

The Influence of Plyometrics and Weight Training Exercises on Limbs Muscle Power in View of Limbs Muscle Endurance in Volleyball Players Aged 16-18 Years



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ABSTRACT: This research aims to find out: (1) the influence of plyometrics and weight training exercises on limb muscle power, (2) the different influences between volleyball players who have high and low endurance of limb muscle power on limb muscle power, and (3) the interaction between both exercises and the endurance of limb muscle power with limb muscle power. This research is a field experiment with a 2x2 factorial approach. The sample of this research was male 45 volleyball players who were selected by purposive sampling. The test instrument for measuring the endurance of limb muscle by using the wall sit test and limb muscle power by using vertical jump. The data analysis technique uses two ways Anova with a significant level of 0.05. The result of this research has been found as follows: (1) there is a difference in the influence of plyometrics and weight training on limb muscle power in volleyball players aged 16-18 years, (2) there is a difference in the influence between volleyball players who have endurance of limb muscle high and low on limb muscle power, and (3) there is a interaction between plyometrics and weight training exercises and the endurance of limb muscle high and low with limb muscle power in volleyball players aged 16-18 years. It can be proven by all significance values < 0.05 .

KEYWORDS: plyometrics, weight training, limb muscle, volleyball player, age 16-18 years

I. INTRODUCTION

Sport is a physical activity that can be done by all ages to get physical fitness (Manihuruk et al., 2023). Sport is a physical activity that is a favorite by everyone for their daily needs (Manihuruk et al., 2022). In Indonesia, many sports are developing and currently showing good achievements namely volleyball. Volleyball is a sport that can be played by anyone from various groups, ages, races, religions, and genders and everyone has the right to play it together, anywhere and anytime (Azizah et al., 2022).

Volleyball is a game that uses the ball to be bounced into the air back and forth over the net with the aim that the ball falls into the opponent's area with the ball touching the ground in search of victory and in the volleyball game into the air can use the whole body or part of the body from head to toe with a perfect bounce without the ball touching the ground, and the volleyball game is a game played with 6 people in 1 team, each team tries to play as well as possible and can attack, drop the ball to the opponent and defend until it lands itself (Rachmalia et al., 2022). The basic techniques of volleyball include serving, passing, smash, and block (Gazali, 2016; Hanggara et al., 2018).

In a volleyball game, the most important aspect to win is physical condition (Drikos et al., 2022). Physical condition is a factor that greatly affects a person's achievement, without good physical condition techniques and tactics cannot run perfectly in training or during matches and good physical condition is a requirement that must be possessed by an athlete (Agung et al., 2023). The physical conditions that must be possessed by a volleyball athlete are agility, strength, speed, muscle endurance, power, aerobic exercise (cardiovascular endurance), anaerobic exercise (interval, circuit, and excessive speed training), flexibility, concentration (mental exercise), and balance (Calleja-Gonzalez et al., 2019). The above opinion is in line with Ince's opinion who says that volleyball athletes need maximum speed and explosive movements (Ince, 2019).

A volleyball athlete must have maximum physical condition, especially in volleyball matches, jumps are very often done to serve, block, and smash, so that when jumping athletes need physical conditions, especially good leg muscle power (Mardela & Syukri, 2016). Lower muscle power or precisely leg muscle power is an important element in many sports (Suchomel et al., 2016). Leg

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muscle power can be increased by explosive movements and jumping without a prefix such as in basketball and volleyball (Wang et al., 2022). Athletes need to develop leg muscle power by performing speed and acceleration movements then with specific movements in sports (Mesfar et al., 2022). Therefore, coaches certainly need to look at and consider the needs of the sport when training (Schofield et al., 2022).

In addition, when athletes jump up repeatedly and continuously, of course this does not only talk about leg muscle power, but endurance power. (Hammami et al., 2022). However, to increase the power and endurance of leg muscle power must be supported by good endurance in the leg muscles. The above opinion is in line with the opinion of Munizar et al who say leg muscle endurance in volleyball is a physical component that affects the smash technique (Munizar et al., 2016). (Munizar et al., 2016). In addition to developing speed and power, of course, endurance strength needs to be developed (Vassil & Bazanov, 2012).

Power is a combination of speed and strength (Vai et al., 2018). In addition, power is needed by athletes in the field when practicing and competing (Nugroho et al., 2021). Efforts made to develop and increase the leg muscle power of volleyball players certainly use appropriate and programmed training methods (Indrawan et al., 2021). The training method to increase leg muscle power that is often done is the plyometrics training method (Islami et al., 2022). Plyometrics means increasing size. Another definition states that plyometrics is a movement that is done strongly and quickly by emphasizing shortening and lengthening muscle stretches (Chu & Meyer, 2013). Training with plyometrics methods is used to train and develop physical abilities such as strength, speed, and power (Asadi & Ramírez-Campillo, 2016). In addition, the combination of speed and power is a physical biomotor that is very important in various sports (Blocquiaux et al., 2020; Permana et al., 2022).

In addition, another method that is often used is training using one's own body weight or using external loads, often referred to as weight training. Exercises using your own body weight and external weights are very familiar exercises. This exercise involves the weight of one's own body and external loads to hold, lift, pull, push the body or a tool, so the element of strength is in it. Training using one's own body is an alternative to strength training that can be practiced almost anywhere and anytime, while training using external weights can improve physical fitness such as muscle strength, muscle hypertrophy, coordination, and muscle power (Iversen et al., 2021; Vieira et al., 2021). Exercise using weights is recognized as a functional movement training modality because in each movement the muscles of the body work as a whole (Klika & Jordan, 2013). Therefore, training using the plyometrics method and using body weight training is one of the efforts to develop and increase leg muscle power in volleyball players to be able to improve physical conditions and to be able to achieve achievements.

Research conducted by Ballasas et al applied plyometrics training for fifteen weeks on adolescent female volleyball athletes, successfully found to increase leg muscle strength and jump height (Balasas et al., 2022). Research from Bashir et al testing plyometrics and plyometrics exercises combined with weight training showed no significant difference in leg muscle power of male adolescent volleyball players (Bashir et al., 2018). Another study conducted by Novita et al who said that the plyometrics training method on volleyball players, comparing side to side box shuffle and leap to box plyometrics, found that plyometrics training with the leap to box model was better (Novita et al., 2022).

The researcher made observations at the volleyball training ground, precisely at the volleyball extracurricular of SMK Ma'arif NU 1 Sumpiuh, volleyball extracurricular of SMK Giripuro Sumpiuh, and volleyball extracurricular of SMKN 2 Banyumas, on July 18-22, 2022. The author directly observes the training process given by the coach during smash training that the players when jumping are still classified as not high and not optimal. In addition, the training given by the coach does not pay attention to rest so that volleyball players cannot smash optimally. Researchers also conducted interviews related to training methods that are often used when training leg muscle power. The coach stated that the exercise that is often used to improve is the jumping training method. When the author asked about the dosage of training specifically on repetitions and sets used in training using the jumping method, the coach stated that in one set volleyball players can do 10 to 15 repetitions and can be done 4 to 5 sets. Furthermore, the author asked whether there were short rest arrangements such as intervals and long rest or recovery when practicing, the coach replied that there were interval and recovery arrangements in training but did not know how many seconds or minutes to rest when doing the exercise.

This can be the basis that the use of appropriate training methods and setting exercise doses is important. This is reinforced by several studies that the key to successful training is the appropriateness of exercise dosing, because physical exercise can be analogous to medicine so it must be in accordance with the dose (Gronwald et al., 2020; Pontifex et al., 2019; Wasfy & Baggish, 2016; Zubin Maslov et al., 2018). This is because athletes who are given training are humans who have body structures that anatomically and physiological systems must of course be very concerned. In addition to making observations, the author also collected data using a questionnaire. The questionnaire was given via whatsapp given to the coach on July 20, 2022 to July 26, 2022. The results are as follows 100% of the coaches answered "yes" that power is an important biomotor component in the

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sport of volleyball; 100% of the coaches answered "yes" that good leg muscle power is very supportive of the success of jumping to attack and defense; 100% of the coaches answered "yes" that the plyometrics training method is one of the exercises that can be used to increase leg muscle power; 100% of the coaches answered "yes" the weight training method is one that is used to increase leg muscle power; 100% of the coaches answered "yes" that physical exercise must know the dosage of exercise; 100% of the coaches answered "yes" that high intensity is characterized for power training; 100% of the coaches answered "yes" that high intensity and low volume are characteristic of power training; 75% of the coaches answered "yes" and 25% of the coaches answered "no" that power training is given in one week is three times training; 100% of the coaches answered "yes" that the principle of varied training is important so that athletes do not experience saturation; 100% of the coaches answered "yes" that the principle of progressive overload training is important to increase power in volleyball. Based on the results of the questionnaire, it can be observed that 75% and 25% of the coaches answered that power training is done 3 times a week. This is the basis for the coach's hesitation to ascertain how many power exercises in one week.

This study aims to determine: (1) the effect of plyometrics and weight training on leg muscle power, (2) the difference in influence between volleyball players who have high and low leg muscle endurance on leg muscle power, and (3) the interaction between the two exercises and leg muscle endurance with leg muscle power.

II. RESEARCH METHODS

This study uses an experimental method with a 2x2 factorial design, which manipulates 2 main variables given an intervention. Then simultaneously perform calculations of attribute variables to determine the main independent variables that are separated or together, the impact of attribute variables, and the interaction of independent variables with attributes on the dependent variable. Factorial design is a research method and in statistics used to test the effect or influence of several independent variables on the dependent variable in an experiment, and in factorial design, independent variables or factors can have more than two levels (Ahmad et al., 2018).

Table 1. 2x2 Factorial Design

Manipulative Variable Exercise Method (A)	Limb Muscle Endurance Attribute Variable (B)	
	High Limb Muscle Endurance (B ₁)	Low Limb Muscle Endurance (B ₂)
<i>Plyometrics (A₁)</i>	(A ₁ B ₁)	(A ₁ B ₂)
<i>Weight Training (A₂)</i>	(A ₂ B ₁)	(A ₂ B ₂)

The research was conducted at the volleyball field of SMK Ma'arif NU 1 Sumpiuh. The research began on August 10 and ended on September 20, 2022. The training was carried out 16 times a meeting; a week was carried out three times a training; the training was carried out adjusting and varying the training dose settings. The first meeting was conducted once the initial test, then the last meeting was conducted once the final test. The initial and final tests were conducted outside of the 16 meetings. The population in this study were volleyball extracurriculars of SMK Ma'arif NU 1 Sumpiuh, SMK Giripuro Sumpiuh, and SMKN 2 Banyumas. Male gender with a total of 45 athletes; body weight (BB) ± 63-75 kg, height (TB) ± 168-179 cm. Sampling technique with purposive side with the following. criteria: (1) volleyball players are willing to carry out the training program given by the author for 16 times, (2) athletes run the exercise in good health do not have a history of injury to the limbs from ligaments, muscles and joints, (3) volleyball players do the exercise seriously, (4) volleyball players are male, (5) volleyball players have carried out anatomical adaptation training for 8 meetings before running the plyometrics training program and weight training exercises guided by the researcher.

Based on the determination of the sample, 45 volleyball players have been found. The next stage is carried out an initial test which aims to see high and low muscle endurance and divide the plyometrics group and the weight training group. The test to measure leg muscle endurance is the wall sit test. The group division stage uses a ranking system and the percentage taken in the high group is 27% and low is 27% (Wartika et al., 2014). That is, 27% of the high muscle endurance group and 27% of the low muscle endurance of the entire sample of 45. Based on this determination, 24 samples have been found. To divide the plyometrics and weight training groups, the match ordinal pairing formula is used by applying the A-B-B-A system so that the groups are balanced. Therefore, 4 groups (high and low) were found with each group totaling 6 people given plyometrics and weight training exercises.

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The first data collection technique used was interviews. The second collection technique is a questionnaire given via whatsapp to ten coaches as a needs analysis. The third data collection technique is the test and measurement method, namely measuring leg muscle power and leg muscle endurance. Measurement of leg muscle endurance using the wall sit test and the validity value of the wall sit test is 0.97, while the reliability is 0.98, so it can be said to be valid and reliable (Markovic et al., 2004). To measure leg muscle power using a vertical jump and the validity value in the vertical jump test is 0.78 while the reliability is 0.93, so it can be said that the vertical jump has good validity and reliability (Pratama & Erawan, 2019). Data analysis techniques test normality, homogeneity and hypothesis testing using the help of SPSS 23 software.

III. DISCUSSION

From the results of research obtained in the field and analyzed using the SPSS 23 application, it shows that the data is normally distributed, homogeneous and there is an influence. The results of data analysis using SPSS 23 can be seen in the table below:

Table 2. Normality Test

Group		p	Significance	Description
Pretest	A1B1	0,737	0,05	Normality
	A2B1	0,875		Normality
	A1B2	0,700		Normality
	A2B2	0,135		Normality
Posttest	A1B1	0,804		Normality
	A2B1	0,389		Normality
	A1B2	0,473		Normality
	A2B2	0,091		Normality

Based on the statistical analysis of the normality test that has been carried out using the Kolomogorv Simirnov test, all pretest and post-test data on leg muscle power are obtained from the results of the data normality test significance value $p > 0.05$, which means the data is normally distributed.

Table 3. Homogeneity Test

Levene Statistic	df1	df2	Sig.
0,973	1	20	0,426

Based on the statistical test analysis of the homogeneity test that has been carried out using the Levene Test, it shows that the calculation result of the significance value of $0.426 \geq 0.05$. This means that the data group has a homogeneous variant. Thus the population has a similar variant or homogeneity.

Research hypothesis testing is carried out based on the results of data analysis and interpretation of Anova Two-Way analysis. The sequence of hypothesis testing results adjusted to the hypothesis is presented as follows.

1. There is a Difference in Effect between Plyometrics and Weight Training on Limb Muscle Power

The first hypothesis is "there is a difference in the effect of plyometrics and weight training on leg muscle power". Based on data analysis, the results are shown in Table 4 below.

Table 4. Test Results of the Effect of Plyometrics and Weight Training on Limb Muscle Power

Source	Type III Sum Of Square	Df	Mean Square	F	Sig
Exercise Model	322,667	1	322,667	208,172	0,000

From the Anava test results in table 8 above, it can be seen that the significance value of p is 0.000 and the F value is 208.172, because the significance value of p is $0.000 < 0.05$, this means that there is a difference in the effect of plyometric and weight training on leg muscle power.

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2. There is a Difference in the Effect between Volleyball Players Who Have High and Low Limb Muscle Endurance on Limb Muscle Power

The second hypothesis is "there is a difference in the influence between volleyball players who have high and low leg muscle endurance on leg muscle power". Based on data analysis, the results are as follows:

Table 5. Test Results of the Effect between Volleyball Players Who Have High and Low Limb Muscle Endurance on Limb Muscle Power

Source	Type III Sum Of Square	Df	Mean Square	F	Sig
Leg muscle endurance	37,500	1	37,500	24,195	0,000

Based on the results of the Anava test table 9 above, it can be seen that the significance value of p is 0.000 and the F value is 24.95 because the significance value of p is 0.000 < 0.05, this means that there is a difference in influence between volleyball players who have high and low leg muscle endurance on leg muscle power.

3. There is an Interaction between Plyometrics and Weight Training and High and Low Limb Muscle Endurance with Limb Muscle Power

The third hypothesis is "there is an interaction between plyometrics and weight training and high and low leg muscle endurance with leg muscle power". Based on data analysis, the results are shown in Table 6 below:

Table 6. Results of Interaction Test between Plyometrics and Weight Training and High and Low Limb Muscle Endurance with Limb Muscle Power

Source	Type III Sum Of Square	Df	Mean Square	F	Sig
Exercise Model * Leg muscle endurance	32,667	1	32,667	21,075	0,000

Based on the Anava test results in table 10 above, it can be seen that the significance value of p is 0.000 and the F value is 21.075 because the significance value of p is 0.000 > 0.05, this means that there is an interaction between plyometric training and weight training and high and low leg muscle endurance with leg muscle power.

The discussion of the results of this study provides further interpretation of the results of the analysis that has been stated. Based on hypothesis testing, there are two groups of analysis conclusions, namely: (1) there is no significant difference in influence between the main factors of the study; and (2) there is no significant interaction between the main factors in the form of two-factor interaction. The discussion of the analysis results can be presented further as follows:

1. There is a Difference in Effect between Plyometrics and Weight Training on Limb Muscle Power

Based on the results that have been found that plyometrics training and weight training there are significant differences in influence. This study has revealed a significant effect of plyometric training and weight training on leg muscle power. Plyometric exercises have been shown to be effective in increasing leg muscle power. A study by Arif & Alexander showed that plyometric training produced significant improvements in explosive power, speed, and jumping ability in leg muscle power (Arif & Alexander, 2019). Another study conducted by Sutimin et al found that plyometrics training significantly increased leg muscle strength and explosiveness in volleyball athletes (Sutimin et al., 2021). Plyometrics works by utilizing rapid and explosive muscle contractions (Sabillah et al., 2022). This exercise involves movements that optimize the ability of muscles to produce maximum strength in a short time (Juntara, 2019). Plyometrics also uses elastic energy in muscles and tendons to increase muscle power (Mertayasa et al., 2016).

The research obtained also shows that weight training can contribute to increasing leg muscle power. Weight training aims to increase muscle strength and density through the use of external resistance such as dumbbells, barbells or through weights on

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the athlete's self (Kurniawan & Syakib, 2022). When viewed from the training program that has been compiled, the plyometrics training model that is packaged is still classified as general, there are no specifications for training that are converted to techniques in volleyball. While plyometrics training is a power exercise that can be used at a special periodization stage, while here the author does the training program has not entered the special period stage, then in this one year the event that was followed did not exist so that the training program compiled was still general in nature and was to develop physical abilities not to improve. Then, weight training is the basis for forming good strength, if the strength is already owned by the athlete, of course, in further programs will get maximum results to increase power. The average volleyball player used is a beginner volleyball player and is still minimal in participating in matches.

Research shows that both plyometric training and weight training have a significant effect on leg muscle power. Plyometric training tends to be more effective in improving explosive power, speed, and jumping ability, while weight training aims to improve maximal strength and muscle explosiveness. The combination of these two types of exercises can also provide optimal benefits for increasing leg muscle power.

2. There is a Difference in the Effect between Volleyball Players Who Have High and Low Limb Muscle Endurance on Limb Muscle Power

Based on the results that have been found that high and low leg muscle endurance on increasing power has a significant difference. Basically, leg muscle endurance is the ability of leg muscles to last for a long time, such as in activities that require physical endurance and not only rely on muscle strength and power alone (Walker et al., 2017). Meanwhile, leg muscle power is the ability of the leg muscles to produce high forces in a short time, such as when jumping or jumping to do smash (Chandra & Mariati, 2020). Although the two concepts are different, it is possible that there is a relationship between the two. For example, increasing leg muscle endurance can help athletes maintain leg muscle power for longer, thereby improving the quality of performance while playing volleyball (Suchomel et al., 2016).

Several studies have shown that there is a difference in the effect between volleyball players who have high and low leg muscle endurance on leg muscle power. A study conducted by Adhi et al; Supriyanto showed that there was no significant difference in the effect of plyometric training on leg muscle power between volleyball players who had high and low leg muscle endurance (Adhi et al., 2017; Supriyanto, 2018). Increasing leg muscle endurance is still important to improve the overall performance of volleyball players. Because, good leg muscle endurance can help volleyball players to play longer, improve the ability to perform volleyball technical movements, and help prevent injuries (Saputra & Aziz, 2020). Therefore, plyometric and weight training exercises can be combined with leg muscle endurance training, to achieve a balance between leg muscle power and leg muscle endurance (Arazi & Asadi, 2011).

Good leg muscle endurance can help improve a volleyball player's overall performance (Kim & Park, 2016; Wang et al., 2022). Therefore, the combination of plyometric and weight training exercises with leg muscle endurance training can be the right choice to achieve a balance between leg muscle power and leg muscle endurance (Fathi et al., 2019; Vetrovsky et al., 2019). In addition, it is important to pay attention to other factors that can affect the effect of plyometric and weight training on leg muscle power in volleyball players. These factors include the type of exercise used, the intensity and volume of training, the duration of training, the frequency of training, as well as the physical characteristics and health conditions of volleyball players (Komarudin, 2021; Litardiansyah & Hariyanto, 2020; Ramirez-Campillo et al., 2018).

3. There is an Interaction between *Plyometrics* and *Weight Training* and High and Low Limb Muscle Endurance with Limb Muscle Power

Based on the results that have been found there is an interaction of plyometrics training and weight training on high and low leg muscle endurance, it can be said that there is no significant interaction. Plyometric exercises and weight training can provide optimal benefits when combined by considering the level of individual leg muscle endurance (Makhlouf et al., 2018). Players with high leg muscle endurance can benefit from weight training aimed at increasing leg muscle power (Indrawan et al., 2021). Conversely, players with low leg muscle endurance can integrate plyometric exercises to improve their explosive movement capabilities (Hammami et al., 2022).

These results are indicated by pairs that have interactions or pairs that are significantly different (significant) are: (1) A1B1-A2B1, (2) A1B1-A2B2, (3) A2B1-A1B2, (4) A2B1-A2B2, (5) A1B2-A2B2. While the other pairs declared to have no difference in influence are: A1B1-A1B2. From the results of the interaction form, it appears that the main factors of research in the form of two factors show significant interaction. In the results of this study, the interaction means that each cell or group has a difference in the effect of each paired group.

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IV. CONCLUSIONS

Based on the results of the research and the results of data analysis that has been done, the following conclusions are obtained.

(1) There is a difference in the effect of plyometric training and weight training on leg muscle power, (2) There is a difference in the effect between volleyball players who have high and low leg muscle endurance on leg muscle power, (3) There is an interaction between plyometric training and weight training and high and low leg muscle endurance with leg muscle power.

REFERENCES

- 1) Adhi, B. P., Sugiharto, S., & Soenyoto, T. (2017). Pengaruh Metode Latihan dan Kekuatan Otot Tungkai terhadap Power Otot Tungkai. *Journal of Physical Education and Sports*, 6(1), Article 1. <https://doi.org/10.15294/jpes.v6i1.17315>
- 2) Agung, M. R., Yulifri, Y., Nirwandi, N., & Putra, A. N. (2023). Tinjauan Kondisi Fisik Pemain Sekolah Sepakbola. *Jurnal JPDO*, 6(1), Article 1.
- 3) Ahmad, A., Salomon, L. L., & Jessica, J. (2018). Desain Eksperimen Untuk Meningkatkan Kualitas Kekuatan Produk Dengan Pendekatan Analisis Desain Faktorial. *Jurnal Ilmiah Teknik Industri*, 6(3), Article 3. <https://doi.org/10.24912/jitiuntar.v6i3.4247>
- 4) Arazi, H., & Asadi, A. (2011). The effect of aquatic and land plyometric training on strength, sprint, and balance in young basketball players. *Journal of Human Sport and Exercise*, 6(1), 101–111. <https://doi.org/10.4100/jhse.2011.61.12>
- 5) Arif, Y., & Alexander, X. F. R. (2019). Pengaruh Latihan Plyometric Jump To Box Terhadap Power Otot Tungkai Pemain Bola Voli Pada Tim Putri Penjaskesrek Undana. *Jurnal Segar*, 8(1), Article 1. <https://doi.org/10.21009/segar/0801.05>
- 6) Asadi, A., & Ramírez-Campillo, R. (2016). Effects of cluster vs. Traditional plyometric training sets on maximal-intensity exercise performance. *Medicina*, 52(1), Article 1. <https://doi.org/10.1016/j.medic.2016.01.001>
- 7) Azizah, A. R., Hidayatulloh, F., Pambudi, W., & Setiawan, B. (2022). Survei Pembinaan Prestasi Bola Voli Putri SMA N 1 Wadaslantang Tahun 2022. *Jurnal Pendidikan Dan Konseling (JPDK)*, 4(5), Article 5. <https://doi.org/10.31004/jpdk.v4i5.6567>
- 8) Balasas, D. G., Kellis, S., Christoulas, K., & Bampouras, T. M. (2022). An Off-season Plyometric and Resistance Training Programme to Improve Vertical Jump Height in Adolescent Female Volleyball Players. *Journal of Science in Sport and Exercise*, 4(3), 213–220. <https://doi.org/10.1007/s42978-021-00136-y>
- 9) Bashir, B., SulehHayyat, F., & Shafi, S. (2018). Effect of Plyometric Training and Combination of Weight and Plyometric Training on Selected Physical Fitness Variables of College Men Volleyball Players. *Research Guru: Online Journal of Multidisciplinary Subjects (Peer Reviewed)*, 12(2), 633–637.
- 10) Blocquiaux, S., Gorski, T., Van Roie, E., Ramaekers, M., Van Thienen, R., Nielens, H., Delecluse, C., De Bock, K., & Thomis, M. (2020). The effect of resistance training, detraining and retraining on muscle strength and power, myofibre size, satellite cells and myonuclei in older men. *Experimental Gerontology*, 133, 110860. <https://doi.org/10.1016/j.exger.2020.110860>
- 11) Calleja-Gonzalez, J., Mielgo-Ayuso, J., Sanchez-Ureña, B., Ostojic, S. M., & Terrados, N. (2019). Recovery in volleyball. *The Journal of Sports Medicine and Physical Fitness*, 59(6), 982–993. <https://doi.org/10.23736/S0022-4707.18.08929-6>
- 12) Chandra, B., & Mariati, S. (2020). Daya Ledak Otot Tungkai dan Kelentukan Otot Pinggang Memberikan Kontribusi Terhadap Kemampuan Smash Bolavoli. *Jurnal Patriot*, 2(1), Article 1. <https://doi.org/10.24036/patriot.v2i1.526>
- 13) Chu, D. A., & Meyer, G. C. (2013). *Plyometrics*. Human Kinetics.
- 14) Drikos, S., Barzouka, K., Balasas, D. G., & Sotiropoulos, K. (2022). Effect of quality of opposition on game performance indicators in elite male volleyball. *International Journal of Sports Science & Coaching*, 17(1), 169–177. <https://doi.org/10.1177/17479541211013701>
- 15) Fathi, A., Hammami, R., Moran, J., Borji, R., Sahli, S., & Rebai, H. (2019). Effect of a 16-Week Combined Strength and Plyometric Training Program Followed by a Detraining Period on Athletic Performance in Pubertal Volleyball Players. *The Journal of Strength & Conditioning Research*, 33(8), 2117. <https://doi.org/10.1519/JSC.0000000000002461>
- 16) Gazali, N. (2016). Kontribusi Kekuatan Otot Lengan Terhadap Kemampuan Servis Atas Atlet Bolavoli. *Journal of Physical Education Health and Sport*, 3(1), Article 1. <https://doi.org/10.15294/jpehs.v3i1.6496>
- 17) Gronwald, T., Törpel, A., Herold, F., & Budde, H. (2020). Perspective of Dose and Response for Individualized Physical Exercise and Training Prescription. *Journal of Functional Morphology and Kinesiology*, 5(3), Article 3. <https://doi.org/10.3390/jfmk5030048>
- 18) Hammami, R., Ben Ayed, K., Abidi, M., Werfelli, H., Ajailia, A., Selmi, W., Negra, Y., Duncan, M., Rebai, H., & Granacher, U. (2022). Acute effects of maximal versus submaximal hurdle jump exercises on measures of balance, reactive

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- strength, vertical jump performance and leg stiffness in youth volleyball players. *Frontiers in Physiology*, 13. <https://www.frontiersin.org/articles/10.3389/fphys.2022.984947>
- 19) Hanggara, D., Syafrial, S., & Ilahi, B. R. (2018). Implementasi Ekstrakurikuler Bola Voli Di Sma N 1, 2 Dan 3 Bengkulu Tengah. *Kinestetik : Jurnal Ilmiah Pendidikan Jasmani*, 2(1), Article 1. <https://doi.org/10.33369/jk.v2i1.9182>
 - 20) Ince, I. (2019). Effects of Split Style Olympic Weightlifting Training on Leg Stiffness Vertical Jump Change of Direction and Sprint in Collegiate Volleyball Players. *Universal Journal of Educational Research*, 7(1), 24–31.
 - 21) Indrawan, A. P., Wahjoedi, W., & Suratmin, S. (2021). Pengaruh Pelatihan Pliometrik dan Kecepatan Terhadap Daya Ledak Otot Tungkai Pemain Bola Voli Putri SMP. *JURNAL PENJAKORA*, 8(1), Article 1. <https://doi.org/10.23887/penjakora.v8i1.30842>
 - 22) Islami, S., Masrun, M., Hermanzoni, H., & Setiawan, Y. (2022). Pengaruh Latihan Plyometrics terhadap Kemampuan Daya Ledak Otot Tungkai Pemain Bolavoli. *Gladiator*, 2(1), Article 1.
 - 23) Iversen, V. M., Norum, M., Schoenfeld, B. J., & Fimland, M. S. (2021). No Time to Lift? Designing Time-Efficient Training Programs for Strength and Hypertrophy: A Narrative Review. *Sports Medicine*, 51(10), 2079–2095. <https://doi.org/10.1007/s40279-021-01490-1>
 - 24) Juntara, P. E. (2019). Latihan Kekuatan Dengan Beban Bebas Metode Circuit Training Dan Plyometric. *Altius: Jurnal Ilmu Olahraga Dan Kesehatan*, 8(2), Article 2. <https://doi.org/10.36706/altius.v8i2.8705>
 - 25) Kim, Y.-Y., & Park, S.-E. (2016). Comparison of whole-body vibration exercise and plyometric exercise to improve isokinetic muscular strength, jumping performance and balance of female volleyball players. *Journal of Physical Therapy Science*, 28(11), 3140–3144. <https://doi.org/10.1589/jpts.28.3140>
 - 26) Klika, B., & Jordan, C. (2013). High-Intensity Circuit Training Using Body Weight: Maximum Results With Minimal Investment. *ACSM's Health & Fitness Journal*, 17(3), 8. <https://doi.org/10.1249/FIT.0b013e31828cb1e8>
 - 27) Komarudin, K. (2021). Latihan plyometric dalam sepakbola untuk anak usia muda. *Sepakbola*, 1(2), Article 2. <https://doi.org/10.33292/sepakbola.v1i2.101>
 - 28) Kurniawan, G. P. D., & Syakib, A. (2022). Efektifitas Pliometrik Push Up Untuk Meningkatkan Daya Ledak Otot Lengan. *Jurnal Fisioterapi dan Kesehatan Indonesia*, 2(1), Article 1.
 - 29) Litardiansyah, B. A., & Hariyanto, E. (2020). Survei Kondisi Fisik Peserta Ekstrakurikuler Futsal Putra dan Putri Sekolah Menengah Atas. *Sport Science and Health*, 2(6), Article 6.
 - 30) Makhlof, I., Chaouachi, A., Chaouachi, M., Ben Othman, A., Granacher, U., & Behm, D. G. (2018). Combination of Agility and Plyometric Training Provides Similar Training Benefits as Combined Balance and Plyometric Training in Young Soccer Players. *Frontiers in Physiology*, 9. <https://www.frontiersin.org/articles/10.3389/fphys.2018.01611>
 - 31) Manihuruk, F. F., Sukarmin, Y., Sumaryanti, Nugroho, S., & Marpaung, D. R. (2023). Penerapan Latihan Lari Zig-Zag Terhadap Peningkatan Kelincahan Atlet Bulutangkis. *Sains Olahraga : Jurnal Ilmiah Ilmu Keolahragaan*, 7(1), Article 1. <https://doi.org/10.24114/so.v7i1.45138>
 - 32) Manihuruk, F., Irianto, D. P., Suharjana, S., Widiyanto, W., Elumalai, G., & Wali, C. N. (2022). The Effect of Gobak Sodor Game on the Increase of Tai Sabaki in Adolescent Kenshi Dojo Triharjo. *International Journal of Human Movement and Sports Sciences*, 10(3), 484–491. <https://doi.org/10.13189/saj.2022.100316>
 - 33) Mardela, R., & Syukri, A. (2016). Hubungan Daya Ledak Otot Tungkai Dan Koordinasi Mata-Tangan Dengan Kemampuan Jump Service Atlet Bolavoli Putra Tim Universitas Negeri Padang. *Jurnal Performa Olahraga*, 1(01), Article 01. <https://doi.org/10.24036/jpo74019>
 - 34) Markovic, G., Dizdar, D., Jukic, I., & Cardinale, M. (2004). Reliability and Factorial Validity of Squat and Countermovement Jump Tests. *The Journal of Strength & Conditioning Research*, 18(3), 551.
 - 35) Mertayasa, K., Rahayu, S., & Soenyoto, T. (2016). Metode Latihan Plyometrics Dan Kelentukan Untuk Meningkatkan Power Otot Tungkai Dan Hasil Lay Up Shoot Bola Basket. *Journal of Physical Education and Sports*, 5(1), Article 1. <https://doi.org/10.15294/jpes.v5i1.13275>
 - 36) Mesfar, A., Hammami, R., Selmi, W., Gaied-Chortane, S., Duncan, M., Bowman, T. G., Nobari, H., & van den Tillaar, R. (2022). Effects of 8-Week In-Season Contrast Strength Training Program on Measures of Athletic Performance and Lower-Limb Asymmetry in Male Youth Volleyball Players. *International Journal of Environmental Research and Public Health*, 19(11), Article 11. <https://doi.org/10.3390/ijerph19116547>
 - 37) Novita, N., Harahap, P. O., Sagala, R. S., & Pasaribu, A. M. N. (2022). Effect of plyometric exercises on limb muscle power in volleyball players. *Jurnal SPORTIF : Jurnal Penelitian Pembelajaran*, 8(1), Article 1. https://doi.org/10.29407/js_unpgr.v8i1.17810

The Influence of Plyometrics and Weight Training Exercises on Limbs Muscle Power in View of Limbs Muscle Endurance in Volleyball Players Aged 16-18 Years

- 38) Nugroho, R. A., Yuliandra, R., Gumantan, A., & Mahfud, I. (2021). Pengaruh Latihan Leg Press dan Squat Thrust Terhadap Peningkatan Power Tungkai Atlet Bola Voli. *Jendela Olahraga*, 6(2), 40–49. <https://doi.org/10.26877/jo.v6i2.7391>
- 39) Permana, D. A., Kusnanik, N. W., Nurhasan, N., Setijono, H., Arifin, M. Z., & Purwoto, S. P. (2022). Enhancing Strength, Leg Muscle Explosive Power, and Muscle Hypertrophy Using Hurdle-Box Jump Plyometric | Physical Education Theory and Methodology. *Physical Education Theory and Methodology*, 22(1), 113–120. <https://doi.org/10.17309/tmfv.2022.1.16>
- 40) Pontifex, M. B., McGowan, A. L., Chandler, M. C., Gwizdala, K. L., Parks, A. C., Fenn, K., & Kamijo, K. (2019). A primer on investigating the after effects of acute bouts of physical activity on cognition. *Psychology of Sport and Exercise*, 40, 1–22. <https://doi.org/10.1016/j.psychsport.2018.08.015>
- 41) Pratama, M. I., & Erawan, B. (2019). Perbandingan Pengaruh Latihan Squat Jump dan Plyometric Jump to Box terhadap Peningkatan Power Otot Tungkai. *Jurnal Kepeleatihan Olahraga*, 11(2), 77–82. <https://doi.org/10.17509/jko-upi.v11i2.20309>
- 42) Rachmalia, D. S., Susilawati, D., & Lengkana, A. S. (2022). Profil Kondisi Fisik Atlet Bola Voli Pada Klub Tectona Kota Bandung. *Journal Of Sport (Sport, Physical Education, Organization, Recreation, and Training)*, 6(2), Article 2. <https://doi.org/10.37058/sport.v6i2.6375>
- 43) Ramirez-Campillo, R., Alvarez, C., García-Pinillos, F., Sanchez-Sanchez, J., Yanci, J., Castillo, D., Loturco, I., Chaabene, H., Moran, J., & Izquierdo, M. (2018). Optimal Reactive Strength Index: Is It an Accurate Variable to Optimize Plyometric Training Effects on Measures of Physical Fitness in Young Soccer Players? *The Journal of Strength & Conditioning Research*, 32(4), 885. <https://doi.org/10.1519/JSC.0000000000002467>
- 44) Sabillah, M. I., Tomoliyus, T., Nasrulloh, A., & Yuniana, R. (2022). The effect of plyometric exercise and leg muscle strength on the power limb of wrestling athletes. *Journal of Physical Education and Sport*, 22(6), 1403–1411. <https://doi.org/DOI:10.7752/jpes.2022.06176>
- 45) Saputra, N., & Aziz, I. (2020). Tinjauan Tingkat Kondisi Fisik Pemain Bolavoli Putra Sma 2 Pariaman. *Jurnal Performa Olahraga*, 5(1), Article 1. <https://doi.org/10.24036/jpo137019>
- 46) Schofield, K. L., Thorpe, H., & Sims, S. T. (2022). “This is the next frontier of performance”: Power and knowledge in coaches “proactive” approaches to sportswomen’s health. *Sports Coaching Review*, 11(3), 324–345. <https://doi.org/10.1080/21640629.2022.2060635>
- 47) 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>
- 48) Supriyanto, S. (2018). Pengaruh Metode Latihan Plyometric dan Latihan Beban dengan Kecepatan Reaksi terhadap Power Otot Tungkai Pemain Bolavoli Putra. *Gelanggang Olahraga: Jurnal Pendidikan Jasmani Dan Olahraga*, 2(1), Article 1. <https://doi.org/10.31539/jpjo.v2i1.423>
- 49) Sutimin, Syafei, M., Budi, D. R., Kusnandar, Suhartoyo, T., & Nurcahyo, P. J. (2021). Plyometric Double Leg Tuck Jump: Pengaruhnya Terhadap Power Otot Tungkai Atlet Bola Voli. *Sprinter: Jurnal Ilmu Olahraga*, 2(1), Article 1. <https://doi.org/10.46838/spr.v2i1.92>
- 50) Vai, A., Ramadi, R., & Johannes, B. (2018). Hubungan Antara Power Otot Lengan Dan Bahu, Power Otot Tungkai Dan Kelentukan Pergelangan Tangan Dengan Dengan Hasil Smash Pada Voli Tim Bola Voli Pendor Univeristas Riau. *Journal Of Sport Education (JOPE)*, 1(1), Article 1. <https://doi.org/10.31258/jope.1.1.1-8>
- 51) Vetrovsky, T., Steffl, M., Stastny, P., & Tufano, J. J. (2019). The Efficacy and Safety of Lower-Limb Plyometric Training in Older Adults: A Systematic Review. *Sports Medicine*, 49(1), 113–131. <https://doi.org/10.1007/s40279-018-1018-x>
- 52) Vieira, A. F., Umpierre, D., Teodoro, J. L., Lisboa, S. C., Baroni, B. M., Izquierdo, M., & Cadore, E. L. (2021). Effects of Resistance Training Performed to Failure or Not to Failure on Muscle Strength, Hypertrophy, and Power Output: A Systematic Review With Meta-Analysis. *The Journal of Strength & Conditioning Research*, 35(4), 1165. <https://doi.org/10.1519/JSC.0000000000003936>
- 53) Walker, S., Haff, G. G., Häkkinen, K., & Newton, R. U. (2017). Moderate-Load Muscular Endurance Strength Training Did Not Improve Peak Power or Functional Capacity in Older Men and Women. *Frontiers in Physiology*, 8. <https://www.frontiersin.org/articles/10.3389/fphys.2017.00743>
- 54) Wang, J., Fu, H., QiangZhang, Zhang, M., & Fan, Y. (2022). Effect of Leg Half-Squat Training With Blood Flow Restriction Under Different External Loads on Strength and Vertical Jumping Performance in Well-Trained Volleyball Players. *Dose-Response*, 20(3), 15593258221123672. <https://doi.org/10.1177/15593258221123673>

The Influence of Plyometrics and Weight Training Exercises on Limbs Muscle Power in View of Limbs Muscle Endurance in Volleyball Players Aged 16-18 Years

- 55) Wartika, I. K, I Made Candiasa, M. K., & Ni Ketut Suarni, M. S. (2014). Pengaruh Penerapan Model Pembelajaran Kooperatif Tipe Stad Berbasis Asesmen Kinerja Terhadap Hasil Belajar Fisika Ditinjau Dari Sikap Ilmiah (Studi Eksperimen Pada Siswa Kelas XI IPA SMA Negeri 1 Kuta). *Jurnal Penelitian Dan Evaluasi Pendidikan Indonesia*, 4(1), Article 1. <https://doi.org/10.23887/jpepi.v4i1.1162>
- 56) Wasfy, M. M., & Baggish, A. L. (2016). Exercise Dose in Clinical Practice. *Circulation*, 133(23), 2297–2313. <https://doi.org/10.1161/CIRCULATIONAHA.116.018093>
- 57) Zubin Maslov, P., Schulman, A., Lavie, C. J., & Narula, J. (2018). Personalized exercise dose prescription. *European Heart Journal*, 39(25), 2346–2355. <https://doi.org/10.1093/eurheartj/ehx686>



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