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# EFFECT OF PLYOMETRIC TRAINING WITH DIFFERENT INTENSITIES ON KINEMATICS VARIABLES IN FOSBURY-FLOP HIGH JUMP

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## Abstract

*Purpose.* This study aims to identify weather plyometric training with varying high intensity of depth jump exercises has greater effects on the physical and kinematics variables and Fosbury-Flop high jump achievements than fixed high intensity plyometric training or not.

*Methods.* Twenty-four third year physical education students recruited to participate in this study. They have been divided into two experimental groups each consists of 12 students, each have participated in plyometric Training program for 12 weeks, 3 times per week. The first experimental group used different high intensity plyometric exercises at 70-90% of maximum box height, while the second experimental performed plyometric exercises at 80% of box height. Vertical jump, long jump, 30 meters sprint, Fosbury-Flop high jump as well as kinematics analysis (the height of the jumper's body mass centre of (MC) at the end of take-off (H1), the height that the jumper raises his MC during the flight (H2), the difference between the maximum height reached by the MC and the height of the crossbar (H3), horizontal velocity at beginning and end of takeoff phase, vertical velocity at beginning and end of takeoff phase, maximum knee flexion angle during takeoff, takeoff angle, thigh angle, takeoff time) have been measured before and after training in both groups. T independent and T paired were used to identify statistical differences between groups and pre-post measurements in the same group; respectively.

*Results.* Vertical jump improved by 21.81% and 11.17% in the first and second group respectively (first group: 42.83±2.98 to 52.17±2.89 cm, $P < 0.05$; second group: 43.25±2.86 to 48.08±1.62 cm, $P < 0.05$). There was an improvement in the kinematic variables; i.e. vertical velocity at the end of takeoff phase has improved in the first and second group by 3.0% and 1.7%, respectively ( first group: 3.66±0.28 to 3.77 ±0.24 m/s, $P < 0.01$, second group: 3.53 ±0.14 to 3.57 ±0.13 m/s, $P < 0.05$). Fosbury-Flop high jump performance has also improved (first group: 159±5.58 to 171.75±5.45 cm, $P < 0.05$, second group: 156.50cm ±5.55 to 162.25cm ±4.86, $P < 0.05$).

*Conclusion.* Plyometric exercise training with different exercise intensities have shown greater effects than plyometric exercise training with fixed intensity in improving explosive power, kinematic variables and Fosbury-Flop high jump, which attributed to the participation of greater number of motor units in muscle contraction with different intensity than the fixed intensity.

*Key words.* plyometric training, fosbury-flop, high jump.

Plyometric Training plays an effective role in developing explosive power abilities. Fosbury-Flop High Jump requires both speed and power skills to achieve high performance level (Gambetta, 1987).

Most of international standardized records in high jump achieved through successful approach and take off; therefore training programs should focus on developing motion path for approach and take off as well as teaching tactics over the bar (Tonics, 1986; Myers, 1989; Tellez, 1993) .

Plyometric training deemed to be the most important exercises for production of explosive power required during take-off phase in the high jump to reach the maximum possible height over the bar (Raid, 1989). Plyometric training helps muscle to reach maximum strength in the shortest possible time, and this called the explosive power; which is highly needed in jump, sprint and shooting competitions. (Dintiman, et al., 1998). Plyometric training aims to develop the explosive power of leg muscles, where muscles are exposed to sudden expansion under the influence of decentralized contraction immediately followed by high-speed centralized contraction and the main purpose of this method of training is to activate the reflection mechanism and mechanical properties of muscle fibers (Wilkerson, 1990; Donald, 1998). Motor activity produced by body falling from height to ground lead to light bending in the joints then stopping movement along muscles in both horizontal and vertical directions; then enter shift phase from decentralized to centralized contraction; the best form of plyometric training is deep jump ( Jacoby, 1983). There are many forms of plyometric exercises like leaps; jump on the barriers and deep jump; could be performed by one foot or two feet, in order to develop leg muscles explosive power giving quick results as shown by vertical jump from stability and 30 m sprint tests (George, 1999).

Explosive power degree associated with number of aroused motor units and becoming more and more in

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stability, where the student stand behind take off line, feet little far, the student swing arms, bent knees and jump, student have three trials, best one to be recorded. 30 m sprint with flying start, student start sprint before fixed distance with 10 meter to calculate exact time of 3o meter sprint to calculate the actual speed, Fosbury-Flop high jump as per IAAF laws)

Researchers also used videograph to perform pre and post kinematic analysis (height of the COG at the end of take-off phase (h1), height that the jumper raises his MC during the flight (h2), the difference between the maximum height reached by the MC and the height of the crossbar(h3), horizontal velocity at the start of take-off phase [touch-down] (Vh_TD), horizontal velocity at the end of take-off phase (Vh_TO), vertical velocity at the start of take-off phase (Vv_TD), vertical velocity at the end of take-off phase (Vv_TO), maximum knee angle in the take-off phase, takeoff angle, hip angle, takeoff time).

2 Video cameras were uses with 240 frame/second speed and one camera with 30 frame/second speed, each camera fixed on three dimension holder camera (1) perpendicular on left approach curve to videograph competitors using there right leg, far from curve-mid with 35 meter and 1.15 meter high, videograph area 9.5 meter, camera (2) perpendicular on right approach curve to videograph competitors using their left leg, far from curve-mid with 35 meter and 1.15 meter high, videograph area 9.5 meter, camera (3) perpendicular on the bar from left side far from the bar-mid with 6 meter, 1.65 meter height, videograph area 3 meter, Dartfish program used for kinematic analysis.

Training program consisted of 36 training sessions, 3 units weekly for 12 weeks. Both experimental groups used the same program for Fosbury-Flop High Jump with difference only in intensity distribution form to determine the best experimental group using two forms of plyometric training (Single Leg Depth Jump, Depth Jump)

Example: While training with six boxes, in different high intensity training boxes will be 70% and 90% intensity alternativel, so total intensity will be (3 × 70) + (3 × 90) = 480 , while for fixed intensity same number of boxes used with 80% intensity for all boxes so total intensity will be (6 × 80) = 480 Thus, the training intensity is the same, with difference only in intensity distribution. Figure 1 show training intensity distribution during the program.

the case of arousing the largest possible number of muscle motor units, this controlled by stimuli degree as increasing intensity, which lead participation of a larger number of motor units and thus increase the explosive power (Ref.). Motor units requires a certain amount of arousal or stimulation and do not respond without the occurrence of such amount of arousal which is called threshold i.e. minimum nerve arousal which motor unit respond with contraction to maximum contraction degree and do not respond if arousal degree is lower than threshold and this called law of all (All - Or- No Response). All muscle fibers in the motor unit receive the same nerve stimuli and thus all the muscle fibers of this motor unit contract to maximum level it as soon as arousal degree reach threshold level (Abu ElEala , 2003). From all what mentioned above, researchers found that there is no studies about wave intensity plyometric training as training done only with fixed intensity, So they worked to complete the previous studies by developing a new model for the form of plyometric exercises as they believe in importance of this training method in developing explosive power, and consequently improving standardized level for Fosbury-Flop High Jump.

## Methods

Twenty-four student- third year physical education students had been recruited to participate in this study. They have been divided into two experimental groups each consists of 12 students. The first experimental group used different high intensity exercises, while the second experimental used fixed intensity for the same exercises.

The two experimental groups were homogenous: first group (age 19.76± 0.37, height 1.78 ± 3.34 cm, body mass 72.17± 3.24kg, best record during competition were159.00± 5.58 cm) and second group (age 19.46± 0.39, height 1.81± 2.84cm, body mass 74.08± 3.55kg, best record during competition were156.00± 5.55cm)

The researchers used (high Jump test from stability, where the student face the wall, arm raised height, after sipping fingers in water to mark the highest points in standing position, the student swing arms, bent knees and jump high, making another mark with hand, distance between the two marks to be recorded, each student have three trials, and the best one recorded for analysis. Long jump test from

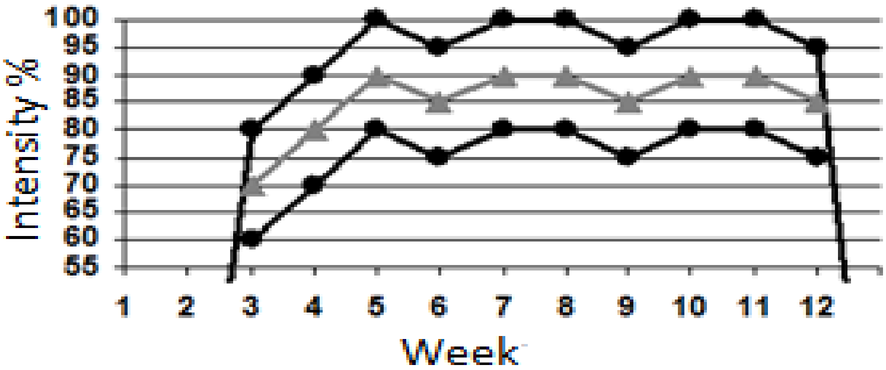

Figure 1. Training intensity dynamic during the training program for boxes height for both experimental group

Researchers used the following statistical factor and methods: average, standard deviation, Skewness, independent t test, paired T test)

**Results**

Vertical jump improved by 21.80% and 11.17% in the first and second group respectively (first group: 42.83±2.98 to 52.17±2.89 cm, P <0.05; second group: 43.25±2.86 to 48.08±1.62 cm, P <0.05). Horizontal jump improved by 13.24% and 6.22% in the first and second group respectively (first group: 228.50±7.39 to 258.75±5.77cm, P <0.05; second group: 231.83±3.88to 246.25±3.47cm, P <0.05). (30 m) improved by 2.68% and 1.33% in the first and second group respectively (first group: 3.73±0.06to 3.63±0.04 s, P <0.05; second group: 3.75±0.06to 3.70±0.05 s, P <0.05). Fosbury-Flop high jump performance has also improved by 8.02% and 3.67% in the first and second group respectively (first group: 159±5.58 to 171.75±5.45 cm, P <0.05, second group: 156.50cm ±5.55 to 162.25cm ±4.86 cm, P <0.05). H1 - height of the COG at the end of take-off phase improved by 0.83% and 0.82% in the first and second group respectively (first group: 1.21±0.04to 1.22±0.03 cm, P >0.05; second group: 1.22±0.03to 1.23±0.03 cm, P >0.05). H2 the height that the jumper raises his MC during the flight improved by 5.23% and 3.53% in the first and second group respectively (first group: 1.72±0.03to 1.81±0.04cm, P <0.05; second group: 1.70±0.05to 1.76±0.05cm, P <0.05). H3 the difference between the maximum height reached by the MC and the height of the crossbar improved by 80% and 33.33% in the first and second group respectively (first group: 0.05±0.02to 0.09±0.03cm, P <0.05; second group: 0.06±0.03to 0.08±0.03cm, P <0.05). Horizontal velocity at the start of take-off phase (touchdown) improved by 1.57% and 0.70% in the first and second group respectively (first group: 5.74±0.10to 5.83±0.11 m/s, P <0.05; second group: 5.68±0.13to 5.72±0.13 m/s, P <0.05). Horizontal velocity at the end of take-off phase improved by 0.84% and 0.57% in the first and second group respectively (first group: 3.57±0.07to 3.60±0.07m/s, P <0.05; second group: 3.50±0.10to 3.52±0.09m/s, P <0.05). Vertical velocity at the start of take-off phase improved by 13.33% and 7.41% in the first and second group respectively (first group: 0.30±0.05to 0.34±0.06m/s, P <0.05; second group: 0.27±0.05to 0.29±0.05m/s, P<0.05). Vertical velocity at the end of take-off phase improved by 3.01% and 1.70% in the first and second group respectively (first group: 3.66±0.28to 3.77±0.24m/s, P <0.05; second group: 3.53±0.14to 3.59±0.13m/s, P <0.05). Maximum knee angle in the take-off phase improved by 3.35% and 1.69% in the first and second group respectively (first group: 146.58±6.19to 142.67±6.81°, P <0.05; second group: 148.25±5.69to 145.75±5.55 °, P <0.05). Take-off angle improved by 1.48% and 1.93% in the first and second group respectively (first group: 39.83±2.62to 40.42±1.88 °, P >0.05; second group: 38.92±1.51to 39.67±1.30 °, P >0.05). Free leg angle at the end of take-off improved by 0.83% and 0.93% in the first and second group respectively (first group: 99.92±3.45to 100.75±3.05°, P <0.05; second group: 97.67±4.12to 98.58±3.37 °, P >0.05). Take-off time improved by 3.57% and 1.98% in the first and second group respectively (first group: 0.196±0.01to 0.189±0.01s, P <0.05; second group: 0.202±0.01to 0.198±0.01s, P <0.05).

Table (1).Average, standard deviation, T value for post measurements in both experimental groups

| **statistical factors**<br>**variable** | **1st experimental group** | | **2nd experimental group** | | **T test value** |
|---|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** | |
| Vertical jump from stability (cm) | 52.17 | 2.89 | 48.08 | 1.62 | 4.27* |
| Long jump from stability (cm) | 258.75 | 5.77 | 246.25 | 3.47 | 6.43* |
| 30 m sprint, flying start (sec) | 3.63 | 0.04 | 3.7 | 0.05 | 3.91* |
| High jump (cm) | 171.75 | 5.45 | 162.25 | 4.86 | 4.51* |
| height of the COG at the end of take-off phase (h1) | 1.23 | 0.03 | 1.22 | 0.03 | 0.84 |
| the height that the jumper raises his MC during the flight(h2) | 1.81 | 0.04 | 1.76 | 0.05 | 2.24* |

| | | | | | |
|---|---|---|---|---|---|
| (cm) | | | | | |
| the difference between the maximum height reached by the MC and the height of the crossbar(h3) (cm) | 0.09 | 0.03 | 0.08 | 0.03 | 0.6 |
| vertical velocity at the start of take-off phase (m/sec) | 5.83 | 0.11 | 5.72 | 0.13 | 2.30* |
| vertical velocity at the end of take-off phase (m/sec) | 3.6 | 0.07 | 3.52 | 0.1 | 2.28* |
| horizontal velocity at the start of take-off phase (touch-down) (m/sec) | 0.34 | 0.06 | 0.29 | 0.05 | 2.31* |
| horizontal velocity at the end of take-off phase (m/sec) | 3.77 | 0.24 | 3.59 | 0.13 | 2.22* |
| Maximum knee angle in the take-off phase (angle) | 142.67 | 6.81 | 145.75 | 5.55 | 1.22 |
| Takeoff angle (angle) | 40.42 | 1.88 | 39.67 | 1.3 | 1.14 |
| Free leg hip angle at the end of take-off (angle) | 100.75 | 3.05 | 98.58 | 3.37 | 1.65 |
| Takeoff time (sec) | 0.189 | 0.01 | 0.198 | 0.01 | 2.22* |

* Significant at 0.05 field (T significant at 0.05 = 2.07)

Table 1 results revealed significant differences between the two experimental groups in favor of first experimental group in physical, skill variables and some kinematic variables

## Discussion

Results of pre-post measurements of both groups which are Vertical jump from stability , Long jump from stability , 30 m sprint, flying start , High jump , , the height that the jumper raises his MC during the flight(h2), the difference between the maximum height reached by the MC and the height of the crossbar(h3), vertical velocity at the start of take-off phase , vertical velocity at the end of take-off phase , horizontal velocity at the start of take-off phase, horizontal velocity at the end of take-off phase , Maximum knee angle in the take-off phase , Free leg hip angle at the end of take-off for first group only, Takeoff time ) that there are significant differences at 0.05 level while there is no significant differences in height of the COG at the end of take-off phase (h1) and takeoff angle for first group, and height of the COG at the end of take-off phase (h1), free leg hip angle and takeoff angle for second group, researchers interpret this for training program effectiveness with its plyometric and skill exercises which lead to enhance post-measurements. Researchers also argue that enhancing physical variables is from the important reasons for enhancing kinematic variables for Fosbury-Flop High Jump, and subsequently the standardized record.

These results in agreement with that plyometric training is one form of explosive exercises which called expansion reverse response where muscles move fast from expansion contracting to shortening contracting and where nerve system respond fast by producing maximum strength in minimum possible tome (Lee, 2006). Plyometric training is specialized training designed to develop nerve explosive power through enhancing motor units work to produce maximum power in lowest possible time (Partic, 2000). Plyometric training aim to develop explosive power for leg muscles as it works to activate reversal mechanism and mechanical properties of muscle fibers under the effect of expansion, which increase strength production and speed (Wilkerson, 1990; G. Donald, 1998). This also in agreement with (Wilmore & Castill, 1994) who argued that plyometric training is jump exercises using what is called response which give the muscle elastic property and enhance jump efficiency.

The height of projection of the COG is dependent on the vertical velocity the athlete is able to obtain at the end of the take-off phase of the jump (Dapena, 1992). Increases in take-off velocity as small as 0.1 m/s can result in a 3-4 cm increase in COG projection height. The two factors that determine the take-off vertical velocity are the horizontal velocity of the approach and the ability of the athlete to convert the horizontal velocity to vertical velocity (Dursenev, 1991).

Researchers return non significant differences in height of the COG at the end of take-off phase (h1) to the stability of sample height, while takeoff and hip angle did not affect by training program due to stability of technical performance of both groups which in turn mean that plyometric training is the base of enhancing kinematic variables related to physical variables, there was little enhancing in hip angle for first group as a result of enhancing physical variables. Researchers return better enhancing percentage in first group to using wave intensity in training program.

Table 1 results reveal that there are significant differences at 0.05 level in post measurements between the two groups in favor of first experimental group in (Vertical jump from stability , Long jump from stability , 30 m sprint flying start, high jump, the height that the jumper raises his MC during the flight(h2), vertical velocity at the start of take-off phase , vertical velocity at the end of take-off phase , horizontal velocity at the start of take-off phase, horizontal velocity at the end of take-off phase, takeoff time). There were no significant differences in (height of the COG at the end of take-off phase (h1), the difference between the maximum height reached by the MC and the height of the crossbar (h3), Maximum knee angle in the take-off phase, Takeoff angle, and free leg hip angle at the end of take-off)

Researchers return that to wave method used within training sessions with first experimental group, which led to positive enhancing percentage in physical, kinematic groups and standardized record.

These results in agreement with (A.Abu ELeala, 2003: N. Ahmed, 2003), who argued that Explosive power degree associated with number of activated motor units and becoming more and more in the case of arousing the largest possible number of muscle motor units, this controlled by stimuli degree as increasing intensity, which lead participation of a larger number of motor units and thus increase the explosive power.

Also agreed with (Abu Eleala, 2003) who argued that motor units requires a certain amount of arousal or stimulation and do not respond without the occurrence of such amount of arousal which is called threshold i.e. minimum nerve arousal which motor unit respond with contraction to maximum contraction degree and do not respond if arousal degree is lower than threshold and this called law of all (All - Or- No Response). All muscle fibers in the motor unit receives the same nerve stimuli and thus all the muscle fibers of this motor unit contract to maximum level it as soon as arousal degree reach threshold level.

Researchers also return that there were no differences in height of the COG at the end of take-off phase (h1) to stability of student height, and difference between the maximum height reached by the MC and the height of the crossbar (h3) to short distance between COG and the crossbar. They also return non-significant differences in Maximum knee angle in the take-off phase, Takeoff angle, free leg hip angle at the end of take-off to enhancing strength and speed and not kinematic positions related to body angle.

Plyometric training lead to increase speed of fast muscle fibers, tendons, muscles to store maximum elastic power, increasing muscles ability to produce explosive power. The importance of plyometric training appear in linking strength and speed together as plyometric training is specialized exercises designed to develop nerve explosive power through enhancing motor units work to produce maximum power in lowest possible time (Partic, 2000)

## Conclusions.

From all what mentioned before researcher conclude that using plyometric training with different wave intensity is better than using fixed intensity plyometric training within training sessions and training program.

## References

Abu Eleala A., 2003, Sport physiology, Dar ELfikr AlArabi, 1st ed., Cairo, 2003 (in Arabic)

Ahmed N., 2003, Sport physiology, applications and theories, Dar ELfikr AlArabi, 1st ed., Cairo, 2003 (in Arabic)

Dapena, J. 1992, Biomechanical studies in the high jump and the implications to coaching. Track and Field Quarterly Review, 92(4), 34-38. 1992.

Dintaman, G., Ward, R., Tellez, T. Sears, 1998, Sport Speed, 2nd ed., Human Kinematics publishers, Champaign Illinois, 1998.

Donald G., P. 1998, Jumping into plyometric, 2nd ed., California

Dursenev, LI, 1991, Concerning one of the concepts of improving high jumpers. Soviet Sports Review, 26(2), 60-61. 1991.

Gambetta, V. 1987, Principles of Plyometric Training, Track Technique No. 97, 1987.

George, D., 1999, Crash Training to state championship, Track coach, Formerly Track Technique, No. 147, Spring, 1999.

Jacoby, E.D.,1983, High Jump applied Techniques in Track & field, New York, pp. 124-129, 1983.

Lee, T. 2006, Plyometric progressions- Mini Book sports Speed Etc www.sportsspeedEtc.com.

Myers, B., 1989, Training for jumps and multi events, track technique, no. 109, pp.3492-3493,

Partic O., 2000, Quantum strength fitness … (coining the winning edge) Patrick's books-corraills or (www.strength fit.com)

Reid, P.1989, Plyometrics and the high jump, new studies in Athletics, pp. 67-74, March.

Tanicis, D.G.,1986, Organization of High Jump Training Track technique, No. 94, P. 3013.

Tellez, K.E., 1993, Elements of the High Jump, track technique, vol. 125 (fall), PP. 3987-3990

Wilkerson, J.D.: 1990, Plyometrics when and how does it work, in strategies, vol. 3, No. 3.

Wilmore, J .H. & Castell, D, L. 1994, Physiology of sport and Exercise Human Kinematics, Champaign, 1994.