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Original Article

Impact of high-intensity interval training with lateral cone jumps on leg muscle explosive power

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Abstract:
Lateral cone jump exercises are plyometric, involving jumping over cones while utilizing the Polar H10 assistive device to monitor heart rate intensity during each jump. This study aimed to evaluate the effects of cone jump training on the frequency of jumps and its impact on explosive power in the leg muscles. This type of lateral cone jump training aims to enhance physical conditioning by executing lateral jumps toward cones, with the intensity gauged by the number of cones cleared. High-intensity interval training (HIIT) aims to improve cardiorespiratory fitness, promote fat burning, and increase muscle strength in a relatively short training time. Path analysis was employed for data processing and analysis. The statistical software utilized included SPSS for direct influence and the Sobel Calculator for indirect influence to determine the outcomes of both pre-test and post-test assessments. Following the completion of the lateral interval cone jump exercise by 40 high school female students, it was observed that the variable representing the number of jumps had a statistically significant effect on leg muscle explosive power, with a significance level of $0.040 < \alpha$ (0.05). The total coefficient of determination derived from path analysis equated to 0.320, indicating that 32% of the variance in leg muscle explosive power among high school sports students could be attributed to the lateral cone jump training variables and the number of jumps, while the remaining 68% could be influenced by other variables not incorporated in the study. Regarding the strength of the research model, the coefficient of determination of 0.32 places it within the moderate or medium category. The positive sign of the coefficient suggests that an increase in the number of jumps correlates with higher explosive power in the leg muscles. This implies that a greater number of jumps contributes to increased leg muscle explosiveness.
Keywords: High-intensity Interval Training, Plyometrics, Polar H10, Lateral cone jumps, and Leg Muscle Explosive Power

Introduction

The term "lateral cone jumps" encompasses physical exercises to enhance the speed, strength, and agility of the legs (Sarkar et al., 2020). Typically, this exercise involves the placement of cones in sequence or specific patterns on the floor to target leg muscles and improve body coordination (Effendi et al., 2019)(Siregar Indra Yan, Nurkadri, Rohaya Nirwana, Muda Sory, 2023). It also encompasses exercises that entail jumping or lateral (sideways) movements around obstacles (Ojeda-Aravena et al., 2021). This exercise is usually used in various sports (Schaffarczyk et al., 2022) that require fast and agile lateral movements, such as football, basketball, tennis, and others (Lin et al., 2012). This exercise aims to increase speed, coordination, leg muscle strength (Syam et al., 2018), and body agility when performing lateral movements (Trisnowiyanto, 2016).

Plyometric exercises, including vertical or lateral jumps, box jumps, or other explosive movements involving leg, hip, and lower body muscles, are integral to improving muscle strength, speed, and flexibility (Anggraini Tiansi Dwi, 2023) (Spieszny & Zubik, 2018). This form of training enhances muscle strength, speed, and explosive power across various sports (such as basketball, volleyball, soccer, and track and field) through rapid, explosive muscle contractions followed by quick muscle contractions after a brief stretch (Hajj-Boutros et al., 2023), (Spieszny & Zubik, 2018). Plyometric exercises usually consist of a series of jumping movements performed in specific sequences (Lin et al., 2012; Poomsalood & Pakulanon, 2015) and often incorporate tools like exercise ladders, jump boxes, or other surfaces to target specific leg muscles (Anggraini Tiansi Dwi, 2023; Boraczy et al., 2023; Schaffarczyk et al., 2022). It is important to remember that plyometric exercises require good coordination (Agi Ginanjar, Adang Suherman, Tite Juliantine, 2023; Lin et al., 2012; Poomsalood & Pakulanon, 2015), and proper guidance and supervision are necessary to prevent injury (Hammami et al., 2021; Hinde et al., 2021; Komarudin, 2021). Individuals should consult a trained fitness professional to ensure that

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plyometric exercises or physical activity are suitable and safe (Honold, 2017; Lubis, Fitrianto, et al., 2021) (Hinde et al., 2021). Plyometric side jumps, a variation of plyometric exercise, aim to enhance strength, speed, agility, and lateral body coordination (Putera et al., 2023) (Boraczy et al., 2023; Trisnowiyanto, 2016). These jumps involve lateral movement from one side to another, often utilizing cones or markers as reference points (Akbar et al., 2019; Ashar et al., 2021). The movement can encompass various patterns, such as zig-zag or side-to-side jumps (Effendi et al., 2019; Wagner et al., 2021), and requires explosiveness, strength, and agility in the leg and lower body muscles (Coratella et al., 2018). Sports that involve frequent changes of direction and lateral movement, like basketball, tennis, and soccer, benefit from plyometric lateral jump exercises (Boby, F. A., 2023) (Abidin et al., 2020; Boraczy et al., 2023; Lin et al., 2012; Spieszny & Zubik, 2018). To prevent injury and optimize the benefits of these exercises, adequate warm-up, proper technique, and gradual difficulty progression are crucial (Haqiyah et al., 2023; Irawan, 2017). It is recommended to perform these exercises under the supervision of a qualified fitness instructor or trainer to ensure correct form and safety (Akbar et al., 2019; Aloui et al., 2020). High-intensity interval training (HIIT) is a condensed form of exercise involving brief bursts of intense activity followed by short recovery periods (Budig et al., 2022). HIIT can improve cardiovascular health, promote effective fat burning, and sustain elevated metabolism post-workout (Hajj-Boutros et al., 2023; Mardhika, 2019; Muhammad, 2023). Typically, HIIT sessions comprise multiple cycles of vigorous exercises such as sprinting, rapid cycling, plyometric drills (e.g., jumping squats, burpees), or high-intensity weightlifting, interspersed with brief rest periods (Dominski et al., 2021) (Lubis, Sukur, et al., 2021). This structured pattern can be repeated according to prescribed workout plans (Lin et al., 2012; Sarkar et al., 2020; Spieszny & Zubik, 2018). HIIT has been proven to improve cardiovascular fitness and muscle strength relatively quickly. As a result, this exercise has become increasingly popular among people looking for a quick way to improve their physical fitness. The purpose of HIIT in Indonesian is to enhance overall physical fitness through a combination of high-intensity exercises interspersed with brief rest periods (Koçak, 2020; Muhamad & Wibowo, 2022). HIIT aims to achieve specific objectives, such as enhancing cardiorespiratory conditioning (Ojeda-Aravena et al., 2021). HIIT exercises, which feature extended periods of exertion followed by short recovery intervals, can effectively enhance cardiovascular and pulmonary endurance. General fitness enhancement: HIIT has been shown to boost strength, endurance, speed, and flexibility. Regular and consistent participation in a HIIT program can lead to improvements in various areas of physical fitness. Reduction of body fat: research indicates that HIIT can effectively burn body fat in a shorter time frame. This can contribute to weight loss or a reduction in body fat levels. Boosting metabolism: HIIT, with its short bursts of intense exercise, can increase the body's metabolism, enabling it to burn more calories post-workout (Lubis et al., 2020; Schaffarczyk et al., 2022).

Time efficiency: HIIT has several advantages, including its ability to optimize heart rate. Heart rate is the number of heartbeats per minute, commonly used to assess an individual's cardiac performance and overall health status. Polar H10 is a popular heart rate sensor among athletes, runners, and fitness enthusiasts, enabling them to monitor their heart rate during physical exertion (Himariotis et al., 2022; Hinde et al., 2021). Worn on the chest, the Polar H10 utilizes advanced technology to accurately track heart rate, and its wireless connectivity allows seamless integration with smartphones, sports watches, or other devices. Users can leverage accompanying apps or devices to monitor and analyze heart rate data, optimizing performance during exercise (Hernández-Vicente et al., 2021; Himariotis et al., 2022; Książek et al., 2023). The Polar H10 is known for its extensive connectivity capabilities, precise heart rate measurement, and ease of use for various workouts or sports. The impact of HIIT with lateral cone jumps on leg muscle explosive power has been a subject of interest in sports science and physical therapy. Research has shown that HIIT can significantly improve leg explosive strength (Javanmardi et al., 2021). Furthermore, HIIT has been found to enhance special qualities such as sprint running, acceleration, vertical take-off, and explosive power, particularly in individuals with weak leg muscle strength and insufficient explosive power (Huang, 2023). When employed as a form of HIIT, jumps can mitigate cardiovascular deconditioning and yield similar beneficial effects on maximum oxygen uptake capacity and cardiovascular health as traditional high-volume, moderate-intensity aerobic training (Kramer et al., 2017).

Plyometric training programs, such as hurdle-box jumps, have been proven to be highly effective in enhancing the explosive power of both horizontal and vertical leg muscles and agility (Permana et al., 2022). Furthermore, specific exercises such as lateral cone hops and hurdle hop training have been demonstrated to impact leg muscle power, with hurdle hop training being more effective than lateral cone hop training (Akbar et al., 2019). Additionally, plyometric exercises have been shown to substantially improve leg muscle explosive power, enhancing athletes' performance in sports such as badminton (Syahriadi, 2020).

Furthermore, the literature emphasizes the significance of leg muscle strength and the rate of force development on various athletic performances, including change of direction, speed, acceleration, and jumping ability (Bimson et al., 2017). Moreover, plyometric depth jump training has been identified as more effective in enhancing leg muscles' explosive power than plyometric rim jump training (Fitrianto et al., 2018). Additionally, training to jump over a bar with added weight has been shown to significantly increase the explosive power of leg muscles (Santika & Subekti, 2020). In conclusion, the literature supports the notion that HIIT, plyometric exercises, and specific jump training regimens can effectively improve leg muscle explosive power, agility, and cardiovascular health. Therefore, we hypothesize that HIIT with lateral cone jumps can impact leg muscle explosive power.

Materials and methods

This study employs an experimental design coupled with path analysis methodology. Data analysis is facilitated through the utilization of SPSS to examine direct influences and the Sobel Calculator to assess indirect influences. Specifically, the intervention involves performing lateral cone jump training while utilizing the Polar H10 to gauge maximum heart rate, alongside measuring the frequency of cone clearance in pre-test and post-test evaluations of leg muscle explosive power. The study included a sample of 40 high school female students, each subject undergoing both pre-test and post-test assessments conducted with identical procedures to ensure consistency and reliability of results.

Descriptive Analysis

Below are the findings from a descriptive analysis examining the frequency of jumps and the explosive power of leg muscles among high school sports students before and after undergoing lateral cone jump training.

Table 1. Descriptive analysis results

Variable	Lateral cone jumps	Minimum	Maximum	Average	Standard deviation
Number of Jumps	Before training	40.00	56.00	46.20	5.58
	After practice	43.00	60.00	50.82	5.14
Explosive Power of Leg Muscles	Before training	19.90	53.00	37.96	7.20
	After practice		66.00	44.48	8.83

Table 1 presents the descriptive statistics for the number of jumps and leg muscle explosive power before and after lateral cone jump training. Prior to training, the number of jumps ranged from a minimum of 40 jumps to a maximum of 56 jumps, with an average of 46 jumps. Following training, the range extended from a minimum of 43 jumps to a maximum of 60 jumps, with an average of 51 jumps. Notably, the average number of jumps increased post-training compared to pre-training. Regarding leg muscle explosive power, before engaging in lateral cone jump exercises, the range spanned from a minimum of 19.90 kg.m/s to a maximum of 53.00 kg.m/s, with an average of 37.96 kg.m/s. Subsequently, following the lateral cone jump exercise regimen, the range expanded from a minimum of 26.90 kg.m/s to a maximum of 66.00 kg.m/s, with an average of 44.48 kg.m/s. On average, leg muscle explosive power exhibited a noticeable increase after the training compared to before the lateral cone jump regimen.

Test Path Analysis Assumptions

Before conducting path analysis, three assumptions must be satisfied: the residual normality test, heteroscedasticity test, and multicollinearity test. These tests were performed on the path analysis model, which encompasses two regression models: model 1 examines the relationship between lateral cone jumps and the number of jumps, while model 2 explores the influence of lateral cone jumps and the number of jumps on leg muscle explosive power.

Table 2. Path analysis assumption test results

Model	Variable	Normality test	Heteroscedasticity test	Multicollinearity test
Lateral cone jump exercise→Number of Jumps	Residual	0.200		
	Lateral Cone Jumps		0.277	TOLL: 1.000 VIF: 1.000
Lateral cone jump exercise, Number of Jumps→Explosive Power of Leg Muscles	Residual	0.200		
	Lateral Cone Jumps		0.949	TOLL: 0.840 VIF: 1.191
	Number of Jumps		0.320	TOLL: 0.840 VIF: 1.191

Table 2 shows that the residuals in both models exhibit significance values exceeding α (0.05). Consequently, it can be inferred that all residuals conform to a normal distribution. Furthermore, the heteroscedasticity test for the first model demonstrates that the lateral cone jump training variable yields a significance value surpassing α (0.05), suggesting the absence of heteroscedasticity. Similarly, in the second model, both the lateral cone jumps and number of jumps training variables exhibit significance values greater than α (0.05). Thus, it can be concluded that neither regression model in this study manifests heteroscedasticity.

Regarding the multicollinearity test, the tolerance values for the lateral cone jump training variable in the first model exceed 0.10, while the VIF values are less than 10, indicating the absence of multicollinearity. Similarly, in the second regression model, both the lateral cone jumps and number of jumps training variables possess tolerance values exceeding 0.10 and VIF values less than 10, indicating no multicollinearity. Consequently, it is confirmed that all three assumption tests have been met, enabling the continuation of path analysis.

Path Analysis

The objective of the path analysis in this study is to analyze the direct and indirect effects of lateral cone jump training on the explosive power of leg muscles based on the frequency of jumps among high school girls.

Results

This study employs the path analysis method within an experimental framework, utilizing SPSS for direct influence analysis and the Sobel Calculator for indirect influence assessment. The primary objective of this plyometric training is to evaluate the jumping strength of high school female students under maximum physical exertion conditions facilitated by the Polar H10. By administering pre-test and post-test assessments, changes in strength and speed among female students are analyzed using SPSS V25.

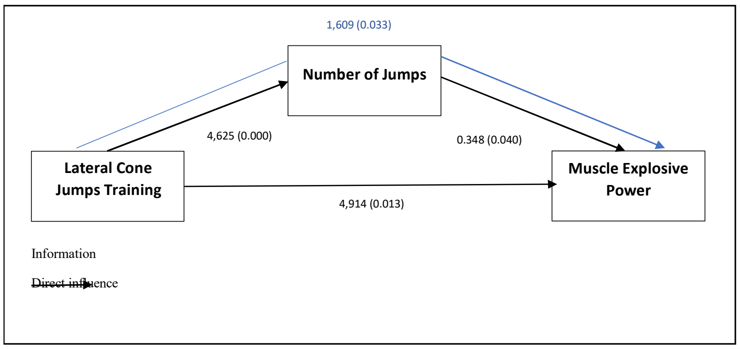

Fig. 1 Research path analysis model

Coefficient of Determination

The coefficient of determination aims to quantify the collective influence of the independent variable on the dependent variable.

Table 3. Coefficient of determination

Model	R2
Lateral cone jumps→Number of jumps	0.160
Lateral cone jumps, number of jumps→Explosive power of leg muscles	0.190

To calculate the total coefficient of determination, the path analysis model utilizes the R-squared (R^2) value, employing the following formula:

$$P_{e1} = \sqrt{1 - R_1^2}$$

$$P_{e1} = \sqrt{1 - 0.160} = 0.916$$

$$P_{e2} = \sqrt{1 - R_2^2}$$

$$P_{e2} = \sqrt{1 - 0.190} = 0{,}900$$

Total coefficient of determination:

$$R_m^2 = 1 - P_{e1}^2 P_{e2}^2$$

$$R_m^2 = 1 - (0.916^2)\,(0.900^2) = 0.320$$

Therefore, the total coefficient of determination from path analysis is 0.320. This signifies that the combined influence of the lateral cone jump training variables and the number of jumps on leg muscle explosive power accounts for 32% of the variance, while the remaining 68% is attributed to other variables not encompassed in the research (Poomsalood & Pakulanon, 2015). Referring to established R-squared values of 0.67 (strong), 0.32 (moderate), and 0.19 (weak), the coefficient of determination of 0.32 in this study places the research model within the moderate or medium category in terms of strength.

Discussion

HIIT is commonly employed to enhance cardiovascular fitness, promote fat loss, and build strength (Komarudin, 2021; Pairi Peprianti, Riswanto Heri, 2023; Siregar Indra Yan, Nurkadri, Rohaya Nirwana, Muda Sory, 2023). This form of training encompasses a variety of activities such as running, cycling, jump rope exercises, and strength training (Irawan, 2017; Muhammad, 2023; Pattisina & Hamidie, Ronald, 2023). Plyometric movements, characterized by rapid muscle contractions followed by powerful ones, are integral to HIIT (Duchateau & Amiridis, 2023; Hammami et al., 2018; Mitchell, 2017). The objective of the lateral cone jump exercise is to enhance the explosive power of leg muscles, typically achieved through swift movements that rely on muscle strength and tendon elasticity. The Polar H10 monitoring device facilitates heart rate measurement during physical activities by connecting to a PC or a smartphone for data tracking (Gąsior et al., 2022; Hajj-Boutros et al., 2023; McCabe & Greer, 2023). The impact of lateral cone jump exercises on leg muscle explosive power, mediated by the frequency of jumps, can be assessed using the Sobel test. Below, we present the results of the Sobel test.

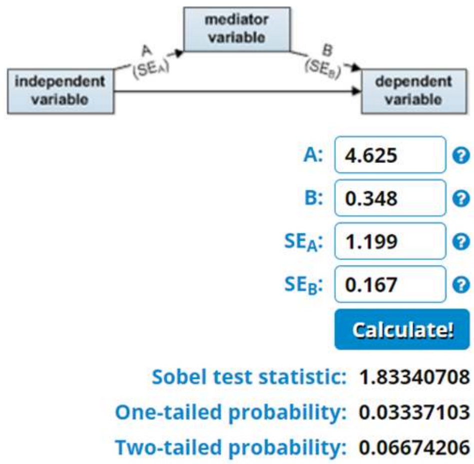

Fig. 2 Sobel test parameters

Indirect Influence

The influence of lateral cone jump exercise on the explosive power of leg muscles through the number of jumps made can be calculated using the Sobel test. Presented below are the results of the Sobel Test.

Table 4. Indirect effects analysis results

Connection	Coefficient	p-value
Lateral cone jump exercise→Number of jumps→Explosive power of leg muscles	1.609	0.033

Based on the results of the Sobel test, it is evident that the significance value is 0.033 < α (0.05), indicating that lateral cone jump exercises significantly influence the explosive power of leg muscles through the number of jumps performed by high school sports students. Moreover, the effect of lateral cone jump training on the explosive power of leg muscles, mediated by the number of jumps executed by students, is positive. This is discernible from the positive coefficient observed. Consequently, this suggests that following lateral cone jump training, the number of jumps tends to increase compared to pre-training levels, thereby resulting in higher explosive power of the leg muscles.

Direct Influence

The results of path analysis for direct influence analysis are presented in Table 3 below.

Table 5. Direct effect analysis results

Connection	Coefficient	p-value
Lateral cone jump exercise→Number of jumps	4.625	0.000
Lateral cone jump exercise→Explosive power of leg muscles	4.914	0.013
Number of jumps→Explosive power of leg muscles	0.348	0.040

Independent variable: lateral cone jump exercise. Dependent variable: leg muscle explosive power. Mediating variable: number of jumps.

From the results of this analysis, it is evident that the significance value of the lateral cone jump training variable on the number of jumps is 0.000 < α (0.05). This indicates that lateral cone jump training significantly influences the number of jumps that can be performed by high school sports students. The positive coefficient associated with the lateral cone jump training variable suggests that after completing lateral cone jump training, the number of jumps tends to increase compared to pre-training levels.

Similarly, in the case of the lateral cone jump training variable on leg muscle explosive power, the significance value is 0.013 < α (0.05). This signifies that lateral cone jump training exerts a significant effect on leg muscle explosive power among high school sports students. The positive coefficient further implies that following lateral cone jump training, there is an increase in leg muscle explosive power compared to pre-training levels (Herbert, 2009; Lin et al., 2012; Poomsalood & Pakulanon, 2015). This indicates a positive impact of lateral cone jump training on the explosive power of leg muscles.

Conclusions

Lateral cone jump exercises are plyometric exercises involving movements over cones. HIIT aims to enhance cardiorespiratory fitness, burn fat, and boost muscle strength within a condensed timeframe. Following the completion of lateral interval cone jump exercises by 40 high school female students, it was observed that the variable "number of jumps" significantly affects the explosive power of leg muscles among high school sports students, with a significance level of 0.040 < α (0.05). The total coefficient of determination derived from path analysis is 0.320, indicating that 32% of the variation in leg muscle explosive power can be attributed to the influence of lateral cone jump training variables and the number of jumps, while the remaining 68% is influenced by external variables not accounted for in the research model. With a coefficient of determination of 0.32, the strength of this research model is moderate or medium. The positive coefficient associated with the number of jumps suggests that an increase in jumps correlates with the higher explosive power of leg muscles. In essence, a higher frequency of jumps leads to enhanced explosive power in leg muscles.

Declaration of interest:
No conflict of interest.

References:

Abidin, D., Muhamad, M., Haqiyah, A., & Gusriadi, A. R. (2020, February). Agility and Balance on the Speed of Dribbling in Soccer. In *1st South Borneo International Conference on Sport Science and Education (SBICSSE 2019)* (pp. 208-210). Atlantis Press. https://doi.org/10.2991/assehr.k.200219.059

Agi Ginanjar, Adang Suherman, Tite Juliantine, Y. H. (2023). The Effect of Plyometric Jump To Box Training on Leg Muscle Explosiveness of Tapin Regency Men's Volleyball Players. *Pendidikan Jasmani Dan Olahraga*, *4*(1), 122–128.

Akbar, M. S., Mulyana, B., Maulana, D., & Agustina, R. S. (2019). Effect of Lateral Cone Hops and Hurdle Hops Training on the Power of Legs Muscles. *3rd International Conference on Sport Science, Health, and Physical Education*, *11*(Icsshpe 2018), 34–36. https://doi.org/10.2991/icsshpe-18.2019.10

Aloui, G., Hermassi, S., Hammami, M., Cherni, Y., & Ardigò, L. P. (2020). Effects of Elastic Band Based Plyometric Exercise on Explosive Muscular Performance and Change of Direction Abilities of Male Team Handball Players. *Frontiers in Physiology*, *11*(December), 1–12. https://doi.org/10.3389/fphys.2020.604983

Anggraini Tiansi Dwi, H. Z. U. (2023). Indonesion Journal of Sport Science and Coaching. *Indonesion Journal of Sport Science and Coaching*, *05*(01), 21–27. https://doi.org/10.22437/ijssc.v5i1.21857

Ashar, A., Setijono, H., & Mintarto, E. (2021). The effect of unilateral and bilateral training circuit with ladder drill and plyometric cone on speed, agility, reaction and balance of elementary school students in Indonesia. *International Journal of Human Movement and Sports Sciences*, *9*(6), 1453–1459. https://doi.org/10.13189/saj.2021.090642

Bimson, L., Langdown, L., Fisher, J., & Steele, J. (2017). Six weeks of knee extensor isometric training improves soccer related skills in female soccer players. *Journal of Trainology*, 6(2), 52-56. https://doi.org/10.17338/trainology.6.2_52

Boby, F. A. (2023). A Study on the Impact of Various Motor Fitness Characteristics on Performing Ability in High and Low-Performing Divisional Women Cricket Players. *Physical Education and Sports: Studies and Research*, *2*(1), 44-58.

Boraczy, M., Magalhães, J., Nowakowski, J. J., & Laskin, J. J. (2023). Short-Term Effects of Lower-Extremity Heavy Resistance versus High-Impact Plyometric Training on Neuromuscular Functional. *Sports*, *11*(193), 1–22. https://doi.org/https://doi.org/ 10.3390/sports11100193

Budig, M., Keiner, M., Stoohs, R., Hoffmeister, M., & Höltke, V. (2022). Heart rate and distance measurement of two multisport activity trackers and a cellphone app in different sports: A cross-sectional validation and comparison field study. *Sensors*, *22*(1), 180. https://doi.org/10.3390/s22010180

Coratella, G., Beato, M., Milanese, C., Longo, S., Limonta, E., Rampichini, S., Cè, E., Bisconti, A. V., Schena, F., & Esposito, F. (2018). Specific adaptations in performance and muscle architecture after weighted jump-squat vs body mass squat jump training in recreational soccer players. *Journal of Strength and Conditioning Research Publish Ahead of Print,* *32*(4), 921-929. https://doi.org/10.1519/JSC.0000000000002463

Dominski, F. H., Serafim, T. T., Siqueira, T. C., & Andrade, A. (2021). Psychological variables of CrossFit participants: a systematic review. *Sport Sciences for Health*, *17*(1), 21–41. https://doi.org/10.1007/s11332-020-00685-9

Duchateau, J., & Amiridis, I. G. (2023). Plyometric exercises: optimizing the transfer of training gains to sport performance. *Exercise and Sport Sciences Reviews*, *51*(4), 117-127. https://doi.org/10.1249/JES.0000000000000320

Effendi, S., Sunarmo, B., & Ar, S. (2019). Effect of plyometric training front core hops and knee tuck jump on muscle explosive strength improvement. https://doi.org/sbicsse 2019

Fitrianto, E. J., Asri, D., & Lubis, J. (2018, December). Comparing the Effects of Plyometric Depth Jump and Rim Jump Training on the Explosive Power of Leg Muscle and the Level of Creatine Phosphokinase of Basketball Players. In *2nd Yogyakarta International Seminar on Health, Physical Education, and Sport Science (YISHPESS 2018) and 1st Conference on Interdisciplinary Approach in Sports (CoIS 2018)* (pp. 503-509). Atlantis Press. https://doi.org/10.2991/yishpess-cois-18.2018.127

Gąsior, J. S., Rosoł, M., Młyńczak, M., Gąsienica-Józkowy, M., Flatt, A., Baranowski, R., & Werner, B. (2022). Validity of the Polar H10 for RR intervals acquisition during different conditions for heart rate variability analysis in ski mountaineers. *Research Square*, 1–21.

Hajj-Boutros, G., Landry-Duval, M. A., Comtois, A. S., Gouspillou, G., & Karelis, A. D. (2023). Wrist-worn devices for the measurement of heart rate and energy expenditure: A validation study for the Apple Watch 6, Polar Vantage V and Fitbit Sense. *European Journal of Sport Science*, *23*(2), 165–177. https://doi.org/10.1080/17461391.2021.2023656

Hammami, M., Gaamouri, N., RAMIREZ-CAMPILLO, R., Shephard, R. J., BRAGAZZI, N. L., CHELLY, M. S., KNECHTLE, B., & GAIED, S. (2021). Effects of high-intensity interval training and plyometric exercise on the physical fitness of junior male handball players. *European Review for Medical and Pharmacological Sciences*, *25*(1), 7380–7389.

Hammami, M., Gaamouri, N., Shephard, R., & Chelly, M. S. (2018). Effects of Contrast Strength vs. Plyometric Training on Lower Limb Explosive Performance, Ability to Change Direction and Neuromuscular Adaptation in Soccer Players. *The Journal of Strength and Conditioning Research*, *33*(8), 2094–2103. https://doi.org/10.1519/JSC.0000000000002425

Haqiyah, A., Sanjaya, K. H., Riyadi, D. N., Lestari, W. D., Kusmasari, W., Lubis, J., & Hanief, Y. N. (2023). Validity of the modified star excursion balance test (mSEBT) in martial art athletes. *Journal of Physical Education and Sport*, *23*(4), 817–823. https://doi.org/10.7752/jpes.2023.04103

Herbert, I. (2009). Business transformation through empowerment and the implications for management control systems. *Journal of Human Resource Costing & Accounting*, *13*(3), 221–244. https://doi.org/10.1108/14013380910995511

Hernández-Vicente, A., Hernando, D., Marín-Puyalto, J., Vicente-Rodríguez, G., Garatachea, N., Pueyo, E., & Bailón, R. (2021). Validity of the polar h7 heart rate sensor for heart rate variability analysis during exercise in different age, body composition and fitness level groups. *Sensors (Switzerland)*, *21*(3), 1–14. https://doi.org/10.3390/s21030902

Himariotis, A. T., Coffey, K. F., Noel, S. E., & Cornell, D. J. (2022). Validity of a Smartphone Application in Calculating Measures of Heart Rate Variability. *Sensors*, *22*(24), 9883. https://doi.org/10.3390/s22249883

Hinde, K., White, G., & Armstrong, N. (2021). Wearable devices suitable for monitoring twenty four hour heart rate variability in military populations. *Sensors (Switzerland)*, *21*(4), 1–20. https://doi.org/10.3390/s21041061

Honold, L. (2017). Article information : *Industrial and Commercial Training*, *22*(1), 202–212. https://doi.org/10.1108/IJOPM-07-2016-0387

Huang, H. (2023). Effectiveness of intensity in sports tactics training of soccer players. *Revista Brasileira De Medicina Do Esporte*, 29. https://doi.org/10.1590/1517-8692202329012022_0355

Irawan, D. (2017). Six Weeks Progressive Plyometrics Training on Badminton Player's Agility. *Health Science International Conference*, *2*(Hsic), 18–21. https://doi.org/10.2991/hsic-17.2017.4

Javanmardi, Z., Jahromi, M., Hemmatinafar, M., Knechtle, B., & Nikolaidis, P. (2021). The effect of simulation-based training on athletic performances among female basketball players. T*he Open Sports Sciences Journal*, 14(1), 51-57. https://doi.org/10.2174/1875399x02114010051

Koçak, Ç. V. (2020). Athlete self-efficacy scale: Development and psychometric properties. *Baltic Journal of Health and Physical Activity*, *12*(6), 41–54. https://doi.org/10.29359/BJHPA.2020.Suppl.1.05

Komarudin, K. (2021). Plyometric training in soccer for young children. *Sepakbola*, *1*(2), 67-77.

Kramer, A., Gollhofer, A., Armbrecht, G., Felsenberg, D., & Gruber, M. (2017). How to prevent the detrimental effects of two months of bed-rest on muscle, bone and cardiovascular system: an rct. *Scientific Reports*, 7(1), 13177. https://doi.org/10.1038/s41598-017-13659-8

Książek, K., Masarczyk, W., Głomb, P., Romaszewski, M., Stokłosa, I., Ścisło, P., Dębski, P., Pudlo, R., Buza, K., Gorczyca, P., & Piegza, M. (2023). The analysis of heart rate variability and accelerometer mobility data in the assessment of symptom severity in psychotic disorder patients using a wearable Polar H10 sensor. *MedRxiv*, *1*(1), 1–18.

Lin, C. F., Huang, T. H., Tu, K. C., Lin, L. L., Tu, Y. H., & Yang, R. Sen. (2012). Acute eVects of plyometric jumping and intermittent running on serum bone markers in young males. *European Journal of Applied Physiology*, *112*(4), 1475–1484. https://doi.org/10.1007/s00421-011-2108-8

Lubis, J., Fitrianto, E. J., Sukiri, Haqiyah, A., Setiakarnawijaya, Y., Robianto, A., Sukriadi, S., Nurulfa, R., Irawan, A. A., & Sumartiningsih, S. (2021). Does aerobic interval training induce a decrease in body weight in pencak silat elite athletes? *Journal of Physical Education and Sport*, *21*(4), 2372–2380. https://doi.org/10.7752/jpes.2021.s4318

Lubis, J., Sukur, A., Haqiyah, A., Irawan, A. A., Suliyanthini, D., Sukriadi, S., & Susianti, E. (2021). Cooling vest (cv-f) to improve recovery effectiveness of pencak silat martial arts student-athletes. *Journal of Engineering Science and Technology*, *16*(4), 2938–2949.

Lubis, J., Thongdaeng, N., Haqiyah, A., Sukur, A., Abidin, D., Irawan, A. A., & Sumartiningsih, S. (2020). The Effect of Five-Week Aerobic Interval Training on The Body Composition of Pencak Silat Elite Athletes. *International Journal of Kinesiology and Sports Science*, *10*(2), 16–24.

Mardhika, R. (2019). Standing Jump Over Barrier Mempengaruhi Keterampilan Menendang Bola (Shooting) Cabang Olahraga Sepakbola. *Jurnal Porkes*, *2*(2), 50–57. https://doi.org/10.29408/porkes.v2i2.1886

McCabe, L. H., & Greer, B. D. (2023). Evaluations of heart rate during functional analyses of destructive behavior. *Journal of Applied Behavior Analysis*, *8*(August), 777–786. https://doi.org/10.1002/jaba.1019

Mitchell, G. E. (2017). Fiscal Leanness and Fiscal Responsiveness: Exploring the Normative Limits of Strategic Nonprofit Financial Management. *Administration and Society*, *49*(9), 1272–1296. https://doi.org/10.1177/0095399715581035

Muhamad, & Wibowo, A. (2022). Principal Leadership in Improving Teacher Performance at SD Negeri 01 Sangkaran Bhakti. *Attractive : Innovative Education Journal*, *4*(3), 487–494.

Muhammad, A. S. (2023). Effect of Mict With Ball Mastery on Aerobic Endurance of Futsal Players at SMA Muhammadiyah 2 Surabaya. *JPO : Jurnal Prestasi Olahraga*, *6*(2), 125–130.

Ojeda-Aravena, A., Herrera-Valenzuela, T., Valdés-Badilla, P., Martín, E. B.-S., Cancino-López, J., Azócar-Gallardo, J., Zapata-Bastías, J., & García-García, J. M. (2021). Effects of High-Intensity Interval Training With Specific Techniques on Jumping Ability and Change of Direction Speed in Karate Athletes : An Inter-individual Analysis. *Frontiers in Physiology*, *12*(November), 1–10. https://doi.org/10.3389/fphys.2021.769267

Pairi Peprianti, Riswanto Heri, H. R. (2023). The Effect of Squat Training Using Resistence Bands on Limb Strength of the Women's Futsal Team of Muhammadiyah University of Palopo. *Journal of S.P.O.R.T*, *7*, 285–295. https://doi.org/https://doi.org/10.37058/sport

Pattisina, F. A., & Hamidie, Ronald, M. (2023). Effect of Plyometric and Plyometric + (Duel) Training on Strength and Explosive Power of Limb and Arm Muscles in Rowing and Jiu Jitsu Students of Ijukai West Bandung Regency. *Journal on Education*, *06*(01), 6171–6187. https://doi.org/http://jonedu.org/index.php/joe

Permana, D., Kusnanik, N., Ardha, M., & Raharjo, S. (2022). A six-week plyometric training program improves explosive power and agility in professional athletes of east java. *Teorìâ Ta Metodika Fìzičnogo Vihovannâ*, 22(4), 510-515. https://doi.org/10.17309/tmfv.2022.4.08

Poomsalood, S., & Pakulanon, S. (2015). Effects of 4-week plyometric training on speed, agility, and leg muscle power in male university basketball players: A pilot study. *Kasetsart Journal - Social Sciences*, *36*(3), 598–606.

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

Santika, I. and Subekti, M. (2020). Training of jump over the bar 30 cm high with burdened 1 kg to eksplosion power leg muscles. *Jurnal Pendidikan Jasmani (Jpj)*, 1(2), 39-46. https://doi.org/10.55081/jpj.v1i2.125

Sarkar, S., Dasgupta, S., Meitei, K. K., Adhikari, S., & Dey, S. K. (2020). Effect of eccentric cycling and plyometric training on physiological and performance related parameters of trained junior track cyclists. *Pol. J. Sport Tourism*, *27*(1), 14–20. https://doi.org/10.2478/pjst-2020-0003

Schaffarczyk, M., Rogers, B., Reer, R., & Gronwald, T. (2022). Validity of the Polar H10 Sensor for Heart Rate Variability Recreational Men and Women. *Sensors*, 1–13.

Siregar Indra Yan, Nurkadri, Rohaya Nirwana, Muda Sory, G. alessandro D. (2023). Contribution of squat jump, leg squat, and walking lunge to mawashi geri kicking ability skills Yan Indra Siregar. *Jurnal SPORTIF: Jurnal Penelitian Pembelajaran*, *9*(2), 355–368. https://doi.org/https://doi.org/10.29407/js_unpgri.v9i2.21014

Spieszny, M., & Zubik, M. (2018). Modification of Strength Training Programs in Handball Players and its Influence on Power during the Competitive Period. *Journal of Human Kinetics*, *63*(1), 149–160. https://doi.org/10.2478/hukin-2018-001

Syahriadi, S. (2020). Latihan pliometrik dan latihan berbeban terhadap jumpingsmash atlet bulutangkis. *Gelanggang Olahraga Jurnal Pendidikan Jasmani Dan Olahraga (Jpjo)*, 3(2), 133-142. https://doi.org/10.31539/jpjo.v3i2.1048

Syam, H., Akib, H., Patonangi, A. A., & Guntur, M. (2018). Principal Entrepreneurship Competence Based On Creativity And Innovation In The Context Of Learning Organizations In Indonesia. *Journal of Entrepreneurship Education*, *21*(3), 1–13.

Trisnowiyanto, B. (2016). Training to Improve Biomotor Ability (Agility, Speed, Balance and Flexibility) with Running Techniques (Shuttle Run, Zig-Zag, Formation 8) in Pugilists. *Jurnal Keterapian Fisik*, *1*(2), 82-89.

Wagner, H., Abplanalp, M., von Duvillard, S. P., Bell, J. W., Taube, W., & Keller, M. (2021). The relationship between on-ice and off-ice performance in elite male adolescent ice hockey players—an observation study. *Applied Sciences*, *11*(6), 2724. https://doi.org/10.3390/app11062724