International Journal of Physical Education, Sports and Health 2022; 9(4): 168-172

P-ISSN: 2394-1685
E-ISSN: 2394-1693
Impact Factor (RJIF): 5.38
IJPESH 2022; 9(4): 168-172

www.kheljournal.com
Received: 13-04-2022
Accepted: 19-05-2022

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Effect of plyometric training on repeated countermovement jump performance of collegiate athletes

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DOI: https://doi.org/10.22271/kheljournal.2022.v9.i4c.2589

Abstract
The goal of the present study was to find out the effect of plyometric training on repeated countermovement jump performance of collegiate athletes. A total of six variables of repeated countermovement jump, i.e., height (HT), take-off force (TOF), impact force (IF), maximum concentric power (MCP), peak speed (PS), and take-off speed (TOS), were selected to fulfil the objective of the study. A total of twenty (N=20) participants were randomly selected from a physical training centre of the Gwalior area of India as the subjects for the study. The average age of the participants was 18.40±1.19 years. The subjects were randomly divided into two groups. Each group consists of ten participants. One group was treated as the experimental group, and another was treated as the control group. To find out the effect of plyometric training a randomized control group pre-test post-test design was adopted in which the experimental group received eight weeks of plyometric training whereas the control group received dummy training. The training was given twice a week to both groups. Pre and post-data were collected before and after the eight weeks of plyometric training. The statistical technique independent t-test was used to compare the performance of the experimental and control groups, whereas paired t-tests were used to compare pre-and post-test data at 0.05 level of significance. The findings showed that eight weeks of plyometric training significantly improved the variable height, take-off force and maximum concentric power.

Keywords: Repeated countermovement jump, plyometric training, take-off force, impact force, maximum concentric power, peak speed and take-off speed

1. Introduction

A basic human movement, jumping necessitates dynamic synchronization of the upper and lower extremities of the body [1]. Researchers, coaches, and other sports experts employ different jumping techniques to evaluate players' abilities under different physical situations [2, 3]. The vertical jump is commonly used to assess athletes' and non-athlete participants' functional capacity [4, 5]. In addition, due to their simplicity and availability of result information, strength and conditioning experts, coaches, and health and physical education researchers frequently use vertical jump tests to assess the lower limbs' muscular strength.

The countermovement jump is a variation of the vertical jump used to measure the explosive strength of the lower limbs. The initial countermovement that comes before the take-off phase distinguishes the countermovement jump from other jump types. In the countermovement jump, the athlete starts from a standing position and moves downward before leaping with an upward motion. The body utilizes and transfers energy through a stretch-shortening cycle involving an eccentric action swiftly followed by a concentric motion [6]. More force and power can be applied during the concentric phase of the jump due to the stretch-shortening cycle. For an excellent countermovement jump, the neuromuscular process, muscle physiology, and skeletal system all function together. By measuring the jump height and examining the kinematics of the movement, the effectiveness of countermovement jumps can be indirectly assessed. In order to enhance performance and increase the vertical jump, researchers frequently alter the kinematic characteristics of the countermovement jump. In a few research studies, the countermovement jump test is used to assess the metabolic properties of muscular endurance over a time span ranging from 5 to 6 seconds [7, 8, 9].

In that case, the countermovement jump must be performed continuously during the time allotted for its execution and is called a repeated countermovement jump. In a repeated countermovement jump, the participant repeatedly jumps while counter moving in the direction of 90° knee bends. The repeated countermovement jump is one of the variations of vertical jumps employed in research activities to evaluate different jump parameters that can't be measured using simple vertical jumps [7, 10]. Recent studies have shown that the repeated countermovement jump test is valid and reliable for evaluating anaerobic performance [11, 12].

The improvement in vertical jump performance has been the subject of many studies. It is reported that the performance of the vertical jump can be improved using various training techniques, including heavy resistance training, explosive type resistance training, electro stimulation training, and vibration training [13, 14, 15]. It is well known that the idea of training is not new. Ancient people often trained for military and Olympic events. Today's athletes train to get ready for a specific goal. To perform better during competitions, athletes must train to increase their functional capacity, skill effectiveness, and psychological attributes. Nowadays, the plyometrics training technique is used by athletes in all types of sports to increase strength and explosiveness. Most coaches and researchers agree that plyometric training is the best way to improve vertical jump ability and leg muscle power [13, 16, 17, 18]. However, plyometric training can take numerous forms, including specific lower and upper extremity exercises [19, 20]. The user of plyometrics should understand how to exercise and execute and change the routine to make the most of it.

In previous studies of plyometric training, results supported the improvements in specific physical abilities in as little as eight weeks of plyometric training, which can be useful during the last preparatory phase before in-season competition for athletes [21, 22, 23]. Another researcher has reported that eight weeks of plyometric exercises can develop horizontal jump performance [24, 25]. Eight weeks of plyometric training added to the standard training program of athletes was highly likely to improve young athletes' lower limb speed and explosive strength. Previously researcher has stated that there is no difference between the low and high volume of a periodized training program; combining an eight-week plyometric program with athletics training might have significantly developed long jump and general athletic performance as well biomechanical parameters [19, 26, 27, 28].

However, the literature review does not reveal any studies attempted to investigate the effect of plyometric training on Repeated Countermovement Jump performance. Given that plyometric training is a common type of training used to improve explosive power and jump performance, it is possible that plyometric training could improve Repeated Countermovement Jump performance. However, until research is conducted on this topic, there is no way to know whether plyometric training is effective for this purpose or not. Therefore, the current study was being conducted to determine the effect of plyometric training on repeated countermovement jump performance. And it was hypothesized that plyometric training would improve Repeated Countermovement Jump performance.

2. Materials and methods

2.1 Participants of the study

A total of twenty (N=20) collegiate level athletes were randomly selected from a physical training centre of Gwalior area of India as the participants of the study. The participants were equally and randomly assigned to the experimental and control groups (10 participants in each group). The experimental group went through 8 weeks of plyometric training, whereas the control group went through dummy training for an equal amount of time. The average age of the participants was 18.40 years, with a standard deviation of 1.19. All the participants were informed about the study, after which they voluntarily agreed and provided written consent to participate in the study.

2.2 Variable of the study

To evaluate the performance of repeated countermovement jump, six (6) variables were selected for the study. They were height (HT), take-off force (TOF), impact force (IF), maximum concentric power (MCP), peak speed (PS), and take-off speed (TOS). The HT is the average height of repeated countermovement jumps and will be measured in the unit centimeter; the TOF is the average force exerted by the performer during take-off while performing repeated countermovement jumps and it will be measured in kilo newton; the IF is the average force impact on the ground while landing from the jumps and it will also be measured in the unit kilo newton; the MCP is a method to measure the maximum muscular contraction during the concentric phase of jumps and the unit of measurement is kilowatt; the PS is the maximum speed of propulsion of the body from the ground during the jump and it will be measured in the unit metre per second, and the TOS is the speed of take-off from the ground during the repeated countermovement jumps and the unit of measurement is metre per second.

2.3 Experimental design

The study's design was a randomized control-group pretest posttest design [23] in which both groups were trained twice a week. The experimental design can be understood using Figure 1. The pretest data of the participants were collected before the start of training sessions, and finally the post test data were collected after the completion of the training session. The statistical test was applied for analysis after completion of the post test.

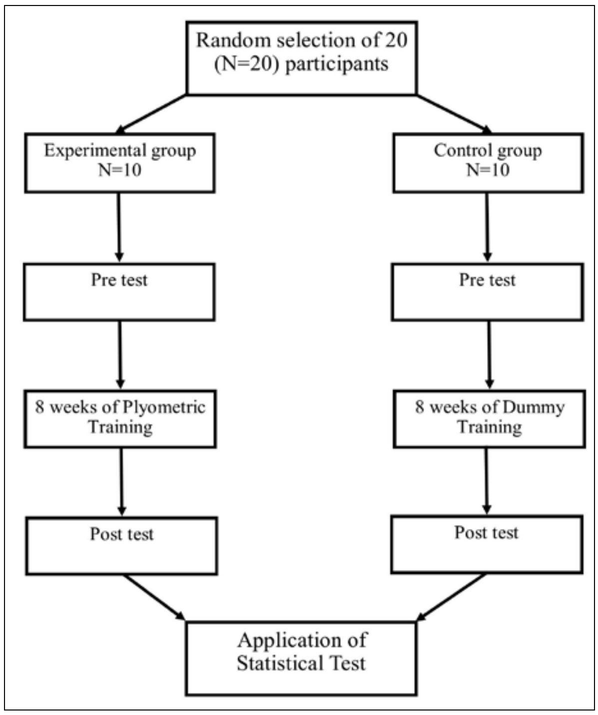

Fig 1: Experimental design

2.4 Training programme
The training sessions were prepared according to the recommendation of Bedoya *et al.* [24] and Çimenli *et al.* [25]. The training commenced with 10 minutes of warm-up exercises, continued with 35-45 minutes of plyometric exercises, and concluded with 10 minutes of cool-down exercises. Accordingly, the workouts' volume, intensity, and frequency also increased with increased training duration.

2.5 Testing protocol
The BTS G-WALK® system was used to collect the data for the study. The BTS G-WALK® system consists of a device called 'G-Sensor' and specialised software called 'G-Studio.' The system is a highly reliable and valid instrument for measuring gait and jump-related variables.
The tests were administered inside a laboratory. As per the standard instruction mentioned in the manual of the instrument, the G-Sensor device was positioned behind the lumbosacral passage, between the two dimples of Venus, using a belt. The participants performed the countermovement jump repeatedly on the command of the tester. The 'G-Studio' software records the participants' data while executing the jumps. After completion of the data collection, the software will display the reports on various variables including the six variables selected for the purpose of the study.

2.6 Statistical test
Simple descriptive statics was applied to explain the participants' characteristics and variable-related data. To compare the experimental and control groups, an independent t-test was applied, whereas to compare between the pre-test and post-test data, paired t-test was applied. All the statistical tests were performed using IBM SPSS Statistics version 20.0. For all the statistical tests, the level of significance was set at 0.05.

3. Results
The overall age of the participants was 18.40±1.19 years, with height 1.72±0.07 centimetres and weight of 64.70±5.35 kg. While the age of the participants in plyometric group was 18.40±1.35 years, their height was 1.73±0.07 centimetres and their weight was 64.00±5.56 kg. The average age of the control group participants was 18.40±1.07 years, with a height of 1.70±0.07 centimetres and weight of 65.40±5.34 kg.

Table 1: Descriptive statistics of the characteristics of the participants

Training	Age	Height	Weight
Plyometric	18.40±1.35	1.73±0.07	64.00±5.56
Control	18.40±1.07	1.70±0.07	65.40±5.34
Overall	18.40±1.19	1.72±0.07	64.70±5.35

The results of the study (Table 2) revealed that during the initial test, there was no significant difference between the experimental and control group for any of the selected variables (HT: t (18) = 0.291, p = 0.774; TOF: t (18) = -1.310, p = 0.207; IF: t (18) = 1.110, p = 0.282; MCP: t (18) = -0.404, p = 0.691; PS: t (18) = 0.708, p = 0.488 and TOS: t (18) = -0.265, p = 0.794). However, after the 8 weeks of plyometric training significant difference was found between the experimental and control group over the variables HT (t (18) = 2.328, p = 0.032), IF (t (18) = 2.219, p = 0.040) and PS (t (18) = 2.381, p = 0.028). The separate paired t-test (pre vs post) for both the experimental and control group revealed that, significant improvement was observed for the variables HT (t (9) = -7.214, p = 0.000, Δ% =20.12), TOF (t (9) = -3.432, p = 0.007, Δ% =12.87) and MCP (t (9) = -4.224, p = 0.002, Δ% =14.62) of the experimental group after 8 weeks of plyometric training. However, none of the variables of the control group had exhibited significant improvement after 8 weeks of plyometric training.

Table 2: Results of statistical tests for both the experimental and control groups

Variables		Experimental (N=10)	t-test Results (Pre vs. Post) t(df) = t value, p = Sig. value, Δ % = Percentage change	Control (N=10)	t-test Results (Pre vs. Post) t(df) = t value, p = Sig. value, Δ % = Percentage change	t-test Results (Experimental vs. Control) t (df) = t value, p = Sig. value, Δ = Mean difference
HT	Pre	22.02±3.86	t (9) = -7.214, p = 0.000, Δ % = 20.12*	21.47±4.57	t (9) = 0.030, p = 0.977, Δ % = -0.14	t (18) = 0.291, p = 0.774, Δ = -0.55
	Post	26.45±4.40		21.44±5.19		t (18) = 2.328, p = 0.032, Δ = -5.01*
TOF	Pre	1.01±0.23	t (9) = -3.432, p = 0.007, Δ % = 12.87*	1.15±0.25	t (9) = -1.356, p = 0.208, Δ % = 5.22	t (18) = -1.310, p = 0.207, Δ = 0.14
	Post	1.14±0.28		1.21±0.25		t (18) = -0.545, p = 0.592, Δ = 0.07
IF	Pre	0.75±0.12	t (9) = -1.861, p = 0.096, Δ % = -8.00	0.60±0.11	t (9) = 0.151, p = 0.884, Δ % = 1.67	t (18) = 1.110, p = 0.282, Δ = -0.15
	Post	0.69±0.12		0.61±0.09		t (18) = 2.219, p = 0.040, Δ = -0.08*
MCP	Pre	2.12±0.53	t (9) = -4.224, p = 0.002, Δ % = 14.62*	2.25±0.89	t (9) = -0.925, p = 0.379, Δ % = 4.44	t (18) = -0.404, p = 0.691, Δ = 0.13
	Post	2.43±0.60		2.35±0.69		t (18) = 0.270, p = 0.790, Δ = -0.08
PS	Pre	2.35±0.25	t (9) = -2.255, p = 0.051, Δ % = 5.53	2.27±0.28	t (9) = 0.506, p = 0.625, Δ % = -2.20	t (18) = 0.708, p = 0.488, Δ = -0.08
	Post	2.48±0.24		2.22±0.24		t (18) = 2.381, p = 0.028, Δ = -0.26*
TOS	Pre	2.07±0.26	t (9) = -1.522, p = 0.162, Δ % = 6.76	2.10±0.19	t (9) = 0.909, p = 0.387, Δ % = -2.38	t (18) = -0.265, p = 0.794, Δ = 0.03
	Post	2.21±0.32		2.05±0.14		t (18) = 1.483, p = 0.155, Δ = -0.16

* Significant difference

4. Discussion
The study was conducted to find out the effect of 8 weeks of plyometric training on repeated countermovement jump performance. The performance of repeated countermovement jump was evaluated by employing 6 variables, i.e., height, take-off force, impact force, maximum concentric power, peak speed, and take-off speed. The result of the study revealed that the variables: height, take-off force and maximum concentric power have exhibited significant improvement after 8 weeks of plyometric training.
Few previous studies conducted on countermovement jumps reported similar results about the effect of plyometric training on jumping performance, however, none of them considered measuring the height of repeated countermovement jumps. The current study reported a 20.12% increase in repeated countermovement jump height after 8 weeks of plyometric training. A similar increase (21.3%) in jump height was reported by [16], but that was for a simple countermovement jump and after 6 weeks of plyometric training. Some other studies also reported the increase in jump height after plyometric training; however, all of them were regarding countermovement jumps [13, 31–33]. In a repeated countermovement jump, the participant performs the countermovement jumps repeatedly. Therefore, owing to the

nature of the countermovement jump, the present study also reported improvement in jump height after 8 weeks of plyometric training.

The study also reported a 12.87% improvement of the variable take-off force. The take-off force is the force required to lift up the body during a jump. In general, the human body works like a machine for a movement like walking, jumping etc. In this machine, different bones, ligaments, and muscles form different levers that enable a human to move or perform a particular activity. The performance of the activity can be modified by changing the performance of the body's levers. Bridgett & Linthorne [34] reported that take-off force of long jumpers could be altered by changing their jump technique. In the current study, the participants might have developed the technique to produce more take-off force during jump after 8 weeks of plyometric training.

Another significant result of the current study was a 14.62% increase in maximum concentric power. Maximum concentric power is the amount of power output that causes tension on a muscle as it shortens. Plyometric exercises involve exercises which requires a systematic execution of eccentric contraction followed by an immediate explosive concentric contraction [19]. This might be the reason because of which improvement was observed in maximum concentric power after 8 weeks of plyometric training.

The world of sport is constantly evolving, with new techniques and training methods being discovered continuously. One of the latest trends in training came in the form of plyometric training. While the name may conjure images of jumping for joy, the reality is that plyometric training can be used to improve athletic performance. The key to plyometric training is to perform exercises that use a lot of force and impact. This means that the exercises should be performed at a high intensity, aiming to generate maximum muscle power and shockwaves in the muscle tissue. This can be achieved by performing the exercises as quickly as possible, with as much force as possible.

5. Conclusions

In conclusion, it can be said that the obtained results in the current study support the already reported results. Plyometric training is an excellent method to improve an athlete's explosive strength. However, more research can be undertaken to understand its physiological effects on the human body.

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