, & Silverman, 2015; Latif & Purnomo, 2023). Although the absence of a control group limits internal comparison, the pretest–posttest model remains appropriate for applied school-based training contexts where participant availability is restricted (Maksum, 2018; Granacher et al., 2020).

Contrast training integrates heavy resistance exercises with lighter, explosive movements within a structured sequence to induce post-activation performance enhancement (PAPE) (Seitz & Haff, 2016; Blazevich & Babault, 2019). This design allows evaluation of neuromuscular adaptations resulting from combined strength–power stimuli, which have been shown to improve rate of force development and motor unit recruitment efficiency (Boullosa et al., 2020; Suchomel et al., 2018). The intervention duration of four weeks aligns with evidence indicating that short-term neuromuscular adaptations in youth are primarily neural rather than hypertrophic (Lloyd et al., 2016; Moran et al., 2017).

Participants and Data Sources

Primary data were obtained directly from performance testing of 10 adolescent weightlifters (aged 13–15 years) enrolled in the weightlifting extracurricular program at SMPN 2 Tuban. All participants had a minimum of one year of structured training experience, consistent with recommendations for safe resistance training exposure in youth populations (Faigenbaum et al., 2016; Lesinski et al., 2020). The study focused on changes in clean and jerk performance following a structured contrast training protocol. The intervention was conducted over four weeks with a frequency of three sessions per week, reflecting optimal training frequency for adolescent strength development (Granacher et al., 2020). Each session applied paired sets consisting of 70% one repetition maximum (1RM) loads to stimulate maximal strength and 30% 1RM loads to enhance explosive power. This loading configuration is supported by research demonstrating that moderate-to-heavy intensities optimize neuromuscular potentiation while lighter loads enhance bar velocity and power output (Comfort et al., 2019; Dobbs et al., 2019).

Data Collection Procedures

Performance data were collected using the 1RM clean and jerk test, a valid and reliable indicator of maximal Olympic lifting performance (Suchomel et al., 2018; Haff & Triplett, 2016). Baseline measurements (pretest) were conducted prior to the intervention to determine each athlete's maximal lifting capacity. Participants then completed the four-week contrast training program under supervised and standardized conditions to ensure load accuracy, technical consistency, and safety.

Following the intervention, a posttest was administered using the identical 1RM protocol to evaluate performance changes. All assessments adhered to standardized warm-up procedures and rest intervals consistent with strength testing guidelines to

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ensure reliability and minimize fatigue effects (Comfort et al., 2019; Faigenbaum et al., 2016). The use of identical testing conditions enhances measurement consistency and reduces systematic bias (Thomas et al., 2015).

Data Analysis

Descriptive statistics were calculated to determine mean and percentage changes between pretest and posttest scores. Given the small sample size and potential non-normal distribution of paired data, the Wilcoxon Signed-Rank Test was applied to assess statistical significance. Non-parametric approaches are recommended in youth sport studies when sample sizes are limited (Maksum, 2018; Field, 2018). Statistical significance was set at $p < 0.05$.

This analytical approach enables evaluation of whether contrast training produces meaningful improvements in clean and jerk performance, consistent with prior evidence demonstrating that neuromuscularly oriented interventions significantly enhance explosive strength outcomes (Seitz & Haff, 2016; Boullosa et al., 2020).

RESULTS AND DISCUSSION

Result

The results of this study present empirical data on clean and jerk performance collected to evaluate the effectiveness of a four-week contrast training intervention in adolescent weightlifters at SMPN 2 Tuban. Clean and jerk performance was assessed using the one-repetition maximum (1RM) test, which is widely recognized as a valid indicator of maximal strength and Olympic lifting performance (Suchomel et al., 2018; Haff & Triplett, 2016). Improvements in maximal lifting capacity reflect neuromuscular adaptation, motor unit recruitment enhancement, and improved rate of force development (Comfort et al., 2019; Cormie et al., 2016).

Following data collection, descriptive statistical analysis was conducted to determine the minimum, maximum, mean, standard deviation, and performance change (Δ). Given the small sample size (N=7), inferential analysis was performed using the Wilcoxon Signed-Rank Test, which is recommended for paired non-parametric data in youth sport studies (Field, 2018; Granacher et al., 2020).

Descriptive Analysis

Table 1.
Clean and Jerk Pretest and Posttest Results (kg)

No	Initial	Pretest (kg)	Posttest (kg)	Δ (kg)
1	S	55	60	5
2	C	75	80	5
3	N	65	70	5
4	AS	110	117	7
5	E	102	112	10
6	R	32	35	3
7	I	85	90	5
	Mean	**74.86**	**80.57**	**5.71**
	Minimum	**32**	**35**	**3**
	Maximum	**110**	**117**	**10**
	SD	**26.14**	**28.64**	**2.36**

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Based on Table 1, all participants (100%) demonstrated improvements in clean and jerk performance following the intervention. The mean pretest score of 74.86 kg increased to 80.57 kg in the posttest, with an average gain of 5.71 kg (≈7.6%). This magnitude of improvement is consistent with short-term neuromuscular adaptation responses reported in youth resistance training literature (Lloyd et al., 2016; Lesinski et al., 2020).

The largest absolute improvement was observed in participant E (+10 kg), while AS recorded the highest maximal load overall (117 kg). These findings align with evidence that contrast training enhances motor unit synchronization and potentiation effects, particularly through post-activation performance enhancement (PAPE) mechanisms (Blazevich & Babault, 2019; Boullosa et al., 2020). The combination of moderate-to-heavy loads (70% 1RM) followed by explosive efforts (30% 1RM) likely optimized neuromuscular stimulation, increasing bar velocity and force output (Dobbs et al., 2019; Comfort et al., 2019).

Significance Test (Wilcoxon Signed-Rank Test)

Given the small sample size and violation of normality assumptions, the Wilcoxon Signed-Rank Test was applied to determine whether the observed improvements were statistically significant. Non-parametric testing is recommended in applied sports research when sample sizes are limited and data distribution is uncertain (Field, 2018).

Table 2.
Wilcoxon Signed-Rank Test Results

Variable	N	Z	Asymp. Sig. (2-tailed)	Decision
Clean & Jerk Performance	7	-2.401	0.016	Significant

The analysis revealed a significance value (Asymp. Sig.) of 0.016, which is lower than the alpha level of 0.05 (0.016 < 0.05). Therefore, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_a) is accepted. This indicates a statistically significant improvement in clean and jerk performance following the contrast training intervention.

These findings are supported by prior research demonstrating that contrast training significantly enhances maximal strength and explosive performance through potentiation of the neuromuscular system (Seitz & Haff, 2016; Suchomel et al., 2018; Boullosa et al., 2020). The improvement observed in adolescent athletes further confirms that youth populations can benefit from properly structured strength–power training interventions, primarily through neural adaptation rather than hypertrophic changes (Moran et al., 2017; Granacher et al., 2020).

The descriptive and inferential results consistently demonstrate that the one-month contrast training program produced meaningful and statistically significant improvements in clean and jerk performance. The observed gains are theoretically explained by enhanced motor unit recruitment, increased rate of force development, and improved intermuscular coordination associated with PAPE-based training strategies (Blazevich & Babault, 2019; Comfort et al., 2019).

Overall, these findings provide empirical support for the application of contrast training in adolescent weightlifting programs and contribute to expanding evidence-

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based strength and conditioning practices within school-based athletic development contexts.

Discussion

The findings of this study demonstrate that a four-week contrast training intervention significantly improved clean and jerk performance in adolescent weightlifters. The observed increase in mean 1RM reflects meaningful neuromuscular adaptation to the applied training stimulus. In Olympic weightlifting, performance enhancement is closely associated with improvements in maximal force production, rate of force development (RFD), and intermuscular coordination (Suchomel et al., 2018; Comfort et al., 2019). The average improvement of 5.71 kg (≈7.6%) over four weeks indicates that the contrast training stimulus was sufficient to induce short-term neural adaptations, which are known to dominate strength gains in youth populations (Lloyd et al., 2016; Moran et al., 2017).

The effectiveness of contrast training can be explained through its dual stimulation of maximal strength and explosive power within the same training sequence. The heavy-load component (70% 1RM) increases neuromuscular activation and motor unit recruitment, particularly high-threshold motor units responsible for generating large force outputs (Blazevich & Babault, 2019; Boullosa et al., 2020). Subsequent lighter, explosive loads (30% 1RM) capitalize on this potentiated state to enhance bar velocity and power production. This strength–power pairing aligns with evidence showing that contrast and complex training methods improve power-related performance more effectively than traditional linear training models (Seitz & Haff, 2016; Dobbs et al., 2019).

In the context of the clean and jerk, improved motor unit recruitment and synchronization are critical. The lift requires rapid triple extension of the hip, knee, and ankle, followed by dynamic stabilization in the jerk phase. Enhanced intramuscular coordination improves force transmission within individual muscles, while intermuscular coordination optimizes timing between muscle groups (Suchomel et al., 2018; Comfort et al., 2019). The present findings support the argument that contrast training enhances the quality of neuromuscular coordination, thereby improving technical force application during the lift.

The physiological mechanism underlying this improvement is consistent with the concept of post-activation performance enhancement (PAPE), formerly described as post-activation potentiation (PAP). Contemporary literature differentiates acute PAP effects from longer-term PAPE adaptations but acknowledges that both involve heightened neuromuscular responsiveness following heavy contractions (Blazevich & Babault, 2019; Boullosa et al., 2020). Heavy-load contractions increase phosphorylation of myosin regulatory light chains, enhancing the sensitivity of actin–myosin cross-bridges to calcium ions, which leads to stronger and faster muscle contractions (Tillin & Bishop, 2009; Seitz & Haff, 2016). In youth athletes, whose neuromuscular systems are highly plastic, such stimuli may produce pronounced neural adaptation (Lloyd et al., 2016; Granacher et al., 2020).

The magnitude of improvement observed in this study is comparable with previous findings in strength and conditioning research. Studies have reported that contrast training

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significantly improves maximal strength, jump performance, and explosive output in trained populations (Dobbs et al., 2019; Boullosa et al., 2020). Although most prior research has focused on adult or elite athletes, emerging evidence suggests that adolescents respond positively to structured resistance and power training when properly supervised (Faigenbaum et al., 2016; Lesinski et al., 2020). The present results extend this body of knowledge by providing sport-specific evidence within an Olympic weightlifting context.

Importantly, the study demonstrates that contrast training may help overcome performance stagnation caused by monotonous programming. Training plateaus frequently occur when athletes are exposed to repetitive loading patterns without sufficient variation in intensity or neuromuscular stimulus (Bompa & Buzzichelli, 2021; Granacher et al., 2020). Variation in training load and contraction velocity stimulates different motor unit recruitment patterns and promotes continued adaptation. This aligns with periodization principles emphasizing progressive overload and variation to optimize long-term athletic development (Suchomel et al., 2018; Comfort et al., 2019).

Adolescent athletes may exhibit particularly favorable adaptations due to developmental characteristics. During early and mid-adolescence, strength improvements are primarily attributed to neural mechanisms, including improved motor learning, enhanced neural drive, and better coordination (Lloyd et al., 2016; Moran et al., 2017). Because the clean and jerk is a technically demanding lift, improvements in coordination likely contributed significantly to the observed gains. This suggests that contrast training not only enhances physical capacity but may also reinforce motor learning through repeated high-quality explosive efforts.

However, it is important to acknowledge that performance gains were likely influenced by additional factors such as technical proficiency, prior training experience, and adherence to the training protocol. Olympic lifting performance is multifactorial, integrating strength, technique, mobility, and psychological readiness (Suchomel et al., 2018). While contrast training enhances neuromuscular output, optimal performance outcomes depend on maintaining technical efficiency during high-intensity efforts. Therefore, supervision and coaching quality remain critical components of program effectiveness (Faigenbaum et al., 2016).

Despite the significant findings, this study presents several limitations. The sample size was relatively small (N=7), which may limit statistical power and generalizability. The absence of a control group restricts the ability to attribute improvements exclusively to the intervention, as natural maturation effects may also contribute to strength development in adolescents (Granacher et al., 2020). Additionally, the four-week duration captures short-term neural adaptations but does not reflect long-term structural changes such as hypertrophy, which typically require extended training periods (Lesinski et al., 2020).

Future research should incorporate randomized controlled designs with larger samples to strengthen causal inference. Longer intervention durations and additional performance metrics such as bar velocity, rate of force development, or electromyographic activity would provide deeper insight into the mechanisms underlying performance improvements. Moreover, comparing contrast training with

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traditional linear or block periodization models could clarify its relative effectiveness in youth weightlifting programs.

Overall, the present findings reinforce the empirical evidence that contrast training is an effective method for enhancing maximal strength and explosive power in adolescent weightlifters. By integrating heavy and light loads within a structured session, coaches can stimulate neuromuscular potentiation and improve clean and jerk performance. The results provide a scientific foundation for evidence-based programming in school-level weightlifting development and contribute to expanding the application of PAPE-oriented training strategies in youth sport contexts.

CONCLUSION

Based on the findings of this study, it can be concluded that contrast training is an effective method for improving clean and jerk performance in adolescent weightlifters. The significant increase in 1RM results following a four-week intervention indicates that the combination of moderate-to-heavy loads (70% 1RM) and lighter explosive loads (30% 1RM) successfully stimulated neuromuscular adaptations. These improvements are conceptually aligned with post-activation performance enhancement (PAPE) mechanisms, where prior heavy contractions enhance subsequent force production capacity through increased motor unit recruitment and improved neuromuscular efficiency.

Empirically, the magnitude of performance gains observed in this study is consistent with contemporary strength and conditioning research demonstrating that contrast training enhances maximal strength, rate of force development, and explosive power, particularly in youth populations whose adaptations are predominantly neural in nature. The structured pairing of strength and power stimuli appears to optimize intramuscular and intermuscular coordination, which is essential for executing technically complex lifts such as the clean and jerk.

Therefore, contrast training can be recommended as an evidence-based alternative training strategy for school-level weightlifting programs to overcome performance stagnation and promote progressive athletic development.

ACKNOWLEDGMENTS

The author also deeply appreciates all participating athletes for their dedication, discipline, and active engagement throughout the four-week training program and performance testing sessions. Their commitment reflects the importance of athlete adherence in achieving meaningful physiological adaptation.

Finally, the author acknowledges the academic supervisors for their insightful guidance, constructive criticism, and continuous encouragement. Their scholarly direction ensured that this study was conducted systematically, ethically, and in accordance with contemporary research standards in sports science.

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