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Combined Plyometric Trainings and its Effectiveness in Improving Muscle Strength and Power among Male Adolescents

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Abstract

Objectives. This study aimed to evaluate the impact of combined plyometric training on increasing muscle strength and explosive power among male high school students.

Materials and methods. The study was performed using quasi-experimental design with randomized pretest and posttest design. Fourty-five students were divided into three groups: SKSQ (squat jump and skater hops); IODJ (ins and outs jump and depth jump); CTRL (conventional training program). The treatments were given three times a week for six weeks. The strength and power of muscle legs were assessed before and after the intervention using Leg Dynamometer and Jump MD. The statistical analysis was conducted using SPSS 29 and GraphdPad Prism.

Results. A paired sample t-test revealed that each group experienced a significant increase ($p < 0.05$), with the most notable improvements in strength ($\Delta = 5.40\,\%$) and power recorded in SKSQ ($\Delta = 18.33\,\%$). In contrast, CTRL showed the smallest yet significant gains in both strength and power. From this findings, participants in SKSQ and IODJ demonstrated a greater increase compared to those in the control group.

Conclusions. The results highlighted the effectiveness of combined plyometric trainings in enhancing athletic performance. Further research could explore the underlying mechanisms of these adaptations.

Keywords: muscle power, plyometric training, strength, physical performance, stretch-shortening cycle.

Introduction

Physical fitness is shaped by a variety of key physiological characteristics, with strength being a very important component (Putera et al., 2022). Strength is not only important for daily activities, but also for achieving peak performance in sports that require explosive movements, such as sprinting, jumping, and weightlifting (Alemdaroğlu et al., 2013; Suchomel et al., 2016). In addition to its direct impact on athletic performance, strength training improves other physical abilities, including endurance, speed, and economical movement, by improving muscle and nerve function (Hughes et al., 2018). Regular strength training also increases muscle hypertrophy, strengthens bones and tendons, and increases tendon stiffness, all of which contribute to greater force production and injury prevention (Brumitt & Cuddeford, 2015).

In addition to strength, power is emerging as another important element that influences athletic performance across a broad spectrum of sports (Marwat et al., 2022). Muscle power allows athletes to do more work in the same period of time or complete the same amount of work faster (Loturco et al., 2015). This ability is very important for high-intensity activities such as sprinting and jumping, as well as for making rapid changes of direction (Saeed, 2013). In particular, the relationship between strength and performance can vary depending on an athlete's level of training, age, and sport, with moderate strength often providing the greatest benefits for skills such as jumping and sprinting. Therefore, integrating targeted strength and power training into a fitness routine is essential to optimize the general health and performance of the specific sport (DeWeese et al., 2015).

Given the importance of both strength and power in sports, there has been considerable interest from researchers

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and coaches in developing effective training programs that can enhance these attributes simultaneously (Wang et al., 2023). One of the widely adopted training methods to improve various aspects of physical performance is plyometric training, which is characterized by explosive movements such as jumps, jumps, and bonds that target large muscle groups and quickly build strength and power (Hariyanto et al., 2022; Wiriawan et al., 2024) Plyometric training applies the principle of the stretch-shortening cycle (SSC), (Pardos-Mainer et al., 2021; Prianto et al., 2024a; Ramirez-Campillo et al., 2020) which activates the neuromuscular system and employs the stretch reflex (Seiberl et al., 2021), leveraging the elastic properties of muscle fibers and connective tissues (Deng et al., 2023), resulting in the production of greater muscular force and power (Davies et al., 2015; Morio et al., 2011).

Over the past few decades, extensive research has documented the benefits of plyometric training (PT), with the majority of studies concluding that it is an effective exercise modality for enhancing various physical attributes (Davies et al., 2015; Oliver et al., 2023). For instance, previous studies demonstrated that PT enhanced sprinting ability, jumping performance, and change-of-direction (CoD) (Aloui et al., 2021), muscle power and strength on soccer players (Bulqini, Achmad, et al., 2023). This improvement is due to the unique biomechanical principles of plyometrics, specifically the stretch-shortening cycle, which improves neuromuscular efficiency and explosive power production. However, plyometric training is not designed to be a standalone method; its benefits are enhanced when integrated with other training programs (Faigenbaum et al., 2007). For instance, combining plyometric exercises with a periodized strength training or balance training has been found to enhance vertical jump performance, muscular power, and proprioception (Chaouachi et al., 2014; Mazurek et al., 2018; Slimani et al., 2016).

Despite these advances, there is still a glaring gap in the literature regarding the effects of combined plyometric exercise programs in particular on adolescent populations. Most previous research has focused on comparing plyometric exercises with conventional endurance exercises or exercise-specific exercises, while the potential synergistic effects of different combinations of plyometric exercises are poorly understood. In addition, the long-term impact and optimal protocols for maximizing strength and power adaptation in adolescents warrant further exploration, especially considering the effects of maturation and growth on exercise response. Therefore, this study aimed to evaluate the effectiveness of two different combinations of plyometric exercises on muscle strength and power in adolescent male students. By addressing these gaps, this study seeks to provide evidence-based recommendations to optimize adolescent athletic development through targeted integrative training strategies.

Materials and methods

Study Participants

This study employed a quasi-experimental design that aimed to evaluate the effects of two different combinations of plyometric exercises on muscle strength and power in adolescent boys. A total of 45 male junior high school students, aged 13 to 15, were recruited from public junior high schools using systematic random sampling to ensure a representative sample. Inclusion criteria included not having a musculoskeletal injury and no prior experience with structured plyometric exercises. The students were then divided into three groups, each comprised fifteen students: SKSQ (combined squat jumps and skater hops); IODJ (depth jump and ins-and-outs), and CTRL (conventional training).

Study Organization

Each group followed supervised training sessions three times a week over a six-week period, for a total of 18 sessions. Sessions are scheduled on non-consecutive days to provide at least 48 hours of recovery time between training sessions, optimizing adaptation and minimizing the risk of injury (Colberg et al., 2016). The intensity of the exercise was initially set at 60% of the participant's maximum rep (RM) and gradually increased by 10% every two weeks, reaching 80% RM in the final phase. Each session lasts approximately 45 to 60 minutes and includes a standardized warm-up and cool-down period.

Prior the training program, baseline data were collected for all participants. Measurements of height, weight, and body mass index (BMI) were obtained using stadiometers and digital scales calibrated following standard protocols. Meanwhile, pulse rate and blood pressure were measured using a Heart Rate monitor and a sphygmomanometer. After an anthropometric assessment, muscle strength and power were measured using validated instruments. Strength was assessed using Back Leg Dynamometer (Takei Scientific Instruments Co., Ltd.), which measures the maximum isometric strength of the lower leg. Participants conducted three experiments and the highest scores were recorded for analysis. Meanwhile, power was measured using the Jump MD which calculates vertical jump height and power output through force plate technology. Participants performed three countermovement jumps with their hands on their hips to minimize the influence of arm swings, with the best jumps being used for data analysis. All assessments were conducted and evaluated by trained testers.

Statistical Analysis

Data were analyzed using SPSS version 29 (IBM Corp., Armonk, NY) and GraphPad Prism for Mac. Descriptive statistics, including means and standard deviations, were calculated for all variables. Within-group changes from pre- to post-intervention were analyzed using paired t-tests. Between-group differences were assessed using one-way ANOVA, followed by Least Significant Difference (LSD) post-hoc tests to identify specific group contrasts. Statistical significance was set at $p < 0.05$. Assumptions of normality and homogeneity of variance were verified prior to conducting parametric tests.

Results

Table 1 displays the baseline anthropometric characteristics of participants where statistical analysis revealed that the subjects were relatively homogeneous

Table 1. Descriptive statistic of subjects (mean ± SD)

Variable	SKSQ	IODJ	CTRL
Age (years)	14.65 ± 0.78	15.30 ± 0.60	15.12 ± 0.45
Bodyweight (kg)	45.55 ± 4.32	43.82 ± 8.17	41.91 ± 8.90
Height (cm)	157.18 ± 8.12	153.91 ± 8.37	154.55 ± 8.91
Body mass index (kg/m^2)	18.48 ± 0.76	18.72 ± 0.55	17.67 ± 0.70
Heart rate (bpm)	78.65 ± 12.88	77.00 ± 9.09	77.82 ± 10.12
Systole (mmHg)	109.24 ± 6.97	105.69 ± 4.68	107.35 ± 6.44
Diastole (mmHg)	79.35 ± 5.43	72.82 ± 4.05	76.52 ± 6.16

Table 2. Paired t-test analysis results

Groups		Strength (kg)			Power (watt)		
		T-score	Mean ± SD	sig.	T-score	Mean ± SD	sig.
SKSQ	Pre-test	7.26	48.85 ± 7.30	0.001*	8.96	232.10 ± 30.14	0.000*
	Post-test		54.25 ± 6.75			250.43 ± 31.05	
IODJ	Pre-test	3.92	48.40 ± 4.50	0.000*	6.24	211.60 ± 28.58	0.000*
	Post-test		53.00 ± 4.65			223.15 ± 31.62	
CTRL	Pre-test	3.10	49.22 ± 7.07	0.001*	5.28	199.54 ± 20.18	0.000*
	Post-test		52.79 ± 6.39			202.05 ± 21.71	

across all groups. The average age between the groups was relatively the same, ranging from 14.65 to 15.30 years. Weight was slightly higher in the SKSQ group (45.55 kg) compared to IODJ (43.82 kg) and CTRL (41.91 kg), while height also showed minimal variation, with SKSQ being the tallest (157.18 cm) and the shortest IODJ (153.91 cm). BMI values are quite consistent, although slightly higher in the IODJ group (18.72 kg/m^2). Heart rate was comparable among all groups, ranging from about 77–79 bpm. Notably, the SKSQ group showed the highest systolic (109.24 mmHg) and diastolic (79.35 mmHg) blood pressure, while the IODJ group showed the lowest values for both (105.69/72.82 mmHg). Overall, the two groups were relatively homogeneous in terms of physical and cardiovascular characteristics, with only a slight difference observed.

Table 2 shows the results of paired t-tests evaluating changes in power (kg) and power (watts) before and after the intervention in three groups: SKSQ, IODJ, and CTRL. All three groups showed statistically significant improvements in both strength and power, as indicated by a p< value of 0.05 (marked with *).

The SKSQ group exposed the largest increase, with power increasing from 48.85 ± 7.30 kg to 54.25 ± 6.75 kg (T = 7.26, p = 0.001) and power increasing from 232.10 ± 30.14 watts to 250.43 ± 31.05 watts (T = 8.96, p = 0.000). The IODJ group also increased significantly, with power increasing from 48.40 ± 4.50 kg to 53.00 ± 4.65 kg (T = 3.92, p = 0.000), and power from 211.60 ± 28.58 watts to 223.15 ± 31.62 watt (T = 6.24, p = 0.000). The CTRL group, although not exposed to the special training intervention, also showed a modest but significant increase in strength (49.22 ± 7.07 kg to 52.79 ± 6.39 kg, T = 3.10, p = 0.001) and power (199.54 ± 20.18 watts to 202.05 ± 21.71 watts, T = 5.28, p = 0.000).

All groups demonstrated significant increases in strength after six weeks of their respective training programs (p<0.05), with the SKSQ showing the greatest improvement (Δ=5.40%). A similar trend was observed in power, where all groups exhibited significant enhancements (p<0.05), with SKSQ experiencing the highest increase in leg muscle power (Δ=18.33%) (Table 2 and 3). Meanwhile, CTRL had the smallest significant increases in both strength (2.51%) and power (3.57%) (Figure 1).

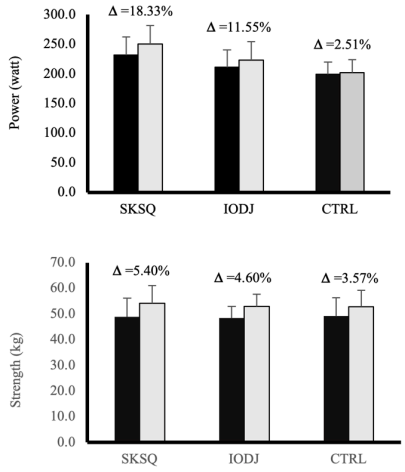

Fig. 1. The increases in muscle strength (left) and power (right) after six weeks of combined plyometric training program

These results suggest that the SKSQ and IODJ interventions are effective in improving muscle strength and power, with SKSQ showing the most pronounced improvement. Interestingly, even the control group experienced an increase, which may be due to natural development, general physical activity, or other external factors.

The LSD test indicated significant differences in strength between SKSQ and CTRL (p=0.000) and between IODJ and

Table 3. Between group differences in the changes of strength and power of muscle leg (mean ± SD)

Group	Δ Strength (kg)	sig.	Δ Power (watt)	sig.
SKSQ	5.77 ± 2.27		18.71 ± 2.18	
IODJ	3.68 ± 1.48	0.000*	14.56 ± 2.89	0.005*
CTRL	1.91 ± 1.02		6.71 ± 1.06	

Table 4. Post-hoc analysis of significant differences in measured variables

Pair-wise Group		Strength	Power
SKSQ	IODJ	0.070	0.236
	CTRL	0.000*	0.000*
IODJ	CTRL	0.011*	0.020*

CTRL (p=0.011). For power, significant differences were also found between SKSQ and CTRL (p=0.000) and between IODJ and CTRL (p=0.020) (Table 4).

Discussion

Recent studies have shown that plyometric exercise (PT) significantly improves leg muscle strength and power, with the SKSQ and IODJ groups showing much greater improvements compared to the CTRL group. Specifically, the SKSQ group given combined plyometric exercises between squat jump and skater hop showed the most pronounced improvement in terms of leg muscle strength and power measured at the end of the intervention at week six. These findings underscore the effectiveness of plyometric exercises in stimulating neuromuscular adaptations resulting in increased power production and explosive power (Prianto et al., 2024b). The superior performance of the SKSQ group can be attributed to the dynamic and multi-planar nature of the exercise, which is likely to encourage greater recruitment of fast-twitch muscle fibers and improve the efficiency of stretch-shortening cycles (Maciejczyk et al., 2021). This is in line with previous studies that have reported significant improvements in lower limb strength and power after plyometric training protocols that emphasize vertical and lateral jumping movements (Bulqini, Widodo, et al., 2023). In addition, the substantial increase in power observed is in line with the work of Putera et al. (2023) and Wīrīawan et al. (2024) which highlights that plyometric training not only improves muscle strength but also endurance and flexibility, which contributes to overall athletic performance.

In contrast, the IODJ group, which combined depth jump and ins-and-out, also showed significant improvements in strength and power, although their gains were slightly less prominent compared to the SKSQ group. These differences may reflect the different biomechanical demands and neuromuscular stimuli posed by the two training protocols. Depth jumps, known for their high-impact eccentric loads, are effective for developing strength and reactive power, especially in stretch-shortening cycles (Louder et al., 2023). However, the combination with ins-and-outs, which emphasize rapid lateral movements, may have distributed training stimuli across different muscle groups and movement patterns, resulting in a more balanced but less than maximal increase in isolated force and force size. These findings are in partial contrast to some previous studies that have shown that depth jumps alone result in greater power gain than combined plyometric exercises suggesting that exercise selection and combination may affect training outcomes (Sánchez-Sixto et al., 2021).

The minimal increase in CTRL groups reinforces the idea that conventional training methods without plyometric components may be less effective in elicit rapid neuromuscular adaptation in adolescent populations. Overall, the results support the growing consensus in sports science that well-structured plyometric training, especially when combining various jump modalities, is essential for optimizing muscle strength and power development in young athletes (Guo et al., 2021; Kobal et al., 2017a; Zhou et al., 2022).

Mechanistically, the effectiveness of PT lies in its exploitation of the stretch-shortening cycle, which allows muscles to store and release elastic energy, thereby enhancing force production and movement efficiency (Davies et al., 2015). Studies have shown that PT can induce beneficial changes in muscle-tendon unit characteristics through neuromuscular regulation, enhancing both strength and flexibility (Hirayama et al., 2017; Silva et al., 2019). The specific combination of exercises used in this study effectively shortened the transition between eccentric and concentric phases, thereby improving jumping ability and leg muscle strength (Louder et al., 2015). Among the experimental groups, SKSQ showed greater improvements due to its focus on single-leg movements, which have been found to be more effective than double-leg exercises for enhancing power and balance (Karimah et al., 2024). This finding is supported by literatures indicating that single-leg plyometric training yields greater explosive force and jump height improvements compared to double-leg training (Ramirez-Campillo et al., 2020).

The observed increases in power among subjects were also linked to exercise intensity. The moderate to high-intensity training employed in this study aligns with previous findings that high-intensity exercises can lead to immediate enhancements in power capacity (Kobal et al., 2017b). Neuromuscular adaptations likely contributed to these improvements, further supporting the effectiveness of PT in enhancing athletic performance (Chelly et al., 2010). Taken together, the results of this study emphasize the importance of exercise specificity and the strategic combination of plyometric modalities in maximizing strength and power outcomes. Future research may benefit from exploring variations in volume, intensity, and recovery periods, as well as long-term adaptations to plyometric training in different adolescent populations.

Conclusions

Plyometric training induces significant adaptations through SSC mechanism, resulting in the increase on strength and power. Given its numerous benefits, PT is recommended as an integral component of exercise programs for individuals. However, the small sample size limits the generalizability of the findings and increases the potential for random errors and bias. Future research should also consider extending the exercise duration beyond six weeks to better observe long-term muscle adaptations.

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Conflict of Interest

The authors declare no conflict of interest.

References

Putera, S. H. P., Setijono, H., Wiriawan, O., Muhammad, H. N., & Hariyanto, A. (2022). The Effect of Six-Week Plyometric Training on Enhancing Sports Performance of Adolescent Students. *Physical Education Theory and Methodology, 22*(3), 37-44. https://doi.org/10.17309/tmfv.2023.1.06

Alemdaroğlu, U., Dündar, U., Köklü, Y., Aşci, A., & Findikoğlu, G. (2013). The effect of exercise order incorporating plyometric and resistance training on isokinetic leg strength and vertical jump performance: A comparative study. *Isokinetics and Exercise Science, 21*(3), 211-217. https://doi.org/10.3233/IES-130509

Suchomel, T. J., Nimphius, S., & Stone, M. H. (2016). The Importance of Muscular Strength in Athletic Performance. *Sports Medicine, 46*(10), 1419-1449. https://doi.org/10.1007/s40279-016-0486-0

Hughes, D. C., Ellefsen, S., & Baar, K. (2018). Adaptations to Endurance and Strength Training. *Cold Spring Harbor Perspectives in Medicine, 8*(6), a029769. https://doi.org/10.1101/cshperspect.a029769

Brumitt, J., & Cuddeford, T. (2015). Current Concepts of Muscle and Tendon Adaptation to Strength and Conditioning. *International Journal of Sports Physical Therapy, 10*(6), 748-759.

Marwat, M. K., Nizami, R., Farah, H., & Gillani, S. M. B. (2022). Role of Strength and Power In Athletic Performance. *Journal of Positive School Psychology, 6*(7), 2969-2980.

Loturco, I., Nakamura, F. Y., Kobal, R., Gil, S., Abad, C. C. C., Cuniyochi, R., Pereira, L. A., & Roschel, H. (2015). Training for power and speed: Effects of increasing or decreasing jump squat velocity in elite young soccer players. *Journal of Strength and Conditioning Research, 29*(10), 2771-2779. https://doi.org/10.1519/JSC.0000000000000951

Saeed, K. K. (2013). Effect of complex training with low-intensity loading interval on certain physical variables among volleyball infants (10-12 ages). *Ovidius University Annals, Series Physical Education and Sport/Science, Movement and Health, 13*(1), 16-22.

DeWeese, B. H., Hornsby, G., Stone, M., & Stone, M. H. (2015). The training process: Planning for strength–power training in track and field. Part 1: Theoretical aspects. *Journal of Sport and Health Science, 4*(4), 308-317. https://doi.org/10.1016/j.jshs.2015.07.003

Wang, X., Soh, K. G., Samsudin, S., Deng, N., Liu, X., Zhao, Y., & Akbar, S. (2023). Effects of high-intensity functional training on physical fitness and sport-specific performance among the athletes: A systematic review with meta-analysis. *PloS One, 18*(12), e0295531. https://doi.org/10.1371/journal.pone.0295531

Hariyanto, A., Pramono, B. A., Mustar, Y. S., Sholikhah, A. M., & Prilaksono, M. I. A. (2022). Effect of Two Different Plyometric Trainings on Strength, Speed and Agility Performance. *Advances in Health Sciences Research. 5th International Conference on Sport Science and Health (ICSSH 2021),* Malang, Indonesia. https://doi.org/10.2991/ahsr.k.220203.017

Wiriawan, O., Setijono, H., Putera, S. H. P., Sholikhah, A. M., Kaharina, A., & Pranoto, A. (2024). Positive Effect of Sand-Based Plyometric Jump Training on Increasing Muscle Strength and Power in Young Student-athletes. *International Journal of Disabilities Sports and Health Sciences, 7*(1), Article 1. https://doi.org/10.33438/ijdshs.1367696

Pardos-Mainer, E., Lozano, D., Torrontegui-Duarte, M., Cartón-Llorente, A., & Roso-Moliner, A. (2021). Effects of Strength vs. Plyometric Training Programs on Vertical Jumping, Linear Sprint and Change of Direction Speed Performance in Female Soccer Players: A Systematic Review and Meta-Analysis. *International Journal of Environmental Research and Public Health, 18*(2), 401. https://doi.org/10.3390/ijerph18020401

Prianto, D. A., Wiriawan, O., Setijono, H., Muhammad, H. N., Putera, S. H. P., Sholikhah, A. M., Muhyi, M., Taufik, M. S., & Purwoto, S. P. (2024a). The impact of different combinations of plyometric training on the physical performances: Experimental study on student-athletes. *Retos: Nuevas Tendencias En Educación Física, Deporte y Recreación,* 58, 361-367.

Ramirez-Campillo, R., Moran, J., Chaabene, H., Granacher, U., Behm, D. G., García-Hermoso, A., & Izquierdo, M. (2020). Methodological characteristics and future directions for plyometric jump training research: A scoping review update. *Scandinavian Journal of Medicine & Science in Sports, 30*(6), 983-997. https://doi.org/10.1111/sms.13633

Seiberl, W., Hahn, D., Power, G. A., Fletcher, J. R., & Siebert, T. (2021). Editorial: The Stretch-Shortening Cycle of Active Muscle and Muscle-Tendon Complex: What, Why and How It Increases Muscle Performance? *Frontiers in Physiology,* 12. https://doi.org/10.3389/fphys.2021.693141

Deng, N., Soh, K. G., Abdullah, B., & Huang, D. (2023). Effects of plyometric training on measures of physical fitness in racket sport athletes: A systematic review and meta-analysis. *PeerJ,* 11, e16638. https://doi.org/10.7717/peerj.16638

Davies, G., Riemann, B. L., & Manske, R. (2015). Current concepts of plyometric exercise. *International Journal of Sports Physical Therapy, 10*(6), 760-786.

Morio, C., Chavet, P., Androuet, P., Foissac, M., Berton, E., & Nicol, C. (2011). Time course of neuro-mechanical changes underlying stretch–shortening cycle during intermittent exhaustive rebound exercise. *European Journal of Applied Physiology, 111*(9), 2295-2305. https://doi.org/10.1007/s00421-011-1859-6

Oliver, J. L., Ramachandran, A. K., Singh, U., Ramirez-Campillo, R., & Lloyd, R. S. (2024). The Effects of Strength, Plyometric and Combined Training on Strength, Power and Speed Characteristics in High-Level, Highly Trained Male Youth Soccer Players: A Systematic Review and Meta-Analysis. *Sports Medicine, 54*(3), 623-643. https://doi.org/10.1007/s40279-023-01944-8

Aloui, G., Hermassi, S., Hayes, L. D., Sanal Hayes, N. E. M., Bouhafs, E. G., Chelly, M. S., & Schwesig, R. (2021). Effects of Plyometric and Short Sprint with Change-of-Direction

Training in Male U17 Soccer Players. *Applied Sciences, 11*(11), Article 11. https://doi.org/10.3390/app11114767

Bulqini, A., Achmad, W., Nurhasan, Heryanto, N. M., Putera, S. H. P., & Sholikhah, A. M. (2023). Plyometric Hurdle Jump Training Using Beach Sand Media Increases Power and Muscle Strength in Young Adult Males. *Physical Education Theory and Methodology, 23*(4), 531-536. https://doi.org/10.17309/tmfv.2023.4.06

Faigenbaum, A. D., McFarland, J. E., Keiper, F. B., Tevlin, W., Kang, J., & Hoffman, J. R. (2007). Effects of a short-term plyometric and resistance training program on fitness performance in boys age 12 to 15 years. *Journal of Sports Science & Medicine,* 6, 519–525

Chaouachi, A., Othman, A. B., Hammami, R., Drinkwater, E. J., & Behm, D. G. (2014). The combination of plyometric and balance training improves sprint and shuttle run performances more often than plyometric-only training with children. *Journal of Strength and Conditioning Research, 28*(2), 401-412. https://doi.org/10.1519/JSC.0b013e3182987059

Mazurek, K., Zmijewski, P., Makaruk, H., Mróz, A., Czajkowska, A., Witek, K., Bodasiński, S., & Lipińska, P. (2018). Effects of Short-Term Plyometric Training on Physical Performance in Male Handball Players. *Journal of Human Kinetics,* 63, 137-148. https://doi.org/10.2478/hukin-2018-0014

Slimani, M., Chamari, K., Miarka, B., Vecchio, F. B. D., & Chéour, F. (2016). Effects of Plyometric Training on Physical Fitness in Team Sport Athletes: A Systematic Review. *Journal of Human Kinetics,* 53, 231. https://doi.org/10.1515/hukin-2016-0026

Colberg, S. R., Sigal, R. J., Yardley, J. E., Riddell, M. C., Dunstan, D. W., Dempsey, P. C., Horton, E. S., Castorino, K., & Tate, D. F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care, 39*(11), 2065-2079. https://doi.org/10.2337/dc16-1728

Prianto, D. A., Wiriawan, O., Setijono, H., Muhammad, H. N., Putera, S. H. P., Sholikhah, A. M., Muhyi, M., Taufik, M. S., & Purwoto, S. P. (2024b). The impact of different combinations of plyometric training on the physical performances: Experimental study on student-athletes. *Retos: Nuevas Tendencias En Educación Física, Deporte y Recreación,* 58, 361–367.

Maciejczyk, M., Błyszczuk, R., Drwal, A., Nowak, B., & Strzała, M. (2021). Effects of Short-Term Plyometric Training on Agility, Jump and Repeated Sprint Performance in Female Soccer Players. *International Journal of Environmental Research and Public Health, 18*(5), 2274. https://doi.org/10.3390/ijerph18052274

Bulqini, A., Widodo, A., Nurhasan, Muhammad, H. N., Putera, S. H. P., & Sholikhah, A. M. (2023). Plyometric Hurdle Jump Training Using Beach Sand Media Increases Power and Muscle Strength in Young Adult Males. *Physical Education Theory and Methodology, 23*(4), 531–536. https://doi.org/10.17309/tmfv.2023.4.06

Putera, S. H. P., Setijono, H., Wiriawan, O., Nurhasan, Muhammad, H. N., Hariyanto, A., Sholikhah, A. M., & Pranoto, A. (2023). Positive Effects of Plyometric Training on Increasing Speed, Strength and Limb Muscles Power in Adolescent Males. *Physical Education Theory and Methodology, 23*(1), 42-48. https://doi.org/10.17309/tmfv.2023.1.06

Louder, T., Thompson, B. J., Woster, A., & Bressel, E. (2023). Kinetics of Depth Jumps Performed by Female and Male National Collegiate Athletics Association Basketball Athletes and Young Adults. *Journal of Functional Morphology and Kinesiology, 8*(3), Article 3. https://doi.org/10.3390/jfmk8030108

Sánchez-Sixto, A., Harrison, A. J., & Floría, P. (2021). Effects of Plyometric Vs. Combined Plyometric Training on Vertical Jump Biomechanics in Female Basketball Players. *Journal of Human Kinetics,* 77, 25-35. https://doi.org/10.2478/hukin-2021-0009

Guo, Z., Huang, Y., Zhou, Z., Leng, B., Gong, W., Cui, Y., & Bao, D. (2021). The Effect of 6-Week Combined Balance and Plyometric Training on Change of Direction Performance of Elite Badminton Players. *Frontiers in Psychology,* 12, 684964. https://doi.org/10.3389/fpsyg.2021.684964

Kobal, R., Loturco, I., Barroso, R., Gil, S., Cuniyochi, R., Ugrinowitsch, C., Roschel, H., & Tricoli, V. (2017a). Effects of Different Combinations of Strength, Power, and Plyometric Training on the Physical Performance of Elite Young Soccer Players. *Journal of Strength and Conditioning Research, 31*(6), 1468-1476. https://doi.org/10.1519/JSC.0000000000001609

Zhou, L., Gong, W., Wang, S., Guo, Z., Liu, M., Chuang, S., Bao, D., & Zhou, J. (2022). Combined balance and plyometric training enhances knee function, but not proprioception of elite male badminton players: A pilot randomized controlled study. *Frontiers in Psychology,* 13, 947877. https://doi.org/10.3389/fpsyg.2022.947877

Hirayama, K., Iwanuma, S., Ikeda, N., Yoshikawa, A., Ema, R., & Kawakami, Y. (2017). Plyometric training favors optimizing muscle–tendon behavior during depth jumping. *Frontiers in Physiology,* 8. https://www.frontiersin.org/article/10.3389/fphys.2017.00016

Silva, A. F., Clemente, F. M., Lima, R., Nikolaidis, P. T., Rosemann, T., & Knechtle, B. (2019). The effect of plyometric training in volleyball players: A systematic review. *International Journal of Environmental Research and Public Health, 16*(16), 2960. https://doi.org/10.3390/ijerph16162960

Louder, T., Bressel, M., & Bressel, E. (2015). The Kinetic Specificity of Plyometric Training: Verbal Cues Revisited. *Journal of Human Kinetics,* 49, 201-208. https://doi.org/10.1515/hukin-2015-0122

Karimah, H. N., Wiriawan, O., & Wibowo, S. (2024). Pengaruh Latihan Squat Jumps Skater Hops Dengan Jump Forheight Ins and Outs Terhadap Kekuatan Dan Power Otot Tungkai. *Jendela Olahraga, 9*(1), Article 1. https://doi.org/10.26877/jo.v9i1.15550

Kobal, R., Loturco, I., Barroso, R., Gil, S., Cuniyochi, R., Ugrinowitsch, C., Roschel, H., & Tricoli, V. (2017b). Effects of Different Combinations of Strength, Power, and Plyometric Training on the Physical Performance of Elite Young Soccer Players. *The Journal of Strength & Conditioning Research, 31*(6), 1468. https://doi.org/10.1519/JSC.0000000000001609

Chelly, M. S., Ghenem, M. A., Abid, K., Hermassi, S., Tabka, Z., & Shephard, R. J. (2010). Effects of in-season short-term plyometric training program on leg power, jump- and sprint performance of soccer players. *Journal of Strength and Conditioning Research, 24*(10), 2670-2676. https://doi.org/10.1519/JSC.0b013e3181e2728f

Комбіновані пліометричні тренування та їх ефективність у покращенні м'язової сили та потужності серед підлітків чоловічої статі

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 4 табл., 1 рис., 42 джерела.

Мета дослідження. Метою цього дослідження було оцінити вплив комбінованих пліометричних тренувань на підвищення показників м'язової сили та вибухової потужності серед учнів чоловічої статі середньої школи.

Матеріали та методи. Дослідження проводилося із застосуванням квазіекспериментального дизайну з рандомізованим методом претесту та посттесту. Сорок п'ять студентів було розділено на три групи: SKSQ — squat jump and skater hops (присідання з вистрибуванням та бічні стрибки з ноги на ногу, що імітують рухи ковзаняра); IODJ — ins and outs jump and depth jump (стрибки у позиції ноги нарізно-ноги разом та стрибки в глибину); CTRL — conventional training program (традиційна програма тренувань). Тренування проходили тричі на тиждень протягом шести тижнів. Оцінювання показників сили та потужності м'язів ніг проводилося на перед- та постінтервенційному етапах дослідження за допомогою динамометра для ніг та приладу Jump MD. Статистичний аналіз проводився із використанням програмного забезпечення SPSS 29 та GraphdPad Prism.

Результати. Т-критерій для парних вибірок встановив, що кожна група зазнала значного підвищення результативності ($p<0.05$), причому найпомітніші поліпшення спостерігалися в показниках сили ($\Delta = 5.40\,\%$) та потужності, зафіксованих у групі SKSQ ($\Delta = 18.33\,\%$). Натомість у групі CTRL відзначено мінімальне, однак суттєве зростання як показників сили, так і потужності. Згідно з отриманими результатами, учасники груп SKSQ та IODJ продемонстрували більший прогрес порівняно з учасниками контрольної групи.

Висновки. Результати підкреслили ефективність комбінованих пліометричних тренувань у підвищенні спортивної результативності. Подальші дослідження можуть бути спрямовані на вивчення механізмів, що лежать в основі зазначених адаптацій.

Ключові слова: м'язова потужність, пліометричне тренування, сила, фізична результативність, цикл розтягування-скорочення.

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