Niğde Ömer Halisdemir Üniversitesi
Spor Bilimleri Fakültesi
BEDEN EĞİTİMİ VE SPOR BİLİMLERİ DERGİSİ

ALT VE ÜST EKSTREMİTE PLİOMETRİK ANTRENMAN PROGRAMININ GENÇ BASKETBOLCULARIN MAKSİMAL KUVVET DÜZEYLERİNE VE VÜCUT YAĞ ORANLARINA ETKİSİ

THE EFFECT OF LOWER AND UPPER EXTREMITY PLYOMETRIC EXERCISE PROGRAM ON MAXIMAL STRENGTH AND BODY FAT RATIO OF YOUNG BASKETBALL PLAYERS

Gönderilen Tarih: 26/06 /2020
Kabul Edilen Tarih: 02/10/2020

Umut CANLI
Tekirdağ Namık Kemal Üniversitesi, Beden Eğitimi ve Spor Yüksekokulu, Tekirdağ, Türkiye
Orcid: 0000-0001-8603-3492
Muammer BAYRU
Ebru Nayim Fen Lisesi, Tekirdağ, Türkiye
Orcid: 0000-0003-2169-2598

* Sorumlu Yazar: Umut CANLI, Tekirdağ Namık Kemal Üniversitesi, Beden Eğitimi ve Spor Yüksekokulu, ucanli@nku.edu.tr

Alt ve Üst Ekstremite Pliometrik Antrenman Programının Genç Basketbolcuların Maksimal Kuvvet Düzeylerine ve Vücut Yağ Oranlarına Etkisi

ÖZ

Araştırmanın amacı genç basketbolculara 9 hafta boyunca uygulanan alt ve üst ekstremite pliometrik antrenman programının maksimal kuvvet düzeylerine ve vücut yağ oranlarına etkisini belirlemektir. Araştırmaya 30 erkek basketbolcu gönüllü olarak katılmıştır. Örneklem grubu randomizasyon yöntemi ile kontrol grubu (n = 15; yaş = 14,7±0,97) ve deney grubu (n = 15; yaş = 14,8±0,54) olmak üzere iki gruba ayrılmıştır. Katılımcıların boy uzunluğu, vücut ağırlığı ve vücut yağ yüzdeleri ölçülmüştür. Maksimal kuvvet düzeyleri 1 tekrar maksimum (1 TM) leg press, 1 TM leg curl, 1 TM bench press, 1 TM overhead press ve 1 TM high pulley testleri ile belirlenmiştir. Ayrıca katılımcıların sıçrama kuvveti counter movement jump (CMJ) testi ile belirlenmiştir. Core kuvveti ise Sport-Specific Core Muscle Strength and Stability Plank Testi ile belirlenmiştir. Grubun (test ve kontrol) ve ölçümün (ön test ve son test) kombine etkisini test etmek için iki yönlü tekrarlanan ölçümler varyans analizi (ANOVA) yapıldı. Kontrol ve deney grubunun boy uzunluğu değişkeni açısından grup-ölçüm ortak etkisi incelendiğinde gruplar arasında anlamlı bir farklılık tespit edilmiştir ($F_{(1-28)}$ = 5,27, p<,05). Vücut ağırlığı ve vücut yağ yüzdesi değişkenleri açısından grup-ölçüm etkisi incelendiğinde ise gruplar arasında anlamlı bir farklılık tespit edilmemiştir (sırasıyla; $F_{(1-28)}$ = 1,86; 5,22, p>,05). Grupların 1 TM leg curl, CMJ, 1 TM bench press, 1 TM overhead press, 1 TM high pulley değişkenleri ile grup-ölçüm sonuçları incelendiğinde deney grubu lehine anlamlı farklılıklar tespit edilmiştir (sırasıyla; $F_{(1-28)}$ = 16,13; 5,20; 4,65; 4,59; 14,7, p<,05). Pliometrik antrenman programının leg press ve plank değişkenleri üzerindeki grup-ölçüm ortak etkileri incelendiğinde gruplar arasında anlamlı bir farklılık tespit edilmemiştir (sırasıyla; $F_{(1-28)}$ = 0,77; 0,02, p>,05). Sonuç olarak; alt ve üst ekstremite pliometrik antrenman programı genç basketbolcuların maksimal kuvvet düzeylerinin gelişmesine katkı sağlamıştır.

Anahtar Kelimeler: 1 tekrar maksimum, vücut yağ oranı, basketbol

The Effect of Lower and Upper Extremity Plyometric Exercise Program on Maximal Strength and Body Fat Ratio of Young Basketball Players

ABSTRACT

The aim of the study is to identify the effects of lower and upper extremity plyometric training on maximal strength and body fat ratio of young basketball players, in a 9 week period. 30 male basketball players voluntarily participated in the study. The sample group was distinguished into the control group (n = 15; age = 14.7 ± 0.97) and the test group (n = 15; age = 14.8 ± 0.54) by randomization. Body height, body weight and body fat ratio of each participant was measured. Maximal strength levels were determined by testing 1 repeat maximum (1 TM) leg press, 1 TM leg curl, 1 TM bench press, 1 TM overhead press and 1 TM high pulley. In addition, the jump strength of the participants was determined by the counter movement jump (CMJ) test. Core strength was determined by the Sport-Specific Core Muscle Strength and Stability Plank Test. Two way repeated measures analysis of variance (ANOVA) was performed to test the combined effect of group (intervention and control) and measure (pre-test and post-test). There was a significant difference between groups according to the body height variable. ($F_{(1-28)}$ = 5.27, p<.05). There was no significant difference between groups according to body weight and body fat percentage variables ($F_{(1-28)}$ = 1.86; 5.22, p>.05; respectively). Significant differences were found in favor of the test group according to 1 RM leg curl, CMJ, 1 RM bench press, 1 RM overhead press, 1 RM high pulley variables. ($F_{(1-28)}$ = 16.13; 5.20; 4.65; 4.59; 14.7, p<.05; respectively). Additionaly, There was no significant difference between groups according to leg press and plank variables. ($F_{(1-28)}$ = 0.77; 0.02, p>.05; respectively). Consequently, the lower and upper extremity plyometric training program contributed to the improvement of the strength level of young basketball players.

Key Words: 1 repetition maximum, body fat percentage, basketball

INTRODUCTION

Basketball is a game that consists of explosive actions such as, speed, acceleration, shooting, rebounding, layup shooting, blocking, organized fast breaks; and requires that these dynamic explosive skills, which constanly change in speed, are applied multiple times throughout a competitive game[1]. Good performance of athletes on the court is connected with the improvement of their basketball skills and basketball skills are affected by many factors such as; elasticity, muscle strength and endurance, and body composition[2]. Among these factors strength is regarded as one of the most important element which affects the level of athletic efficiency. Strength, provides many athletic benefits to athletes[3]. Especially, its contribution to the application of certain motoric characteristics of athletes, is one of the most important benefits of the strength level. In basketball, during practice or a game, strength is needed for fast direction changes, speed performance and high level application of jump performance[4].

In order to support strength improvement and increase strength level in a short period of time, plyometric exercises are the most important among widely used exercise models. The importance of plyometric exercise on strength development, especially for sports branches like football, basketball, volleyball, sprinting and handball which mainly require fast strength, is strongly emphasized[3]. In addition to supporting the improvement of physical performance plyometric exercises also contributes to improving the balance ability of the body and the technical skills specifically for a sports branch[5].

Plyometric exercises are also known as jumping exercises and these exercises have shown to improve jumping performance[6]. However, in recent years besides plyometric exercises targeted to lower extremity, development of various exercises for upper extremity continue and their effects are observed. Basketball players have to intensely use the lower and upper parts of their body. For example, running, jumping and faking require lower extremity, while moves like shooting, rebounding and blocking require upper extremity strength and skills. For this reason, upper extremity plyometric exercises alongside lower extremity plyometric exercises are believed to positively affect skill and strength performance.

Practiced by elite athletes for many years, plyometric exercises[6]have become an exercise model often practiced by adolescent athletes in the recent years[7]. Yet, when applying plyometric exercises to adolescents it is essential to take into account the age and developmental period of the individual[8]. Furthermore, it is a precondition for plyometric exercises that the muscle and skeleton systems are developed to an adequate degree[3], and suggested that the loading intensity is kept low. There are study findings that indicate that in addition to improving strength, plyometric exercises also contribute to the improvement of speed[9], quickness[10], balance, elastacity[11] and anaerobic strength, for adolescents. Especially in team sports directed to speed and quickness, plyometric exercises applied to adolescents have shown positive impact on their jumping, sprinting and shooting performance[6]. Additional studies put forward that fast and explosive jumping in plyometric exercises contribute to the improvement of explosive strength performance[12]. Review of literature resources shows that observations on the overall strength and explosive strength level differences were recorded from plyometric exercises applied to young athletes. It is also understood that there is quite a limited amount of studies researching the improvement of maximal strength levels by plyometric exercises. At this point of the research, it is taken into consideration that lower and upper extremity plyometric exercise programs applied to young basketball players can contribute to the improvement of the maximal strength level of basketball players. This idea forms one of the hypotheses of the study. Also, the consideration that the findings from this research will contribute to literature increases the importance of the study. There are studies stating that strength exercises in young people not only positively affect their strength parameter but also have a benefit on their body composition[13], especially a decreasing effect on body fat percentage[14]. Another hypotheis of the study is that lower and upper extremity plyometric exercises positively affect body fat ratio of young basketball players. Furhtermore, the aim of the study is to research the effect of lower and upper extremity plyometric training program on the maximal strength level and body fat ratio of young basketball players.

MATERIALS AND METHODS

Subjects

30 male basketball players, trained and competing in local youth league games, voluntarily and actively participated to the study. The sample group was distinguished into the control group (n = 15; age = 14.7 ± 0.97) and the test group (n = 15; age = 14.8 ± 0.54) by randomization. Criteria for non-acceptance to the study includes; a chronic ankle instability and lower extremity muscle-skeleton system injury in the prior 6 month period of the study. The tests and exercise programs were clearly defined. Before the initiation of the study, the participants and their parents were informed in written and asked to sign a form. Ethics committee approval was received from Tekirdağ Namık Kemal University Medical Facuty Non-Interventional Clinical Research Ethics Committee Directoral (Ethics Committee Meeting Date: 28.04.2020, Research Protocol Number: 2020.97.04.21). The study was applied according to the Helsinki Declaration.

Data Collection

Body Height Measurement

Portable stadiometer with 0.1 cm sensitivy was used for body height measurement. Participants were measured bare foot. Participants were positioned with their heads up, the soles of their feet flat on the floor, knees tense, heels adjacent and the body upright during the measurement.

Body Weight Measurement

Body weight of participants were measured by an electronic weighing machine with 0.1 kg sensitivity. Participants were bare foot and wearing only a short and t-shirt during the measurement.

Skinfold Thickness Measurement

Holtain brand skinfold caliper which applies 10g/mm² pressure in every gap with 0.2 mm sensitivity was used for sub surface skin measurement. Measurements were done from the right side of the participants' bodies while standing in an upright position. After skin and sub surface skin fat 1 cm far from the measurement point was pulled from the muscle tissue with the index finger and thumb, the caliper was used for measurement. Results seen 2-3 seconds later on the indicator of the caliper were recorded milimetrically. Every participant was measured twice and the average was taken. If the difference between two tests were not within the 1-2 mm limit, then the test was repeated[15]. In the study four skinfold region measurements were done as below.

Triceps: While the arm was released freely next to the body, measurement was taken vertically from the midpoint of the distance between the acromion and olecranon.

Suprailiac: While participants feet were positioned adjacent, body upright and arms released freely from the sides, measurement was taken diagonally from just above the ilium on the midaxillary line.

Subscapula: Measurement was taken diagonally with a 45 degree angle, 1-2 cm below the inferior angle of the scapula.

Biceps: While participants were standing and their arms were slightly suspended, the measurement was taken from the point on the acromion line and the elbow pit when the biceps muscles were most protruded anteriorly[16].

Determination of Body Fat Percentage

By using the skinfold thickness the Durnin-Womersley (D-W) formula (Durnin and Womersley, 1974)[17] was applied to seperately determine the body density (BD) of the participants. Following, the Siri formula (Siri, 1961)[18] was used to calculate the body fat percentage (BFP). The Durnin-Womersley and Siri formulas used in the study are stated below.

D-W equation = BD = 1.1533 - (0.0643 x L)
L= log of the total of the 4 skinfolds (mm)
Siri equation = % BFR = (495 / BD) – 450

Indirect Determination of 1 Repetition Maximum

When used and applied correctly, the test is quite easy, effective, affordable and safe. By using the formulas, 1 RM value can be indirectly calculated with the maximal repetition between 2 and 20 for any weight. Repetitions less than 20 for weight lifting and a linear or curvilinear relationship between the percentages of 1 RM, allow to calculate 1 RM with the formulas. Due to the fact that the research group consists of adolescents and that they are not adequately experienced in strength practicing techniques, it was decided that determination of direct 1 maximum repetition would be dangerous and high risk. Therefore, bench press, overhead press, high pulley press, leg press and leg curl press 1 RM values of the research group was calculated with indirect methods. The lifting technique to be indirectly determined in terms of 1 RM is chosen and the athlete begins warming up with this technique. 1-5 minutes resting time was given after the warm up. Later, lifting continued with few repetitions while weight was gradually increased. The maximum weight the athlete could lift with 10 repetitions was determined[19]. The formula used to indirectly calculate 1 RM is below.

1 RM= (Lifted Weight) / [1,0278-(Repetition*0,0278)]

Counter Movement Jump Test

Countermovement jump was measured via a Myotest accelerometer system (Myotest® Performance Measuring system, Sion, Switzerland). The device calculates jump height through change in position in the vertical plane (2D accelerometer with sampling frequency of 500 Hz). The device was attached to a belt and affixed vertically to the middle of the lower back and all subjects were informed to avoid any involuntary movement in the vertical plane during jumps that could affect jump height. The Myotest device has been shown to be valid and reliable to measure CMJ (ICC = 0.96)[20].

During the session, subjects performed 3 trials of squat jump from a 90° knee joint angle. They were instructed to avoid any countermovement in this position to eliminate utilization of elastic energy. Similarly, three trials were performed for the CMJ and subjects were instructed to perform CMJ test to a self-selected depth. During both tests the subjects were instructed to jump “as high as possible”. Rest intervals between trials were approx. 30-60 seconds and the highest jump was recorded for further analysis.

Sport-Specific Core Muscle Strength and Stability Plank Test

The protocol composed by Mackenzie (Mackenzie, 2005)[21] was used for measuring core stability performance. The validity and reliability studies of sport-specific core muscle strength and stability plank test was undertaken by Tong, Wu and Nie (2014)[22]. This test is used for observing the improvement of core strength and core stability of athletes in a 180 second time period. To execute the test a flat floor, a mat, a chronometer and one person for assistance is required. The assistant’s task is to notify the athlete the next move. The test begins with 60 seconds planking then continues with simultaneously lifting arms and legs (i.e. right arm-left leg) in 15 second intervals while retaining the position. During the last 30 second interval the athlete returns the starting position (plank) and completes the 180 second long test.

Training Protocol

The lower and upper extremity plyometric training program was prepared by the researcher according to the athletes ages and their history in strength exercises. The plyometric exercise applied to the test group was designed in two parts. In the first part before every exercise session, as part of the plyometric exercise a warm up consisting of dynamic strenghtening and stretching exercises were applied. The main parts of the plyometric exercises took place in the second part. The first 5 weeks, twice each week an exercise program consisting of 10 moves were applied to the test group. Taking into consideration the change in the strength level of the test group a different plyometric exercise was designed by re-arranging the moves and exercise-rest intervals, for the last 4 weeks of the research. Circuit training method was used in the plyometric training applied to this group. The plyometric training applied to the test group took approximately 30-35 minutes and the group moved on to basketball practice after completing the plyometric training. The total time of the practice was 90 minutes. The test group had the plyometric training and basketball practice on Mondays and Fridays while only having basketball practice on Wednesdays. The control group only had basketball practice three days of the week (Monday, Wednesday and Friday). The basketball practice applied to both groups were conducted with the same methodology by their own basketball coaches. The basketball practice included exercises to improve technique and also tactical drills. The basketball practice applied to the control group was 90 minutes.

Detailed information about the warm up, the move sequence and exercise-rest intervals of the main parts are presented in plyometric training program
.

Plyometric training program

The first 5 weeks of plyometric training program			The last 4 weeks of plyometric training program		
Warm up exercises	**Exer. no**	**Plyometric exercises**	**Warm up exercises**	**Exer. no**	**Plyometric exercises**
Heel walking - 10 meters	1	Basic box jump	Squat to stand - 8 reps	1	Clapping push up
Toe walking - 10 meters	2	Lat pull down (with theraband)	Straight leg raises - 8 reps each leg	2	Explosive step up
Forward lunges with trunk rotation – 12 reps	3	Continue.broad jumps	Groiners - 10 reps	3	Bench press with theraband
Inchworm push up - 8 reps	4	Explosive bosu push-up	Leg swings front-to-back & side-to-side - 10 reps each leg	4	Squat jumps
Rollovers into V- sits - 8 reps	5	Jumping lunges	Jumping jack - 15 reps	5	Ladder with medicine ball
Spiderman lunges with vertical rotation - 8 reps	6	Press jacks (with 5 kg medicine ball)	Side to side jumps	6	Overhead press (with 5 kg dumbell)
Bent knee iron cross -12 reps	7	Shoulder press (with theraband)	Isometric push up - 15 sec hold	7	Plank skiers
Stretching of whole body	8	Lateral box jumps	Stretching of whole body	8	Skater hoops
	9	Twrowing medice ball 2 kg		9	Burpee
	10	Front to back hurdle hop		10	Side shuffle with chest press

- The plyometric training program for the first 5 weeks consisted of 25 second intervals of exercising and 25 second intervals of resting. The program was applied in 2 sets. 3 minute resting time was given between each set.
- The plyometric training program for the last 4 weeks consisted of 30 second intervals of exercising and 30 second intervals of resting. The program was applied in 2 sets. 2 minute resting time was given between each set.

Procedure

Anthropometric measurement was initially performed on the control and test groups the first day of the tests. Later, counter movement jump (CMJ) test, plank test and 1 RM bench press tests were performed, respectively. On the second day of the tests, overhead press, leg press, high pulley test and leg curl press tests were performed on the participants, respectively. Days 1 and 2 were separated by (at least) 48–72 hours. All tests were performed in a fatigue-free state. The measurements and tests, were applied to the participants by the same researchers in the beginning and in the end, in the exact same test order. Before each test session a standard warm up consisting of a 5 minute jogging following a 5 minute dynamic stretching, was performed. Especially before 1 RM tests, the repetition of moves applied to the participants were applied with low intensity weights. All tests were performed at the same time of the day (17:30–19:30) to avoid the effect of circadian rhythms on the study results.

Statistical Analysis

All statistical analyses were performed using the SPSS version 18.0 software (Statistical Package for Social Sciences; SPSS Inc., Chicago, IL, USA). All data were normally distributed (Skewness and Kurtosis values -1, +1)[23]. The homogeneity of the groups' variance was determined by the Levene test. Measurement by Box's Test of Equality of Covariance Matrices Test, presented that the covariance of the groups in combinations of two had no significant difference between each other. As a result of all of these tests, it was determined that conditions were provided for two way variance analysis by Mixed Meaurements to give reliable results. Two way repeated measures analysis of variance (ANOVA) was performed to test the combined effect of group (intervention and control) and measure (pre-test and post-test). Since only the body weight variable's Box's Test of Equality of Covariance Matrices was close to the level of significance of 0.001, the values of Pillai's Trace criteria were used for the body weight variable[24]. The findings are presented as mean ± SD (standard deviation), and an alpha level of p<.05 was considered statistically significant for all analyses.

FINDINGS

Table 1. Mean and standard deviation values of the age variable of the control and test group

Variables	**Control Group n=15**		**Test Group n=15**	
Age (year)	Mean	Sd	Mean	Sd
	14.7	0.97	14.8	0.54

The mean and standard deviation value of the age variable of the control group is 14.7 ± 0.97 years. The mean and standard deviation value of the age variable of the test group is 14.8 ± 0.54 years (Table 1). Pre-test and Post-test Mean and Standard Deviation Values of the Anthropometric Variables of the Control and Test Groups are presented in detail in Table 2. The measurement sections in Table 3, Table 5 and Table 7 explains that there are no significant differences between the points after the application (post-test) and before the application (pre-test) regardless of the group (all participants in the test and control groups were evaluated). However, the hypothesis of this study is relative to the common effect of MEASUREMENT x GROUP. Therefore, the second section of the table will be interpreted.

Table 2. Pre-test and post-test mean and standard deviation values of anthropometric variables of the control and test groups

Anthropometric Values	**Control Group n=15**				**Test Group n=15**			
	Pre-test		**Post-test**		**Pre-test**		**Post-test**	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Body height (cm)	177.2	8.37	177.4	8.33	174.0	7.17	174.7	6.69
Body weight (kg)	71.8	14.70	71.2	13.34	67.6	11.08	68.2	10.73
Body fat percentage (%)	21.6	6.68	21.0	5.70	21.9	5.22	20.9	5.00

Table 3. Results of two way repeated measures analysis of variance (Anova) regarding the anthropometric values of the groups

Ant. Values	Measure					Measure x Group					Error (Measure)		
	Sum of sq.	df	M.sq	F	p	Sum of sq.	df	M.sq	F	p	Sum of sq.	df	M.sq
Body height (cm)	3.267	1	3.26	16.14	.00	1.06	1	1.06	5.27	.02*	5.66	28	.20
Body weight (kg)	0.017	1	0.01	0.005	.94	6.01	1	6.01	1.86	.18	90.46	28	3.23
Body fat percentage (%)	9.600	1	9.60	8.453	.00	0.60	1	0.60	0.52	.47	31.80	28	1.13

p<,05* ;Ant. Values: Anthropometric Values; Sum of sq: Sum of square; df: degree of freedom; M.sq: Mean square

As a result of the two factored variance analysis, executed through mixed measurements to identify the effect of lower and upper plyometric exercise programs on anthropometric variables such as height, the group-measurement common effect of the test group was found to be significantly more meaningful than that of the control group ($F_{(1-28)}$ = 5.27, p<.05). The group-measurement common effect of body weight has shown no significant difference between the groups ($F_{(1-28)}$ = 1.86, p>.05). The group-measurement common effect of body fat ratio also has not shown any significant difference between the groups ($F_{(1-28)}$ = 5.22, p>.05) (Table 3).

Table 4. Pre-test and post-test mean and standard deviation values of the lower extremity strength variables of the control and test group

Lower extremity strength values	Control Group n=15				Test Group n=15			
	Pre-test		Post-test		Pre-test		Post-test	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Leg press (kg)	120.7	35.24	136.4	34.49	156.2	26.41	177.26	27.63
Leg curl (kg)	80.3	16.41	83.8	13.36	69.7	16.21	86.4	16.30
CMJ (cm)	36.1	6.62	37.2	6.65	36.4	3.62	39.6	3.58

CMJ: counter movement jump

Table 5. Results of two-way repeated measures analysis of variance (Anova) related to lower extremity strength values of the groups

Lower extremity strength values	Measure					Measure x Group					Error (Measure)		
	Sum of sq.	df	M.sq	F	p	Sum of sq.	df	M.sq	F	p	Sum of sq.	df	M.sq
Leg press (kg)	5078.40	1	5078.4	37.08	.00	106.66	1	106.6	0.77	.38	3833.93	28	136.92
Leg curl (kg)	1530.15	1	1530.1	38.16	.00	646.81	1	646.8	16.13	.00*	1122.53	28	40.09
CMJ (cm)	71.942	1	71.942	22.07	.00	16.960	1	16.96	5.20	.03*	91.243	28	3.259

p<,05* ;CMJ: counter movement jump; Sum of sq: Sum of square; df: degree of freedom; M.sq: Mean square

When analyzing the group-measurement common effect of plyometric exercise programs on leg press strength variable, no significant differences between the groups were identified ($F_{(1-28)}$ = 0.77, p>.05). However, when analyzing the group-measurement common effect of plyometric exercise programs on leg curl strength variable, the test group had a significantly higher score increase than the control group ($F_{(1-28)}$ = 16.13, p<.05). Also, when analyzing the group-measurement common effect of plyometric exercise programs on CMJ strength variable, the test group had a significantly higher score increase than the control group ($F_{(1-28)}$ = 5.20, p<.05) (Table 5).

Table 6. Pre-test and post-test mean and standard deviation values of upper extremity strength variables of the control and test group

Upper extremity strength values	**Control Group n=15**				**Test Group n=15**			
	Pre-test		**Post-test**		**Pre-test**		**Post-test**	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Bench press (kg)	40.5	7.69	39.9	7.63	40.9	6.34	43.4	6.90
Overhead press (kg)	31.2	5.77	35.0	5.02	32.0	4.05	38.6	5.39
High pulley (kg)	49.5	8.97	47.9	9.61	43.0	10.43	47.6	8.43
Plank (sec)	103.0	41.75	117.0	45.67	130.4	36.94	146.2	30.79

Table 7. Results of two way repeated measures analysis of variance (Anova) regarding upper extremity strength values of groups

Upper extremity strength values	**Measure**					**Measure x Group**					**Error (Measure)**		
	Sum of sq.	**df**	**M.sq**	**F**	**p**	**Sum of sq.**	**df**	**M.sq**	**F**	**p**	**Sum of sq.**	**df**	**M.sq**
Bench pr. (kg)	14.017	1	14.01	1.771	.19	36.81	1	36.81	4.65	.04*	221.66	28	7.91
Overhead pr. (kg)	405.60	1	405.6	63.44	.00	29.40	1	29.40	4.59	.04*	179.00	28	6.39
High pulley (kg)	33.75	1	33.75	3.454	.07	144.1	1	144.1	14.7	.00*	273.60	28	9.77
Plank (sec)	3330.1	1	3330.1	6.916	.01	10.41	1	10.41	0.02	.88	13482.9	28	481.53

p<,05*; Bench pr: Bench press; Overhead pr: Overhead press; Sum of sq: Sum of square; df: degree of freedom; M.sq: Mean square

When analyzing the group-measurement common effects of plyometric exercise programs on bench press, overhead press, high pulley strength variable, the test group had a significantly higher score increase than the control group ($F_{(1-28)}$ = 4.65; 4.59; 14.7 p<.05; respectively). However, when analyzing the group-measurement common effect of plyometric exercise programs on plank test variable, no significant differences between the groups were identified ($F_{(1-28)}$ = 0.02, p>.05) (Table 7).

DISCUSSION

The aim of the study is to identify the effect of lower and upper extremity plyometric training programs on maximal strength levels and body fat ratios of young male basketball players.

At the end of the 9 week exercise course, a small increase in height was detected in the control and test groups. This increase was found to be statistically significant in favor of the test group. With this information in hand, it is observed that plyometric exercises alongside basketball practice has a larger effect on the increase of height. It is considered that the one of the main reasons of the increase in height of the participant groups, was that the participants were physically in their growth and development period and were physically active. Yorukoglu and Koz (2007)[25] have stated that average height increase in children is a process that starts from birth and continues until maturity. Many studies have explained that participating in a sport supports physical development in children[26].

No significant increase or decrease was found in the groups as a result of the group-measurement effect on body weight. In a study on basketball players between the ages 14-17 by Savucu (2001)[27], group 1 (plyometric) group 2 (classic basketball) and group 3 (sedentary) athletes were weighed before and after the exercises, and the difference between the weights were evaluated as statistically meaningless. There are other studies explaining the lack of significant difference in weight between the group practicing plyometric exercise and the control group in other sport branches, as well[28,29]. Gur (2001)[30] identified in a study that plyometric exercise combined with football practice applied on a group had a statistically meaningful decrease on their body weight. The reason for this weight loss was defined as plyometric exercise alongside football practice putting an extra load on athletes and increasing the coverage. Ates et al. (2007)[12] stated that weight loss in the test group of their study, consisting of a 10 week plyometric exercise applied on a group of male football players between the ages 16-18, occured because of the intensity of the exercise and the decrease of their body fat. Body weight and body mass index can change in relation to the duration, intensity and frequency of the exercise. These parameters can also differ according to the type of the exercise. Maximal strength exercises focused on building muscle hypertrophy usually increases the body weight and body mass index[31].

No meaningful difference in body fat ratio values were detected between the groups, as a result of the group-measurement effect. Carvalho et al. (2014)[32] detected 16.4 % body fat ratio decrease in athletes during their study on applying special plyometric exerecises combined with strength exercises on handball players. Previous studies show that 14 week[33] and 8 week[34] resistance training programs can decrease total fat content. In fact, the development of muscle tissue after a power program seems like an energy consumption supporting the decrease of fat content[34]. It is presumed that lack of detecting meaningful difference in body weight and body fat percentage in the study is due to the limited frequency, coverage and duration of the exercise. In the study, leg press value increase is identified in both groups. Although this increase is higher in the test group, it is determined that the score increase in the test group is not significantly different than that of the control group. Fatouros et al. (2000)[35] stated that leg press levels measured in maximum strength levels are improved more with weight exercises rather than plyometric exercises. It was also expressed that this finding is most likely to be related to the nature of the applied plyometric and weight exercises. Plyometric exercise also shows similar positive impact regardless of usage of fast Stretch Shortening Cycle (SSC) jumps (i.e. drop jump) or only concentric jumps (i.e. squat jump) or even slow SSC jumps (i.e. CMJ). It is indicated that these applications increase the strength performance (1 RM squat, isometric, isokinetic or 1 RM leg press)[36]. Arazi and Asadi (2011)[37] detected a significant difference in the 1 RM leg press of the control and test groups as a result of applying plyometric exercises for 8 weeks on young male baksetball players.

When analyzing the group-measurement common effect of plyometric exercise programs on the leg curl variable, the test group had a significantly higher score increase than the control group. Perez-Gomez et al. (2008)[38] stated in their study that applying plyometric exercise combined with weight lifting exercises on physical education students increased 1 RM leg curl by 15.9%. Also, this difference was statistically significant among the test and control groups. Fattahi et al. (2015)[39] explained that they observed significant increase in leg muscle strength as a result of applying plyometric exercises for 8 weeks on young male volleyball players. The 8 week plyometric exercise showed significant improvement in the leg values of female handball players between the ages 12-16[40].

When analyzing the group-measurement common effect of plyometric exercise programs on the CMJ variable, the test group had a significantly higher score increase than the control group. Taking into consideration the fact that plyometric exercises have positive effects on explosive strength and muscle strength, this result was expected to be found[11]. Matavulj et al. (2001)[41] reported that plyometric training may improve the jump performance in elite young basketball players, and this improvement may be partly related to an increase in the maximum voluntary strength of hip extensors and the strength development rate of knee extensors. Asadi et al. (2017)[42] also reported a significant increase in jumping ability in young basketball players (vertical jump: [Δ14.1%, d = 2.8]; and broad jump: [Δ4.8%, d = 2.4]) after 8 weeks of plyometric training. It is known that plyometric exercises have positive impact on maximal leg strength[43], and that development of the maximal leg strength has a positive impact on vertical jumping performance. Wisløff et al. (2004)[44] defined that maximal strength and vertical jump performance are strongly correlated.

While detecting a decrease in 1 RM bench press post-test results in the control group, this variable in the test group result had increased. Thus, when analyzing the group-measurement common effect on the 1 RM bench press, the test group had a significantly higher score increase than the control group. When analyzing the group-measurement common effect of 1 RM overhead press, which is another representation of upper extremity strength, the test group had a significantly higher score increase than the control group. While detecting a decrease in 1 RM high pulley post-test results in the control group, this variable in the test group result had increased. Therefore, when the group-measurement common effect of the plyometric exercise program on 1 RM high pulley variable representing upper limb back strength was examined, it was determined that the increase in the scores of the test group were significantly higher than the control group. No study was performed in any sport branch or on a sedentary individual aiming to examine the strength parameters related to 1 RM variables of plyometric exercises. For this reason, study findings aimed to research other strength values representing the upper extremity strength were reviewed in this section. Plyometric exercises have been found to positively affect the rate of shooting, as a result of a study consisting of applying plyometric exercises focused on lower and upper extremity to handball players for 8 weeks in order to observe its effect on strength performance and sports-specific skills[9]. In a similar study, it was found that plyometric exercise programs improve the performance of push ups and throwing medicine balls[45]. On another study done on basketball players, the athletes experienced a signficant improvement in their medicine ball throwing performance[46]. As a result of the plyometric exercise applied to male players between the ages of 16-18, it was found that there was a statistically significant improvement in the right and left arm thrust and chest toss performance[47]. According to a study applying upper and lower extremity plyometric exercise on 14 year old female handball players, the back extensor strength and medicine ball throw values were statistically different among the control group and test group, and in favor of the tests group[48]. In light of the findings from the study, it is identified that plyometric exercises improve the 1 RM values of the strength parameters representing the upper extremity.

An increase in the plank test value is detected in the control group and the test group. Yet, when the group-measure common effect of this increase was analyzed no significant difference was identified among the groups. In the study, participants that had basketball training and the participants that had basketball training with lower and upper extremity plyometric exercise, all experienced an increase in their plank value, representing the core strength. Observations show that the test group's plank value is in a higher degree than the value of the control group. However, due to the limited amount of core strengthening moves in the applied lower and upper extremity exercise program, a statistical difference was not found. Taking this into consideration, it can be stated that physical activity or participation in sports have a positive effect on core strength. When reviewing literature resources, no study was found researching the effect of plyometric exercises on the plank as representing the core strength. Although, studies in different sport branches identifying the positive impact of plyometric exercises on the sit up test value was found[47,49,50].

CONCLUSION

During the 9 week lower and upper extremity plyometric exercise program applied on a control and test group consisting of young basketball players, it was detected that the height variable, which represents the anthropometric characteristics of the groups, showed a score increase in favor of the test group. When analyzing the group-measurement common effect of the anthropometric characteristics on body weight and body fat percentage variables, no significant score increase between the two groups were identified. Furthermore, when analyzing the strength parameters representing the lower and upper extremity strength levels, the score increase in the test group was found to be higher than the control group in all strength parameters. However, this score increase among the groups in 1 RM leg curl, CMJ, 1 RM bench press, 1 RM overhead press, 1 RM high pulley values are statistically detected to be significantly different in favor of the test group.

LIMITATIONS

The most important limitation of the study is that the plyometric training program is applied 2 days of the week. It is presumed in the study that increasing the number of exercises will show bigger differences in score increase of the variables between the groups. An additional limitation is that basketball has its own plyometric moves (such as; jumping, passing, rebounding) and these moves are considered to lower the score increase between the groups.

PRACTICAL APPLICATION

Present findings explain that, basketball coaches working especially with young and adolescent basketball players in youth leagues must routinely apply lower and upper extremity plyometric exercises throughout game season in order to obtain maximum strength. The important point is that coaches design the exercise programs for the group to increase the improvement of the athletes according to variables like the strength, skill, sports history and age group. Also, it must not be forgotten that plyometric training programs prepared suitably to the development level of the athletes will avoid the occurrence of injuries.

REFERENCES

1. Gore CJ. (2000). Physiological tests for elite athletes. Human Kinetics. Champaign Illinois.
2. Gollu G. (2006). Effects of 2 month plyometric or plyometric and extensive interval exercises together on pyhsiologic parameters of 14-16 age boy and girl basketball players. Master Thesis, Eskisehir Osmangazi University Institute of Health Sciences. Eskisehir.
3. Muratli S., Kalyoncu O., Sahin G. (2007). Antrenman ve müsabaka. Ladin Matbaası. İstanbul.
4. Karatosun H. (2012). Futbolda fiziksel performans gelişimi. Altıntuğ Ofset. Isparta.
5. Piirainen JM., Cronin NJ., Avela J., Linnamo V. (2014). Effects of plyometric and pneumatic explosive strength training on neuromuscular function and dynamic balance control in 60-70 year old males. Jounal of Electromyography and Kinesiology. 24(2), 246-252.
6. Chu DA., Faigenbaum AD., Falkel JE. (2006). Progressive plyometrics for kids. Health Learning. USA.
7. Stabenow K., Metcalf T. (2009). Strength training in children and adolescents: raising the bar for young athletes? Sports Health. 1(3), 223-226.
8. Cetin HN., Flock T. (2014). Genel kondüsyon antrenmanı ve sporda performans Kontrolü. Matser Ofset. Ankara.
9. Chelly MS., Hermassi S., Aouadi R., Shephard RJ. (2014). Effects of 8-week in season plyometric training on upper and lower limb performance of elite adolescent handball players. The Journal of Strength and Conditioning Research. 28(5), 1401-1410.
10. Faigenbaum AD., McFarland JE., Keiper FB., Tevli W., Ratamess, NA., Kang J., Hoffman JR. (2007). Effects of a short-term plyometric and resistance training program on fitness performance in boys age 12 to 15 years. Journal of Sports Science and Medicine. 6(4), 519-25.
11. Bavli O. (2012). Comparison the effect of water plyometrics and land plyometrics on body mass index and biomotorical variables of adolescent basketball players. International Journal of Sport and Exercise Science. 4(1), 11-14.
12. Ates M., Demir M., Atesoglu U. (2007). The effect of plyometric training on some physical and physiological parameters of 16-18 years old male soccer players. Nigde University Journal of Physical Education and Sports Sciences. 1(1), 1-12.
13. Faigenbaum AD., Kraemer WJ., Blimkie CJ., Jeffreys I., Micheli LJ., Nitka M., Rowland TW. (2009). Youth resistance training: updated position statement paper from the national strength and conditioning association. The Journal of Strength and Conditioning Research. 23(5), 60-79.
14. Harbili S., Ozergin U., Harbili E., Akkuş H. (2005). The effects of strength training on body composotion and some hormones. Hacettepe Journal of Sport Sciences. 16(2), 64-76.
15. Koz M. (2017). Vücut kompozisyonu ve sportif performans ile ilişkisi. http://80.251.40.59/sports.ankara.edu.tr/koz/egz-fizII/vucut.kompz.egz.pdf. [Erişim tarihi: 20.03.2020].
16. Yosmaoglu HB., Baltacı G., Derman O. (2010). Effectiveneses of body fat measurement methods in obese adolescents. Turk Journal of Physiother Rehabilition. 21(3), 125-131.

17. Durnin JVGA., Womersley J. (1974). Body fat assessed from the total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. British Journal of Nutrition. 32(1), 77-97.
18. Siri WE. (1961). Body composition from fluid space and density. İçinde: Brozek J, Hanschel A. (editör). Techniques for measuring body composition. Washington, DC: National Academy of Science; p. 223-244.
19. Ozer MK. (2017). Muscle strength. https://kamilozer.com/wpcontent/uploads/2017/09/Kuvvet.pdf. [Erişim tarihi:03.04.2020].
20. Casartelli N., Müller R., Maffiuletti, NA. (2010). Validity and reliability of the Myotest accelerometric system for the assessment of vertical jump height. The Journal of Strength and Conditioning Research. 24(11), 3186-3193.
21. Mackenzie B. (2005). 101 Performance evaluation tests. Electric World Publication. London.
22. Tong TK., Wu S., Nie J. (2014). Sport-specific endurance plank test for evaluation of global core muscle function. Physical Therapy in Sport. 15(1), 58-63.
23. Morgan GA., Leech NL., Gloeckner GW., Barret KC. (2004). 2.Eds. SPSS for Introductory Statistics: Use and Interpretation. Lawrence Erlbaum Associates. London.
24. Can A. (2017). SPSS ile bilimsel araştırma sürecinde nicel veri analizi. Pegem Akademi. Ankara.
25. Yorukoglu U., Koz M. (2007). The effect of sport school and sport club trainings on physical, physiological and antrophometric properties of boys whose ages range from 10-13. The Journal of Physical Education and Sports Science. 5(2), 79-83.
26. Hekim M., Hekim H. (2015). Overview to strenght development and strenght trainings in children. The Journal of Current Pediatrics. 13 (2), 110-115.
27. Savucu Y. (2001). Effects of regular specific plyometric training on anaerobic power of young basketball players. Master Thesis, Fırat University Institute of Health Sciences. Elazığ.
28. Arslan O. (2004). The effect of the eight-week pliometric training program on some physical and physiological parameters of 14-16 age group female short distance runners. Master Thesis, Gazi University Institute of Health Sciences. Ankara.
29. Yıldırım T. (2010). The effects of plyometric training programme during eigth weeks on selected physical and physiology parameteres to the high school male volleyballers. Master Thesis, Selcuk Unıversity Institute of Health Sciences. Konya.
30. Gur E. (2001). Effect of pliometric training on young football players' anaerobic power performance. Master Thesis, Fırat University Institute of Health Sciences. Elazig.
31. Nindl BC., Harman EA., Marx JO. (2000). Regional body composition changes in women after 6 months of periodized physical training. Journal of Applied Physiology. 88(6), 2251-2259.
32. Carvalho A., Mourão P., Abade E. (2014). Effects of strength training combined with specific plyometric exercises on body composition, vertical jump height and lower limb strength development in elite male handball players: a case study. Journal of Human Kinetics. 41(1), 125–132.

33. Fleck SJ., Mattie C., Martensen HC. (2006). Effect of resistance and aerobic training on regional body composition in previously recreationally trained middle-aged women. Applied Physiology Nutrition and Metabolism. 31(3), 261-270
34. Beni M. (2012). Determining the effect of concurrent strength-endurance training on aerobic power and body composition in non-athletic male students. Annals of Biological Research. 3, 395-401.
35. Fatouros IG., Jamurtas AZ., Leontsini D., Taxildaris K., Aggelousis N., Kostopoulos N., Buckenmeyer P. (2000). Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength. The Journal of Strength & Conditioning Research. 14(4), 470-476.
36. De Villarreal ESS., Requena B., Newton RU. (2010). Does plyometric training improve strength performance? A meta-analysis. Journal of Science and Medicine in Sport. 13(5), 513-522.
37. Arazi H., Asadi A. (2011). The effect of aquatic and land plyometric training on strength, sprint, and balance in young basketball players. Journal of Human Sport and Exercise. 6(1), 101-111.
38. Perez-Gomez J., Olmedillas H., Delgado-Guerra S., Royo IA., Vicente-Rodriguez G., Ortiz RA., Chavarren J., Calbet JA. (2008). Effects of weight lifting training combined with plyometric exercises on physical fitness, body composition, and knee extension velocity during kicking in football. Applied Physiology Nutrition and Metabolism. 33(3), 501-510.
39. Fattahi A., Kazemini H., Rezaei M., Rahimpour M., Bahmani M., Nia SS., Ameli M., Einanloo M. (2015). Effect of different plyometric training on biomechanical parameters of junior male volleyball players. Journal of Scientific Research and Reports. 4(5), 473-479.
40. Agılonu A., Kiratli G. (2015). The examination of the effects of 8-week plyometric training on some physical fitness parameters of women handball players aged between 12-16 years old. International Journal of Human Sciences. 12(1), 1216-1228.
41. Matavulj D., Kukolj M., Ugarkovic D., Tihanyi J., Jaric, S. (2001). Effects of plyometric training on jumping performance in junior basketball players. Journal of sports Medicine and Physical Fitness. 41(2), 159-164.
42. Asadi A., Ramirez-Campillo R., Meylan C., Nakamura FY., Canas-Jamett R., Izquierdo M. (2017). Effects of volume-based overload plyometric training on maximalintensity exercise adaptations in young basketball players. Journal of Sports Medicine and Physical Fitness. 57(12), 1557-1563.
43. Myer G., Ford K., Palumbo J., Hewitt T. (2005). Neuromuscular training improves performance and lower extremity biomechanics in female athletes. Journal of Strength and Conditioning Research. 19(1), 51-60.
44. Wisløff U., Castagna C., Helgerud J., Jones R., Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. British Journal of Sports Medicine. 38(3), 285–288.
45. Cavdar K. (2006) A study on jumping performances of the students performing plyometric exercises. Master Thesis, Marmara University Institute of Health Sciences. Istanbul.

46. Orhan S., Pulur A., Erol AE. (2008). The effects of the rope and weighed rope trainings on the physical and physiological parameters of the basketball players. Fırat University Medical Journal of Health Sciences. 22(4), 205-210.
47. Ateş M., Ateşoğlu U. (2007). The effect of plyometric training on the strength parameters of upper and lower extremities of 16-18 years old male soccer players. The Journal of Physical Education and Sports Science. 5(1), 21-28.
48. Hammami M., Ramirez-Campillo R., Gaamouri N., Aloui G., Shephard RJ., Chelly MS. (2019). Effects of a combined upper-and lower-limb plyometric training program on high-intensity actions in female U14 handball players. Pediatric Exercise Science. 31(4), 465-472.
49. Pancar Z., Biçer M., Özdal M. (2018). Effect of 8-week plyometric training on selected strength parameters of 12-14 aged woman handball players. Journal of Sports and Performance Researches. 9(1), 18-24.
50. Urer S., Kılınc F. (2014). Investigate the effect of applied plyometric trainings for upper and lower extremities on the vertical jump performance and ratio of shoot accuracy over the block of aged 15-17 male handball players. Inonu University, Journal of Physical Education and Sport Sciences. 1(2), 16-38.