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EFFECTS OF VERTICAL AND HORIZONTAL PLYOMETRIC EXERCISES ON RUNNING SPEED

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ABSTRACT

Purpose. The aim of the present study was to compare the effects of vertical, horizontal and a combination of both vertical and horizontal plyometric exercises (depth jumping) on running speed. **Methods.** A purposively selected sample of 80 male students were randomly assigned into either a control group or groups training the vertical depth jump, horizontal depth jump or a combination of both. The experimental groups trained twice weekly for 10 weeks, performing 6 sets of 10 repetitions per session. Drop height was increased from 20 to 40 cm according to the step method. Running speed was measured by a 45.72 m dash test before and after the 10-week period. **Results.** Analysis of covariance was applied to compare scores. A pair-wise comparison was performed using Scheffe's post-hoc test at a 0.05 level of confidence. The results showed significant improvements among the three experimental groups as compared with the control group, whereas a comparison between the three experimental groups was found to be insignificant. The percentage of performance increase from pre-test to post-test running speed was 2.23%, 2.96% and 3.57% for the groups training vertical, horizontal and both vertical and horizontal depth jumps, respectively. **Conclusions.** A combination of both vertical and horizontal depth jumping, with a slightly larger emphasis on horizontal plyometric training, can aid sprinters' performance.

Key words: amortization phase, stretch reflex, vertical depth jump, horizontal depth jump, step progression

Introduction

The term "plyometrics" first made its appearance in sports methodology literature in V.M. Zaciorskij's 1966 work "Fiziceskie Kacestva Sportsmena". Zaciorskij used this term to indicate the greater tension present in a group of muscles when an exercise involved a quick stretching phase followed by an equally quick concentric contraction. In this process, the tension expressed by working muscle (metron) measured externally is found to be higher (plio) than the tension expressed using any other exercise (isometric, isotonic, auxotonic) [1]. An American track and field coach named Fred Wilt offered an explanation of the term in 1975, where, based on its Latin origins, plyometrics was interpreted as "measurable increases". Plyometrics rapidly became known to coaches and athletes as exercises or drills aimed at linking strength with speed of movement in order to produce more power. Plyometric training became essential to athletes who jumped, lifted, or threw. During the late 1970s and into the 1980s, athletes in other sports also began to see the applicability of this concept in their own movement activities. Throughout the 1980s, coaches in sports such as volleyball, football and weightlifting began to use plyometric exercises and drills to enhance their training programmes. If there was any drawback to this enthusiasm, it lay with the lack of expertise that American coaches and athletes had in administering plyometric programmes and a faulty belief that more must be better. Since these early years, however, practitioners have learned through applied research as well as trial and error to establish realistic procedures and expectations [2]. The term "plyometrics" remains to be known as a specific group of exercises that encompass a rapid stretching of a muscle that is undergoing eccentric stress followed by a concentric, rapid contraction of that muscle for the purpose of developing a forceful movement over a short period of time [3]. For example, as an athlete lands on the ground during a plyometric exercise, a stretch occurs in the involved muscle fibres. Proprioceptors within the muscle tissue immediately sense this stretch and send a message to the spinal cord through an afferent or sensory neuron. The spinal cord sends a message immediately back to the muscle fibre via an efferent or motor neuron, telling it to contract to keep it from overstretching. This is known as the "stretch reflex" and is one of the body's built-in protection mechanisms for preventing muscle tissue injuries. Plyometric drills can be used to train the body to emit these sensor signals in a shorter period of time, causing the affected muscle to react ever more quickly [4].

Researchers have focused on using depth jumping as a form of plyometric training [5]. Two types of depth jumping in particular were described by Chu [2]. The first is the vertical depth jump, performed by stepping off a box and landing on both feet all the while trying to anticipate the landing. As soon as contact is made,

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it is necessary to spring up as quickly as possible so as to keep the body from "settling" on the landing, keeping ground contact to a minimum. The second is termed as the horizontal depth jump, also performed by taking a step off a box and landing on both feet. However, upon landing, the participant jumps immediately as far forward as possible, again landing on both feet.

The aim of this study was to investigate the influence of both vertical and horizontal depth jump training, as well as a combination of both vertical and horizontal depth jumping, on running speed, by calculating an optimal drop height and applying a depth jumping training programme.

Material and methods

Purposive sampling was used to select eighty (n = 80) male physical education students aged between 18 to 21 years. All participants were full time students attending classes according to their college curriculum. All were deemed medically fit to undergo the study's training programme and signed an informed consent form prior to participation. The Joint Research Board of the university approved all procedures for the study.

The eighty participants were randomly assigned into three experimental groups and one control group. Group VP (n = 20) performed only the vertical depth jump twice a week, Group HP (n = 20) performed only horizontal depth jumping twice a week, Group CP (n = 20) trained with vertical depth jumping on one day and horizontal depth jumping on another day, while Group CG (n = 20) served as the control group. Those participating in the training sessions attended an instruction session before the first test to ensure proper technique and an understanding of the testing process. A demonstration was also provided by a trained athlete. The participants were tested for proper execution of the vertical depth jump from a drop height of 45 cm (44.3 ± 5.13 cm). To ensure data uniformity, the subjects were always tested in the morning by the same group of examiners.

A pilot study was conducted to determine training intensity and load progression. Ten participants were randomly selected from the original sample and performed first a standing vertical jump and then the depth jump from a height of 10, 20, 30, 40, 50 and 60 cm. Mean maximum vertical jump height was measured at 46.25 cm. Mean maximum depth jump height was found to be 48.64 cm taken from a step height of 20 cm, with depth jump performance remaining above the initial vertical jump height up to a step height of 40 cm (Fig. 1). Therefore, a drop height of 20 cm, where depth jump performance was at a maximum and higher than vertical jump performance, was taken to be the initial training intensity [2]. Drop height was then increased across the training sessions according to the step method from a height of 20 cm up to 40 cm (Tab. 1).

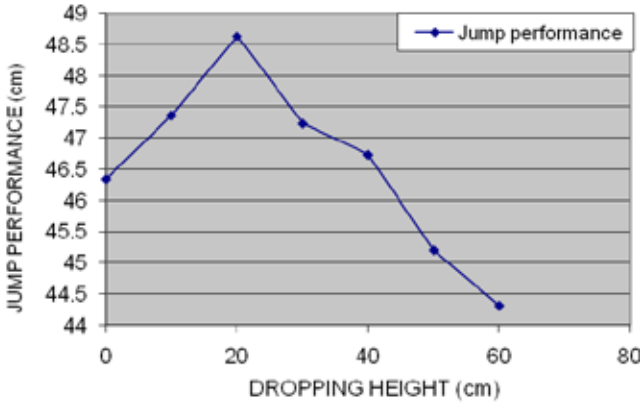


Figure 1. Mean vertical and depth jump performance in the pilot study

Table 1. Progression of drop height during the experiment

Week	I	II	III	IV	V	VI	VII	VIII	IX	X
Drop Height (cm)	20	25	30	25	30	35	30	35	40	35

Each of the experimental groups trained twice a week for 10 weeks at identical intensities and volumes. The training sessions were administered by dividing each group into four smaller subgroups. After a brief warm-up, the group was trained simultaneously on four stations, with the five participants of each subgroup performing in rotation one by one at a station. Each of the participants performed 6 sets of 10 repetitions per session [6]. Fifteen seconds of rest was provided as recovery between repetitions by performing a short walk to a cone placed 11 m in front of the station when training the vertical depth jump, or 12.1 m when training the horizontal depth jump [7, 8]. Rest between sets was completed by a 1.5–2 min slow jog to a cone placed 220 meters from the first cone [9]. After training, the participants engaged in a cool down.

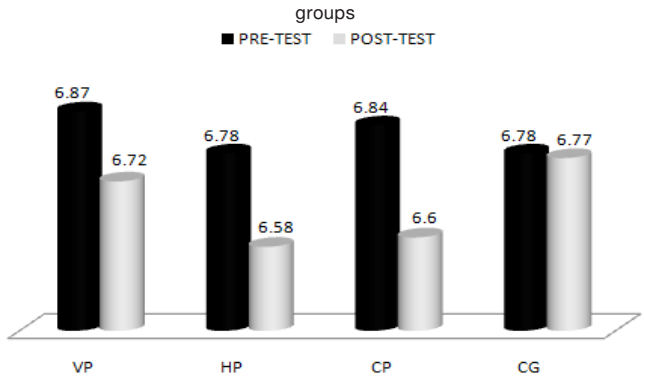
The running speed of each participant was measured before and after the 10-week period according to the recommendations by the American Alliance for Health, Physical Education and Recreation [10]. Two lines were marked 45.72 m apart and parallel to each other on an area that included enough room for stopping after crossing the finish line. Two subjects ran at the same time, both starting from a standing position. The commands "Are you ready?" and "Go!" were given. At "Go!" the starter dropped his arm so that the time keepers at the finish line could begin timing. The elapsed time from the starting signal until the runner crossed the finish line was recorded to the nearest hundredth of a second.

Analysis of covariance was applied to find a significant difference among the groups. Pre-test scores were used as the covariate and post-test scores, adjusted for covariance, were the dependent measures. When a sig-

nificant *F*-value was found, a pair-wise comparison was performed using Scheffe's post-hoc test to identify significant differences between groups. The alpha level was set at 0.05.

Results

The mean pre-test and post-test running speeds of the three experimental groups and control group are presented in Figure 2. The significant differences among the various groups at an *F*-value of 113.29 was found to be greater than the tabulated value of 2.73 for degrees of freedom (3, 75) at the 0.05 level of confidence (Tab. 2). Furthermore, Scheffe's post-hoc test was employed to study the direction and significance of differences between the paired adjusted final means. Significant improvements in the three experimental groups as compared to control group were found (Tab. 3). However, the differences for the remaining paired means were found to be insignificant.



VP – vertical depth jump group, HP – horizontal depth jump group, CP – vertical and horizontal depth jump group, CG – control group

Figure 2. Pre-test and post-test running speed means (s) of the experimental and control

Table 2. Analysis of covariance for the experimental groups and control groups

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	*F*-value
Between-group	0.578	3	0.1927	
Within-group	0.127	75	0.0017	113.29*

* Significant at the 0.05 level $F_{0.05}$ (3, 75) = 2.73

Discussion

Analysis of the data revealed that vertical and horizontal plyometric training, as well a combination of both jumps, is effective in bringing about a significant increase in running speed. Similar findings pertaining to running speed performance have been reported by Gemer [11], Tamrakar and Singh [12] and Polhemus and Osina [13]. Luhtanen and Komi [14] recognized the effects of eccentric-concentric coupling on running speed. They partitioned the total contact time of the feet on the ground as either negative contact time or positive contact time, where, assuming that the initial foot plant is at a position with the lowest centre of gravity, the contact leg's extensor muscles contract eccentrically and perform negative work. The later portion of contact time consists of concentric contractions with a rise in the centre of gravity, making the work being performed positive [14]. This was further supported by Lundin and Berg [15], who attributed improved efficiency of running at higher speeds to the effects of the stretch reflex and use of elastic energy.

In the light of above descriptions by Luhtanen and Komi [14] and Lundin and Berg [15], the findings of the present study are in line with the observations presented by Chu [2], who explained that plyometric depth jumping is an activity that acts to increase the neuromuscular system's ability to more effectively perform concentric contraction, as the forces encountered in plyometric exercises lead to greater motor unit synchronous activity and earlier recruitment of larger motor units via the myotatic reflex [2]. Furthermore, Miller et al. [16] concluded that six weeks of plyometric training reduced the time spent on the ground when compared with a control group. In another study, six weeks' plyometric training significantly reduced the rebound time in the depth jump [17]. According to Pettitt [18], plyometric training leads to physiological adaptations such as a reduction

Table 3. Significance of differences of paired adjusted final means for the experimental and control groups

Means (s)				Difference between means	Scheffe's critical differences
Group VP#	Group HP#	Group CP#	Group CG#		
6.674	6.6113			0.0627	0.1177
6.674		6.5784		0.0956	0.1177
6.674			6.8009	0.1269*	0.1177
	6.6113	6.5784		0.0329	0.1177
	6.6113		6.8009	0.1896*	0.1177
		6.5784	6.8009	0.2225*	0.1177

* Significant at 0.05; VP# – vertical depth jump group, HP# – horizontal depth jump group, CP# – vertical and horizontal depth jump group, CG# – control group

of the amortization phase and greater cross-sectional recruitment and threshold elevation for the inverse stretch reflex.

Analyses of the differences between the paired adjusted final means of three experimental groups showed no statistically significant result. However, the percentage of performance increase from pre-test to post-test running speed was 2.23%, 2.96% and 3.57% for the groups training vertical (VP), horizontal (HP) and both vertical and horizontal (CP) depth jumps, respectively. Thus, the results are in favour of the CP group, which Chu [2] had originally posited that training involving a horizontal and vertical component could be the most successful in contributing to an improvement in running performance. This is further supported by Dintiman et al. [19], who evaluated the stride length and stride rate of athletes. These authors recommend drills emphasizing vertical displacement for athletes who present a weakness in stride rate or in the vertical jump and, conversely, drills with a larger horizontal displacement component for athletes who present a larger weakness in stride length or in tests such as the standing long jump. Furthermore, a comparison of groups VP and HP showed a trend in favour of group HP, which is in conformity with results of Mach et al. [20], who believe that stretch-shortening drills performed horizontally can improve the speed component of athletes' speed-power properties.

Conclusions

A combination of both vertical and horizontal depth jumping can aid running performance, especially in the case of sprinters in training. However, horizontal plyometric training in itself was more effective in improving running speed performance than solely vertical plyometric training. Thus, while planning a plyometric training programme for sprinters, coaches and physical education teachers should provide slightly more emphasis on horizontal plyometric training.

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