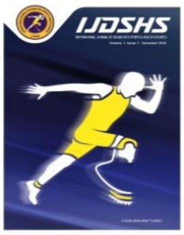

International Journal of
Disabilities Sports and Health Sciences

e-ISSN: 2645-9094

RESEARCH ARTICLE

Positive Effect of Sand-Based Plyometric Jump Training on Increasing Muscle Strength and Power in Young Student-athletes

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Abstract
Muscle strength and power are considered fundamental components of successful athletic performance. However, what type of training method is effective and efficient in increasing muscle strength and power has not been well resolved. Therefore this study aimed at analyzing the effects of five weeks of sand-based plyometric jump training on improving muscle power and strength. The pretest-posttest randomized experimental design was conducted on student-athletes which then classified into three groups: the plyometric knee tuck jump (TJ, n=11), hurdle jump (HJ, n=11), and control (C, n=11). Subjects in TJ and HJ groups were assigned to five weeks of plyometric exercise, comprising 15 sessions in total, with intensities ranging from 80% to 100%. Data were obtained using NordBord and Force Decks prior to and after they completed the whole set of exercises. Data were analyzed using SPSS 23 and presented descriptively in mean and standard deviation. Paired sample t-test and one-way ANOVA were done to compare the differences between groups. Five weeks of TJ and HJ resulted in similar improvements in strength and power ($p \leq 0.05$). However, statistically significant between groups differences at the post-test were noted for HJ (p=0.000) in favor of both measured variables. Based on these findings, it was concluded that plyometric training in general increased strength and power of muscle leg better than conventional training.

Keywords
Athletic Performance, Hurdle Jump, Muscle Power, Plyometric Training, Tuck Jump

INTRODUCTION

A number of underlying physical condition components may contribute to physical fitness, which strength being one the most important factors, thus become the key role for maximum achievement in any sport requiring explosive action (Alemdaroğlu et al., 2013; Maio Alves et al., 2010; Suchomel et al., 2016). Therefore, explosive strength is considered as a fundamental components of successful athletic performance (Silva et al., 2019). However, other components such as power also plays important role that influences performance in various type of sport (Marwat et al., 2022). Muscular power allows a given muscle to exert a greater magnitude of work in the same time, or the equal amount of work in shorter time, which is important for jumping,

Received: 01 Ocotober 2023 ; Revised ;25 October 2023 ; **Accepted:** 21 Decemberr 2023; **Published:** 25 January 2024

How to cite this article: Wiriawan, O., Setıjono, H., Putera, S.H.P., Sholikhah, A.M., Kaharina, A. And Pranoto, A. (2024). Positive Effect of Sand-Based Plyometric Jump Training on Increasing Muscle Strength and Power in Young Student-athletes. *Int J Disabil Sports Health Sci*;7(1):188-196. https://doi.org/10.33438/ijdshs.1367696

sprinting (Peterson et al., 2006; Silva et al., 2019), and making quick changes of direction (CoD) (Saeed, 2013). Therefore, many researchers and coaches have been concerned with the type of training methods that is effective to use to increase power as well as strength (Wang et al., 2022).

Plyometric training, which follows the form of human movement (Wang et al., 2022), has been widely applied to enhance explosive athletic performance and regarded as one of the most effective training methods for its comprehensive neuromuscular and motor control benefit (Putera et al., 2022). It applies the mechanism of "stretch-shortening cycle" (SSC) to change the elastic potential energy in the lengthening phase (i.e. eccentric) to kinetic energy in the shortening phase (i.e. concentric) of the same muscle and tissue in the shortest possible time (Pardos-Mainer et al., 2021; Ramirez-Campillo et al., 2018; Wang et al., 2023). Because plyometric training includes muscle lengthening, it also increases flexibility (Silva et al., 2019), stimulates more stored elastic energy in the muscle (Kubo et al., 2007), and increases the amount of muscle units, resulting in higher firing frequency (Pienaar & Coetzee, 2013) and joint proprioception (Swanik et al., 2016). Additionally, recent studies in last decade have observed that the combination of plyometric training and other exercise program such as strength training, is able to optimize muscular power, vertical jump performance, and acceleration in general (Mazurek et al., 2018; Putera et al., 2023; Slimani et al., 2016). Thus, plyometric training especially in lower limb can be applied in almost all type of sports (Haff, 2015).

The aforementioned of plyometric training effectiveness can be improved by modifying several variables such as intensity, volume, and the type of jump (Ramirez-Campillo et al., 2018). However, some environment-related variables such as the type of practice plane or surface (e.g. hard surface, grass, sand, water, etc) should also be taken into account during developing the plyometric training program (Chen et al., 2023; Ramirez-Campillo et al., 2020; Sanchez-Sanchez et al., 2022; Wahba & El Nahass, 2017). Previous study done by (Impellizzeri et al., 2008) compared the effect of plyometric training done on grass vs sand surface in improving vertical jump. The result showed that sand surface significantly induced higher jump improvement (9.25%) compared to grass (5.02%), but greater increase in sprint ability was observed for grass compared to sand surface (27.86% vs 25.07%). Another study found that the improvement in countermovement jump, CoD, and sprint ability were in favour of combined-surface plyometric training (sand, wood, land-dirt, tartan-track, gym mat) compared to single surface (grass) that both were done for 8 weeks (Ramirez-Campillo et al., 2020).

Previous meta analyses have explained that type of surface may cause the training outcomes to vary, however, the most effective type of surface for plyometric training has not been decided until now, especially among team-sports (Ahmadi et al., 2021). In addition, many longitudinal studies on the effect of plyometric jump training on physical performance have been documented in recent years, however, less is known about the acute effect of different type of jump exercises on strength and power of muscle leg. Besides, recent studies in few decades have shown that the effect of plyometric training was influenced by the type of jump (Ramirez-Campillo et al., 2020), thus, an investigation into this could be helpful to coaches in adjusting training program in accordance with the principles of training, and it would also provide fresh and pertinent information regarding this topic. Therefore, the purpose of this study was to investigate the acute effect of sand-based plyometric training on increasing power and strength of student-athletes.

MATERIALS AND METHODS

Participants

This research used pretest-posttest randomized experimental design, involving 33 student-athletes as participants. The inclusion criteria applied on this study were: (1) age 18-24 years old; (2) male students; (3) an active undergraduate student majoring at sport-coaching education (4) free from any chronic conditions, respiratory disease, or injury that would have impact on their ability to run the exercise; (5) no participation in any other training program outside this study; and (6) willing to complete the whole training sessions. All participants were informed the details of training protocol and instructed to avoid heavy or high-intensity activity at least 24 hours before the test. Then, each participant was classified into experimental groups who received an intervention using sand-based plyometric tuck jump (TJ, n=11) and hurdle jump (HJ, n=11), and control group (C, n=11). All participants had been explained the aims and objectives of this research and voluntarily and consciously provided a statement of consent by filling out and signing an informed consent. The study was done in accordance with the research policy procedures of Universitas Negeri Surabaya and and approved by the Health Research Ethics Committee, Faculty of Public Health Universitas Airlangga, Surabaya, Indonesia No. 156/EA/KEPK/2022.

Training protocols

Plyometric training was done three times a week for five weeks (15 sessions) on non-consecutive which days, namely Monday, Wednesday, and Friday (**Hariyanto et al., 2022**). At the beginning of each training, participants completed each for 5 minutes of warm-up and cool-down lower-body stretching **(Pranoto et al., 2023**), then continued with the plyometric training done in 3 sets of 12-15 reps and rest between sets 60 seconds. Plyometric training was performed with maximum intensity (80-100% 1RM) with progressively improved intensity every two weeks. All sessions were thoroughly monitored and recorded in the exercise logbook for each subject.

All participants were also measured the peak force of power and strength of muscle leg before (pretest) and after (posttest) the last training period. The measurements were performed using portable NordBord (Vald Performance, Newstead, Australia) to measure strength and ForceDecks (Vald Performance, Newstead, Australia) for power testing, both operated according to the manufacturer's recommendations. Power measurement was done by performing a jump on the device's force plate. Subjects performed three attempts of countermovement jump (CMJ) with a 30-second break between each jump. Peak force was considered as the maximum force generated before take off **(Chavda et al., 2018; Sarvestan et al., 2020**). The measures of jumping height (cm) and jumping peak power (W) were recorded. All measurements were done by an experienced laboratory technician.

Prior to the first session, the main sociodemographic (age) and anthropometric variables (body weight, height, body mass index, oxygen saturation, blood pressure, resting heart rate) were measured as baseline characteristic. Bodyweight was assessed using digital scale (Omron HN-289, Osaka, Japan) at the nearest 0.1 kg. Portable stadiometer (Seca 213, Seca Ltd., California, US) was used to measure standing height. Resting heart rate (HR) was monitored using a polar heart rate monitor (Polar H10 Bluetooth Heart Rate Sensor & Fitness Tracker, Kempele, Finland), and blood pressure was measured using a digital blood pressure meter (Omron Deluxe HEM-8712, Osaka, Japan).

Statistical analysis

All measured variables were presented descriptively as means and standard deviations (SD). After normality test was verified using Saphiro-Wilk test, then paired t-test was done to analyse the differences in measured variables before and after the training was conducted. One-way Anova was applied to examine group differences between TJ, HJ, and C. Further post-hoc analysis was performed using Least Significant Different (LSD) post-hoc test to find out which pairs were different. Differences between groups were considered statistically significant for $p \leq 0.05$. All statistical evaluations were performed using GraphPad Prims 9.0 for Mac (GraphPad Software Inc., San Diego, USA) and SPSS 23 for Windows (SPSS Inc., Chicago, USA).

RESULTS

A total of 33 males student-athletes, with the average age (19.48 ± 0.50 years), had normal body mass index (20.90 ± 1.35 kg/m^2), normal blood pressure (systolic: 115.23 ± 5.48 mmHg; diastolic: 74.50 ± 5.12 mmHg), normal resting heart rate (66.32 ± 5.88 bpm), and normal oxygen saturation (96.23 ± 1.15 %) participated in this study. From Table 1, it can be obtained that baseline characteristic of participants in all groups were equally homogenous ($p \geq 0.05$). All participants have completed the whole training programs for five weeks. There were neither injury of lower limb nor spine, and no drop out reported during the experimental period.

Table 1. Baseline characteristic

Variable	C	TJ	HJ	*p*-value
Age (years)	19.27 ± 0.46	19.63 ± 0.50	19.54 ± 0.52	0.222
Height (cm)	168.27 ± 5.76	171.72 ± 5.33	173.54 ± 4.15	0.065
Weight (kg)	55.18 ± 4.60	56.81 ± 5.01	53.81 ± 3.70	0.304
BMI (kg/m^2)	21.19 ± 1.44	21.51 ± 1.72	20.82 ± 0.76	0.079
SBP (mmHg)	115.80 ± 3.71	114.80 ± 7.98	115.10 ± 4.33	0.752
DBP (mmHg)	75.25 ± 3.56	76.10 ± 4.69	75.60 ± 3.98	0.591
HR (bpm)	65.90 ± 5.23	64.82 ± 4.99	65.76 ± 6.31	0.145
SpO_2 (%)	97.00 ± 1.25	97.50 ± 1.65	97.40 ± 1.43	0.430

Description: BMI: Body mass index; C=Control group; DBP: Diastolic blood pressure; HJ: Plyometric tuck jump group; HR: Heart rate; SBP: Systolic blood pressure; SpO_2: Oxygen saturation; TJ: Plyometric hurdle jump group. All data were presented in mean and standard deviation (mean±SD).

Figure 1 disclosed the comparison result in muscle power and muscle strength pre and post-subjects performed plyometric jump training. We observed significant differences in the experimental group where five weeks of plyometric jump training that was performed on sand increased muscle power and strength ($p \leq 0.05$). The highest improvement of muscle power was found in HJ which increased from 4152.82±519.02 watt to 4768.64±718.82 watt (Delta (Δ) = 615.82±314.71 watt; percentage increase with pre = 14.66±6.423 %). The greatest improvement was also seen in strength for HJ, from 116.45±20.47 kg to 135.82±21.28 kg (Δ = 19.37±10.98 kg; percentage increase with pre = 14.21±7.57 %) (Figure 2).

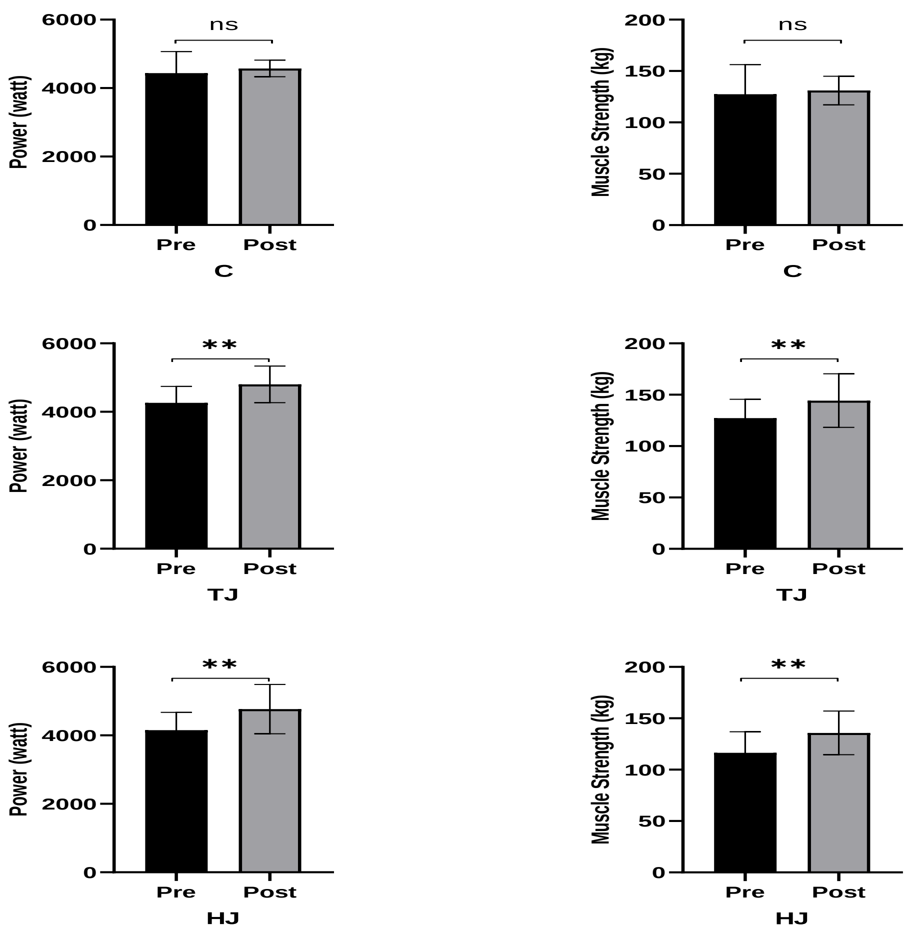

Figure 1. Analysis of power and muscle strength in all groups. C=Control group; TJ: Plyometric hurdle jump group; HJ: Plyometric tuck jump group. All data were presented in mean±SD. p-value is obtained by paired sample t-test. (ns) Not significant. (**) Significant at pre ($p \leq 0.001$).

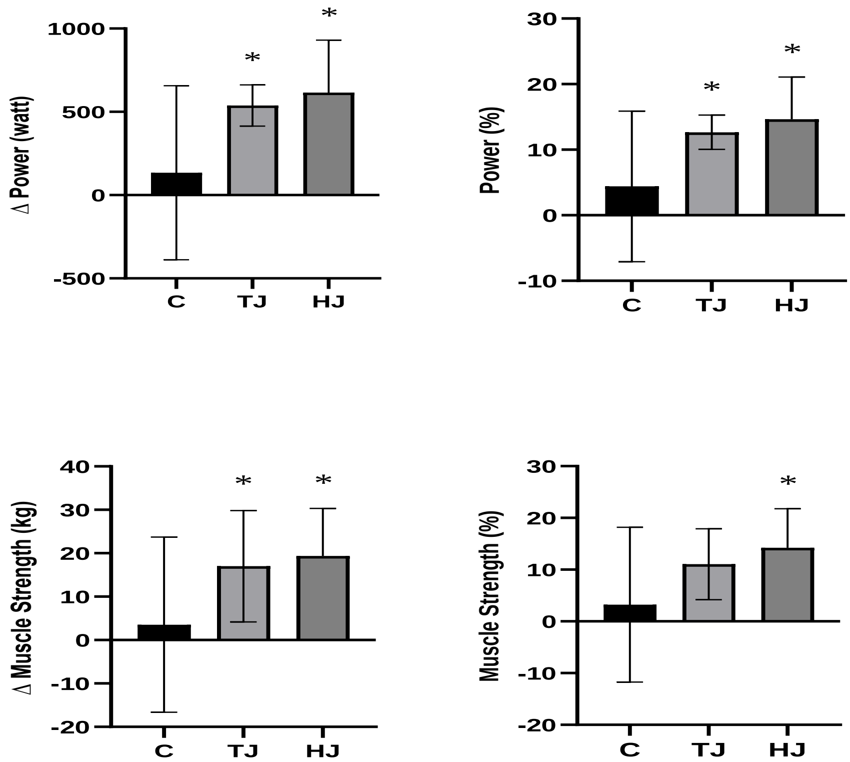

Figure 2. The differences of power and muscle strength between groups (C vs. TJ vs. HJ). (*) Significant at Control (C) ($p \leq 0.05$).

DISCUSSION

Previous experimental studies regarding the effect of plyometric trainings on individuals discovered that PT contributes to the increase of sport performance as well as improve several health parameters (**Hariyanto et al., 2022**), such as lowering fat mass and optimizing bone health when integrated with daily training routines **(Wang & Zhang, 2016**). This study revealed that plyometric jump training done on sand was effective to increase power and strength of muscle legs in student-athletes. Our hypothesize that higher gains would occur in experimental group compared to control group was clearly seen in present study, as the given plyometric jump trainings resulted in significantly greater increase in both measured variables by the fifth week. The highest improvement was reported in HJ group, where a change of 14.83% and 16.63% indicated that significant adaptation in power and strength was occurred after five weeks of treatment. The finding of present study was supported by previous investigation conducted by **Putera et al**. (**2023**) where six-week of plyometric training significantly enhanced muscle power and strength of lower limb in young adults. Another study also reported small but significant increase in strength after subjects was given plyometric training with an intensity of 60-80% HRmax for five weeks (**Hariyanto et al., 2022**). The same results have also been observed that plyometric training also significantly increases strength, agility, and speed in quadriceps and hamstring muscles before and after plyometric training compared to non-plyometric training group (**Elnaggar et al., 2019**).

Plyometric training applies the mechanism of continuous SSC, which comprise of eccentric followed immediately by concentric phase of the muscle (**Bulqini et al., 2023; Hariyanto et al., 2022; Putera et al., 2022; Silva et al., 2019**). Because of this continuous repeated cycle, **Kobal et al.** (**2017**) in their research has made clear that PT can lead to greater improvement in physical performance in fatigue-free state. In line with that, other study stated that plyometric exercise done in only one session was sufficient to change muscle-tendon characteristics by modifying neuromuscular activity which in turn caused tendon to lengthen and shorten more frequently than fascicles (**Hirayama et al., 2012**). Different from the acute effect of other trainings, PT will escalate the performance of SSC exercises differently, with muscle tendon unit (MTU) behavior changes in a favorable way, adjusting to the change of tendon stiffness and muscle strength (**Fouré et al., 2010; Wu et al., 2010; Hirayama et al., 2017**). Tuck jump (TJ) and hurdle jump (HJ) that were done in experimental groups were able to shorten the muscle transition from eccentric to concentric phase, which will also improve jumping ability and support the muscle's capacity for explosive movements that increase power and strength of muscle leg (**Louder et al., 2015**). In addition to that, because plyometric exercise involves muscle lengthening, it may also enhance the amount of elastic energy that is stored in the muscles (**Kubo et al., 2007**), induce more muscle units (**Pienaar & Coetzee, 2013**) which lead to a higher (neural) firing frequency, and enhance joint proprioception (**Swanik et al., 2016**).

Significant increase in measured variables was found in all groups, but we observed that HJ gained largest increase compared the rest of groups. It might be explained that jumping over hurdles requires more effort and better coordination than usual jumping **(Healy et al., 2020**) or traditional countermovement jump (**Cappa & Behm, 2011**). The urge to overcome an obstacle like a box or a hurdle might affect the SSC mechanism, resulting in adjusment of concentric and eccentric jump parameters, which may eventually influence the resultant training adaptations over time (**Janikov et al., 2023**). However, present study did not investigate concentric and eccentric parameters further which become limitation of this study.

Present study confirmed that both types of plyometric training increase muscle power and muscle strength in student-athletes, but plyometric hurdle jump training is more effective in increasing sport performances than plyometric knee tuck jump training. This study found a positive relationship between increased muscle strength and muscle power. Given that improvements are roughly equivalent for both type of plyometric training, it is crucial to take into account the reduction in soreness or injury in athletes when using different kind of jump training to supplement conditioning training.

Acknowledment

We would like to thank the support from the Faculty of Sport and Health Sciences, Universitas Negeri Surabaya in this project. The author also thanks profusely to all those who have helped in the completion of this project.

Conflict of interest

The authors declared to have no conflict of interest. In addition, no financial support was received.

Ethics Committee

All procedures for this study were approved by the Health Research Ethics Committee, Faculty of Public Health Universitas Airlangga, Surabaya, Indonesia (Ethical Approval No. 156/ EA/ KEPK /2022).

Author Contributions

Study Design; OW-HS, Data Collection; OW-AK-SHPP-AMS, Statistical Analysis; AP Data Interpretation; AP, Manuscript Preparation; OW-AMS-AP, Literature Search; OW-AK-SHPP. Authors have read and agreed to the published version of the manuscript.

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