

Effects of combined free-weight and elastic training with cluster sets during clean pull exercises on peak power in elite junior weightlifters

SAGSAK THITISAK¹, CHANINCHAI INTIRAPORN², CHAIPAT LAWSIRIRAT³

^{1,2,3}Faculty of Sports Science, Chulalongkorn University, THAILAND

Published online: May 31, 2022

(Accepted for publication May 15, 2022)

DOI:10.7752/jpes.2022.05157

Abstract:

The purpose of this study was to compare the effects of combined free-weight and elastic training with cluster sets (CFEC) on peak power during clean pull (CP) exercises on youth weightlifters. Sixteen male and female elite junior weightlifters volunteered to participate in this study. The participants were randomly assigned into two groups (control and CFEC) of eight participants (four males and four females) using match pairs of relative CP strength. An undulatory periodized plan with 85–93% CP strength was employed for both groups. Both groups were required to perform a CP exercise with similar intensity. While the control group performed a 100% of traditional free-weight training, CFEC employed combined 90% free-weight and 10% elastic training with a 40-s rest between repetitions. Peak power (PP), relative peak power (RPP), peak force (PF), relative peak force (RPF), and peak velocity (PV) were assessed by a ballistic measurement system before and after 6-week of training. The Shapiro–Wilk test indicated that all dependent variables were normally distributed. Moreover, two independent t-tests were performed and confirmed that there were no statistical differences between the control and CFEC groups for all dependent variables at pre-test. ANCOVA was used to analyze dependent variables using pre-test values as covariates. The results showed the participants in CFEC significantly improved PP and RPP when compared to the control group at post-test ($p < 0.05$). However, the results found no statistical differences in PF, RPF, or PV between the two groups. Our results indicated that CFEC is an effective training program for improving PP and RPP with minimal injury risks in junior weightlifters.

Key Words: athletic training, ballistic training, weightlifting, combined resistance training

Introduction

Strength and power are critical factors for weightlifting performance. Successful lifts require enough strength and power to carry load resistance and overcome load inertia. As a result, weightlifters need to exert very high forces in short periods of time during triple extension or explosive extension of the hip, knee, and ankle joints. Strong evidence has shown that elite and highly trained athletes exhibit greater neural activation during ballistic movement (Hammett & Hey, 2003; James et al., 2018; Kraemer & Newton, 2000). As a result, ballistic training requires more muscle activities and is often used to enhance strength and power (Cormie et al., 2010; James et al., 2018; Newton et al., 1999).

The clean pull (CP) is considered to be a weightlifting-style ballistic training exercise (Suchomel et al., 2014). CP is derived from a power clean exercise. Unlike the power clean exercise where participants need to catch the barbell after the third pull, the CP requires participants to release the barbell after the third pull phase. Excluding the receiving phase helps limit injury risks while allowing participants to train with greater resistance load (Everett, 2012; Kulund et al., 1978; Stone et al., 1994; Takano, 2012). Although CP allows participants to train with relatively heavier resistance than the power clean, it is difficult for participants to maintain their power performance within each training set due to fatigue.

One strategy to overcome fatigue during training is to utilize cluster sets. Cluster set training is a method of breaking sets into small clusters of repetitions while adding a short rest period between repetitions (Iglesias-Soler et al., 2014). Allowing participants to have a short pause between repetitions helps participants replenish their adenosine triphosphate phosphocreatine (ATP-PC) faster (Tufano et al., 2016). Participants, therefore, have refreshed energy to generate maximum power for each repetition and maintain their power performance throughout the training program. Therefore, cluster set training has been found to be effective in improving power production in athletes (Moreno et al., 2014; Oliver et al., 2016; Tufano et al., 2016).

The combination of free-weight and elastic training has received wide attention among researchers. Researchers have found that combining free-weight and elastic training improves power and strength in participants (Bellar et al., 2011; García-López et al., 2016; Paditsaeree et al., 2016; Wallace et al., 2006). Adding elastic training to free weight requires participants to generate forces throughout the whole range of motion. Therefore, muscles are under more tension, and more auxiliary muscles need to be recruited under a combined free-weight and elastic training program than under a free-weight program (Bergquist et al., 2018; Ronca et al., 2020). A combined free-weight and elastic training program has higher injury risks than a traditional free-weight

training program where the barbell is pulled by an elastic tube and falls more quickly than in free-weight exercises. Athletes have less time to receive the barbell and may sustain injuries during the barbell receiving phase (Paditsaeree et al., 2016). Because CP limits injury risks due to exclusion of the third pull phase, CP is suitable for a combined resistance training program.

This study compared the effects of combining free-weight and elastic training with cluster sets (CFEC) on power during CP exercises in youth weightlifters. Because combined resistance training increases muscle energy due to increases in workload and because cluster set training is beneficial for energy replenishment, adding cluster sets to combined resistance training takes advantage of the benefits of the two training programs and helps improve power in participants. We hypothesized that PP, PF, and PV are statistically significant under CFEC when compared to a traditional training program.

Materials & methods

This study was designed to investigate the effects of PP, RPP, PF, RPF, and PV of the CP under a CFEC. There were two tests for this study: a pre-test and a post-test. The experimental group did a combination of free-weight and elastic training with cluster sets, whereas the control group did free-weight training with traditional sets.

Participants

Sixteen (eight males and eight females) youth weightlifters volunteered for this study. Descriptive statistics of the participants are presented in Table 1. The participants regularly participated in weightlifting competitions annually. They had regular training of 2 hours per day for 6 days a week for at least 3 years. No participants had prior history of musculoskeletal injuries or prior experiences with training with combined free-weight and elastic training and/or cluster sets. The participants were excluded from the study if they were not willing to continue or if they had injuries and/or illness that affected performance. Participants were recruited from both genders because it is common practice for youth weightlifters of both genders to share training programs (Lloyd et al., 2012). Ethics approval was granted by the Human Research Ethics Review Committee of the university and compiled with the principles of the Declaration of Helsinki. All participants and their parents were informed of the risks and benefits of the study, and written informed consent was received from all participants and their parents before they began participating in the study.

Table 1: Descriptive characteristics of the participants

Variable	Mean $\pm$ SD (n=16)
Age (y)	15.50 $\pm$ 1.62
Height (m)	1.61 $\pm$ 0.13
Body mass (kg)	53.13 $\pm$ 9.11
Relative clean pull (CP) strength	1.79 $\pm$ 0.23

Procedure

The participants were randomly assigned to two groups of eight participants (four males and four females) using a match-paired relative strength. The participants performed two testing sessions, i.e., a pre-test and post-test. The training was performed 3 days a week (Monday, Wednesday, and Friday) for 6 weeks. The load resistance and intensity were designed using the concept of an undulatory periodized plan because it is a common practice in weightlifting (Bompa & Buzzichelli, 2015). Figure 1 depicts the scheme of training used in this study.

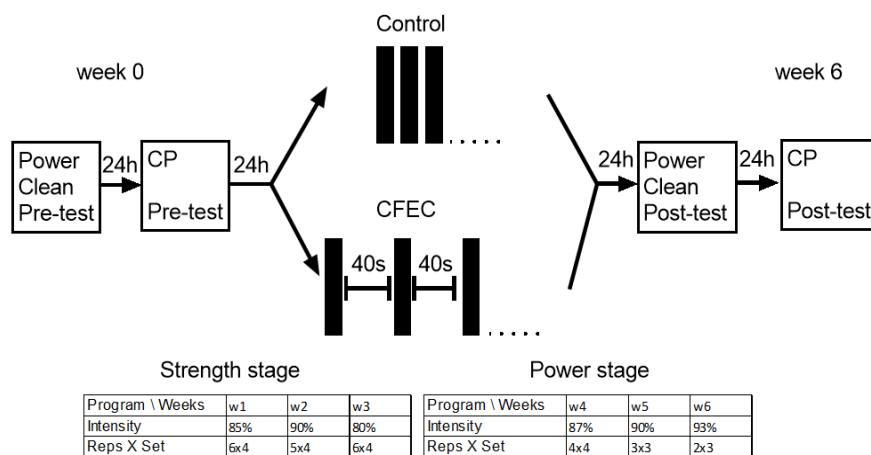


Fig. 1: Schematic design of this study

Combined free-weight and elastic training with a cluster set program (CFEC)

In the CFEC group, the participants performed a CP exercise with 90% of total intensity calculated from their CP strength in free-weight training combined with 10% of total intensity calculated from their CP strength in elastic tube training. The number of repetitions and sets used for each week is shown in Fig. 1. In CFEC, a 40-s rest was introduced during repetitions to allow the participants to have enough rest time to replenish their ATP-PC (Hardee et al., 2013; Ho et al., 2021). The participants had 120–180-s rest periods between sets. Prior to the training, the elastic resistance was calibrated so that the elastic tube produced no tension from the starting position (at the knee level) and started to provide tension from above the knee level onward to 10% at the end of the range of motion (Paditsaeree et al., 2016).

Traditional training program (control group)

In the traditional training program, the participants performed a CP exercise with 100% total intensity calculated from their CP strength in free-weight exercises. The number of repetitions and sets used each week was similar to that of CFEC. Similarly, the rest period between sets was 120–180 s.

In every training session for both groups, the participants had a general warm-up session where they gradually increased the weight of CP until they reached 80% of their weekly training weight, as shown in Fig. 1. After the warm-up, the subjects underwent the training program they were assigned. After the training program, the participants did a cool-down for 10 min.

1RM Power clean assessment (preliminary assessment)

A senior coach who trained several youth athletes at Bangkok Sports School assisted with 1RM power clean testing protocols. All participants reported that they had enough rest before the assessment. The preliminary assessment was scheduled on Saturday (24 h from the latest training session). The protocol for 1RM power clean followed the study by Faigenbaum et al. (2012). The results from the 1RM power clean were used to compute the warm-up and testing intensities for the CP power assessment, which was scheduled for the next day.

CP power assessment (primary assessment)

All participants underwent a CP power assessment on Sunday (24 h from the latest power clean assessment). Similar to the power clean assessment, the CP power assessment also followed the procedure from Faigenbaum et al. (2012). The participants performed a progressive series of 5 submaximal sets of 1–2 repetitions for warm-up and maximal sets of 3 trials for 1RM attempts. They performed a CP with 2 reps of 80% power clean in the first set, 2 reps of 85% power clean in the second set, 1 rep of 90% power clean in the third set, 1 rep of 95% power clean in the fourth and fifth sets as a warm-up, followed by 1 rep of 100% power clean for 3 trials in the last set. The attempts of CP that yielded the highest PP were used for data analysis. Moreover, PP, RPP, PF, RPF, and PV of the attempts were collected and used for statistical analysis. These values were obtained from a Ballistic Measurement System (BMS, Innervations Inc, Australia).

The participants performed CP power assessments on a force plate (400S, Fitness Technology, Australia) with a linear position transducer (PT5A, IDM Instrument, Australia) and a Ballistic Measurement System. The force plate and linear position transducer were both sampled at 600 Hz and calibrated prior to the testing session. Force calculations were filtered using a low pass Butterworth filter with a cut-off frequency of 10 Hz. All equipment and instruments were calibrated prior to testing.

CP strength assessment

Following the CP power assessment session, we continued to test the CP strength by using a linear position transducer to record the CP's maximum vertical displacement while the participants stood on tiptoe with the calf raised, elbow locked, and shoulders shrugged (Everett, 2012). This position was defined as the "cut-off point." Every time a participant performed the CP successfully, a 5% weight increase was added to their total. The testing was terminated when the participant failed to complete a CP. In other words, this occurred when the participant was unable to lift the barbell over the cut-off point. The maximum weight achieved during a successful effort was recorded as the CP strength and was utilized only for grouping and calculating training intensity following the pre-test.

Data collection and analysis/statistical analysis

Data was analyzed using IBM SPSS, Version 28.0 (SPSS, Inc., Chicago, IL, USA) software for Windows. Data are displayed as means and standard deviations. The Shapiro–Wilk test of normality revealed that all data were normally distributed. Two independent t-tests were used to compare the pre-test values between the control and CFEC. Univariate ANCOVAs were used to test for differences between groups (control and CFEC) for all dependent variables (PP, RPP, PF, RPF, and PV). The covariates were the pre-test values. The significant level was set at 0.05.

Results

The means and standard deviations of PP, RPP, PF, RPF, and PV are presented in Table 2. The two independent t-tests indicated no statistical significance for PP, RPP, PF, RPF, and PV between the control and CFEC. After performing ANCOVA analysis, the results showed that the PP and RPP of CFEC were statistically different from the PP and RPP of the control group. For PP, $F_{1,13} = 9.34$, $p = 0.009$, and partial eta squared (η^2) = 0.418. When controlling pre-test values, CFEC improved PP by +478.3 W compared to +97.9 W for the

control. For RPP, $F_{1,13} = 13.89$, $p = 0.003$, and partial eta squared (η^2) = 0.517. When controlling pre-test values as a covariate, CFEC improved their RPP by +9.6 W/kg, while the control group's relative power decreased marginally by -0.7 W/kg. The results found no statistical differences in PF, RPF, and PV between the control and CFEC, as shown in Fig. 2.

Table 2: Means $\pm$ Standard Deviations for PP, RPP, PF, RPF, and PV

	Pre-test (week 0)	Post-test (week 6)	Mean change
Peak Power (PP)			
Control	1131.8 $\pm$ 331.4 W	1229.7 $\pm$ 472.5 W	8.6%
CFEC	1063.3 $\pm$ 383.6 W	1541.5 $\pm$ 641.2 W*	45%
Relative Peak Power (RPP)			
Control	21.3 $\pm$ 3.0 W/kg	20.6 $\pm$ 4.0 W/kg	-3.3%
CFEC	19.8 $\pm$ 5.2 W/kg	26.4 $\pm$ 9.0 W/kg*	33.3%
Peak Force (PF)			
Control	1029.8 $\pm$ 397.7 N	1135.1 $\pm$ 466.4 N	3.4%
CFEC	974.7 $\pm$ 246.6 N	1173.8 $\pm$ 461.6 N	20.4%
Relative Peak Force (RPF)			
Control	18.9 $\pm$ 4.4 N/kg	20.0 $\pm$ 4.5 N/kg	5.8%
CFEC	18.4 $\pm$ 3.2 N/kg	22.0 $\pm$ 5.9 N/kg	19.6%
Peak Velocity (PV)			
Control	1.236 $\pm$ 0.163 m/s	1.150 $\pm$ 0.100 m/s	-7%
CFEC	1.153 $\pm$ 0.147 m/s	1.109 $\pm$ 0.115 m/s	-3.8%

* Indicates a significant difference (post - pre) when the pre-test value was used as a covariate, $p < 0.05$.

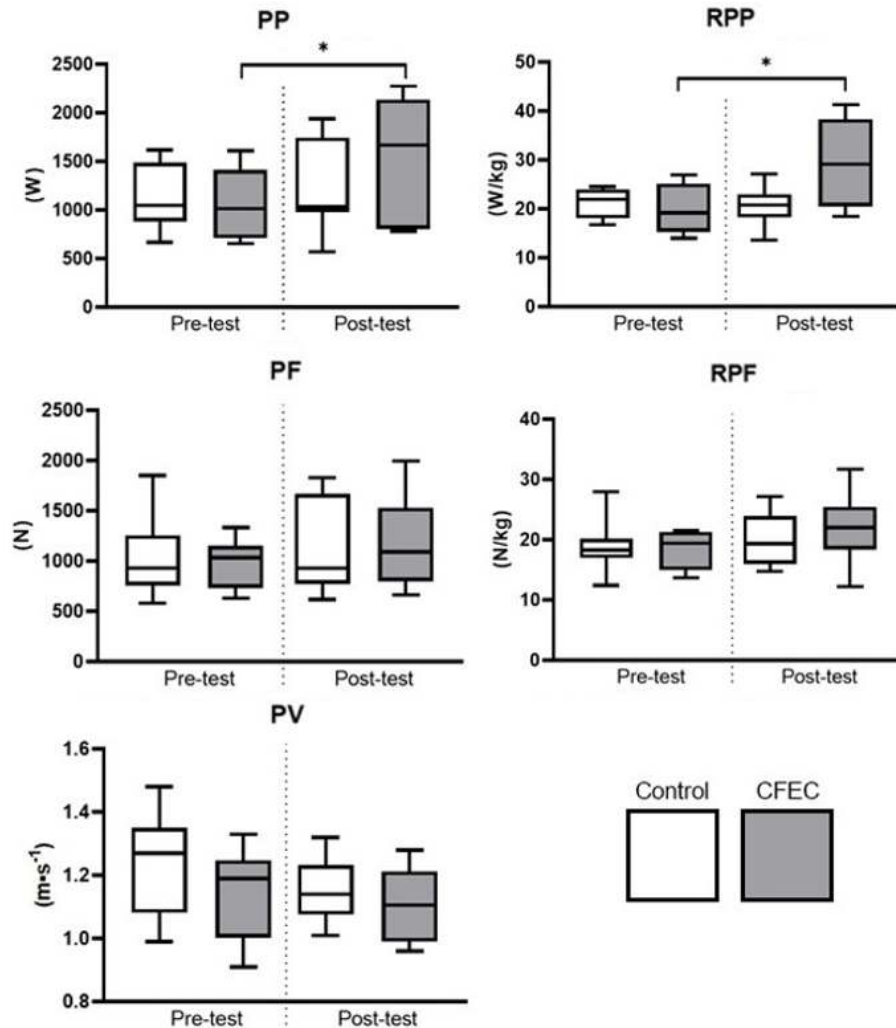


Fig. 2: Box plot of kinematic data for each variable.

* Indicates significant difference (post - pre) when the pre-test score was used as a covariate, $p < 0.05$.

Discussion

The purpose of this study was to compare the effects of CFEC training during a 6-week period on PP, RPP, PF, RPF, and PV. The results showed that CFEC was able to improve PP and RPP when compared to the control group. However, the results found no statistical differences among PF, RPF, and PV between the two groups. Our findings suggest that combining free-weight and elastic training with cluster sets enhances power development. The combined training program capitalized on the benefits of elastic resistance training and cluster set training. Combining elastic training has been effective for power improvement. In our study, the load was controlled. The participants in the CFEC group began the lift with a slightly lighter load than the participants in the control group. With a slightly lighter load, the participants in CFEC may be able to perform the first pull with higher acceleration and, thus, higher velocity. As the lift continued, the resisting load increased in CFEC, which resulted in increases in muscle activations (Jakobsen et al., 2012). Because of the higher velocity during the first pull and longer muscle activation during the second pull, the lifts in CFEC were in a smoother transition, successfully producing triple extension and, thus, creating maximum power during the clean pull. When combining combined resistant training with cluster sets, the cluster sets allowed the participants to have a 40-s mini break between repetitions. The 40-s mini break allowed the participants to reduce fatigue by replenishing their ATP-CP systems. After energy replenishment, the participants were able to start each lift with maximum power, allowing cluster sets to improve power development. While our results showed improvement in power development, no statistical differences were found in PF, RPF, or PV. This may be because our participants were elite junior weightlifters whose strength was relatively high. However, the participants in CFEC showed more improvement in PF and RPF than in the control group. It was also possible that the training period was too short and not sufficient for force development. There were some drawbacks to this study that need to be addressed. First, the participants in this study were elite youth weightlifters who were between 13 and 17 years of age. The growth rate may influence the results; however, because the duration of the study was only 6 weeks, the influence of growth rate should be minimal. Moreover, the use of ANCOVA helped control the effects of growth rate. Another drawback related to the small group of participants. There are not many young players in weightlifting compared to players of same ages in other sports. Moreover, our participants were elite junior weightlifters who competed regularly. Thus, our selected groups of participants were valuable to this study. Of note, our group was composed of male and female participants. However, the number of male and female participants was equal in both groups. Moreover, male and female junior weightlifters often share the same training program. Our study highlighted the benefits of the CFEC training program in which junior weightlifters were able to improve PP and RPP while maintaining PF by using less effort. CFEC required the participants to start lifting 90% free-weight compared to 100% free-weight for the control group. The 10% reduction from the beginning was offset by the elastic tube at the later stage. Due to the lighter load, CFEC involves smaller injury risks and, thus, is beneficial for young athletes. Additionally, our program was a 6-week program. Our results were consistent with the study by Ioannides et al. (2020), whose 6-week training program was able to improve power development in elite male and female athletes.

Conclusions

The purpose of this study was to compare the impacts of traditional training with those of combining free-weight and elastic training with cluster sets during a 6-week period on PP, RPP, PF, RPF, and PV. Sixteen elite junior weightlifters volunteered to participate in this study. The participants were randomly assigned into two groups: control and CFEC. An undulatory periodized plan was employed for both groups. Both groups were required to perform a CP exercise with similar intensity. While the control group performed traditional free-weight training, CFEC employed a combined 90% free-weight and 10% elastic program with a 40-s rest between each repetition. PP, RPP, PF, RPF, and PV were assessed before the training and after 6 weeks using a modified CP exercise. The results showed that the combined elastic training and cluster sets were able to improve PP and RPP compared to the control group. However, the results found no statistical differences in PF, RPF, or PV between the two groups. Our results indicated the benefits of CFEC in which it was able to improve PP and RPP while controlling the injury risks. Moreover, our results implied that the combined free weight and elastic training with cluster sets during the clean pull exercise is an effective power training program for junior weightlifters. It is a safe training program with limited injury risks while significantly improving power production. Coaches, therefore, should consider employing the CFEC technique with CP to increase the power-to-weight ratio.

Acknowledgments

This research was supported by the 90th anniversary of Chulalongkorn University Fund Ratchadaphiseksomphot Endowment Fund). The authors would like to thank all the athletes and coaches who participated in this study. The authors would like to thank Falcon Scientific Editing (<https://falconediting.com>) for proofreading the English language in this paper. **Conflicts of interest** - The authors declare no conflicts of interest.

References:

Bellar, D. M., Muller, M. D., Barkley, J. E., Kim, C. H., Ida, K., Ryan, E. J., Bliss, M. V., & Glickman, E. L. (2011). The Effects of Combined Elastic- and Free-Weight Tension vs. Free-Weight Tension on One-

- Repetition Maximum Strength in the Bench Press. *The Journal of Strength & Conditioning Research*, 25
- Bergquist, R., Iversen, V. M., Mork, P. J., & Fimland, M. S. (2018). Muscle activity in upper-body single-joint resistance exercises with elastic resistance bands vs. free weights. *Journal of human kinetics*, 61(1), 5
- Bompa, T., & Buzzichelli, C. (2015). *Periodization training for sports*, 3e. Human kinetics.
- Cormie, P., McGuigan, M. R., & Newton, R. U. (2010). Adaptations in athletic performance after ballistic power versus strength training. *Med Sci Sports Exerc*, 42(8), 1582–1598.
- Everett, G. (2012). *Olympic weightlifting for sports*. Catalyst Athletics.
- Faigenbaum, A. D., McFarland, J. E., Herman, R., Naclerio, F., Ratamess, N. A., Kang, J., & Myer, G. D. (2012). Reliability of the one repetition-maximum power clean test in adolescent athletes. *Journal of strength and conditioning research/National Strength & Conditioning Association*, 26(2), 432.
- García-López, D., Hernández-Sánchez, S., Martín, E., Marín, P. J., Zarzosa, F., & Herrero, A. J. (2016). Free-weight augmentation with elastic bands improves bench press kinematics in professional rugby players. *Journal of strength and conditioning research*, 30(9), 2493–2499.
- Hammett, J. B., & Hey, W. T. (2003). Neuromuscular adaptation to short-term (4 weeks) ballistic training in trained high school athletes. *Journal of strength and conditioning research*, 17(3), 556–560.
- Hardee, J. P., Lawrence, M. M., Zwetsloot, K. A., Triplett, N. T., Utter, A. C., & McBride, J. M. (2013). Effect of cluster set configurations on power clean technique. *Journal of sports sciences*, 31(5), 488–496.
- Ho, I. M., Luk, J. T., Ngo, J. K., & Wong, D. P. (2021). Effects of different intraset rest durations on lifting performance and self-perceived exertion during bench press exercise. *The Journal of Strength & Conditioning Research*, 35(8), 2114–2120.
- Iglesias-Soler, E., Carballeira, E., Sánchez-Otero, T., Mayo, X., & Fernández-del-Olmo, M. (2014). Performance of maximum number of repetitions with cluster-set configuration. *International journal of sports physiology and performance*, 9(4), 637–642.
- Ioannides, C., Apostolidis, A., Hadjicharalambous, M., & Zaras, N. (2020). Effect of a 6-week plyometric training on power, muscle strength, and rate of force development in young competitive karate athletes. *Journal of Physical Education and Sport*, 20(4), 1740–1746.
- Jakobsen, M. D., Sundstrup, E., Andersen, C. H., Bandholm, T., Thorborg, K., Zebis, M. K., & Andersen, L. L. (2012). Muscle activity during knee-extension strengthening exercise performed with elastic tubing and isotonic resistance. *International Journal of Sports Physical Therapy*, 7(6), 606.
- James, L. P., Gregory Haff, G., Kelly, V. G., Connick, M., Hoffman, B., & Beckman, E. M. (2018). The impact of strength level on adaptations to combined weightlifting, plyometric, and ballistic training. *Scandinavian journal of medicine & science in sports*, 28(5), 1494–1505.
- Kraemer, W. J., & Newton, R. U. (2000). Training for muscular power. *Physical medicine and rehabilitation clinics of North America*, 11(2), 341–368.
- Kulund, D., Dewey, J., Brubaker, C., & Roberts, J. (1978). Olympic weight-lifting injuries. *The Physician and sportsmedicine*, 6(11), 111–119.
- Lloyd, R. S., Oliver, J. L., Meyers, R. W., Moody, J. A., & Stone, M. H. (2012). Long-term athletic development and its application to youth weightlifting. *Strength & Conditioning Journal*, 34(4), 55–66.
- Moreno, S. D., Brown, L. E., Coburn, J. W., & Judelson, D. A. (2014). Effect of Cluster Sets on Plyometric Jump Power. *The Journal of Strength & Conditioning Research*, 28(9). https://journals.lww.com/nsca-jscr/Fulltext/2014/09000/Effect_of_Cluster_Sets_on_Plyometric_Jump_Power.5.aspx
- Newton, R. U., Kraemer, W. J., & Haekkinen, K. (1999). Effects of ballistic training on preseason preparation of elite volleyball players. *Medicine and science in sports and exercise*, 31, 323–330.
- Oliver, J. M., Kreutzler, A., Jenke, S. C., Phillips, M. D., Mitchell, J. B., & Jones, M. T. (2016). Velocity drives greater power observed during back squat using cluster sets. *The Journal of Strength & Conditioning Research*, 30(1), 235–243.
- Paditsaeree, K., Intiraporn, C., & Lawsirirat, C. (2016). Comparison between the effects of combining elastic and free-weight resistance and free-weight resistance on force and power production. *Journal of strength and conditioning research*, 30(10), 2713–2722.
- Ronca, F., Spendiff, O., & Swann, N. (2020). An electromyographic analysis of combining weights and elastic tubes as a method of resistance for exercise. *Translational Sports Medicine*, 3(2), 164–170.
- Stone, M. H., Fry, A. C., Ritchie, M., Stoessel-Ross, L., & Marsit, J. L. (1994). Injury potential and safety aspects of weightlifting movements. *Strength & Conditioning Journal*, 16(3), 15–21.
- Suchomel, T. J., DeWeese, B. H., Beckham, G. K., Serrano, A. J., & Sole, C. J. (2014). The Jump Shrug: A Progressive Exercise Into Weightlifting Derivatives. *Strength & Conditioning Journal*, 36(3), 43–47.
- Takano, B. (2012). *Weightlifting programming: A winning coach's guide*. Catalyst Athletics.
- fano, J. J., Conlon, J. A., Nimphius, S., Brown, L. E., Seitz, L. B., Williamson, B. D., & Haff, G. G. (2016). Maintenance of Velocity and Power With Cluster Sets During High-Volume Back Squats. *International journal of sports physiology and performance*, 11(7), 885–892. <https://doi.org/10.1123/ijspp.2015-0602>
- Wallace, B. J., Winchester, J. B., & McGuigan, M. R. (2006). Effects of elastic bands on force and power characteristics during the back squat exercise. *The Journal of Strength & Conditioning Research*, 20(2), 268–272.