EVALUATION OF THE EFFECT OF PLYOMETRIC EXERCISES ON THE SPEED OF THE BALL AND THE HITTING PERCENTAGE DURING A SERVICE

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SUMMARY

In this study, the effect of the plyometric exercises on the speed and the hitting percentages of the services in tennis players was investigated. 40 male volunteer tennis players aged between 20-25 were included the study. The participants were balanced and divided into the study (n=20) and the control (n=20) groups via unbiased allocation. The participants in the study group attended the plyometric exercise programme in addition to the classical eight-week tennis exercise (3 days in a week, 2 sets in each day) while the participants in the control group continued only the classical tennis exercise. The measurements of the dependent variables were done at the beginning of the study, at the end of the fourth and the eighth weeks. The mixed between-within subjects ANOVA was used to evaluate the effects of the exercise programme on the dependent variables. It was seen that the significant differences in the mean peak torque scores was originated from the study group and it was particularly in the resistance velocity of 60^0/second and 120^0/second (right extension/right flexion) for the lower body and in the resistance velocity of 60^0/second (external rotation) for the upper body ($p<.05$). The maximum speed improvement in services used in both right and left was significantly higher in the study group, the improvements in the hitting scores in all services was seen in the study group ($p<.05$).

As a result it was seen that the plyometric exercises performed in addition to the classical tennis exercises has caused positive effects on the shoulder and leg strength of the tennis players and also it has improved the shooting and hitting speeds and the percentage of the hitting.

Key words: tennis, plyometric exercise, service speed and hitting

TENİSÇİLERDE PLİOMETRİK ANTRENMANLARIN SERVİS ATIŞINDA TOPUN HIZINA VE İSABETİ YÜZDELERİNE ETKİSİNİN İNCELENMESİ

ÖZET

Bu çalışmada, tenisçilerde pliometrik antrenmanların servis vuruş süratleri ve vurulan hedefe isabet yüzdelerine etkisi araştırılmıştır. Çalışmaya, yaşları 20-25 arasında 40 erkek tenisçi gönüllü olarak katıldı. Katılımcılar yaşlarına göre karşılıklı olarak dengelendi ve yansız atama yolu ile deney (n=20) ve kontrol (n=20) grubuna ayrıldı. Deney grubu üyeleri sekiz haftalık klasik tenis antrenmanlarına ilave olarak pliometrik antrenman programına katılırken (haftada 3 gün, günde 2 set), kontrol grubu bu süreçte sadece klasik tenis antrenmanına devam etti. Bağımlı değişkenlere ilişkin ölçümler çalışmanın başlangıcında, 4. haftanın ve 8. haftanın sonunda yapıldı. Antrenman programının bağımlı değişkenler üzerindeki etkilerini değerlendirmek için Mixed between-within subjects ANOVA kullanıldı. Ortalama pik tork skorlarındaki anlamlı değişimlerin alt vücut için özellikle 60^0/sn ve 120^0/sn deki direnç hızlarında (sağ ekstansiyon / sağ fleksiyon), üst vücut için 60^0/sn deki direnç hızında (dış rotasyon) deney grubundan kaynaklandığı görülmüştür ($p<.05$). Serviste sağ ve soldan kullanılan vuruşlardaki maksimum hız gelişimleri deney grubunda anlamlı olarak daha fazla olmuş, isabet skorlarındaki gelişim tüm servis atışlarında deney grubunda ortaya çıkmıştır ($p<.05$).

Sonuç olarak, klasik tenis antrenmanına ilave olarak uygulanan pliometrik egzersizlerin tenisçilerin omuz ve bacak kuvveti üzerinde olumlu etkiler yaptığı, atış ve vuruş hızları ile birlikte isabet oranlarınıda geliştirdiği görülmüştür.

Anahtar kelimeler: tenis, pliometrik antrenman,servis,sürat ve isabet

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INTRODUCTION

Tennis is a performance sport that includes both aerobic and anaerobic overload and necessitate a good degree of biological motor features such as strength, speediness, endurance, elasticity and coordination (Weber, 1982; Ferrauti et al., 2002).

An effective service is very important in manifesting a successful performance in the field of this sport. The most important criteria in determination of the performance of the service is the speed of the ball during the service. The tennis players always try to increase the speed of the balls in their service to have the edge over their competitor (Dangel, 1993). The well-directed shots in services with high speed causes to get more scores thatincrease the probability of winning a tennis match (Brody, 1988; 2003).

The previous studies suggest that there is a medium-low degree of relationship between the speed of the ball and the isokinetic strength of the upper extremity (Ellenbecker et al., 1991; Cohen et al., 1994). To sum up the strength during a service shot, come true by the kinetic chain produced by the body. The strength produced by the leg muscles at the beginning of the service is transmitted first to the waist and the shoulder and then it is transmitted to the elbow, wrist and the racket (Elliott et al., 1995; Bahamonde, 2000). The strength parameters that are one of the most important necessities in service shot must undoubtedly be practiced. The strength exercises were stated to increase functional aims and athletic performance by various authors (Treiber et al., 1998; Ellenbecker et al., 1988; 2002).

The aim of this study is to determine the relationship between the isokinetic strength parameters of the tennis players and the speed of the ball and the hitting percentage in a service shot.

MATERIAL AND METHOD

40 male tennis players aged between 20-25 in the level of tournament who were in Turkish tennis league and in severalty were included the study. The population forms the sample as well. The exercise types used in the study were chosen according to the skill tests to be performed. The exercise in the study group was plyometric exercise of 35 minutes and classical tennis exercise of 70 minutes. The exercises were done as two sets three times a week with 12 repeats and with a maximal heart rate of 60-70% and a resting interval of 1-2 minutes. The control group has done classical tennis exercise of 105 minutes only.

The tests were performed in the laboratory of Physical Theraphy and Rehabilitation Department of Konya Selçuk University. All the participants were told not to exercise one day before the mesurements and to eat a small breakfast on the morning of the measurements. All the participants were informed about the test procedures and the possible risk factors. Then the age, height and weight measurements of the participants were done in the same day. Following this the strength tests of the arm and leg were performed.

Study Model

In this study within-groups and between-groups models including repeated measurements were used (Mixed-model Ax(BxS).

Exercise as between-groups factor (study and control) and time period including the repeated measurements (pre-test, intermediate test and last test) as within-group factor were used.

Anthropometric Measurements

By preparing a questionnaire to the sportsmen involved in our study, age, weight and height were determined. The measurements of weight were done with a weighing scale that has a degree of accuracy of 100 g. The measurements were recorded as kg (Zorba andZiyagil 1995). The measurements of height were done with Martin type of Anthropometer. A device of a

degree of accuracy of 1 cm was used in height measurements (Zorba and Ziyagil 1995).

The tests of ball speed measurements in service shots

All services were done in a closed tennis court in order to control the effect of the air on the measurement of the speed of the ball. The participants were warmed up to reach the maximum level of service speed (20 minutes). The tests were performed 3 minutes after warming up procedure and they were told to serve with 5 maximum speeds as right and left. The fastest shots and the hitting number were analyzed by video shoot recordings.

The pistol radar was used in measurements of the speed of the ball (Sports Radar, Astro Products, CA). The counter floor line of the pistol radar used in measurement of the speed of the balll was fixed at the return point. As per the tennis rules, cross service box, backhand service return was requiredand when the ball was hit to the net or outside the service box (out), the hitting were not recorded as score.

The speed of the service shots that has been done were declared to the players in order to make the maximum effort. All the services were done to the right and left service can. All the service players were told to use smooth service and hitting technique and the services were evaluated by two tennis trainer. In order to analyze data, the fastest of the 5 services with maximum speed (km/hour) was analyzed as maximum service(Vmax).

Isokinetic Muscle Strength Measurement

Isokinetic investigation was performed with Biodex System 3Pro Multijoint System Isokinetic (Biodex Medical Inc, Shirley, NY, USA) dynamometer according to the standards. The measurements of internal and external rotator muscle strengths of the shoulder were tested as concentric-concentric isokinetic at 90° abduction of the shoulder. During the movement of the joint, for internal rotation of the shoulder, pectoralis major, subscapularis, latissimusdorsi and teres major are the primary muscles. For the external rotation of the shoulder infraspinatus and teres minor are the primary muscles. All the sportsmen were done warm up exercises with arm ergometer for upper extremity and bicycle ergometer for lower extremity before the test. The loading of warm up was adjusted according to the heart rate of the individual, the heart rate was hold as 100-120 beat/minute and the warm up was ended at the fifth minute of this heart rate interval.

In order to prevent possible injuries, stretching exercises for five minutes wereperformed before and after the test. According to the test protocol, before starting the records, for the preparation and adaptation of the sportsmen to the tests, after performing shoulder rotation at submaximal force at a rate of 60-180 ve 300°/sec for 3 repeats, they passed to the main protocol. The procedure was told to the sportsmen in a detailed manner and oral feedback was done during the exercise. The test measurements were taken at the low speed of 60°/sec with five repeats, at the intermediate speed of 180°/sec with five repeats and at the high speed of 300°/sec with five repeats at the end. A resting period of 60 seconds was given between the tests. The measurement of the muscle strength of the knee muscles was done bilaterally. Before starting the records, for the preparation and adaptation of the sportsmen to the tests, after performing extension-flexion of the knee at submaximal force at a rate of 60-120 and 180°/sec for 3 repeats, they passed to the main protocol. The first movement during the test was knee extension and EHA of 90°was allowed. The test measurements were done at the low speed of 60°/sec with five repeats, at the intermediate speed of 120°/sec with five repeats and at the high speed of 180°/sec with five repeats at the end. A resting period of 60 seconds was given between the tests.

The parameters of isokinetic test data were;

*Peak:*The maximum torque value that a group of muscles produce during the determined movement interval. The unit is Newton-meter (Nm).

Peak/Body weight: The ratio of the value of maximum force to the body weight. This makes the data (according to weight) specific to the individual. The evaluation of peak value according to the body weight brings a new dimension to the interpretation of the results. The individual differences can be evaluated by dividing the variables such as peak, work and force into the body weight. The total body weight is used more frequently than the lean body weight. The other test variables can also be normalized by dividing into the body weight.

Data Analysis

The independent two-tailed t-test was used to analyze whether there is any difference between the study and the control groups at the beginning.

The two-way (2x3) (exercise/time) Mixed ANOVA variance analysis was used to evaluate the effects of the exercise programme on the dependent variables at each test interval. Analyses wereperformed with sphericity control.

The analysis were continued in the presence of a significant interaction in two-way (2x3) Mixed ANOVA and one-way repeated measures ANOVA variance analysis was used for each group. In the presence of a significant difference, Bonferroni confirmation was used for multiple comparisons.

Descriptive statistics (mean, standard deviation) was used for each parameter.

The level of significance was determined as $p \leq 0.05$ at the beginning and SPSS 14.0 programme was used for statistical analysis.

RESULTS

The main physical characteristics of the participants in both exercise groups were evaluated and analyzed before analysis of the results associated with the basic dependent variables. The data consists of age, height and weight.

The data achieved from the shoulder joint at 60^0/sec, 180^0/sec and 300^0/sec; and the knee joint at 60^0/sec, 120^0/sec and 180^0/sec were presented.

The data achieved from the shoulder joint at 60^0/sec, 180^0/sec and 300^0/sec are the values of peak during internal and external rotation (60İR / 60ER, 180İR / 180ER, 300İR / 300ER) and the ratio of peak-body weight during internal and external rotation (bw60İR / bw60ER, bw180İR / bw180ER, bw300İR / bw300ER).

The data achieved from the knee joint at 60^0/sec, 120^0/sec and 180^0/sec are the peak during right and left extension (60RE / 60LE, 120RE / 120LE, 180RE / 180LE), the peak during right and left flexion (60RF / 60LF, 120RF / 120LF, 180RF / 180LE), the ratio of peak-body weight during right and left extension (bw60RE / bw60LE, bw120RE / bw120LE, bw180RE / bw180LE) and the ratio of peak-body weight during right and left flexion (bw60RF / bw60LF, bw120RF / bw120LF, bw180RF / bw180LE)

Table 1. Main characteristics of the study and the control groups.

	GROUP	N	Average	Ss	p†
Age (year)	Experiment	20	22.1	1.33	.822
	Control	20	22	1.45	
Height (cm)	Experiment	20	177	8.21	.499
	Control	20	178.8	8.47	
Body Weight (kg)	Experiment	20	73.8	6.81	.789
	Control	20	73.1	9.39	

†P: p value for T test, SD: Standart deviation

There is no significant difference between the basal values of the two groups (p>.05). This data shows that the groups had similar chararteristics at the beginning.

Table 2.1. The variation of the peak and the ratio of peak-body weight in shoulder joint in both groups (Nm).

Groups	**Experiment n=20 Avg.Ss**			**Control n=20 Avg.Ss**		
Weeks	1st W	4th W	8th W	1st W	4th W	8th W
60İR	56.1(13.7)	60.9 (16)	59.8 (15.8)	57.5 (16.5)	58.4 (14.3)	56.3(13.6)
60ER	49.6a(9.48)	50.7a(8.7)	52.4b(8.7)	48.9a(10.8)	49.3a(10.6)	49.5a(10.3)
bw60İR	144.3(56.1)	155.1(49)	155.5(55.4)	153.4(57.7)	156.7(57.6)	148.5(53.1)
bw60ER	117.1(35.9)	122.8(28.7)	127.2(30.2)	120.2(33.6)	122.5(31.4)	126.6(28.4)
180İR	43.8(16.8)	44(12.5)	45.6(18.6)	44.4(17.7)	44.8(18)	49.6(16.2)
180ER	38.2(9.7)	38.5(7.7)	42.1(10.5)	38.2(10.4)	36.3(10.7)	42.4(11.8)
bw180İR	112.2(50.5)	111.9(38.5)	120.8(57.3)	114.2(56.5)	123.9(54.4)	125.8(52.7)
bw180ER	102.6(39.5)	100.3(28.1)	111.8(29.7)	100.3(35.5)	103.2(41.1)	108.5(31.2)
300İR	37.1(21.5)	39.9(17)	40.6(23.6)	41.8(19.4)	42.2(19.8)	42(17.6)
300ER	31.7(10.7)	32(10)	34.4(11.2)	32.5(10.9)	31.3(11.2)	34.9(9.8)
bw300İR	95.3(54.2)	106.2(46.2)	103.2(60.3)	102.2(59.1)	111.3(54.7)	106.1(57.7)
bw300ER	89.8(41.1)	88.4(34.2)	89.5(38.3)	88.4(40.5)	94.2(44.9)	95.3(33.8)

The two-way (2x3) Mixed ANOVA results of 60ER are as follows:

The variations in both groups are not similar, D (1.74,66.08) =10.041, p = .000. The discrepancy (D) has begun from the 4th week and it results from the study group.

When the group factor is ignored, there is a significant increase in 60ER in the time period, D (1.74,66.08) = 24.683, p = .000.

When the group factor is ignored, there is a significant increase in pt60ER, D (1.74,66.08) = 24.683, p = .000.

The two-way (2x3) Mixed ANOVA results of 180ER are as follows:

The interaction effect between the groups and the time is not significant, D (2,76) = .323, p = .725. This effect shows that the variations in both groups are similar.

When the group factor is ignored, there is a significant increase in 180ER scores in the time period, D (2,76) = 7.601, p = .001.

When the test factor is ignored, there is no significant difference between the study ($\bar{X}$=39.46) and the control groups ($\bar{X}$=38.99) in terms of 180 ER scores,D (1, 38) = .026, p = .872.

The two-way (2x3) Mixed ANOVA results of 60İR / bw60İR – ER / 180İR – ER / bw180İR – ER / 300İR – ER / bw300İR – ER/ (Nm) are as follows:

1- The effect of interaction between the group and time is not significant; this effect shows that the variation in both groups is similar.

2- The main time effect is not significant; this effect shows that there is no significant variation in scores during the time period when the group factor is ignored

3- The main group effect is not significant; this effect shows that there is no significant difference in scores of both the study and the control groups when the test factor is ignored.

Table 2.1. The variation of peak and the ratio of peak-body weight during extension in both groups during the process (Nm)

Groups	**Experiment n=20 Avg.Ss**			**Control n=20 Avg.Ss**		
Weeks	1st W	4th W	8th W	1st W	4th W	8th W
60RE	170a(47.6)	179.1b(48)	199.6c(51.1)	180.5a(50.7)	182.5a(51.5)	188.1b(51.7)
60LE	168.2(52.6)	168.9(49.8)	192.5(64)	164.7(51.4)	174.2(53.9)	172.5(52.4)
bw60RE	447a(108.5)	469.4a(97.1)	509.2b(108.6)	497.4(119.9)	481(134)	491.8(106.1)
bw60LE	440.9(114.1)	445.3(101)	486.3(131.6)	453.8(113.8)	453.6(109.6)	450.6(102.9)
120RE	128.2(49.6)	138.2(45.5)	149.5(44.9)	134.5(45.8)	128.2(49.6)	147.6(45.1)
120LE	141.3(89.4)	130(41.9)	147.4(47.6)	128.4(46.1)	128.9(48.5)	140.8(45.1)
bw120RE	285.3(119.9)	318(116.5)	346.6(131.8)	336.1(123.2)	304.5(123.4)	335.8(105.1)
bw120LE	297.5(119.7)	305.3(115.9)	347.4(137.6)	329(126.5)	311.2(119.7)	321.4(112.7)
180RE	125.6(87.9)	109.3(46.5)	145.3(78.1)	106.9(44.7)	102.4(47.6)	121.4(42.1)
180LE	105.8(45.2)	107.4(38.4)	126.1(44.1)	106.5(42.1)	103.9(44.8)	116.6(37.5)
bw180RE	236.8(118.1)	246.9(113.3)	296.4(101.5)	247.7(125)	235(106.4)	230.1(128.7)
bw180LE	233(111.1)	254.7(104.5)	279.7(130.8)	276(121.2)	257.1(119.8)	279.1(99.8)

The two-way (2x3) Mixed ANOVA results of 60RE are as follows:

The variations in both groups are not similar, D (1.468, 55.767)=19.947,p=.000. The discrepancy (D) has begun from the 4th week and it results from the study group.

When the group factor is ignored, there is a significant increase in 60RE in the time period, D (1.468, 55.767)=19.947, p=.000.

When the test factor is ignored, there is a significant difference between the study ($\bar{X}$=182.93) and the control groups ($\bar{X}$=183.763) in terms of 60RE scores, D (1, 38) = .003, p = .958.

The two-way (2x3) Mixed ANOVA results of 60LE are as follows:

The effect of interaction between the group and time is not significant D (2,76) =2.220, p = .116.; this effect shows that the variation in both groups is similar.

When the group factor is ignored, there is a significant increase in 60LE in the time period, D (2,76) = 3.631, p = .031.

When the test factor is ignored, there is no significant difference between the study ($\bar{X}$=176.57) and the control groups ($\bar{X}$=170.51) in terms of 60 LE scores, D (1, 38) = .150, p = .701.

The two-way (2x3) Mixed ANOVA results of bw60RE are as follows:

The variations in both groups are not similar, D (2,76) =4.184, p = .019. The discrepancy (D) has begun from the 4th week and it results from the study group.

When the group factor is ignored, there is a significant increase in bw60RE in the time period, D (2,76) = 3.488, p = .036.

When the test factor is ignored, there is no significant differrence between the study ($\bar{X}$=475.22) and the control groups ($\bar{X}$=490.11) in terms of bw60RE scores, D (1, 38) = .203, p = .655.

Table 2.2. The variation of peak and the ratio of peak-body weight during flexion in both groups during the process (Nm)

Groups	**Experiment n=20 Avg.Ss**			**Control n=20 Avg.Ss**		
Weeks	1st W	4th W	8th W	1st W	4th W	8th W
60RF	116.8(52.8)	118.2(43.3)	142.3(40.8)	111.4(38.9)	119(45.4)	121.4(46.5)
60LF	130.1(73.9)	123.8(64.9)	152.4(56.2)	117.7(55.8)	129.5(46.4)	118.7(54)
bw60RF	237.7(149.2)	244.8(122.9)	294.2(168.5)	245.9(105.7)	254(119.4)	239.6(85.6)
bw60LF	251.9(119.1)	246.4(118.6)	291.3(141.4)	252.3(113.7)	289(127.5)	252.4(104.9)
120RF	107.6(108.3)	92.2(28.1)	107.2(29.9)	88.1(28.3)	90.5(35.3)	93.1(33.6)
120LF	85.8(30.2)	90.4(27.5)	100.8(26.7)	83.1(30.7)	88.5(34.5)	89(29.8)
bw120RF	188.4a(78.4)	212.8ab(66.2)	240.9b(81.9)	222.3a(74.8)	221.7a(100.3)	225.1a(78.7)
bw120LF	199.2(74.8)	203.7(62.6)	227.3(73.5)	204.7(78.5)	214.8(89.7)	210.7(69.5)
180RF	83.1(46.2)	76.6(28.7)	98.4(40)	70.7(29.5)	73.4(34.8)	79.2(31)
180LF	75.1(27)	74.4(26.5)	82.4(25)	69.7(24.9)	73.7(33.2)	76.4(25.6)
bw180RF	171.5(61.3)	171.1(62.7)	204.8(57.8)	174.4(70)	173.1(81.6)	181.6(67.8)
bw180LF	168.5(58)	165.9(57.3)	181.1(53.9)	174.6(65.1)	174.5(79.7)	169.6(49.7)

The two-way (2x3) Mixed ANOVA results of 60RF are as follows:

The effect of interaction between the group and time is not significant D (2,76) =1.791, p =.174. This effect shows that the variation in both groups is similar.

When the group factor is ignored, there is a significant increase in 60RF scores. D (2,76) =4.861, p =.010.

When the test factor is ignored, there is no significant difference between the study ($\bar{X}$=125.82) and the control groups ($\bar{X}$=117.33) in terms of 60RF scores, D (1, 38) =.465, p = .499.

The two-way (2x3) Mixed ANOVA results of bw120RF are as follows:

The variations in both groups are not similar, D (2,76) = 3.909, p = .024. The discrepancy (D) has begun at the beginning and it results from the study group.

When the group factor is ignored, there is a significant increase in bw120RF in the time period, D (2,76) = 4.881, p = .010.

When the test factor is ignored, there is no significant difference between the study ($\bar{X}$=214.07) and the control groups ($\bar{X}$=223.07) in terms of bw120RF scores, D (1, 38) = .148, p = .702.

In comparison of the scores of mean peak during right and left extension (120RE / 120LE, 180RE / 180LE), peak during right and left flexion (60LF, 120RF / 120LF, 180RF / 180LE), the ratio of peak-body weight during right and left extension (bw60LE, bw120RE / bw120LE, bw180RE / bw180LE)), and the ratio of peak-body weight during right and left flexion (bw60RF / bw60LF, bw120LF, bw180RF / bw180LE);

1- The effect of interaction between the group and time is not significant; this effect shows that the variation in both groups is similar.

2- The main time effect is not significant; this effect shows that there is no significant variation in scores during the time period when the group factor is ignored

3- The main group effect is not significant; this effect shows that there is no significant difference in scores of both the study and the control groups when the test factor is ignored.

Table 3.The variation of maximum speed (km/hour) and hitting number of right-left services in groups during the process.

Groups	**Experiment n=20 Avg. Ss**			**Control n=20 Avg. Ss**		
Weeks	1st W	4th W	8th W	1st W	4th W	8th W
Right service max. speed(km/s)	123.8a (10.8)	129.4b (10.3)	144.8c (10.6)	117a (10.3)	121.9b (10.1)	128.4c (9.9)
Right service accuracy count	2.45a (.51)	2.90b (.31)	4c (.56)	2.50a (.69)	2.70ab (.47)	3.20c (.62)
Left service max. speed(km/s)	124.a (10.4)	130.1b (10.3)	141.5c (12.2)	115.5a (9.6)	119.7b (9.7)	126c (10.2)
Left service accuracy count	2.30a (.47)	2.95a (.22)	3.55c (.60)	2.55a (.60)	2.70ab (.47)	3.15c (.59)

Note: The groups in the same line with the same sub-symbol (a or b) are not significantly different (p<.05)

The two-way (2x3) Mixed ANOVA results of mean Maximum Speed of right service are as follows:

The variations in both groups are not similar, D (1.16,44.18) =66.754, p = .000. The discrepancy (D) has begun from the 4th week and it results from the study group.

When the group factor is ignored, there is a significant increase in Maximum Speed in the time period, D (1.16,44.18) =626.75, p = .000.

When the test factor is ignored, there is significant difference between the study ($\bar{x}$=132.68) and the control groups ($\bar{x}$=122.45) in terms of Maximum Speed Scores, D (1,38) =9.976, p = .003.

The two-way (2x3) Mixed ANOVA results of mean hitting number of right service are as follows:

The variations in both groups are not similar, D (2,76) =10.850, p = .000. The discrepancy (D) has begun from the 4th week and it results from the study group.

When the group factor is ignored, there is a significant increase in hitting number in the time period, D (2,76) =76.237, p = .000.

When the test factor is ignored, there is significant difference between the study ($\bar{x}$=3.12) and the control groups ($\bar{x}$=2.80) in terms of hitting number, D(1,38) =5.778, p =.021.

The two-way (2x3) Mixed ANOVA results of mean Maximum Speed of left service are as follows:

The variations in both groups are not similar, D (1.26,48.02) =34.340, p = .000. The discrepancy (D) has begun from the 4th week and it results from the study group.

When the group factor is ignored, there is a significant increase in the hitting number in the time period, D (1.26,48.02) =525.614, p = .000.

When the test factor is ignored, there is significant difference between the study ($\bar{x}$=131.92) and the control groups ($\bar{x}$=120.45) in terms of Maximum Speed Scores, D (1,38) =12.258, p = .001.

The two-way (2x3) Mixed ANOVA results of the mean hitting number of left service are as follows:

The variations in both groups are not similar, D (2,76) =6.085, p = .004. The discrepancy (D) has begun from the 4th week and it results from the study group.

When the group factor is ignored, there is a significant increase in the hitting number in the time period, D (2,76) =8.608, p = .000.

When the test factor is ignored, there is no significant difference between the study ($\bar{x}$=2.93) and the control ($\bar{x}$=2.80) groups in terms of hitting number scores, D (1,38) =1.322, p = .257.

DISCUSSION AND CONCLUSION

Plyometric exercises in the present time have become an exercise technique that is used by all sportsmen for all sports to increase the general force and the explosive force. Plyometric includes the rapid stretching of the muscle (eccentric movement) and the subsequent concentric contraction of the same muscle or the soft tissue. The elastic energy stored in the muscle is used to produce a force greater than the force produced by a single concentric movement (Miller et al.2006)

The remarkable result obtained at the end of a 8-week study was the variation in the peak torque achieved from the knee joint at 60^0/sec. The peak torque values at 60^0/sec during right extension demonstrated an increase in both groups during the process and this increase was significantly higher in the study group beginning from the 4^{th} week. Similarly the ratio of peak torque-body weight values also demonstrated an increase in both groups during the process and this increase was significantly higher in the study group beginning from the 4^{th} week. Also the values of peak torque at 60^0/sec during left extension and the ratio of peak torque-body weight at 60^0/sec during right flexion showed similar progression in both groups.

Another notable significant variation was the variation in the peak torque achieved from the knee joint at 120^0/sec during right flexion. The ratio of peak torque-body weight values at 120^0/sec during right flexion demonstrated an increase in both groups during the process however this increase was significantly higher in the study group from the beginning. Besides the values of peak torque at 120^0/sec during right extension and left flexion showed similar progression in both groups. In addition to this, the values of peak torque at 180^0/sec during left extension showed similar progression in both groups.

According to the isokinetic findings achieved from the shoulder joint, the values of peak torque at 60^0/sec during external rotation demonstrated an increase in both groups during the process, nevertheless the increase in the study group was found to be significantly higher than the control group beginning from the 4^{th} week. Another progress related to peak torque of the shoulder joint is the similar progression of peak torque values at 180^0/sec during external rotation in both groups. No significant progression was found in other peak torque parameters (internal rotation at different speeds) achieved from the shoulder joint.

These findings show similarity with the positive effects of the plyometric exercises on the strength parameters. In many studies it was demonstrated that plyometric exercises are very beneficial methods. Especially when plyometric exercises are combined with weight exercises, they become more superior (Ebben 2002). It was shown that plyometric exercises applied to different specialties has improved the jumping performance (Baktaal 2008), speediness (Miller et al. 2006), the strength of upper and lower extremity (Ateş 2007), and the anaerobic strength (Sağıroğlu 2008).

As noticed in our study, the remarkable variations in peak torque values achieved from the knee joint were especially at 60^0/sec and 120^0/sec and from the shoulder joint were at 60^0/sec. This finding suggests that, the resistance at 60^0/sec and 120^0/sec are more suitable resistances during the evaluation of peak torque parameters of the tennis players. Because the resistance at high angular velocities such as 180^0/sec and 300^0/sec has low resistance properties and an aspect that should not be overlooked is that it mostly serves to measure the endurance of the muscles. In this respect, it is significant not to see any significant improvements in these resistance speeds. Stojanovic et al. (2002) pointed out that plyometric exercises are speed-force studies and they are formed by combination of these two factors and the basic of plyometric exercises depends on the rate of the change

in eccentric and concentric contractions. In this respect as the resistances at 60^0/sec and 120^0/sec are more forcible than the resistances at 180^0/sec and 300^0/sec, it can be said that these resistances at 60^0/sec and 120^0/sec represent the plyometric effect consisting of the speed and the strength more than the resistances at 180^0/sec and 300^0/sec. And also the lack of the expected improvements in the strength of the upper extremity at 180^0/sec and 300^0/sec can be attributed to the content of the exercise programme applied in this study.

In addition to this, the lack of the improvements during internal rotation that were seen during external rotation suggests shoulder instability. In a study (Saccol et al.2007) it was shown that tennis players exhibit more dominant internal rotation strength of shoulder during bilateral concentric and eccentric isokinetic tests and also the males have more dominant improvement of external rotation strength.

And also in some studies different strength gain and different performance results were obtained in upper and the lower extremities. For instance, Wilson et al. (1993) established that there is an increase in strength in lower extremities without an increase in upper extremities when they compared the eccentric and concentric force production of the muscles of the upper and the lower extremity after a 8-week plyometric exercise programme. They stated that this difference results as the muscle mass in upper extremity is less than the lower extremity and also the loading to the upper and the lower extremities are not in the same severeness and the force. They pointed out that loading to the lower extremity muscles can be eightfold the upper extremity.

The nature of plyometric exercises and the place of it in training period are the other factors that must be paid attention. As the plyometric exercise is a kind of exercise that uses explosive movements to improve the muscle strength (Salonikidis and Zafeiridis 2008), before combination of the training with the plyometric exercises one should be aware of the possible risks of the injury and the stress on the body due to the forceful stress occuring during training and the performances.

Salonikidis and Zafeiridis (2008), mentioned that plyometric exercises should only be done by sportsmen with good condition having a well level of strength and elasticity. And also they mentioned that in order to perform these exercises it is not necessary to use the tennis court and the sneakers as it is so hard and it increases the likelihood of the injury so the ideal is to do it on the meadows by wearing comfortable running shoes.

In this study it is possible to say that obtaining better strength values in rotation movements for the upper extremity and right and left extension/flexion movements for the lower extremity are the results convenient to the nature of the tennis sport. Because it was shown that greater dominant forearm extension, flexion and pronation strength in young healthy tennis players is a normal situation (Ellenbeckeret al.2006).

According to the data related to the service shooting, there has been an improvement in the speed of the right service and hitting number during the process in both groups, however it was seen that from the beginning of the 4^{th} week, the improvements in the study group was significantlybetter than the control group. Besides upon looking the mean change of the maximum speed and hitting number during the process it was seen that the study group showed better improvement than the control group.

It was seen that the left service shooting speed and the hitting number showed progression in both groups during the process however the progression in the study group from the beginning of the 4^{th} week was significantly higher than the control group. When we looked at the mean change of maximum speed at the end of the process, it was seen that the study group

had more improvement than the control group.

These results mean that the applied plyometric exercises provides quite important improvements in shooting speed and the hitting numbers of the sportsmen. In the present time during tennis sport, if we consider that approximately 75% of the shooting consists forehand and services (Ellenbecker et al 2006)and the role of the upper extremity on these shooting is quite high, these improvements are very important.

The improvements in shooting velocity and the hitting performance in parallel to the improvements in strength can be explained with the force of the shoulder. Because the plyometric exercises consists of very rapid eccentric and concentric strong muscle contractions in nature and it is certain that it affects the nervous system. Plyometric exercises causes the nervous system to respond so rapidly while enforcing the same muscle for rapid extension and then shortening with a maximum force. This process is known as stretching-shortening cycle which is the most rapid reflexes of the human body. (http://www.donchu.com/articles, Access date:November 8th2011.)

In a study showing increased hitting performance parallel to the increased upper extremity strength, it was stated that plyometric exercises has increased the strength of the internal rotator muscles of the shoulder and at the same time in parallel to this improvement plyometric exercises of the upper extremity has increased the performance of the shooting and launcing (Fortun et al.1997).

As a result it was seen that the plyometric exercises performed in addition to the classical tennis exercises has caused positive effects on the shoulder and leg strength of the tennis players and also it has improved the shooting and hitting speeds and the percentage of the hitting.

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