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The Effectiveness of Different Combinations of Plyometric Training on Increasing Muscle Strength and Power in Healthy Adolescents Students

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Abstract. This study aims to assess the impact of plyometric training on increasing leg muscle strength and explosive power. The research method applied is quasi-experimental research with pre-test and post-test design. The research subjects were divided into three groups, consisting of 11 students each. The first group (K1) received a combination of squat jump and skater hops exercise, K2 received a combination of a jump for height and ins and outs exercise, while K3 received conventional training. All subjects were then instructed to perform a six-week respected training program consisting of three sessions a week, making it a total of 18 sessions. The intensity was set at 60% RM and gradually increased to 80% RM. Pre-test and post-test on strength and power were obtained using Leg Dynamometer and Jump MD. Data were presented descriptively and bivariate analysis was done using SPSS 23 for Windows. Paired sample t-test showed that each group had a significant increase ($p < 0.05$) after six weeks of treatment, with the highest improvement in strength and power observed in K1 (Δ strength = 11.57%, Δ power = 7.57%). Meanwhile, K3 had the smallest but significant increase in both strength and power. Based on the aforementioned explanation, it can be concluded that subjects assigned to PT had a greater increase compared to those in the control group. It indicated that PT induces adaptations in neural and musculoskeletal systems, which lead to producing greater muscle force, resulting in higher gain in measured variables.
Keywords: *explosive force, muscle strength, power, plyometric training, stretch-shortening cycle*

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INTRODUCTION

Strength and power are both key components of physical fitness, with strength playing a particularly crucial role in explosive actions required for maximum performance in sports (Alemdaroğlu et al., 2013; Suchomel et al., 2016). These attributes are essential for building optimal physical performance (Silva et al., 2019), as well as for enhancing athletic outcomes such as sprinting, jumping, and changes-of-direction (CoD) (Silva et al., 2019; Saeed, 2013). As a result, the best training program which is able to increase both power and strength have drawn the attention of numerous researchers and coaches (Wang et al., 2022).

Plyometric is one of the most widely used training methods to enhance various physical performances, known for improving motor control and providing neuromuscular benefits (Bulqini et al., 2023; Putera et al., 2022, 2023). Conceptually, plyometric training (PT) uses the mechanism of stretch-shortening or SSC which occurs during the transitions from stretching phase (i.e eccentric) to shortening phase (i.e concentric) (Pardos-Mainer et al., 2021; Prianto et al., 2024; Ramirez-Campillo et al., 2018). This mechanism involves pre-activation of neuromuscular and stretch-reflex (Seiberl et al., 2021), which utilises the elastic characteristics of muscle fibre and connective tissue (Deng et al., 2024), facilitating muscles to store elastic energy during the phase of deceleration and release it during the acceleration phase to produce greater amount of muscular force and and power (Davies et al., 2015; Morio et al., 2011).

Over the past few decades, numerous studies on the benefit of plyometric training have been documented, with most of these studies concluding that PT is an effective exercise for improving agility (Asadi, 2012), balance (Ramachandran et al., 2021), speed (Michailidis et al., 2013), and other sport performances. Aloui et al. (2021) in their experiment study revealed that a single type of PT done for eight weeks was able to improve sprinting, jump performance, and change-of-direction (CoD) in soccer player. Another finding reported that PT done by young adult for six weeks increased leg’s muscle power and strength (Bulqini et al., 2023). However, PT is not designed to be a stand-alone exercise method. The beneficial effect of PT is more pronounced when combined with other training program as reported by previous studies (Faigenbaum et al., 2007). A combination of plyometric with a periodized strength training program was able to enhance vertical jump performance, muscular power, and proprioception in general (Mazurek et al., 2018; Slimani et al., 2016). Similar findings was reported by Chaouachi et al. (2014) in their study that employed a combination of PT and balance training program for eight weeks, which exhibited better outcome on sprint performance and shuttle run in athletes.

To the best of our knowledge, there are few studies on the combination of different types of PT in adolescents. In earlier studies involving youth, the effect of PT exercises was mostly compared to a 'control' condition that comprised of conventional training program, or other methods such as resistance or strength training. The different combination of PT and its impact on strength and power have not been clearly explored. Thus, the purpose of this study was to analyse the effectiveness of two different combinations of plyometric exercise on strength and power of male adolescent students.

DATA AND METHODS

Study design and sample

It was quasi-experimental research that involves treatment or training to the subjects. The results of the treatment will be described through the collection of pre-test and post-test data. A total of 33 subjects were selected using systematic random sampling from the student population at state junior high school in Surabaya who actively participated in any sport clubs or activities. The inclusive criteria of the subjects were as follows: (1) male students age 13-16 years; (2) students were in good health, identified by the absence of any injury in lower limbs; (3) committed to follow the whole training program that had been prepared; and (4) registered as active member of sport clubs. Before the treatment began, all subjects and their guardians were explained about the nature of training procedures along with its benefits and possible harms or risks related to their participation in this research. The written informed consent was then acquired from each guardian prior to the experimental. All procedures and protocols applied in this study followed the ethical conduct of research involving human subjects by Helsinki World Medical Association Declaration. This study is approved by Ethics Committee of XXX University (2024/015).

Study Organization

The students were divided into three groups which were experimental groups (K1, K2) and control group (K3) through ordinal pairing system. Each group consisted of 11 students with homogenous baseline characteristics. Subjects in K1 would be assigned to combine training consisted of regular squat jumps and skater hops training program. Subjects in K2 were assigned to jump-for-height and the ins-and-outs training program. Meanwhile, K3 was assigned to a conventional or regular training program.

Experimental procedure was led by professional testers from Sports Science Fitness Centre (SSFC) at Universitas Negeri Surabaya. Plyometric exercise was individualized for each subject according to the results of maximum strength and power during the pre-test. The training programs were held three times a week for six weeks, made it a total of eighteen sessions. Each session took place on non-consecutive days as suggested by previous studies to provide a minimum of 48 hours of recovery time (Colberg et al., 2016; Hariyanto et al., 2022; Putera et al., 2022). Before each session began, all subjects were asked to perform a proper warming-up exercise for ten minutes, then followed by three-sets of actual training program with two minutes of resting period between set. The intensity of the training program was set at 60% RM, and it was gradually increased by 10% every two weeks until reaching 80% RM. After they completed the training program for each session, all subjects were instructed to cool down with light stretches to relax the muscles and prevent soreness. Every training session was monitored and the logbook of each subject was recorded every week by the testers.

Data Measurement

The measurement was done twice, before the first session of experimental period (pre-test) and right after the last session ended (post-test). Subjects were not allowed to engage in any heavy physical activity related to jumping prior to 24 hours before the testing day. Before the first session, the anthropometric measurements consisted of bodyweight (kg), height (cm), and body mass index (kg/m^2) were obtained for each subject. Bodyweight was measured using digital scale (Omron HN-286, Osaka, Japan) and height was measured using portable stadiometer (Seca 213, Hamburg, Germany).

After anthropometric measurement was done, each subject was assessed for muscle strength and power by the testers. Strength measurement was done using Back Leg Dynamometer. Subjects were instructed to lift and pull straight up against dynamometer as hard as possible using their leg muscle while keeping the back in straight position. They need to hold the pull for about 2-3 seconds and ensure the subject did not use excessive upper body force, as the goal is to measure the strength of muscle leg. The dynamometer would display the peak force exerted which was recorded in kilograms (kg). Each participant was given three attempts, with 30 seconds of resting period between each attempt. The best value was used for further analysis.

Leg muscle power was measured using Jump MD with belt. Subject was instructed to stand upright on the mat with feet shoulder width apart, toes pointing forward, and hand naturally hold the hip at the sides. The subject then started to dip into a squat position and immediately did upward jump as high as possible with explosive force. The result was then calculated into the formula to obtain the output of peak power in watt. Each subject was allowed to jump three times with 1-2 minutes of rest between each attempt to ensure consistent performance. The reading of highest score from the device was used for analysis.

Data Analysis

All statistical analysis was done using SPSS 23 for Windows and GraphPad Prism v.10.3.1 for Mac. Normality test was used for all measured variables using Saphiro-Wilk. Follow up analysis was done using paired t-test to compare the mean differences between pre-test and post-test results on each group. One-way Anova was applied as well to examine the mean differences between three groups. Afterward, a confirmatory analysis was done to find out pair-wise difference using Least Significant Different (LSD) test. Mean and standard deviation were presented descriptively for all measured variables, and p-values < 0.05 were considered statistically significant.

RESULTS

All thirty-three subjects (15.02 ± 0.55 years old; 43.76 ± 6.44 kg; 155.21 ± 7.96 cm; 18.29 ± 0.68 kg/m^2) were actively followed all protocols and completed the whole training programs. No injury, muscle soreness or subject drop out reported over the six-weeks of experimental period.

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

Variable	All	K1 (n=11)	K2 (n=11)	K3 (n=11)
Age (years)	15.02 ± 0.55	14.65 ± 0.78	15.30 ± 0.60	15.12 ± 0.45
Bodyweight (kg)	43.76 ± 6.44	45.55 ± 4.32	43.82 ± 8.17	41.91 ± 8.90
Height (cm)	155.21 ± 7.96	157.18 ± 8.12	153.91 ± 8.37	154.55 ± 8.91
Body mass index (kg/m^2)	18.29 ± 0.68	18.48 ± 0.76	18.72 ± 0.55	17.67 ± 0.70

K1 = squat jump + skater hops; K2 = jump-for-height + ins-and-outs; K3 = conventional training

Table 1 shows the descriptive value of baseline anthropometric characteristic of all subjects participated in this study. Subjects in K2 had the greatest average of age and body mass index which were 15.30 ± 0.60 years and 18.72 ± 0.55 kg/m^2, respectively. Meanwhile, the highest average of bodyweight and height were found in K1, which were 45.55 ± 4.32 kg and 157.18 ± 8.12 cm. Statistical test reported no significant difference (p > 0.05) between groups in regard to anthropometric characteristics, thus it could be assumed that subjects in all groups were equally homogenous.

Table 2.
Paired t-test analysis of measured variables over six weeks of experimental period

Groups		Strength (kg)			Power (watt)		
		T-score	Mean ± SD	sig.	T-score	Mean ± SD	sig.
K1	Pre-test	8.42	44.09 ± 21.30	0.000*	9.55	228.40 ± 43.28	0.000*
	Post-test		49.86 ± 20.26			247.11 ± 41.10	
K2	Pre-test	3.53	41.77 ± 12.57	0.003*	6.21	199.50 ± 50.35	0.000*
	Post-test		45.45 ± 12.94			214.06 ± 53.24	
K3	Pre-test	4.22	54.32 ± 22.18	0.001*	4.18	190.25 ± 38.36	0.000*
	Post-test		56.23 ± 22.18			196.96 ± 39.42	

K1 = squat jump + skater hops; K2 = jump-for-height + ins-and-outs; K3 = conventional training
*significant at α = 0.05 using paired t-test

Table 3.
Between group differences in the changes of strength and power of muscle leg

Group	Δ Strength (kg)	%	sig.	Δ Power (watt)	%	sig.
K1	5.77 ± 2.27	11.57	0.000*	18.71 ± 2.18	7.57	0.005*
K2	3.68 ± 1.48	8.10		14.56 ± 2.89	6.80	
K3	1.91 ± 1.02	3.40		6.71 ± 1.06	1.06	

K1 = squat jump + skater hops; K2 = jump-for-height + ins-and-outs; K3 = conventional training
*significant at α = 0.05 using one-way Anova

Table 2 and 3 display the results of pre-test and post-test of measured variables, including its change in percentage. Significant rises in strength were exhibited in all groups, where all subjects had a quite significant change after given their respected training programs for six weeks ($p < 0.05$). Highest change in strength was observed in K1, which improved from 44.09 ± 21.30 kg to 49.86 ± 20.26 kg (Δ = 11.57%). Similar result was found in power as well, where all groups showed significant improvement after six-week of experimental period ($p < 0.05$). Highest increase was found in K1, where the average power of muscle leg rose from 228.40 ± 43.28 watt to 247.11 ± 41.10 watt (Δ = 7.57%). Meanwhile, control group or K3 had the smallest but significant increase of both strength and power, which were 3.40% in strength and 1.06% in power (Figure 1).

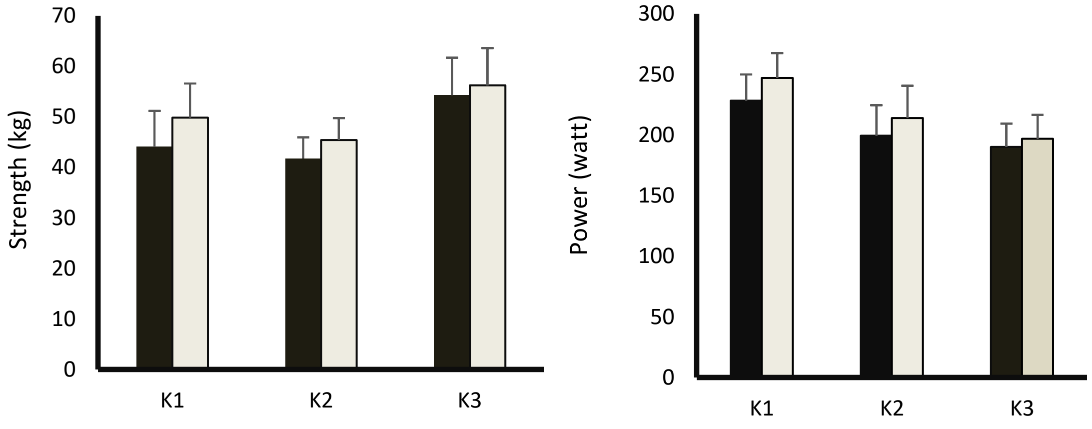

Fig. 1. The increases in muscle strength (left) and power (right) after six weeks of combined plyometric training program

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

Pair-wise Group		sig. Strength	sig. Power
K1	K2	0.007	0.236
	K3	0.000*	0.000*
K2	K3	0.020*	0.030*

K1 = squat jump + skater hops; K2 = jump-for-height + ins-and-outs; K3 = conventional training
*significant at α = 0.05 using Least Significant Different

LSD test discovered that strength was significantly different between K1 and K3 ($p = 0.000$),
as well as between K2 and K3 ($p = 0.020$). In regard to power, we observed two pairs that were statistically different. Those were between K1 and K3 ($p = 0.000$), along with K2 and K3 ($p = 0.030$) (Table 4). It could be concluded that strength and power of subjects in both groups that were given combined plyometric trainings for six weeks were different compared to those who practiced conventional training program for the same duration.

DISCUSSION

The current study revealed that plyometric training produced notable enhancements in the measured variables, particularly in terms of leg muscle strength and power. The hypothesis that greater improvements would occur in the plyometric training groups (K1 and K2) compared to the control group (K3) was strongly supported, as the implemented training protocol, specifically combined plyometric squat jump and skater hops (K1), led to significantly greater strength and power gained by the sixth week. The most substantial changes were observed in the K1 group, where 11.57% and 7.57% increase indicated a significant adaptation in muscle strength and power.

These findings were confirmed by earlier studies that investigated the effects of plyometric training on physical fitness (Bulqini et al., 2023; Muthukumar & Sokkanathan, 2014; Putera et al., 2023; Wiriawan et al., 2024). Most of those studies found that PT contributed to the increase of muscle power, strength, endurance, jumping ability, and flexibility better than other training regimens. Similar results were also revealed by previous RCT study where Muthukumar & Sokkanathan (2014) found significant improvement in muscle strength on subjects that were given the PT protocol. Elnaggar et al. (2019) in their study also observed the same findings where subjects in PT group showed significant enhancement in hamstring and quadriceps' strength better than their peers in non-PT group.

Plyometric training (PT) relies on SSC cycle which comprised of eccentric and concentric phase of muscle transition (Davies et al., 2015; Prianto et al., 2024). Because of the continuous process, PT is not only able to produce fast and explosive movements (Anwer & Nuhmani, 2015) but also greater force to enhance speed, strength, and muscle flexibility (Silva et al., 2019). Previous study conducted by Hirayama et al. (2012) reported that PT performed in one session was able to induce the change of muscle-tendon unit (MTU) characteristics by regulating the activity of neuromuscular. Consequently, the process of shortening and lengthening of MTU will occur more often than fascicles. Different from the other acute trainings' effect, PT has its own way to improve the SSC performance where MTU characteristic works in favourable condition, adapting to the change of muscle strength and tendon stiffness (Fouré et al., 2010; Hirayama et al., 2017; Wu et al., 2010). The combination of PT that were applied in this study were able to shorten the transition of eccentric (lengthening) phase to concentric (shortening). This condition will soon affect the jumping ability, supported by muscles' function to generate explosive force which led to the improvement of leg muscle strength (Louder et al., 2015).

Between the experimental groups, subjects in K1 (squat jumps and skater hops) had a better average increase in both measured variables compared to K2 (jump-for-height and ins-and-outs) and K3 (conventional exercise). Training program designed for K1 consisted of skater hop which is an exercise that uses alternating of one-legged movements. The development of exercises that use one-legged jumps is known to be better than two legs in increasing power and balance (Karimah et al., 2024). Similar findings were also obtained from Galeko et al. (2022) and Kusnanik & Isnaini (2015) which stated that exercises using one leg were more effective than two legs even though statistically both exercises have significant improvements. The findings of these study are in line with others that prove that single-leg jump training increases jump height faster than double-leg jump training. Several of these literatures showed that single-leg plyometric training was better than double-leg training in producing greater explosive force, so it could be used as an effective method (Ramirez-Campillo et al., 2018).

Regarding the increase in power among subjects in experimental groups, we found that it was related to exercise intensity. In this study, subjects performed moderate to high intensity exercises at 60% to 80% RM for six weeks, when we referred to previous study, the acute effect of high-intensity exercise was able to enhance the power capacity shortly after the exercise was done (Kobal et al., 2017). For instance, Smilios et al. (2005) showed an immediate change in jump height after 60% RM of half squats done in 1-2 sets. In addition, several studies have addressed the effectiveness of PT in enhancing vertical jump performances, with one study suggesting that the improvement of muscle power in lower limb might be attributed to the force variable related to SSC mechanism, combined with high velocity production during vertical jump take off (Ben Ayed et al., 2020). Neuromuscular adaptation that induced the power production could also be possible explanation for the increases of power that occurred (Chelly et al., 2010).

Based on the aforementioned explanation, we can conclude that PT induces various beneficial adaptations in neural and musculoskeletal systems, as well as performance and muscle function of healthy individuals (Markovic & Mikulic, 2010). With its many benefits, previous studies believed that plyometric training (PT) could be integrated as an important part of health-promoting lifestyle for people of all ages, especially young individuals such as students, to improve muscular fitness (Peitz et al., 2018; Sole et al., 2021).

Limitations

A limitation of this study is due to small sample size which limits the ability to generalize the findings to a larger and more diverse population as it would also increase the likelihood of random errors and bias. In addition, future study must consider to use longer duration of exercise (> 6 weeks). A short duration of exercise will limit the ability to observe long term muscle adaptation in the subjects, so it may not be able to reveal the effect of plyometric training on measured variables which lead to improper conclusion regarding its effectiveness.

CONCLUSIONS

The combination of plyometric exercises in this study was able to shorten the transition of eccentric phase to concentric during SSC mechanism. The interrelated process would soon affect the jumping ability as it was supported by muscles' function to generate explosive force which led to the improvement of leg muscle strength and power. Furthermore, greater increase was found in plyometric group involving a single leg jump as it would generate more explosive force.

REFERENCES

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

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

Anwer, U., & Nuhmani, S. (2015). Lower quarter plyometric for soccer players. *Saudi Journal of Sports Medicine*, *15*(1), 20. https://doi.org/10.4103/1319-6308.149524

Asadi, A. (2012). Effects of six weeks depth jump and countermovement jump training on agility performance. *Sport Science*, *5*(1), 67–70.

Ben Ayed, K., Ben Saad, H., Ali Hammami, M., & Latiri, I. (2020). Relationships of the 5-jump test (5jt) performance of youth players with volleyball specific' laboratory tests for explosive power. *American Journal of Men's Health*, *14*(6), 1557988320977686. https://doi.org/10.1177/1557988320977686

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

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

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

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

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

Deng, N., Soh, K. G., Abdullah, B. B., Huang, D., Xu, F., Bashir, M., & Zhang, D. (2024). Effects of plyometric training on health-related physical fitness in untrained participants: A systematic review and meta-analysis. *Scientific Reports*, *14*(1), 11272. https://doi.org/10.1038/s41598-024-61905-7

Elnaggar, R. K., Elbanna, M. F., Mahmoud, W. S., & Alqahtani, B. A. (2019). Plyometric exercises: Subsequent changes of weight-bearing symmetry, muscle strength and walking performance in children with unilateral cerebral palsy. *Journal of Musculoskeletal & Neuronal Interactions*, *19*(4), 507–515.

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.

Fouré, A., Nordez, A., & Cornu, C. (2010). Plyometric training effects on Achilles tendon stiffness and dissipative properties. *Journal of Applied Physiology (Bethesda, Md.: 1985)*, *109*(3), 849–854. https://doi.org/10.1152/japplphysiol.01150.2009

Galeko, J. P., Sulistyono, Wali, C. N., Suharjana, Louk, M. J. H., Komarudin, Guntur, & Martono. (2022). Single leg hop and double leg hop exercises on leg muscle strength on leg power for soccer athletes. *Journal of Physical Education and Sport*, *22*(10), 2582–2588. https://doi.org/10.7752/jpes.2022.10327

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*. 109–115. https://doi.org/10.2991/ahsr.k.220203.017

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

Hirayama, K., Yanai, T., Kanehisa, H., Fukunaga, T., & Kawakami, Y. (2012). Neural modulation of muscle-tendon control strategy after a single practice session. *Medicine and Science in Sports and Exercise*, *44*(8), 1512–1518. https://doi.org/10.1249/MSS.0b013e3182535da5

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. (2017). 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
Kusnanik, N. W., & Isnaini, L. M. Y. (2015). The effects of single leg hop progression and double legs hop progression exercise to increase speed and explosive power of leg muscle. *Sport Mont*, *XIII*(43-44–45), 70–74.
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
Markovic, G., & Mikulic, P. (2010). Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports Medicine (Auckland, N.Z.)*, *40*(10), 859–895. https://doi.org/10.2165/11318370-000000000-00000
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.
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
Michailidis, Y., Fatouros, I. G., Primpa, E., Michailidis, C., Avloniti, A., Chatzinikolaou, A., Barbero-Álvarez, J. C., Tsoukas, D., Douroudos, I. I., Draganidis, D., Leontsini, D., Margonis, K., Berberidou, F., & Kambas, A. (2013). Plyometrics' trainability in preadolescent soccer athletes. *Journal of Strength and Conditioning Research*, *27*(1), 38–49. https://doi.org/10.1519/JSC.0b013e3182541ec6
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
Muthukumar, A., & Sokkanathan, G. (2014). Effect of plyometric training and combination of weight and plyometric training on selected physical fitness variables of college men volleyball players. *Indian Journal of Applied Research*, *4*(11), 633–637.
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
Peitz, M., Behringer, M., & Granacher, U. (2018). A systematic review on the effects of resistance and plyometric training on physical fitness in youth- What do comparative studies tell us? *PLoS ONE*, *13*(10), e0205525. https://doi.org/10.1371/journal.pone.0205525
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. (2024). 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.
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
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
Ramachandran, A. K., Singh, U., Ramirez-Campillo, R., Clemente, F. M., Afonso, J., & Granacher, U. (2021). Effects of plyometric jump training on balance performance in healthy participants: A systematic review with meta-analysis. *Frontiers in Physiology*, *12*, 730945. https://doi.org/10.3389/fphys.2021.730945

Ramirez-Campillo, R., Álvarez, C., García-Hermoso, A., Ramírez-Vélez, R., Gentil, P., Asadi, A., Chaabene, H., Moran, J., Meylan, C., García-de-Alcaraz, A., Sanchez-Sanchez, J., Nakamura, F. Y., Granacher, U., Kraemer, W., & Izquierdo, M. (2018). Methodological Characteristics and Future Directions for Plyometric Jump Training Research: A Scoping Review. *Sports Medicine (Auckland, N.Z.)*, *48*(5), 1059–1081. https://doi.org/10.1007/s40279-018-0870-z

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.

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

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

Slimani, M., Chamari, K., Miarka, B., Del Vecchio, F. B., & Chéour, F. (2016). Effects of plyometric training on physical fitness in team sport athletes: A systematic review. *Journal of Human Kinetics*, *53*, 231–247. https://doi.org/10.1515/hukin-2016-0026

Smilios, I., Pilianidis, T., Sotiropoulos, K., Antonakis, M., & Tokmakidis, S. P. (2005). Short-term effects of selected exercise and load in contrast training on vertical jump performance. *Journal of Strength and Conditioning Research*, *19*(1), 135–139. https://doi.org/10.1519/14463.1

Sole, S., Ramírez-Campillo, R., Andrade, D. C., & Sanchez-Sanchez, J. (2021). Plyometric jump training effects on the physical fitness of individual-sport athletes: A systematic review with meta-analysis. *PeerJ*, *9*. https://doi.org/10.7717/peerj.11004

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

Wang, X., Lv, C., Qin, X., Ji, S., & Dong, D. (2022). Effectiveness of plyometric training vs. complex training on the explosive power of lower limbs: A Systematic review. *Frontiers in Physiology*, *13*, 1061110. https://doi.org/10.3389/fphys.2022.1061110

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

Wu, Y.-K., Lien, Y.-H., Lin, K.-H., Shih, T. T.-F., Wang, T.-G., & Wang, H.-K. (2010). Relationships between three potentiation effects of plyometric training and performance. *Scandinavian Journal of Medicine & Science in Sports*, *20*(1), e80-86. https://doi.org/10.1111/j.1600-0838.2009.00908.x