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Long-Term High-Intensity Plyometric Training Increases Muscle Strength and Power of The Lower Body in Young Healthy Males

El entrenamiento pliométrico de alta intensidad a largo plazo aumenta la fuerza muscular y la potencia de la parte inferior del cuerpo en hombres jóvenes sanos

*Slamet Raharjo, **Nguyen Tra Giang, ***Raja Mohammed Firhad Raja Azidin, ****Mustika Fitri, *Mahmud Yunus, *****Ramdan Pelana

*Universitas Negeri Malang (Indonesia), **University of Management and Technology Hochiminh City (Vietnam), ***Universiti Teknologi MARA (Malaysia), ****Universitas Pendidikan Indonesia (Indonesia), *****Universitas Negeri Jakarta (Indonesia)

Abstract. This research aims to effect of long-term high-intensity plyometric training on the strength and power of the lower body muscles in young healthy males. A total of 40 healthy men, aged 20–24 years, with no history of chronic disease, were recruited to become research subjects and were divided into 2 groups: the control group (CTRL; n=20) and the high-intensity plyometric training group (HIPT; n=20). The intervention was carried out for six weeks, with a frequency of four times per week. Meanwhile, at CTRL, no special training is given. Measurements of muscle strength and power were carried out between the pretest and posttest. The data analysis technique uses a paired sample t-test with a significance level of 5%. The results showed the average muscle strength between the pretest and posttest on CTRL (117.75±19.39 to 118.55±16.27 kg, p=0.704), and HIPT (116.55±19.64 to 132.25±19.15 kg, p=0.000). Muscle power between the pretest and posttest on CTRL (52.10±6.95 to 52.70±6.53 cm, p=0.055), and HIPT (53.05±6.72 to 66.85±8.07 cm, p=0.000). This research proves that long-term high-intensity plyometric training increases lower-body muscle strength and power in healthy young males.
Keywords: Muscle strength, muscle power, physical condition, physical performance, plyometric training.

Resumen. Esta investigación tiene como objetivo estudiar el efecto del entrenamiento pliométrico de alta intensidad a largo plazo sobre la fuerza y la potencia de los músculos de la parte inferior del cuerpo en hombres jóvenes sanos. Se reclutó a un total de 40 hombres sanos, de entre 20 y 24 años, sin antecedentes de enfermedades crónicas, para que se convirtieran en sujetos de investigación y se dividieron en 2 grupos: el grupo de control (CTRL; n=20) y el grupo de entrenamiento pliométrico de alta intensidad. grupo (HIPT; n=20). La intervención se realizó durante seis semanas, con una frecuencia de cuatro veces por semana. Mientras tanto, en CTRL no se imparte ninguna formación especial. Se realizaron mediciones de fuerza y potencia muscular entre el pretest y el postest. La técnica de análisis de datos utiliza una prueba t de muestras pareadas con un nivel de significancia del 5%. Los resultados mostraron la fuerza muscular promedio entre el pretest y el postest en CTRL (117,75±19,39 a 118,55±16,27 kg, p=0,704) y HIPT (116,55±19,64 a 132,25±19,15 kg, p=0,000). Potencia muscular entre el pretest y postest de CTRL (52,10±6,95 a 52,70±6,53 cm, p=0,055) y HIPT (53,05±6,72 a 66,85±8,07 cm, p=0,000). Esta investigación demuestra que el entrenamiento pliométrico de alta intensidad a largo plazo aumenta la fuerza y potencia de los músculos de la parte inferior del cuerpo en hombres jóvenes sanos.
Palabras clave: Fuerza muscular, potencia muscular, condición física, rendimiento físico, entrenamiento pliométrico.

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Slamet Raharjo
slamet.raharjo.fik@um.ac.id

Introduction

Lack of exercise or physical inactivity is a major and widespread cause of health issues worldwide (Kocjan et al., 2024). Physical inactivity causes 3.3 million global deaths annually, with 70% of them in poorer countries and 6–10% from non-communicable diseases (Shiferaw et al., 2024). Many serious diseases and early death are associated with low physical activity, which is the most frequent risk factor, including heart disease, diabetes, several types of cancer, and mental health problems (Xu et al., 2022). Nowadays, people tend to sit or be inactive for most of their 13–14 hours of waking time (Andrade, 2024). Given that 27.5% of adults and 81% of adolescents don't meet the aerobic exercise guidelines from the 2010 Global Recommendations on Physical Activity for Health, there's an urgent need to prioritize and invest in services promoting physical activity across health and other key sectors (Bull et al., 2020).

Lack of physical activity in young adults may affect the function and structure of muscle cells and cause muscle loss (Pišot, 2021). Muscular strength is important for health and disease prevention, as it relates to physical fitness, death risk, and chronic illness intervention (Lopez-Jaramillo et al., 2022). On the contrary, being active has become more essential for our health, acting as a key factor in promoting physical fitness, enhancing work efficiency, bolstering the immune system, and maintaining psychophysical equilibrium (Pišot, 2021). However, the worldwide advancement in diminishing levels of physical inactivity has been sluggish (Santos et al., 2022).

Accordingly, this study aims to evaluate the effectiveness of long-term plyometric training in enhancing the strength and power of lower body muscles in healthy young men (Kons et al., 2023). We hypothesize that plyometric training will not only improve physical performance (Deng et al., 2024) but also contribute to muscle health (Wang, et al., 2023), offering a potential strategy to mitigate the adverse effects of physical inactivity (Ramírez-delaCruz et al., 2022). Plyometric training is more common nowadays to improve power and strength (Ali et al. 2023). The enhancement in peak muscle strength due to plyometric training can be attributed to alterations in muscle structure, including an increase in the angle and length of muscle fascicles, and changes in the rigidity of various elastic components such as the plantar flexor tendon complex (Chen et al., 2023). The effective use of the SSC is related to the contributions of different mechanisms that facilitate greater mechanical work production in subsequent concentric muscle actions, such as the accumulation of elastic energy, pre-load, an increase of the time to muscle activation, muscle history dependence (force enhancement), stretch-reflexes, and muscle-tendon interactions (Kons et al., 2023). Plyometric consists of rapid muscle lengthening followed by contraction of the same muscle and connective tissue (Chandra et al., 2023). Plyometrics utilizes exercises such as various types of jumps, skipping, and hopping to enhance the efficiency of the muscle's stretch-shortening cycle (Gaamouri et al., 2023). Plyometrics follow the form of human movement (Wang et al., 2023), so plyometrics are considered a secure, readily accessible, and time-efficient method of training for the younger population (Ramirez-Campillo et al., 2023). Hence, our objective is to explore the impact of long-term high-intensity plyometric training on the strength and power of the lower body muscles in young healthy males.

Material and Methods

This was true experimental research with a pretest-posttest control group design. A total of 40 healthy male participants, aged 20–24 years and with no history of chronic disease, were recruited for the study. They were randomly divided into two groups: the control group (CTRL; n=20), which did not receive any specific intervention, and the high-intensity plyometric training group (HIPT; n=20), which underwent the designated training regimen. Before participating in this research, all subjects were explained about the research that would be carried out, and the subjects voluntarily filled out and signed informed consent. All procedures applied in this study were ethical principles for medical research involving human subjects and approved by the Health Research Ethics Committee, Faculty of Medicine, Universitas Brawijaya Malang (No: 260/EC/KEPK/09/2021).

Plyometric training was carried out by combining single-leg plyometric sprint jumps with hurdle jumps, which are done for 30-35 minutes per session with high-intensity (80–90% HRmax) and frequency 4x/week for 6 weeks. Monitoring of intensity training using the Polar H10 heart rate sensor (Yunus et al., 2024). This monitoring was not merely for the purpose of enhancing athletic performance but also served as a critical measure for assessing the health benefits associated with muscle conditioning. By ensuring the training intensity remained within the targeted range, the study aimed to optimize the myriad of benefits that plyometric training can confer on muscle health and functionality, extending beyond the simplistic metric of jump height.

The data collection technique was carried out by measuring pretest-posttest leg muscle strength with the back and leg dynamometer, while pretest-posttest leg muscle power was measured with the vertical jump test. The instruments used to measure muscle strength and power have been validated by previous studies (Puspodari et al., 2022; Putera et al., 2023).

Statistical analysis was presented using descriptive tests, normality tests using the Shapiro-Wilk test, difference tests using the parametric paired sample t-test, and an independent sample t-test with a significance level of 5%. Statistical analysis was applied with SPSS version 25 for Windows.

Results

Based on the results of the analysis in Table 1, it is reported that there are no significant differences in subject characteristic data in the two groups so both groups are at the same starting point. Meanwhile, the results of the analysis of muscle strength and power are presented in Figures 1-4.

Table 1.
Description of subject characteristics

Parameters	CTRL (*n* = 20)	HIPT (*n* = 20)	Independent sample t-test
Age, yrs	20.35±1.23	20.45±1.24	0.799
Weight, kg	60.05±5.09	59.50±3.89	0.719
Height, m	1.66±0.04	1.67±0.05	0.703
BMI, kg/m^2	21.58±0.89	21.41±1.02	0.592
SBP, mmHg	116.20±3.78	116.45±3.66	0.833
DBP, mmHg	74.90±3.49	74.75±4.39	0.905
HR, bpm	65.45±4.51	65.40±4.82	0.973
SpO_2, %	97.25±1.45	97.55±1.28	0.491

Description: BMI: Body mass index; DBP: Diastolic blood pressure; HR: Heart rate; SBP: Systolic blood pressure. SpO_2: Oxygen saturation.

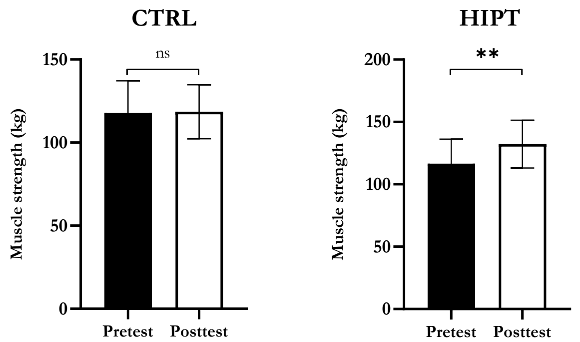

Figure 1. Differences in pretest and posttest muscle strength in both groups.
Description: (ns) not significant. (**) Significant at pretest ($p \leq 0.001$).

The results of the paired sample t-test analysis in Figure 1 show that there was a significant difference in pretest and posttest muscle strength in HIPT (116.55±19.64 to 132.25±19.15 kg, p=0.000), but no significant difference was found in CTRL (117.75±19.39 to 118.55±16.27 kg, p=0.704). Likewise, muscle power was found to have no significant difference between the pretest and posttest on CTRL (52.10±6.95 to 52.70±6.53 cm, p=0.055), whereas on HIPT there was a significant difference (53.05±6.72 to 66.85±8.07 cm, p=0.000) (Figure 2). Meanwhile, the differences in the results of muscle strength and power analysis between CTRL and HIPT are shown in Figure 3-4.

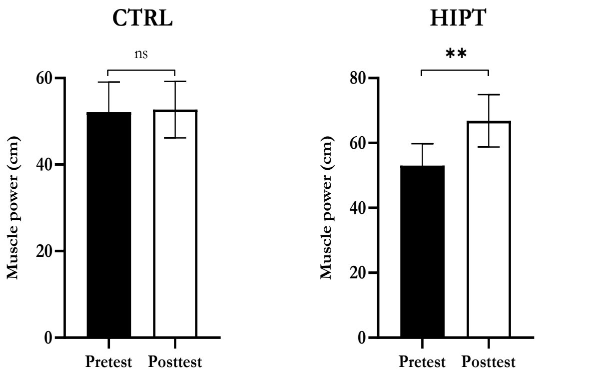

Figure 2. Differences in pretest and posttest muscle power in both groups. Description: (ns) not significant. (**) Significant at pretest ($p \leq 0.001$).

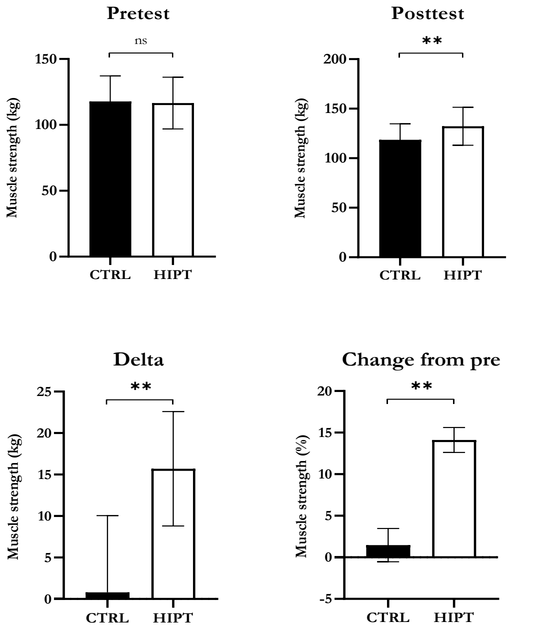

Figure 3. Difference in average muscle strength in CTRL and HIPT. Description: (ns) Not significant. (**) Significant at CTRL ($p \leq 0.001$).

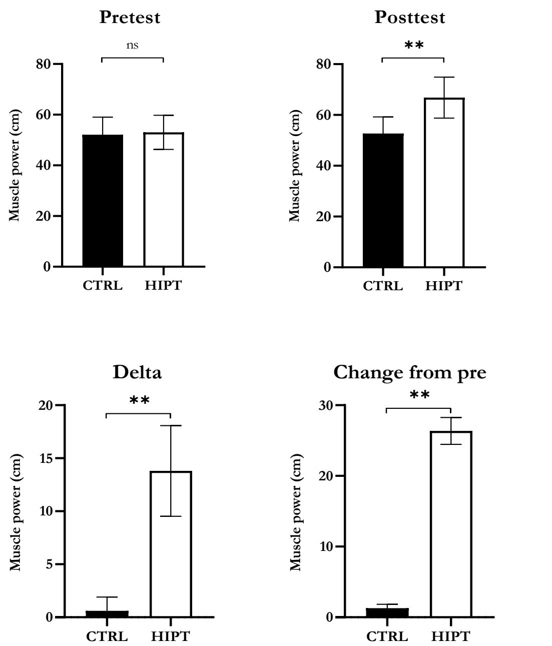

Figure 4. Difference in average muscle power in CTRL and HIPT. Description: (ns) not significant. (**) significant at CTRL ($p \leq 0.001$).

Discussion

Based on research results, it was found that high-intensity plyometric training was proven to be effective in increasing lower-body muscle strength and power in healthy young males. This aligns with Grgic et al. (2021) findings, which state that plyometric training has been proven to enhance the strength and power of lower extremity muscles. They compared plyometrics with resistance training and stated that plyometrics is more effective. Wiriawan et al. (2024) in their research reported that high-intensity plyometric training was proven to be effective in increasing muscle strength and power in young males. Likewise, the study by Putera et al. (2023) reported that high-intensity plyometric training was effective in increasing muscle power in adolescent males. Additional research indicated that despite its numerous advantages, plyometrics also has several detrimental impacts (Hasan, 2023). It may be because the term "plyometric" is formally defined as rapid and forceful performance in sports (Huang et al., 2023). Also, a considerable number of prior scholarly investigations, which were centered around the implications of plyometric programs, predominantly targeted athletes (Kryeziu et al., 2023). Investigations have shown that plyometric training can notably enhance performance in sports-specific activities (Garcia-Carrillo et al., 2023).

The substantial volume of research exploring the impacts of plyometric training on physical abilities has seen a considerable expansion, paralleled by an increase in systematic reviews and meta-analysis studies (Kons et al., 2023). Results by Kryeziu et al. (2023) revealed that plyometric exercise is safe to perform on non-athletes and provides more concrete results because it is not influenced by other exercise programs. Meta-analyses indicate that plyometric training can enhance physical performance in healthy individuals and athletes, impacting vertical jump height, sprint speed, and muscle strength (Kons et al., 2023). The primary objective in the case of physical inactivity is to enhance body composition. Body composition, a vital health and fitness component, is linked to chronic diseases, with low muscle mass and high fat content potentially leading to conditions like Type 2 diabetes, heart disease, cancers, and increased mortality risk (Ramirez-Campillo et al., 2022). Physical exercise is a powerful intervention that can bring about significant cardiometabolic health benefits, such as better insulin sensitivity, cholesterol levels, and blood pressure (Khalafi et al., 2024). Plyometrics is a form of exercise that is regarded as a safe, convenient, and time-saving method of training for the younger population (Ramirez-Campillo et al., 2023) because it mimics the natural patterns of human movements (Wang et al., 2023).

The empirical evidence suggests that plyometric training constitutes a viable and secure modality of exercise, offering substantial potential to enhance a spectrum of performance, functional, and health-related outcomes in the elderly demographic (Vetrovsky et al., 2019). Consequently, it is reasonable to infer that such training modalities are equally safe and potentially beneficial when applied to younger male cohorts, thereby addressing the prevalent issue of muscle-related health problems stemming from physical inactivity. It has been clearly shown in recent years that skeletal muscle acts as an endocrine organ (Romagnoli et al., 2019). We now understand that the effects of physical inactivity and sedentary behavior on the whole body, tissues, and cells are not just the reverse of those caused by exercise (Bowden Davies et al., 2019). Being inactive and eating unhealthy is a well-known cause of obesity and other health problems (Boutari & Mantzoros, 2022). Physical inactivity in young adults can impair the muscle cells' function and structure and lead to muscle loss (Pišot, 2021). To overcome this, being physically active is one of the most feasible solutions to do. Being active alone is good, let alone with a minimum of balancing the muscle capacity of the body with the body fat level. This can be associated with metabolic health. To be physically active, plyometric training can be an option to be applied by athletes and non-athletes, as reported in this study. It has been demonstrated that plyometric training is an effective intervention to decrease the prevalence of physical inactivity and to improve health outcomes for both daily activities and athletic performance. This study has a methodological constraint as it solely assessed the impact of plyometric training on strength and power outcomes. Future investigations should explore the potential benefits of plyometric training on body composition indicators.

Conclusion

The findings of this study demonstrate that long-term high-intensity plyometric training enhances the strength and power of lower body muscles in young, healthy males. Therefore, these results can serve as a basis for coaches and athletes to consider improving the strength and power of lower body muscles to support the achievement of optimal performance.

Conflicts of Interest

The authors declare no conflict of interest in this study.

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Datos de los autores y traductor/a:

Slamet Raharjo	slamet.raharjo.fik@um.ac.id	Autor/a
Nguyen Tra Giang	giang.nguyen@umt.edu.vn	Autor/a
Raja Mohammed Firhad Raja Azidin	firhad@uitm.edu.my	Autor/a
Mustika Fitri	mustikafitri@upi.edu	Autor/a
Mahmud Yunus	mahmud.yunus.fik@um.ac.id	Autor/a
Ramdan Pelana	ramdanpelana@unj.ac.id	Autor/a
Rahmatya Ikhwanurrosida	lingolinkpro@gmail.com	Traductor/a