EFFECTS OF LOWER AND UPPER BODY PLYOMETRIC TRAINING ON CARDIOVASCULAR VARIABLES OF ATHLETES

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Abstract

Plyometric training is a form of specialised strength training that uses fast muscular contractions to improve power and speed in sports conditioning by coaches and athletes. Despite its useful role in sports conditioning programme, the information about plyometric training on the athlete's cardiovascular health have not been established in the literature. The purpose of the study was to determine the effects of lower and upper body plyometric training on cardiovascular variables of male athletes in Nnamdi Azikiwe University, Nnewi Campus. The study was guided by five null hypotheses. Quasi–experimental research design was adopted for the study. All male athletes in Nnewi Campus (Seventy-two) aged 18 to 24 years that measured 18.5 -25kg/m² in body mass index (BMI) constituted the population of the study. Thirty male athletes volunteered to participate in the study, but only twenty-three completed the study. The volunteered athletes were apparently healthy, physically active and free of any lower and upper extremity bone injuries for past one year and they had no medical or orthopedic injuries that may affect their participation in the study. Ten participants each were purposively assigned to one of the three groups: lower body plyometric training (LBPT), upper body plyometric training (UBPT) and control (C).Training consisted of six plyometric exercises: lower (ankle hops, squat jumps, tuck jumps) and upper body plyometric training (push-ups, medicine ball-chest throws and side throws) with low to moderate intensity. A modern automated blood pressure with monitor measured in mmHg was used to determine the heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP) and after which the mean arterial pressure (MAP) and rate pressure product (RPP) were calculated from SBP and DBP of male university athletes. The data were collated and analysed using Statistical Package for Social Science (SPSS) version 22.0.The research questions were answered using mean and standard deviation, while analysis of co-variance (ANCOVA) was used to test the hypotheses. The results revealed that athletes who were trained using LBPT and UBPT had reduced HR, SBP, DBP, MAP and RPP better than the control group. The findings also showed that athletes *who were trained using LBPT and UBPT indicated no significant differences following ten weeks plyometric training and those in the control group in all the cardiovascular variables. Based on the findings, it was recommended among others that coaches should include both LBPT and UBPT as part of athletes' overall training programme of university athletes to optimise performance as well as reduce the risk of cardiovascular diseases and promotes good healthy lifestyle.*

Introduction

The term plyometric may sound unfamiliar, but most sports enthusiasts have at one time or the other taken part in plyometric training. It is a form of specialised strength training that uses fast muscular contractions to improve power and speed in the sports conditioning programme by coaches and athletes. It has been a useful training technique for optimising performance in most popular sports by coaches and athletes in the preparation for professional competitions. Plyometric training involves a rapid stretching of muscle (eccentric phase) immediately followed by a concentric or shortening action of the same muscle and connective tissue. This rapid combination of eccentric and concentric action by muscle is called Stretch-Shortening Cycle (SSC). As a muscle stretches and contracts eccentrically, it lengthens while it contracts to produce storable energy (Abbas, 2005). The stored elastic energy within the muscle is used to produce more force than can be provided by using only concentric contraction alone (American College of Sports Medicine, 2009). Plyometric training bridges the gap between speed and strength. The two main categories of plyometrics are lower and upper body plyometric training (Quinn, 2013). Lower body plyometric training includes jumps, hops, bounds and lunges, while the upper body plyometric training requires the use of a medicine ball throws and plyometric push-ups (Walker, 2014). Studies have shown that plyometric training greatly improved measures of muscular strength, power, speed, vertical jump, leg strength, agility and running economy after the training (Beardsley, 2014; Matz, 2013; Quinn, 2013).

Plyometric training originated in the late 1960's from Soviet Union and was developed by Russian exercise scientist and coach, Yuri Verkhoshansky (Beardsley, 2014). Verkhoshanky wanted to discover ways to develop the jumping ability of his Olympic athletes. He used depth jumps focusing on reducing the ground contact times, switching from eccentric to concentric action more quickly to increase the speed and explosiveness of his athletes. The landing and takeoff were executed in an extremely short period of time. This training process at that time was called "shock method" (Patalas, 2013). The term "plyometric" was later coined by an American athlete Fred

Wilt, who after watching the Soviets dominate the Olympics during the 60-70's, decided to investigate how they were training (MacDonald, 2013). As the Soviets began to produce superior athletes in various sports including track and field, gymnastics and power lifting, interest regarding this training increased. Since then other sports across the globe started incorporating plyometrics into their sports training programmes to help their athletes become faster, and exhibit more explosive power.

The cardiovascular health is currently a global issue to all and sundry. Cardiovascular relates to the circulatory system, which comprises the heart and blood vessels that carry nutrients and oxygen to the tissues of the body and remove carbon dioxide and other wastes from the body (Medicine Net, 2015).Therefore athletes' cardiovascular responses to training cannot be ignored. Training places an increased demand on the cardiovascular system. The cardiovascular variables fluctuate on beat to beat basis during any physical activity depending on the type of training. The variables may include the following: Heart Rate (HR), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Mean Arterial Pressure (MAP), Rate Pressure Product (RPP) and to mention but a few. Plyometric training may demonstrate strong influences on cardiovascular variables in student-athletes which are capable of antagonizing the sympathetic effects on the heart and blood vessels. Independently, the decrease in blood pressure (BP), heart rate (HR), mean arterial pressure (MAP) and rate pressure product (RPP) reduces the risk of cardiovascular diseases such as arterial hypertension.

Despite the important role of the plyometric training, the information about this kind of training on the athlete's cardiovascular health especially on BP has not been described in the literature. Only a few studies known to the researcher have directly investigated the cardiovascular responses following plyometric training but without including the athletes. These that few studies investigated the cardiovascular responses to plyometric training have focused on the elderly, obese and patients with different aliments. More so, athletes have different health and fitness requirements from other general population in any sport conditioning programme. The study by Lobo (2012) on cardiovascular responses to plyometric focused on elderly; Moro, Ewan, and Gerardo (2013) used the obese individuals, while Ankur and Maulik (2013) used the patients with different aliments and they were not done in Nigeria. There is need therefore for this study, so as probably to close this existing gap and provide a baseline data for future research. Therefore, the purpose of this study was to determine the effect of 10 weeks lower and upper body plyometric training on cardiovascular variables of male athletes in Nnamdi Azikiwe University, Nnewi Campus.

Method

The study adopted a quasi-experimental research design. It was pretest, posttest and control group but no randomisation. It is a design where the observations are made in the study groups before and after interventions and subjects are assigned to groups but without proper randomisation. This design was also considered appropriate because it was not possible to place participants in groups by random assignment without disrupting the athletes in their team groups and the training venues. The participants were purposively assigned into one of the three groups: two experimental groups using LBPT, UBPT and Control based on the type of sports the athlete plays.

The target population of this study consisted of all the male athletes in Nnamdi Azikiwe University, Nnewi Campus. However, only the volunteered male athletes were used for the study. Seventy –two university male athletes aged 18 to 24years constituted the population of the study. Thirty male athletes volunteered to participate in the study, but only twenty-three completed the study. The volunteered athletes were apparently healthy, physically active, and free of any lower and upper extremity bone injuries for past one year and they had no medical or orthopedic injuries that may affect their participation in the study. Ten athletes each were purposively assigned to one of the three groups: lower body plyometric training (LBPT), upper body plyometric training (UBPT) and control (C) based on the type of sports the athlete plays.

Athletes had previous strength training experience and were working out on a regular basis. However, these athletes neither had previous plyometric training experience nor were they undergoing assessment of any cardiovascular response to any exercise.

A week before conducting the study, all participants were gathered at the gymnasium room and received a complete explanation of the purpose of the study and the need to complete the training programme. During this session, each participant was instructed in the proper form and technique of lower and upper body plyometric exercises through explanation of proper technique, demonstration and risk involved (familiarisation session). Pretest and posttest were conducted before and after 10 weeks plyometric training programme. The main variables measured in this study were HR, SBP, DBP, MAP and RPP parameters, after which it was analysed by an expert in the field of cardiology. Additional variables include age; height and weight (BMI) of the participants were also measured.

Body mass index (BMI) measure was used as an estimate of body composition. Body height was measured to an accuracy of 1cm, with the participant in an upright position with a Standard Stadiometre. Body weight was measured to the nearest 0.1kg, with participants lightly dressed and in stocking feet. BMI was calculated using the standard formula: {mass (kg)/height (m)} ^{2}. The participants that measured between 18.5 - 25kg/m² (Normal Weight) in BMI were used for the study.

The LBPT and UBPT groups were required to perform three times per week on alternate days (Tuesday, Thursday and Saturday) for 10 weeks. Thus, the programme entailed thirty training workouts for each participant in both experimental groups. Training session in both experimental groups lasted 50 minutes and began with a 10-minute warm-up: 5 minutes of jogging and 5 minutes stretching, 35 minutes LBPT and UBPT, and 5 minutes cooling down. Both experiments were performed on outdoor at different venues. The training programme employed by each experimental group is outlined in Table 1. Specifically, the control group was advised to avoid plyometric exercises and continue with their normal training routine. The participants were also advised to avoid alcohol, caffeine and smoking throughout the period under study.

Table 1: Training programme for the Lower and Upper Body Plyometric Training (LBPT and UBPT)

LBPT **Exercice X sets X reps**	**UBPT** **Exercice X sets X reps**
Wk 1 ankle hops 3 X 3 X 8	push-ups 3 X 3 X 8
Wk 2 ankle hops 3 X 5 X 10	push-ups 3 X 5 X 10
Wk 3 ankle hops 3 X 7 X 10	push-ups 3 X 7 X 10
Wk 4 ankle hops 3 X 8 X 10	push-ups 3 X 8 X 10
Wk 5 squat jumps 3 X 7 X 10 X 10	chest throws (medicine ball) 3 X 7
Wk 6 squat jumps 3 X 8 X 10 10	chest throws (medicine ball) 3 X 8 X
Wk7 squat jumps 3 X 10 X 10 X 10	chest throws (medicine ball) 3 X 10
Wk 8 tuck jumps 3 X 8 X 10 10	side throws (medicine ball) 3 X 8 X
Wk 9 tuck jumps 3 X 10 X 10 X 10	side throws (medicine ball) 3 X 10
Wk 10 tuck jumps 3 X 12 X 10 10	side throws (medicine ball) 3 X 12 X

Table 1 showed that during the first weeks, the training intensity was 50-60% of 1RM with one minute rest between sets in order to familiarise themselves with the training. For the remaining nine weeks, the intensity and duration of exercise were gradually increased both in sets and repetitions to accommodate the scientific principle of progressive over-load. From fourth week, the load was raised to 60-70% of 1RM with two-three minutes rest between sets and maintained until the final week of the programme. However, the duration of each training session, as well as the duration of rest between sets, was the same for both groups. Treatment sessions were initiated between 4- 6pm. Only low to moderate intensity training was used for the study. The training programme was also based on the interval training principle, which comprised series of plyometric exercises work intervals, interspersed with relief intervals. The progressive resistance training principle was also used in determining the dosage at every period of training.

The data were collated and analysed using statistical package for social science (SPSS) version 22.0.The research questions were answered with mean and standard deviation, while statistical analysis was performed using analysis of covariance (ANCOVA).The level of significance was set at $P \leq 0.05$. However, ANCOVA was used in the study since the volunteered athletes were used intact without proper randomisation which indicated that the subjects were not equal at the baseline and the population was small. ANCOVA removes the initial differences between groups so that the selected or pretested groups can be correctly considered as equivalent for generalisation.

Results

The results of the study showed great reduction in cardiac variables in both lower and upper body plyometric training groups, when the post training variables were compared with the pre training cardiac variables.

Table 2 also shows that athletes who were trained using LBPT had reduced posttest mean scores of HR, SBP, DBP, MAP and RPP better than their counterparts in the control group. In Table 3, athletes who were trained using UBPT had reduced posttest mean scores of HR, SBP, DBP, MAP and RPP better than those in the control group. Whereas in the control group, no significant differences were found between the pre training and post training values. Analysis of covariance (ANCOVA) indicated that using LBPT and UBPT have no significant effect on the heart rate, systolic blood pressure, diastolic blood pressure, mean arterial blood pressure and rate pressure product of university athletes and those in the control groups. Thus, all the null hypotheses (Ho1-5) were therefore not rejected.

Table 2: Mean and Standard Deviation scores on HR, SBP, DBP, MAP and RPP of athletes who were trained using lower body plyometric training (LBPT)

Variables		Pretest		Posttest	
	N	Mean	SD	Mean	SD
Experimental Group					
HR	8	63.38	10.81	56.38	7.27
SBP	8	110.38	10.14	104.13	8.59
DBP	8	76.38	7.98	66.25	6.45
MAP	8	87.71	8.25	78.88	5.85
RPP	8	6987.25	1344.80	5842.00	651.99
Control Group					
HR	8	67.00	7.80	61.50	7.98
SBP	8	114.50	15.48	107.13	15.08
DBP	8	75.13	10.89	70.25	12.28
MAP	8	88.53	8.62	82.53	9.53
RPP	8	7602.13	755.25	6648.63	1605.97

HR=heart rate, SBP= systolic blood pressure, DBP= diastolic blood pressure, MAP= mean arterial pressure, RPP=rate pressure product

Table 3: Mean and Standard Deviation scores on HR, SBP and DBP of athletes trained who were using upper body plyometric training (UBPT)

Variables		Pretest		Posttest	
	N	Mean	SD	Mean	SD
Experimental Group					
HR	8	59.13	16.85	56.13	7.34
SBP	8	110.50	7.48	102.25	4.30
DBP	8	70.50	5.61	72.38	3.81
Control Group					
HR	8	67.00	7.80	61.50	7.98
SBP	8	114.50	15.48	107.13	15.08
DBP	8	75.13	10.89	70.25	12.28

HR=heart rate, SBP= systolic blood pressure, DBP= diastolic blood pressure, MAP= mean arterial pressure, RPP=rate pressure product

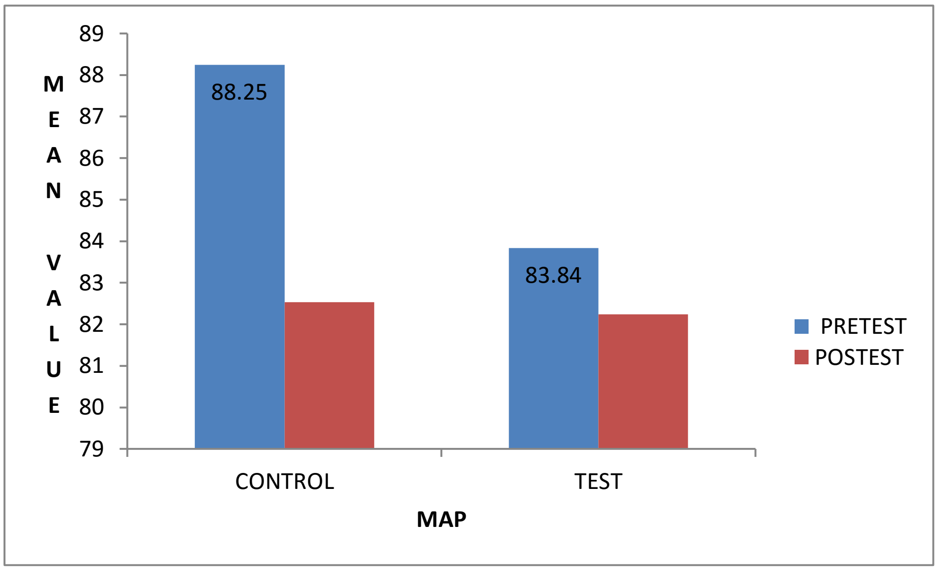

Fig.1. Bar chart showing MAP values for both control and test
MAP= mean arterial pressure

Figure 1 show that athletes who were trained using UBPT had slightly reduced posttest mean scores of MAP (82.24±3.34) better than their counterparts in the control group (82.52± 9.53).

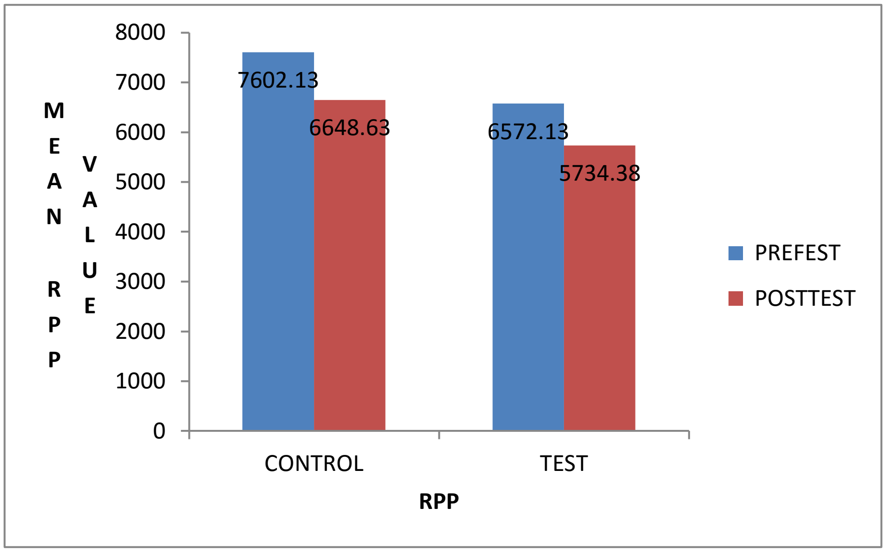

Fig.2. Bar chart showing RPP values for both control and test
RPP= rate pressure product

The Figure 2 also revealed that athletes who were trained using UBPT had reduced posttest mean scores of RPP (5734.38) better than the control group (6648.63).

Table 4: Age, BMI adjusted comparison in cardiovascular parameters between the athletes who were trained using lower body plyometric training and those in the control group at post-test condition

Variables	Control	LBPT	F-value	P-value
HR	61.50 ± 7.98	56.37 ± 7.26	2.13	0.169
SBP	107.12 ± 15.07	104.12 ± 8.59	0.20	0.659
DBP	70.25 ± 12.27	66.25 ± 6.45	0.59	0.455
MAP	82.52 ± 9.53	78.87 ± 5.84	0.74	0.406
RPP (x1 0^3)	6.65 ± 1.60	5.84 ± 0.65	1.64	0.225

HR=heart rate, SBP= systolic blood pressure, DBP= diastolic blood pressure, MAP= mean arterial pressure, RPP=rate pressure product
Values are represented as Mean± Standard Error

Table 4 shows mean cardiovascular parameters of athletes who were trained using the lower body plyometric training and those in the control group at post-test condition. Analysis of covariance (ANCOVA) indicated lack of significant differences between the LBPT group and those in the control group in all the parameters.

Table 5: Age, BMI adjusted comparison in cardiovascular parameters between those athletes who were trained using the upper body plyometric training and those in the control group at post-test condition

Variables	Control	UBPT group	F-value	P-value
HR	61.50 ± 7.98	56.12 ± 7.33	1.96	0.186
SBP	107.12 ± 15.07	102.25 ± 4.30	0.66	0.432
DBP	70.25 ± 12.27	72.37 ± 3.81	0.24	0.628
MAP	82.52 ± 9.53	82.23 ± 3.34	0.002	0.969
RPP (x 10^3)	6.65 ± 1.60	5.73 ± 0.75	1.97	0.186

HR=heart rate, SBP= systolic blood pressure, DBP= diastolic blood pressure, MAP= mean arterial pressure, RPP=rate pressure product

Values are represented as Mean± Standard Error

Table 5 shows mean cardiovascular parameters of athletes who were trained using the upper body plyometric and those in the control group at post-test condition. Analysis of covariance (ANCOVA) indicated lack of significant differences between the UBPT group and the control in all the parameters.

Discussion

The results of the present study indicate that the ten-week lower and upper body plyometric training can improve the cardiovascular health of young athletes. The finding of this study revealed that there was no significant difference in the mean scores of HR, SBP, DBP, MAP, RPP of athletes who were trained using lower and upper body plyometric training. Although many studies have examined the effects of plyometric training on cardiovascular variables depending on the type of plyometric, intensity, duration of exercise and different methodologies used to evaluate different individuals of general population, results are sometimes dispersed. In fact the data available in literature, these few studies that investigated the cardiovascular responses to plyometric training have focused on the elderly, obese and patients with different aliments. More so, athletes have different health and fitness requirements from other general population in any sport conditioning programme. The study by Lobo (2012) on cardiovascular responses to plyometric focused on elderly; Moro, Ewan, and Gerardo (2013) used the obese individuals, while Ankur and Maulik (2013) used the patients with different aliments and they were not done in Nigeria. So, the present study was aimed at bridging this gap.

This is the first study to compare the effects of lower and upper body plyometric training on cardiovascular variables of young university athletes. The results demonstrated that athletes who were trained using lower and upper body plyometric training had reduced heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure and rate pressure product better than those in the control group. However, the findings of the study supported what was initially stated by Arazi, Asadi, Rahimzadeh and Moradkhani (2013) that the low intensity and high intensity protocols showed greater reduction in SBP and DBP at 40-70th minute in 10-50th minute post exercise. It therefore concludes that plyometric exercise can reduce SBP and DBP for post-exercise hypotension. It could be because the present study used low to moderate intensity plyometric training which leads to greater reduction in cardiovascular parameters. These findings suggested that LBPT and UBPT could be used in an overall training programme to properly prepare university athletes for competitions such as NUGA and NIMSA while it concomitantly promote good healthy lifestyle.

Studies done in the past have focused on the information concerning the effect of moderate intensity resistance, aerobic or combined training on blood pressure in overweight and obese individuals (Suleen, Satvinder, Hills & Sebely, 2012). Evidence suggests that there are no any significant changes in SBP, DBP or augmentation index (AI) between the interventions when assessed the entire cohort, although there were significant improvement in a subgroup of responders. The strongest points of this study included the multiple variables studied (HR, SBP, DBP, MAP and RPP) especially on BP, and most importantly the focus on the young university athletes. When compared, the two studies used the moderate intensity but the probable reason for this could be that the present study utilised proper plyometric training technique while Suleen et al. used training methods. It could thus be deducted from this study that plyometric training produce lower cardiovascular response than concentric exercise alone (Ankur & Maulik, 2013). However, there is need for coaches to plan the preparation phase for competitions to involve low intensity plyometric training of longer duration. This will give athletes a base as they move into more intense plyometric training such as depth jump during the second half of the preparatory phase for competitions as well as promote good healthy lifestyle.

This finding was not surprising because plyometric training involves lengthening (eccentric) muscular contraction quickly followed by shortening (concentric) muscular contraction. This finding is in line with views of Bhavna and Sarika (2010) to the effect that eccentric and concentric group improved but significantly more improvement was seen in concentric group when compared to eccentric group. The result of the study showed that eccentric exercise produced lower cardiovascular response than concentric exercise. A possible explanation of this could be that the lower and upper body plyometric training involves first the movement of eccentric immediately followed by a concentric muscle contraction. The findings could be attributed to the proper application of plyometric techniques which produced better result. The findings are also in agreement with that of Ankur and Maulik (2013) which revealed that eccentric exercise produced lower cardiovascular response than concentric exercise. These findings suggested that LBPT and UBPT could be used in an overall programme to properly prepare athletes for competition in events that require both aerobic and anaerobic metabolism components.

Plyometric training can be used often by athletes who need to generate quick burst of maximal effort, movement required in most popular sports such as football, basketball, track and field, racket games, rugby and martial arts in a short amount of time (Comyns, 2012; Idea Health Fitness, 2009; Quinn, 2013). Despite the numerous studies on plyometric training, only a few studies (Arazi, Abbas, Seyed, & Seyed, 2014) compared the effect of post-plyometric exercise hypotension and heart rate in normotensive individuals, and they found out that after an acute exercise bout, blood pressure (BP) levels are reduced for minutes or hours in relation to post-exercise levels. This phenomenon is called post-plyometric exercise hypertension and has been highly recommended for the treatment and prevention of arterial hypertension. Additionally, Moro, et al. (2013) investigated the blood pressure and heart rate responses to two resistance training techniques of different intensity in obese individuals, the subjects showed the same cardiovascular response to different intensity.

The findings of the present study is not in accordance with Arazi, et al. (2014) that suggested that plyometric exercise increased heart rate, systolic and diastolic blood pressure, and RPP after each set of exercises. Plyometric did not induce any significant changes in muscle soreness. These findings suggested that LBPT and UBPT could be used in an overall training programme to properly prepare university athletes for competitions such as NUGA and NIMSA while it concomitantly promote good healthy lifestyle.

Conclusion

The study revealed that the use of LBPT and UBPT had reduced the cardiovascular variables especially the BP of young university athletes better than those in the control group. This implies that these two plyometric training can principally improve the explosive abilities of an athlete while it concomitantly promotes good healthy lifestyle. Moreover, in this study, athletes progress gradually from simple plyometric training to more intense drills.

However, this study has some important limitations, such as the small population size, the discrepancies in the BP measurement procedures and the subjects were not camped to monitor and control their behaviours at home therefore they may tend to behave mechanically and fake most of their actions which may likely interfere with the dependent variables. Further research is needed to determine whether lower and upper body plyometric training could affect the cardiovascular variables and ECG of young athletes.

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