EFFECTS OF PLYOMETRIC TRAINING ON ARM AND LEG STRENGTH IN TENNIS AND FIELD HOCKEY PLAYERS

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Abstract

The present study was to examine the effect of plyometric training and the ability to reinforce the arm and leg strength in tennis and hockey players. Plyometric refers to "Exercise that enables a muscle to reach maximum force in the shortest possible time. The muscle is loaded with an eccentric to concentric action. A total of 25 Tennis and 25 Hockey players aged 18-22years selected by cluster sampling from four Universities which participated in All India Inter Universities competition (i.e. 2006-2007) served as subjects. The study was carried out for 3 months (12 weeks, 3days/week). The work schedule and the experimental training were given to the players by the concerned Physical Director in their campus. The results were statically analyzed using ANOVA and their group means were compared by Duncan's Multiple Range Test (DMRT). The study revealed better improvement in arm and leg strength of Tennis players than Hockey players.

Key words: Plyometric training, Tennis, Hockey, Arm strength, Leg strength, Improvement.

Introduction

Plyometrics are training techniques used by athletes in all types of sports to increase strength and explosiveness (Chu. 1998). Plyometrics consists of a rapid stretching of a muscle (eccentric action) immediately followed by a concentric or shortening action of the same muscle and connective tissue (Baechle and Earle, 2000). The stored elastic energy within the muscle is used to produce more force than can be provided by a concentric action alone (Miller et al, 2002; Pfeiffer, 1999; Wathen, 1993).

Researchers have shown that plyometric training when used with a periodized strength- training program, can contribute to improvements in vertical jump performance, acceleration, leg strength, muscular power, increased joint awareness and overall pro-perception (Adams, et al., 1992; Potteiger et al., 1999; Paasuke et al., 2001; Miller et al., 2002).

Tennis is one of the most widespread and popular recreational sports world-wide (Kraemer et al. 1995). In addition, several researchers and teachers have identified lower extremity motion including the knees, as an important component of the closed stance forehand swing (Groppel, 1984: Bollettieri, 1984).

Tennis unlike many other sports does not have time limits on matches. This can result in matches lasting less than one hour or as long as five hours. This variability requires successful tennis athletes to be highly trained both aerobic and anaerobic to aid in recovery during and after play (Kovacs, 2006).

Field Hockey is one of the most popular team sports in the world. It is a multiple high intensity activity sport with a multidirectional nature. The ability to change direction rapidly while maintaining balance without loss of speed-that is agility-is therefore an important physical component necessary for successful performance in field hockey (Lemmink et al., 2004).

Match analyses make clear that field hockey is a high intensity non-continuous game in which the physiological demands are considerable. Players carry out “heavy exercises” To perform at the highest level they need a well developed interval endurance capacity. It is the aerobic capacity that is needed for efficient recovery during short rest periods (Elferink-Gemser et al., 2005).

Though several researchers carried out many experiments to retain the arm and leg strength of players (Chad Fortun and Thomas, 1998; Kent Adams et al., 1992; Christos Kotzamanidis, 2006) No research studies have documented the effectiveness of plyometric training in reinforcement of arms and legs in players in

a very short duration. Thus our aim of the study was designed to investigate the effect of plyometric training and strengthening the arm and legs between Tennis and Hockey players.

Methodology

Twenty-five Tennis players and 25 Hockey players were selected by clusters sampling of 4 Universities (Rajasthan, Madras, Shivaji and Mumbai) in All India Inter University tournament held in Kerala Kottayam. The experimental duration was 3 months. (12 weeks, 3 days/week) The groups were divided into 5, based on the test and training given. Group 1 served as control; Group 2 as experimental group; Group 3 as Pre test group; Group 4 as mid test and Group 5 served as Post test group. The study was delimited to selected physiological variables namely arm, shoulder, wrist, leg, knee and ankle strength. Training was given to all the players of the selected concerned physical director in their campus.

Training Program to Maintain Consistence

Subjects were required to complete 12 training sessions, at a frequency of 3 sessions per week and with at least 48 hours between sessions. The leg, arm strength including shoulder, wrist, knee and ankle strength training programs were matched for repetitions, sets, progression, and rest intervals between sets.

Instructions included safety issues and subjects were advised to use an exercise mat for all push ups training sessions.

General training exercise includes warm up and stretching exercises, jogging, aerobic exercise, cycling dumbbells, parallel bar, grasp bar, grasp curl bar, cable curl, vertical jumps, high jumps, depth jumps, leg press and bench-press.

Weight training was the initial training to both of the subjects to develop and toning of the muscles. Training exercise for strengthening leg such as regular warm up-vertical jumps, one legged vertical jumps and split-squat jumps were given

For arm strengthening, exercises such as plyometric push ups and dynamic push ups were given for the upper body development.

Table-A
Summary of the number of repetitions of each exercise during the 12 weeks of training

Exercise	Repetition	Set
Week :1		
General Exercise for warm-up	1 Time	
Arm Plyometric:		
Chest Pass	0 to 5	3
Vertical Toss	0 to 5	3
Shoulder Plyometric:		
Dumbbell Overhead Press	0 to 5	3
Shoulder Muscle Exercise	0 to 5	3
Wrist Plyometric:		
Wrist Muscle Exercise	0 to 5	3
Dumbbell Inversions	0 to 5	3
Leg Plyometric:		
Plyometric Bounding	0 to 5	3
Zig Zag Hops	0 to 5	3
Knee Plyometric:		
No Arm Hops	0 to 5	3
Double Leg Hops	0 to 5	3
Ankle Plyometric:		
Ankle Hops	0 to 5	3
Rim Jump	0 to 5	3

Exercise	Repetition	Set
Week :2		
General Exercise for warm-up	1 Time	
Arm Plyometric:		
Incline Push up depth jump	5 to 7	3
Plyometric Push up	5 to 7	3

Shoulder Plyometric:		
Standing Barbell Shoulder Press	5 to 7	3
Stag Push Ups	5 to 7	3
Wrist Plyometric:		
Bench Curl	5 to 7	3
Rope Lift	5 to 7	3
Leg Plyometric:		
Accelerations	5 to 7	3
Single – Leg Bounding	5 to 7	3
Knee Plyometric:		
Leg Press	5 to 7	3
Squats	5 to 7	3
Ankle Plyometric:		
Seated Calf Raise	5 to 7	3
Dorsal Flexion	5 to 7	3

Exercise	Repetition	Set
Week :3		
General Exercise for warm-up	1 Time	
Arm Plyometric:		
Plyometric Push up	7 to 9	3
Dumbbell Curl	7 to 9	3
Shoulder Plyometric:		
Shoulder Muscle Exercise	7 to 9	3
Standing Barbell Shoulder Press	7 to 9	3
Wrist Plyometric:		
Wrist Muscle Exercise	7 to 9	3
Rope Lift	7 to 9	3
Leg Plyometric:		
Zig Zag Hops	7 to 9	3
Lateral Barrier Jumps	7 to 9	3

Knee Plyometric:		
Double Leg Hops	7 to 9	3
Leg Press	7 to 9	3
Ankle Plyometric:		
Seated Calf Raise	7 to 9	3
Dorsal Flexion	7 to 9	3

Exercise	Repetition	Set
Week :4		
General Exercise for warm-up	1 Time	
Arm Plyometric:		
Vertical Toss	9 to 11	3
Incline Push up depth jump	9 to 11	3
Shoulder Plyometric:		
Dumbbell Overhead Press	9 to 11	3
Standing Barbell Shoulder Press	9 to 11	3
Wrist Plyometric:		
Dumbbell Inversions	9 to 11	3
Bench Curl	9 to 11	3
Leg Plyometric:		
Plyometric Bounding	9 to 11	3
Lateral Barrier Jumps	9 to 11	3
Knee Plyometric:		
No Arm Hops	9 to 11	3
Leg Press	9 to 11	3
Ankle Plyometric:		
Ankle Hops	9 to 11	3
Rim Jump	9 to 11	3

Exercise	Repetition	Set
Week :5		
General Exercise for warm-up	1 Time	
Arm Plyometric:		
Vertical Toss	11 to 13	2
Incline Push up depth jump	11 to 13	2
Plyometric Push up	11 to 13	2
Shoulder Plyometric:		
Shoulder Muscle Exercise	11 to 13	2
Standing Barbell Shoulder Press	11 to 13	2
Stag Push Ups	11 to 13	2
Wrist Plyometric:		
Dumbbell Inversions	11 to 13	2
Bench Curl	11 to 13	2
Rope Lift	11 to 13	2
Leg Plyometric:		
Zig Zag Hops	11 to 13	2
Lateral Barrier Jumps	11 to 13	2
Accelerations	11 to 13	2
Knee Plyometric:		
Double Leg Hops	11 to 13	2
Leg Press	11 to 13	2
Squats	11 to 13	2
Ankle Plyometric:		
Rim Jump	11 to 13	2
Calf Exercise	11 to 13	2
Seated Calf Raise	11 to 13	2

Exercise	Repetition	Set
Week :6		
General Exercise for warm-up	1 Time	
Arm Plyometric:		
Incline Push up depth jump	13 to 15	2
Plyometric Push up	13 to 15	2
Dumbbell Curl	13 to 15	2
Shoulder Plyometric:		
Dumbbell Overhead Press	13 to 15	2
Standing Barbell Shoulder Press	13 to 15	2
Stag Push Ups	13 to 15	2
Wrist Plyometric:		
Wrist Muscle Exercise	13 to 15	2
Bench Curl	13 to 15	2
Rope Lift	13 to 15	2
Leg Plyometric:		
Plyometric Bounding	13 to 15	2
Accelerations	13 to 15	2
Single – Leg Bounding	13 to 15	2
Knee Plyometric:		
No Arm Hops	13 to 15	2
Leg Press	13 to 15	2
Squats	13 to 15	2
Ankle Plyometric:		
Rim Jump	13 to 15	2
Calf Exercise	13 to 15	2
Dorsal Flexion	13 to 15	2

Exercise	Repetition	Set
Week :7		
General Exercise for warm-up	1 Time	
Arm Plyometric:		
Chest Pass	17 to 19	2
Vertical Toss	17 to 19	2
Incline Push up depth jump	17 to 19	2
Shoulder Plyometric:		
Dumbbell Overhead Press	17 to 19	2
Shoulder Muscle Exercise	17 to 19	2
Stag Push Ups	17 to 19	2
Wrist Plyometric:		
Wrist Muscle Exercise	17 to 19	2
Dumbbell Inversions	17 to 19	2
Bench Curl	17 to 19	2
Leg Plyometric:		
Zig Zag Hops	17 to 19	2
Lateral Barrier Jumps	17 to 19	2
Single – Leg Bounding	17 to 19	2
Knee Plyometric:		
Double Leg Hops	17 to 19	2
Leg Press	17 to 19	2
Squats	17 to 19	2
Ankle Plyometric:		
Ankle Hops	17 to 19	2
Rim Jump	17 to 19	2
Dorsal Flexion	17 to 19	2

Exercise	Repetition	Set
Week :8		
General Exercise for warm-up	1 Time	
Arm Plyometric:		
Chest Pass	19 to 21	2
Incline Push up depth jump	19 to 21	2
Plyometric Push up	19 to 21	2
Shoulder Plyometric:		
Shoulder Muscle Exercise	19 to 21	2
Standing Barbell Shoulder Press	19 to 21	2
Stag Push Ups	19 to 21	2
Wrist Plyometric:		
Wrist Muscle Exercise	19 to 21	2
Bench Curl	19 to 21	2
Rope Lift	19 to 21	2
Leg Plyometric:		
Plyometric Bounding	19 to 21	2
Zig Zag Hops	19 to 21	2
Single – Leg Bounding	19 to 21	2
Knee Plyometric:		
Double Leg Hops	19 to 21	2
Leg Press	19 to 21	2
Squats	19 to 21	2
Ankle Plyometric:		
Ankle Hops	19 to 21	2
Rim Jump	19 to 21	2
Calf Exercise	19 to 21	2

Exercise	Repetition	Set
Week :9		
General Exercise for warm-up	1 Time	
Arm Plyometric:		
Chest Pass	21 to 23	1
Vertical Toss	21 to 23	1
Incline Push up depth jump	21 to 23	1
Plyometric Push up	21 to 23	1
Dumbbell Curl	21 to 23	1
Shoulder Plyometric:		
Dumbbell Overhead Press	21 to 23	1
Shoulder Muscle Exercise	21 to 23	1
Standing Barbell Shoulder Press	21 to 23	1
Stag Push Ups	21 to 23	1
Wrist Plyometric:		
Wrist Muscle Exercise	21 to 23	1
Dumbbell Inversions	21 to 23	1
Bench Curl	21 to 23	1
Rope Lift	21 to 23	1
Leg Plyometric:		
Plyometric Bounding	21 to 23	1
Zig Zag Hops	21 to 23	1
Lateral Barrier Jumps	21 to 23	1
Accelerations	21 to 23	1
Single – Leg Bounding	21 to 23	1
Knee Plyometric:		
No Arm Hops	21 to 23	1
Double Leg Hops	21 to 23	1
Leg Press	21 to 23	1
Squats	21 to 23	1

Ankle Plyometric:		
Ankle Hops	21 to 23	1
Rim Jump	21 to 23	1
Calf Exercise	21 to 23	1
Seated Calf Raise	21 to 23	1
Dorsal Flexion	21 to 23	1

Exercise	Repetition	Set
Week :10		
General Exercise for warm-up	1 Time	
Arm Plyometric:		
Chest Pass	23 to 25	1
Vertical Toss	23 to 25	1
Incline Push up depth jump	23 to 25	1
Plyometric Push up	23 to 25	1
Dumbbell Curl	23 to 25	1
Shoulder Plyometric:		
Dumbbell Overhead Press	23 to 25	1
Shoulder Muscle Exercise	23 to 25	1
Standing Barbell Shoulder Press	23 to 25	1
Stag Push Ups	23 to 25	1
Wrist Plyometric:		
Wrist Muscle Exercise	23 to 25	1
Dumbbell Inversions	23 to 25	1
Bench Curl	23 to 25	1
Rope Lift	23 to 25	1
Leg Plyometric:		
Plyometric Bounding	23 to 25	1
Zig Zag Hops	23 to 25	1
Lateral Barrier Jumps	23 to 25	1
Accelerations	23 to 25	1
Single – Leg Bounding	23 to 25	1

Knee Plyometric:		
No Arm Hops	23 to 25	1
Double Leg Hops	23 to 25	1
Leg Press	23 to 25	1
Squats	23 to 25	1
Ankle Plyometric:		
Ankle Hops	23 to 25	1
Rim Jump	23 to 25	1
Calf Exercise	23 to 25	1
Seated Calf Raise	23 to 25	1
Dorsal Flexion	23 to 25	1

Exercise	Repetition	Set
Week :11		
General Exercise for warm-up	1 Time	
Arm Plyometric:		
Chest Pass	25 to 27	1
Vertical Toss	25 to 27	1
Incline Push up depth jump	25 to 27	1
Plyometric Push up	25 to 27	1
Dumbbell Curl		
Shoulder Plyometric:		
Dumbbell Overhead Press	25 to 27	1
Shoulder Muscle Exercise	25 to 27	1
Standing Barbell Shoulder Press	25 to 27	1
Stag Push Ups	25 to 27	1
Wrist Plyometric:		
Wrist Muscle Exercise	25 to 27	1
Dumbbell Inversions	25 to 27	1
Bench Curl	25 to 27	1
Rope Lift	25 to 27	1

Leg Plyometric:		
Plyometric Bounding	25 to 27	1
Zig Zag Hops	25 to 27	1
Lateral Barrier Jumps	25 to 27	1
Accelerations	25 to 27	1
Single – Leg Bounding	25 to 27	1
Knee Plyometric:		
No Arm Hops	25 to 27	1
Double Leg Hops	25 to 27	1
Leg Press	25 to 27	1
Squats	25 to 27	1
Ankle Plyometric:		
Ankle Hops	25 to 27	1
Rim Jump	25 to 27	1
Calf Exercise	25 to 27	1
Seated Calf Raise	25 to 27	1
Dorsal Flexion	25 to 27	1

Exercise	Repetition	Set
Week :12		
General Exercise for warm-up	1 Time	
Arm Plyometric:		
Chest Pass	27 to 29	1
Vertical Toss	27 to 29	1
Incline Push up depth jump	27 to 29	1
Plyometric Push up	27 to 29	1
Dumbbell Curl	27 to 29	1
Shoulder Plyometric:		
Dumbbell Overhead Press	27 to 29	1
Shoulder Muscle Exercise	27 to 29	1
Standing Barbell Shoulder Press	27 to 29	1
Stag Push Ups	27 to 29	1

Wrist Plyometric:		
Wrist Muscle Exercise	27 to 29	1
Dumbbell Inversions	27 to 29	1
Bench Curl	27 to 29	1
Rope Lift	27 to 29	1
Leg Plyometric:		
Plyometric Bounding	27 to 29	1
Zig Zag Hops	27 to 29	1
Lateral Barrier Jumps	27 to 29	1
Accelerations	27 to 29	1
Single – Leg Bounding	27 to 29	1
Knee Plyometric:		
No Arm Hops	27 to 29	1
Double Leg Hops	27 to 29	1
Leg Press	27 to 29	1
Squats	27 to 29	1
Ankle Plyometric:		
Ankle Hops	27 to 29	1
Rim Jump	27 to 29	1
Calf Exercise	27 to 29	1
Seated Calf Raise	27 to 29	1
Dorsal Flexion	27 to 29	1

Before the start of the training period, experimental subjects were thoroughly instructed on how to do the plyometric exercises, including demonstration and supervised practice. They were also given logbooks listing the regimens by day and week, and each experimental subject kept a written record of running, plyometric training and any other exercise done throughout the study period. Control subjects also kept written logs of running and other exercises. Experimental subjects were contacted periodically throughout the training period to check on compliance.

Experimental Design and Statistical Analysis

The purpose of the study was to find out the effect of plyometric training and the significant difference between Tennis and Hockey players on selected criterion variables used as experimental design in this study. The data were measured using dynamometer and stopwatch for measuring all variables accurately by giving their mean values. The collected data on selected criterion variables were statistically analyzed by using ANOVA and the group means were compared by Duncan's Multiple Range Test (DMRT) to find out the significant difference between tennis and Hockey players. In all the cases, 0.05 level of confidence was fixed to test the significance, which was considered as an appropriate.

Table 1
Effect of plyometric training and gaining strength in arm, shoulder and wrist in Tennis and Hockey players in Rajasthan University

Groups	Tennis			Hockey		
	Arm	Shoulder	Wrist	Arm	Shoulder	Wrist
Control	25.56±0.06[a]	81.75±1.5 [a]	4.65±0.01[a]	24.48±0.5[a]	80.77±1.5[a]	4.5±0.02 [a]
Expt+Players	27.23±0.08[b]	82.46±2.2 [b]	5.2 ±0.02 [b]	26.5±0.3[b]	83.5±2.5[b]	4.7±0.05[b]
Expt+Pretest	29.50± 0.1[c]	86.96±5.25[c]	5.8 ±0.03[c]	28.8±0.45[c]	87.5±2.4[c]	5.3±0.06[c]
Expt+Midtest	31.30 ±0.5[d]	89.96 ±5.6[d]	6.2 ±0.06[d]	30.8± 0.3[d]	88.8±2.8[d]	5.8±0.02[d]
Expt+Posttest	34.6± 0.1[e]	93.2 ±6.2[e]	6.9 ±0.07[e]	32.5 ±0.2[e]	89.3±3.2[e]	6.0±0.01[e]

Values are given as mean ±SD for 5 players in each group. Values are statistically significant at 0.05 level of confidence. Pre test and mid test groups are compared with Post test groups. Post test shows that the values are significant at $p \leq 0.05$ levels.

Value not sharing a common superscript letter (a, b, c, d and e) differ significantly at $p<0.05$ (Duncan's multiple range test)

Table 1a:
Effect of plyometric training and gaining strength in leg, ankle and knee in Tennis and Hockey players of Rajasthan University

Groups	Tennis			Hockey		
	Leg	Knee	Ankle	Leg	Knee	Ankle
Control	73.2± 0.5 [a]	26.1±0.01[a]	4.2 ±0.01[a]	72.5± 1.5 [a]	26.4±0.02[a]	3.9 ±0.02[a]
Expt+Players	76.1±1.25[b]	28.2±0.02[b]	4.4±0.02 [b]	74.5 ±1.3 [b]	29.2±0.25[b]	4.1± 0.05[b]
Expt+Pre test	78.5± 2.2 [c]	31.3±0.05[c]	5.1±0.03[c]	76.4±1.85[c]	30.5±0.04[c]	4.6 ±0.06[c]
Expt+Midtest	82.6 ±3.2[d]	34.9±0.06[d]	5.6±0.04[d]	77.2± 1.8[d]	31.2±0.06[d]	5.0± 0.02[d]
Expt+Posttest	86.7± 4.2[e]	41.8±0.07[e]	6.3 ±0.02[e]	81.5 ±1.5[e]	36.3±0.02[e]	5.3 ±0.01[e]

Values are given as mean ±SD for 5 players in each group. Values are statistically significant at 0.05 level of confidence. Pre test and mid test groups are compared with Post test groups. Post test shows that the values are significant at p≤0.05 levels.

Value not sharing a common superscript letter (a, b, c, d and e) differ significantly at p<0.05 (Duncan's multiple range test)

Table 2
Effect of plyometric training and gaining strength in arm, shoulder and wrist in Tennis and Hockey players of Madras University

Groups	Tennis			Hockey		
	Arm	Shoulder	Wrist	Arm	Shoulder	Wrist
Control	24.66±0.06[a]	83.75±1.8[a]	4.25±0.01[a]	24.26±0.5 [a]	82.77±1.5[a]	3.5 ±0.02 [a]
Expt+Players	25.43±0.08[b]	86.6 ±2.2 [b]	4.59±0.03[b]	25.25±0.08[b]	84.5±2.5[b]	4.1± 0.05 [b]
Expt+Pre test	26.50±0.09[c]	89.9±1.75[c]	5.85±0.08[c]	25.95±0.45[c]	86.5±2.4[c]	4.25±0.06[c]
Expt+Midtest	32.36±0.15[d]	92.36±2.6[d]	6.5 ±0.09[d]	26.41±0.32[d]	88.8±2.8[d]	4.9± 0.02[d]
Expt+Posttest	36.46±0.25[e]	97.2 ±3.2[e]	6.9 ±0.29[e]	28.84±0.06[e]	90.3±3.2[e]	5.25±0.01[e]

Values are given as mean ±SD for 5 players in each group. Values are statistically significant at 0.05 level of confidence. Pre test and mid test groups are compared with Post test groups. Post test shows that the values are significant at p≤0.05 levels.

Value not sharing a common superscript letter (a, b, c, d and e) differ significantly at p<0.05 (Duncan's multiple range test)

Table 2a
Effect of plyometric training and gaining strength in leg, ankle and knee in Tennis and Hockey players of Madras University

Groups	Tennis			Hockey		
	Leg	Knee	Ankle	Leg	Knee	Ankle
Control	74.92±3.5 [a]	22.75±0.05[a]	4.23±0.01[a]	74.5±3.25 [a]	23.4±0.02 [a]	4.00±0.02[a]
Expt+Players	76.55±3.33[b]	24.32±0.02[b]	4.6±0.02 [b]	75.6±1.3[b]	24.5±0.05 [b]	4.1± 0.05 [b]
Expt+Pre test	79.5± 3.82[c]	27.42±0.05[c]	4.8±0.03 [c]	77.8±1.85 [c]	25.25±0.04[c]	4.36±0.06[c]
Expt+Midtest	83.6 ±3.2[d]	29.9 ±0.06[d]	5.5±0.07[d]	80.3± 2.8[d]	26.42±0.06[d]	4.80±0.02[d]
Expt+Posttest	89.7± 4.2[e]	31.8 ±0.07[e]	5.9 ±0.08[e]	81.5 ±3.5[e]	27.26±0.02[e]	5.3 ±0.01[e]

Values are given as mean ±SD for 5 players in each group. Values are statistically significant at 0.05 level of confidence. Pre test and mid test groups are compared with Post test groups. Post test shows that the values are significant at p≤0.05 levels.

Value not sharing a common superscript letter (a, b, c, d and e) differ significantly at p<0.05 (Duncan's multiple range test)

Table 3
Effect of plyometric training and gaining strength in arm, shoulder and wrist in Tennis and Hockey players of Shivaji University

Groups	Tennis			Hockey		
	Arm	Shoulder	Wrist	Arm	Shoulder	Wrist
Control	25.66±0.06[a]	83.85±2.28[a]	4.5±0.01 [a]	22.46±0.05[a]	83.77±1.75[a]	4.15±0.06[a]
Exp+Players	26.13±0.02[b]	85.1 ±2.5 [b]	4.9±0.03 [b]	23.26±0.10[b]	84.25 ±2.5 [b]	4.3± 0.05 [b]
Expt+Pretest	27.30±0.05[c]	87.9 ±2.75[c]	5.46±0.07[c]	26.82±0.15[c]	84.85 ±2.8[c]	4.65±0.04[c]
Expt+Midtest	27.6 ±0.03[d]	89.36 ±3.6[d]	5.85±0.08[d]	28.86±0.32[d]	86.18± 3.2[d]	5.04±0.06[d]
Expt+Posttest	32.46±0.06[e]	91.2 ±3.2[e]	6.29±0.02[e]	30.18±0.20[e]	88.15 ±2.2[e]	5.25±0.07[e]

Values are given as mean ±SD for 5 players in each group. Values are statistically significant at 0.05 level of confidence. Pre test and mid test groups are compared with Post test groups. Post test shows that the values are significant at p≤0.05 levels.

Value not sharing a common superscript letter (a, b, c, d and e) differ significantly at p<0.05 (Duncan's multiple range test)

Table3a
Effect of plyometric training and gaining strength in leg, ankle and knee in Tennis and Hockey players of Shivaji University

Groups	Tennis			Hockey		
	Leg	Knee	Ankle	Leg	Knee	Ankle
Control	75.62±4.2[a]	23.5±0.08[a]	4.38±0.03[a]	74.7±3.25[a]	22.97±0.02[a]	4.1±0.03[a]
Expt+Players	76.66±3.8[b]	24.2±0.05[b]	4.49±0.05[b]	75.98±1.3[b]	23.25±0.04[b]	4.22±0.02[b]
Expt+Pretest	78.2±2.62[c]	26.5±0.07[c]	5.5±0.06[c]	76.23±5.25[c]	24.33±0.24[c]	4.86±0.06[c]
Expt+Midtest	82.1 ±3.6[d]	28.4±0.09[d]	5.8±0.08[d]	78.3± 2.7[d]	25.12±0.16[d]	5.2± 0.02[d]
Expt+Posttest	84.3± 4.7[e]	30.5 ±0.09[e]	6.2 ±0.09[e]	80.32 ±2.2[e]	27.26±0.02[e]	5.3 ±0.01[e]

Values are given as mean ±SD for 5 players in each group. Values are statistically significant at 0.05 level of confidence.Pre test and mid test groups are compared with Post test groups. Post test shows that the values are significant at p≤0.05 levels.

Value not sharing a common superscript letter (a, b, c, d and e) differ significantly at p<0.05 (Duncan's multiple range test)

Table 4
Effect of plyometric training and gaining strength in arm, shoulder and wrist in Tennis and Hockey players of Mumbai University

Groups	Tennis			Hockey		
	Arm	Shoulder	Wrist	Arm	Shoulder	Wrist
Control	22.3± 0.1[a]	84.5 ±1.8[a]	4.52±0.01[a]	22.16±0.25[a]	83.27±1.5[a]	4.11 ±0.03[a]
Expt+Players	23.1±0.2[b]	84.8 ±2.9[b]	4.76±0.01[b]	23.06±2.10[b]	83.85±2.5[b]	4.2±0.02[b]
Expt+Pre test	24.30±0.2[c]	86.19±1.7[c]	5.26±0.05[c]	23.82±0.15[c]	85.15±2.1[c]	4.5 ±0.04[c]
Expt+Mid est	28.5±0.23[d]	87.56±1.6[d]	5.47±0.01[d]	24.06±1.32[d]	86.78±3.2[d]	5.1± 0.02[d]
Expt+Posttest	30.26±0.16[e]	91.25±3.26[e]	6.00±0.03[e]	26.55±1.20[e]	88.75±3.2[e]	5.15±0.08[e]

Values are given as mean ±SD for 5 players in each group. Values are statistically significant at 0.05 level of confidence. Pre-test and mid test groups are compared with Post test groups. Post test shows that the values are significant at p≤0.05 levels.

Value not sharing a common superscript letter (a, b, c, d and e) differ significantly at p<0.05 (Duncan's multiple range test)

Table 4a
Effect of plyometric training and gaining strength in leg, ankle and knee in Tennis and Hockey players of Mumbai University

Groups	Tennis			Hockey		
	Leg	Knee	Ankle	Leg	Knee	Ankle
Control	74.22±2.2[a]	25.8±0.05[a]	4.23±0.03[a]	74.6±2.25[a]	25.27±0.01[a]	3.71±0.03[a]
Expt+Players	75.36±3.2[b]	26.2±0.02[b]	4.6±0.02[b]	75.08±2.38[b]	26.05±0.02[b]	3.92±0.08[b]
Expt+Pretest	76.5±3.12[c]	27.8±0.03[c]	5.2±0.08[c]	75.83±1.25[c]	26.63±0.14[c]	4.16±0.04[c]
Expt+Midtest	79.1 ±2.6[d]	28.9±0.01[d]	5.58±0.05[d]	76.23± 1.7[d]	27.1± 0.10[d]	4.6± 0.02[d]
Expt+Posttest	80.15±2.7[e]	30.1±0.02[e]	5.92±0.08[e]	78.52±2.12[e]	27.9 ±0.02[e]	4.93±0.03[e]

Values are given as mean ±SD for 5 players in each group. Values are statistically significant at 0.05 level of confidence. Pre test and mid test groups are compared with Post test groups. Post test shows that the values are significant at $p \leq 0.05$ levels.

Value not sharing a common superscript letter (a, b, c, d and e) differ significantly at $p<0.05$ (Duncan's multiple range test)

Results

Table-1 showed the effect of plyometric training and gaining strength in arm, shoulder and wrist in Tennis and Hockey players in Rajasthan University. There was a significant improvement in arm, shoulder and wrist strength of both players. But better strength gain was found only in Post test group of Tennis players than Hockey players.

Table -1a illustrates the effect of plyometric training and gaining strength in leg, ankle and knee in Tennis and hockey players of Rajasthan University. We found a significant increase in leg strength of both players in all experimental training groups when compared to control. Plyometric training enhances better results in Tennis players in Post test than Hockey players.

Table 2 shows the effect of plyometric training and gaining strength in arm, shoulder and wrist in Tennis and hockey players of Madras University. Significant increase was seen in arm,

shoulder and wrist strength of both players in plyometric training groups when compared to control. It was also found that more gain of strength in Tennis players when compared to Hockey players.

Table 2a shows the effect of plyometric training and gaining strength in leg, ankle and knee in Tennis and hockey players of Madras University. There was an elevation in levels of strength gaining in plyometric training groups compared to control. Whereas in Post test group of Tennis players proved much better than Hockey players.

Table 3 shows the effect of plyometric training and gaining strength in arm, shoulder and wrist in Tennis and Hockey players of Shivaji University.

Significant improvement was seen in both players. In Tennis players showed significant increase in gaining strength of arm, shoulder and wrist in Post test group when compared to Hockey players.

Table 3a depicts the effect of plyometric training and gaining strength in leg, ankle and knee in Tennis and hockey players of Shivaji University. Post test group showed an increase in leg strength of Tennis players than Hockey players.

Table 4 shows the effect of plyometric training and gaining strength in arm, shoulder and wrist in Tennis and Hockey players of Mumbai University. Comparative effect of plyometric training in gaining the arm strength was seen in Post test group of both players. There was a significant increase in the levels of arm, shoulder and wrist strength in Tennis players than Hockey players.

Table 4a shows the effect of plyometric training and gaining strength in leg, ankle and knee in Tennis and Hockey players of Mumbai University. Plyometric training showed a better improvement in post test group of Tennis players.

Thus from our results we observed that there was a significant increase in gaining the arm and leg strength of both the players. The study also reveals better improvement in Tennis players than Hockey players after the completion of 12 week training.

Discussion

In the present study, performing plyometric training resulted in an improvement in arm and leg strength of both groups of players. The Tennis players had better improvement after completion of the post test training.

Previous study has shown that plyometric training increases muscle fiber size (Jeffery et al, 1999). Researchers found that in plyometric training, the amortization phase between eccentric and concentric movements are shortened, allowing greater power production (Steben and Steben, 1981). By taking advantage of stored elastic energy and the stretch reflex (Komi 1988), the muscle is capable of performing more work in the concentric phase. This would allow for improvements in sports performance.

Stone and O'Bryant (1984) suggested that increases in power and efficiency due to plyometrics may enhance agility training objectives and plyometric activities have been used in sports such as football, tennis, soccer or other sporting events in which agility is primary requirement for successful performance.

Studies also show that plyometric training has been proposed as a training mode designed to enhance movement patterns that are used in motor activities such as sprinting and jumping (Asmussen and Bonde -Peterson, 1974).

Recent findings showed that the upper body strength and endurance as measured by 1RM bench press and push-ups respectively were significantly higher in the hockey players compared with soccer players. One explanation for the hockey players having a stronger upper body is that the demands of the game require them to wield a stick as a part of the game (Lemmink et al., 2004).

Upper body strength indices have been the focus of the majority of tennis strength research, even though the majority of tennis injuries have been reported to occur in the lower body (Bylak and Hutchinson, 1998). It would therefore be important to

include lower body strengthening exercises for tennis players (Bergeron, 1988). Unlike the asymmetrical differences seen in upper body strength, lower body strength measures have been shown to be symmetrical in tennis players (Ellenbecker and Roetert, 1995). Although more research is required on lower body strength and tennis play, it may be beneficial for tennis players to undertake both bilateral and unilateral strength exercises to improve performance and reduce the risk of injury (Kovacs, 2006).

Hence in our study showed that tennis players show far better improvement in leg and arm strength due to the effective planning and training programmes will help in designing a safe, effective and productive programme to help optimize performance. It is also recommended, like all sports that coaches should design training programmes for tennis players in a specific manner to improve tennis performance and prevent injury.

Conclusion

The results from our study are very encouraging and demonstrate the benefits of plyometric training on improving the arm and leg strength in hockey and tennis players. Not only can athletes use plyometrics to break the monotony of training but they can also improve their strength and explosiveness while working to become more agile. In addition, our results support that improvement in arm and leg strength can occur as such in a short duration of 12 weeks of plyometric training that can be much efficient during the last preparatory phase before in-season competition for athletes.

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