Advances in Health Sciences Research, volume 45
5th International Conference on Sport Science and Health (ICSSH 2021)

# Effect of Two Different Plyometric Trainings on Strength, Speed and Agility Performance

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*Abstract*—**Plyometric training (PT) is a popular form of physical conditioning among individuals involved in various dynamic sports to improve physical performances. This study focused on analyzing the effect of plyometric training on improving strength, speed, and agility of students following two kinds of plyometric exercise. It was an experimental research using pretest-posttest control group design. A total of 30 students were randomly assigned to three groups: two plyometric training groups of high hurdle jump (HHJ), forward and lateral hurdle jump (FLJ), and one group served as the control (C). Afterward, students in HHJ and FLJ were assigned to respected exercise for five weeks consisted of three sets of each session (total of 16 sessions), with intensity start from 50% to 70%. Pretest and posttest measures were done to obtained data regarding strength, speed, and agility. Data were analyzed using SPSS 20 and were presented as mean and standard deviation. Wilcoxon Signed Rank Test and Kruskall-Wallis were done to compare between-groups difference before and after exercise. Results showed that strength, speed, and agility of students in HHJ and FLJ increased significantly ($p<0.05$) after 16 sessions of training, while those in control group did not show any different. Between-group difference was only found in strength ($p=0.000$), which were between HHJ-C ($p=0.000$) and FLJ-C ($p=0.002$) pairs. Based on these findings, it was concluded that plyometric training was capable to improve strength, speed, and agility performance.**

***Keywords—forward and lateral jump, hurdle jump, plyometric training, stretch-shortening cycle***

## I. INTRODUCTION

Plyometric training (PT) is one of popular methods of physical conditioning among individuals playing dynamic sports [1]. It consists of an eccentric contraction of the musculotendinous muscle followed by an immediate concentric contraction of the same connective tissues and muscles, which often referred as stretch-shortening cycle (SSC) [2]–[4]. It is kind of exercise where muscle wield maximum force aiming to increase power in shortest possible time [5]. Plyometrics constitute a various type of sport movements, such as jumping, bounding, hopping [3], [6], [7], running, throwing [8] or kicking [9]. There are many factors contributed to the popularity of PT, one of them is that plyometric training can be performed at any intensity levels, ranging from low-intensity exercise such as double-leg hops to high intensity unilateral drills [8].

Previous study referred plyometric training as "explosive-reactive" power training since it involves repeated rapid stretching and contracting of muscles to increase its power [10], such as in repeated jumping [5]. This type of training is also known as a form of "ballistic training" which designed to enhance the jump performance [11]. This training is mostly used by sprinters, high jumpers, or martial artists to build on performance [3]. But nowadays, more athletes in all type of sports used plyometric training [12] to improve skills and physical performances such as speed and agility [13]. It also becomes a suitable method of power training for athlete participating in individual or team sport [5].

Studies about plyometric training has been extensively reviewed over the last decades [14], with most studies agreed that plyometric training is an effective method to ameliorate agility [7], strength, and sprint ability [6]. Studies have shown that plyometric training—when used with a periodized strength training program—can improve acceleration, vertical jump performance, muscular power, leg strength, and proprioception in general [15]. Plyometric training has been long used to enhance explosive sport performance and regarded as one of excellent training method for its comprehensive motor and neuromuscular control benefits [16]. Benefits of plyometric training also include lowering risk and incidence of injury [6]. Thus, it often used by untrained healthy individuals and young subjects such as children and adolescents as a part of their training. Studies about the effect of plyometric training in young subjects support the findings that PT is able to improve motor skill and body composition, such as optimizing bone health and reducing fat mass when combined with daily training routines [3].

Compared to traditional resistance training, many studies stated that plyometric training was better method to develop explosive lower limb as well as to optimize various performance variables such as multiple directional movement speed [16]–[18]. Recent meta analyses have reported that 8 weeks of plyometric training improved high intensity of physical abilities and change-of-direction (CoD) [2]. Another 8 weeks of training done by Chaouachi et al found that PT when combined with balance training program gave better effect on shuttle run and sprint performance [19]. Regarding the jumping variable, an experimental studies found that 12-weeks of plyometric training were more effective on improving jump power, height, contraction time, and stair climbing performance compared to the group that were assigned to resistance training with the same duration [17].

Although plyometric training has been shown to have many benefits on increasing performance variables, little information is available to determine whether short term (< 8 weeks) PT actually improve physical performance. Previous studies related to plyometric training mostly done in long-term duration. Moreover, existing studies on the effects of plyometric training have been limited to adult or athlete subjects. Therefore, this study was conducted to examine the effects of five-weeks plyometric trainings on strength, speed, and agility of muscle legs of high school students.

## II. METHOD

### A. Study design and participants

It was an experimental study with *pretest-posttest control group design*. The samples of this study were male students of class X of Vocational High School (SMK Al Furqan, Driyorejo, Gresik) who were drawn from the population using systematic random sampling. A total of 30 students between 16 and 17 years were selected to participate in this study. Afterward, each subject was randomly assigned to one of three groups consisted of 10 students each, which were high hurdle jump (HHJ) group, forward and lateral hurdle jump (FLJ) group, and one group served as the control (C).

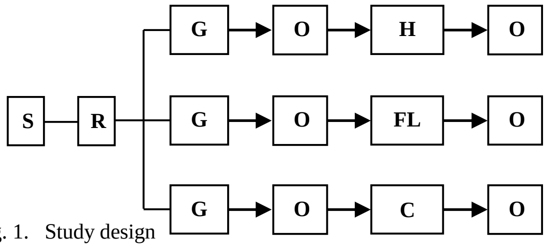


Fig. 1. Study design

Remarks:

S : Samples (n=30)
R : Randomization
G1 : Group 1
G2 : Group 2
G3 : Group 3
HHJ : High Hurdle Jump
FLJ : Forward and Lateral Jump
C : Control
O1 : Pretest before subjects were assigned to HHJ
O2 : Pretest before subjects were assigned to FLJ
O3 : Pretest before subjects were assigned to C
O4 : Posttest after subjects done with HHJ
O5 : Posttest after subjects done with FLJ
O6 : Posttest after subjects done in C group

### B. Procedures

The experiment consisted of two performance tests (pre- and post-exercise test) and a set of two different types of plyometric training—high hurdle jump (HHJ) and forward and lateral jump (FLJ)—conducted for five weeks. Performance tests (pre and posttest) were performed before and after five-weeks of training period. Testing protocol included assessment of body composition and physical performance. Data of weight and height were collected using microtoise and electronic scale. The sum of skinfolds was measured using caliper, triceps, biceps, subscapular, and abdominal skinfold. Physical performances that were measured consisted of strength (back and leg dynamometer), speed (30-m sprint), and agility (Illinois agility test). After pre-exercise test, plyometric training program was assigned, which was then followed by post-exercise test done with the same protocols as pre-exercise test.

Participants in this study were assigned to respective PT trainings for five weeks, included high hurdle jump for group in HHJ and forward lateral jump for FLJ group. While respondents in C group served as control which received regular standard training for five weeks. High hurdle jump was performed by doing forward jump over each hurdle that was set high enough to elicit maximal efforts of the jumper, but not too high to prevent the risk of falling. Forward and lateral jump was done by jumping forward and sideways over the hurdles using the support of and landing on two feet repeatedly [20].

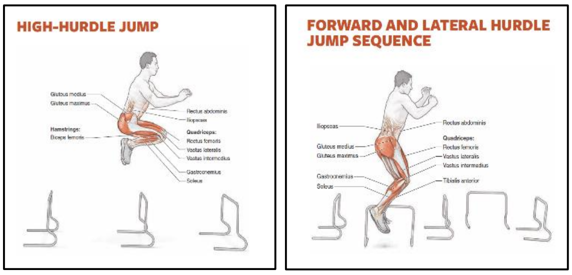


Fig. 2. High hurdle jump (left) and forward lateral jump (right) protocol [20]

Each type of plyometric training was practiced three times a week on non-consecutive days, made it a total of 16 sessions. Each training session starting with a thorough warm up and followed by the actual training that was done in 3 sets with 15-20 repetitions per session. The resting period between session was 2 minutes. The intensity of training was gradually increased every week, starting from 50% to 70%. The detail of plyometric training program was presented as follow:

TABLE I. DETAILS OF GENERAL PLYOMETRIC TRAINING PROGRAM DURING FIVE-WEEKS OF EXPERIMENTAL PERIOD

| Week | Session | Intensity | Set | Rest |
|---|---|---|---|---|
| 1 | 1 | 50% | 3 | 2 minutes |
| | 2 | 50% | 3 | 2 minutes |
| | 3 | 50% | 3 | 2 minutes |
| | 4 | 50% | 3 | 2 minutes |
| 2 | 5 | 50% | 3 | 2 minutes |
| | 6 | 60% | 3 | 2 minutes |
| | 7 | 60% | 3 | 2 minutes |
| 3 | 8 | 60% | 3 | 2 minutes |
| | 9 | 60% | 3 | 2 minutes |
| | 10 | 60% | 3 | 2 minutes |
| 4 | 11 | 60% | 3 | 2 minutes |
| | 12 | 70% | 3 | 2 minutes |
| | 13 | 70% | 3 | 2 minutes |
| 5 | 14 | 70% | 3 | 2 minutes |
| | 15 | 70% | 3 | 2 minutes |
| | 16 | 70% | 3 | 2 minutes |

### C. Statistical analysis

Data were statistically analysed using SPSS 20. Means and standard deviations as descriptive statistic were calculated and presented for the measured variables. All variables were tested for normality using Saphiro-Wilk test. Data were then further analysed using Wilcoxon Signed Rank Test to compare the difference before and after plyometric training were performed. Afterward, Kruskall-Wallis test was performed to find out between-group differences for each measured variable. Post hoc analysis using Mann-Whitney was later performed to locate the pairwise difference. P-value less than 0.05 was used to establish statistical significance.

## III. RESULT

All participants attended all sessions and completed the respective training program. None of the participants reported either current injuries of the spine or the lower extremities and no drop-outs occurred during the five weeks of experiment.

TABLE II. BASELINE CHARACTERISTIC AND BODY COMPOSITION OF PARTICIPANTS

| Characteristic | Groups (n=30) | | | sig. |
|---|---|---|---|---|
| | HHJ | FLJ | C | |
| Age (year) | 15.90 ± 0.74 | 16.20 ± 0.79 | 16.40 ± 0.52 | 0.070 |
| Weight (kg) | 56.5 ± 3.06 | 58.30 ± 6.96 | 57.40 ± 4.45 | 0.063 |
| Height (cm) | 162.50 ± 4.33 | 165.50 ± 9.53 | 165.10 ± 6.35 | 0.318 |
| Body mass index (kg/m$^2$) | 21.40 ± 0.95 | 21.22 ± 0.65 | 21.04 ± 0.80 | 0.295 |
| Triceps (mm) | 12.90 ± 4.46 | 14.10 ± 7.13 | 11.60 ± 4.90 | 0.055 |
| Biceps (mm) | 10.20 ± 2.90 | 8.70 ± 3.74 | 8.60 ± 3.24 | 0.051 |
| Abdominal (mm) | 13.60 ± 5.76 | 11.50 ± 5.04 | 14.10 ± 5.97 | 0.125 |
| Subscapular (mm) | 8.70 ± 2.50 | 10.20 ± 5.41 | 8.40 ± 2.80 | 0.062 |

HHJ = High Hurdle Jump; FLJ = Forward Lateral Jump; C = Control group. Data were presented as mean ± SD

Table 2 presented the baseline characteristic and body composition of each group. HHJ group was found to have the lowest mean of age (15.90 ± 0.74 years), weight (56.5 ± 3.06 kg), and height (162.50 ± 4.33 cm). Body mass index in all groups ranged from 21.04 ± 0.80 to 21.40 ± 0.95 kg/m$^2$, which fell into normal category according to WHO [21]. The lowest mean of triceps, biceps, and subscapular skinfold thickness were found in control group, which were 11.60 ± 4.90 mm, 8.60 ± 3.24 mm, and 8.40 ± 2.80 mm, respectively. While the lowest abdominal skinfold thickness was found in FLJ, which was 11.50 ± 5.04 mm. There were no statistically differences between three groups with respect to the baseline characteristic and body composition ($p > 0.05$), thus we learnt that all samples in three groups were equally homogenous.

Saphiro-Wilk test suggested that all variables were not normally distributed ($p > 0.05$). So further analysis was done using nonparametric statistic.

TABLE III. EFFECT OF PLYOMETRIC TRAINING ON STRENGTH, SPEED, AND AGILITY OF MUSCLE LEG (MEAN ± SD)

| Group | | Strength (kg) Mean ± SD | sig. | Speed (s) Mean ± SD | sig. | Agility (s) Mean ± SD | sig. |
|---|---|---|---|---|---|---|---|
| **HHJ** | pre | 84.79 ± 8.20 | 0,049* | 4.72 ± 0.37 | 0,005* | 18.58 ± 1.29 | 0,005* |
| | post | 89.73 ± 6.93 | | 4.32 ± 0.30 | | 17.87 ± 1.22 | |
| **FLJ** | pre | 86.58 ± 15.06 | 0,005* | 4.48 ± 0.42 | 0,005* | 18.25 ± 1.09 | 0,005* |
| | post | 90.47 ± 17.24 | | 4.16 ± 0.38 | | 17.40 ± 1.25 | |
| **C** | pre | 93.08 ± 16.27 | 0,086 | 4.61 ± 0.29 | 0,070 | 18.05 ± 1.25 | 0,005* |
| | post | 93.22 ± 16.16 | | 4.62 ± 0.24 | | 17.34 ± 1.34 | |

HHJ = High Hurdle Jump; FLJ = Forward Lateral Jump; C = Control group.

Table 3 compared the results of performance tests (strength, speed, and agility) before and after PT were performed for five weeks. Small but significant improvement in strength were found in HHJ and FLJ groups, with $p = 0.049$ and $p = 0.005$, respectively. Significant differences were also found in speed where plyometric training that were performed for five weeks caused the increase of speed in HHJ and FLJ, with the same p-value of both groups ($p = 0.005$). Similar results were found for agility, where the greatest improvement mean of agility decreased after subjects in treatment group performed high lateral jump ($p = 0.005$) and forward lateral jump ($p = 0.005$). In control, there were no changes that were statistically significant in strength and speed. Nevertheless, the only change in control group was found in agility, with slight increase from 18.05 ± 1.25 second to 17.34 ± 1.34 second ($p = 0.005$).

TABLE IV. BETWEEN-GROUP DIFFERENCES IN STRENGTH, SPEED, AND AGILITY OF MUSCLE LEG FOLLOWING FIVE-WEEKS OF PLYOMETRIC TRAINING

| Group | Δ Strength (kg) Mean ± SD | % | sig. | Δ Speed (s) Mean ± SD | % | sig. | Δ Agility (s) Mean ± SD | % | sig. |
|---|---|---|---|---|---|---|---|---|---|
| **HHJ** | 4.94 ± 2.69 | 5.83 | 0,000* | -0.41 ± 0.18 | 8.69 | 0,530 | -0.72 ± 0.37 | 3.88 | 0,492 |
| **FLJ** | 3.90 ± 3.13 | 4.50 | | -0.32 ± 0.19 | 7.14 | | -0.85 ± 0.35 | 4.66 | |
| **C** | 0.14 ± 0.23 | 0.15 | | -0.39 ± 0.21 | 8.46 | | -0.71 ± 0.36 | 3.93 | |

HHJ = High Hurdle Jump; FLJ = Forward Lateral Jump; C = Control group.

Table 4 presented the mean difference between pre- and post-exercise test for all outcome variables. Kruskall-Wallis test revealed the significant difference in strength only, where Δ strength in HHJ, FLJ, and C were 4.94 ± 2.69 kg, 3.90 ± 3.13, and 0.14 ± 0.23, respectively ($p = 0.000$).

TABLE V. POST- HOC ANALYSIS OF SIGNIFICANT DIFFERENCE IN STRENGTH

| Group | | sig. |
|---|---|---|
| **HHJ** | FLJ | 0.315 |
| | C | 0.000* |
| **FLJ** | C | 0.002* |

HHJ = High Hurdle Jump; FLJ = Forward Lateral Jump; C = Control

Further analysis using Mann-Whitney disclosed the difference in strength between HHJ and C ($p = 0.000$), FLJ and C ($p = 0.002$), as stated in Table 5.

## IV. DISCUSSION

### A. *Effects of Plyometric Training on Strength*

Previous studies on the effect of plyometric trainings on health and fitness revealed that PT contributes to the improvement of physical performance as well as the enhance several health parameters [22]. Almost every study found that plyometric trainings were able to increase muscular strength, power, muscular endurance, flexibility, and jumping ability better than other type of trainings [22]. Present study demonstrated that five-weeks of plyometric training was effective in increasing strength, speed, and agility of muscle legs. These findings confirm previous RCT study done by Muthukumar and Sokkanathan where significant difference in muscle strength was found between control group and plyometric training group [22].

A research of Elnaggar, et. al. also found similar result where it has been observed that subjects in PLYO group showed significant improvement in hamstring and quadriceps muscle strength before and after plyometric training was performed, compared to the peers in the non-PLYO group [23]. Some feasible explanations to justify how plyometric training able to produce strength is that PT requires a suitable technical ability and adequate level of both joint coordination and muscle strength, which later it enhances the contraction of inter- and intra-muscle capacity, thus produces force [8]. High hurdle jump and forward lateral jump training that were assigned to experimental groups were able to shorten the change of extrinsic phase to concentric phase. It also escalates the ability to jump, supported by muscle ability to perform explosive moves resulting in the gain of strength and power in leg muscle [24].

Another study revealed that plyometric training enhanced strength performance of the dominant leg in adolescent girl participants [25]. The improvement of muscle strength performance was more visible in U-17 participants when PT was combined with other trainings or exercises for upper and lower body [26]. Combination of PT and other exercise such as resistance training is also found quiet effective to enhance power and strength [18], as stated by numerous studies where PT was found to increase maximal strength from 11 kg to 60 kg when combined with other training modalities (i.e. weight training + plyometric [8].

Silva, et. al. found the benefit of plyometric training on muscle strength in participants regardless the sex and age [27]. A meta-analysis study has reported the effectiveness of plyometric training to improve muscle strength in prepubertal children and adult population [8]. Plyometric training was revealed to be a good and safe exercise to optimize physical performance including muscle strength in children [28]. But contrary to the aforementioned studies, Silva et. al. highlighted that participants' sex and age were essential in planning plyometric training aimed to improve strength. For example, during adolescence, neuronal, muscular, and hormonal changes that occur due to growth spurt will affect the adolescents' ability to produce strength [27]. Thus, it might be resulted in different outcome in strength.

### *B. Effects of Plyometric Training on Speed*

This present study also revealed that high hurdle jump and forward lateral jump were able to increase speed performance by approximately 5.83% for HHJ and 4.50% for FLJ. The training duration and frequency (five weeks, three times a week) that was proposed in this study seems sufficient to improve 30-m sprint performance on male students. It supports the finding of previous study where plyometric training combined with conventional training program promoted certain performances of soccer players, including speed [29]. These results are also in accordance with other studies that employed different types of PT program, where the improvements in sprint performance were shown in young or adult participants [29]–[31]. During the plyometric training, the stretch-shortening cycles are related to the improvement of the sprint results [32]. Earlier investigation on the effects of plyometric training on speed or velocity also revealed similar result as hypothesized that six weeks of PT significantly improve 10-m, 30-m, and 40-m sprint performances [33]. Studies that support the results of present study documented the beneficial effects of PT on speed improvement have used relatively similar training duration ranging from seven to eight weeks with once or twice a week.

Contrary to this result, Ramirez-Campillo, et al on their study reported that vertical plyometric training (i.e. drop jump) performed biweekly for seven weeks did not statistically improve on speed performance [34]. Furthermore, Markovic et. al. did not find the increase of speed in 20-m sprint [35]. The discrepancy in the findings between present and previous studies is due to several factors, but we learnt that it may be attributed to the type of plyometric training used. Nevertheless, from all the analysis regarding the effect of PT on speed performance, it can highlight that the minimum duration of PT to present significant improvement in speed must be at least six weeks [36]. This study supports previous researches that even short-term plyometric training (< 8-weeks) are able to give positive increase in velocity parameters.

### *C. Effects of Plyometric Training on Agility*

Our findings demonstrate that five weeks of plyometric training may induce significant improvements on agility. But we found no significant differences between-groups, which we learnt that speed improvement in HHJ and FLJ group were the same as suggested by Kruskall-Wallis test. Several studies have proposed the possibility that agility can be improved through plyometric training [7], [10], [27], [37], [38]. For instance, a study conducted by Asadi showed that two kinds of plyometric training (depth jump and countermovement jump) subjected to students for six weeks lead to significant improvement on agility performance [7]. The same outcomes were also found in athlete subjects, as reported by Bal, et. al. where basketball players who underwent 6-weeks of PT showed an increase on T test and Illinois agility test [10].

It has been previously suggested that plyometric training improves agility in sports where quick movements such as change of direction or acceleration are involved [1], [10]. Thus, when we aimed to improve agility through specific plyometric training program, the understanding of SSC and its application on training program should be considered [29]. Plyometric training has been widely known to improve this SSC mechanism; hence, it is seen as effective training program recommended by coaches and sport scientists to improve explosive moves including agility [39]. Many researchers agree that the improvements in agility after plyometric training can be attributed to neural adaptation mechanism, especially to the enhance of intermuscular coordination [1], [14], [40]. Therefore, the result of this present study demonstrates the positive benefits of short-term plyometric training on the reduced time in agility.

## V. CONCLUSION

Plyometric training becomes the popular training method that has been widely used by strength and conditioning specialists to increase physical performances. On the basis of the present study, we could conclude that a five-week PT significantly improve strength, speed, and agility of male students. The limitation of this study is regarding the specific sample where high school students may limit the application of these findings to more diverse population. A longer duration of training (>5 weeks) might provide different results. In addition, we must also consider the type or form of plyometrics exercise used. We recommend that sports players provide plyometric exercises to improve agility, strength, and speed performance

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