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The Effects of Combined Weight and Pneumatic Training to Enhance Power Endurance in Tennis Players

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ABSTRACT

Apanukul S, Suwannathada S, Intiraporn C. The Effects of Combined Weight and Pneumatic Training to Enhance Power Endurance in Tennis Players. **JEPonline** 2015;18(2):8-16. The purpose of this study is to investigate whether a combined weight and pneumatic training program provides better power endurance, peak power, and agility adaptations than a free weight training program alone. Thirty competitive male tennis players (mean age = 21.1 ± 0.1 yrs) were subjects in this study. All subjects randomly assigned to 1 of 3 groups: (a) Combined weight and pneumatic training group (CB; n = 10); (b) weight training group (WT; n = 10); and (c) control group (CO; n = 10). The subjects were tested for power endurance, peak power, and agility prior to the training, at the 4th and after the 8th wk of training. Both the CB and the WT groups performed identical training except that CB group used a pneumatic resistance (via cable) attached to an Olympic barbell loaded with plates; whereas, the WT group used just the Olympic barbell loaded with plates. Statistical analyses revealed significant (P<0.05) between-group differences after training. The results showed that the CB group significantly increased power endurance and peak power compared to the WT and the CO groups (P<0.05). Hence, combined weight and pneumatic training is better than free weight training alone for developing power endurance and peak power.

Key Words: Combined Training, Weight Training, Pneumatic Training, Power Endurance

INTRODUCTION

Tennis is a power sport that is constantly and repeatedly requiring short explosive power bursts of energy during the match. There are also quick changes of direction on the court that are produced by the players' strength (19,24). Hence, given the importance of power endurance, resistance training has become an integral component of the elite athlete's physical preparation to enhance sports performance (28). The most common forms of resistance training are free weight training (FWT), which uses gravitational force to oppose the force generated by muscles. However, FWT has a drawback in the achievement of maximal effort due to the body's lever systems. As an example, when a subject begins to perform an arm curl exercise during FWT, the distance between the barbell and the fulcrum (elbow) is the farthest. As a result, the resisting moment is at maximum at this point and, therefore, the biceps brachii must generate enough force to be able to lift the barbell. As the subject continues lifting the weight, the distance between the barbell and the fulcrum continues to decrease (as does the resisting moment). This means that the force required to perform the curl is reduced. This is termed the sticking region, which is the point in the concentric phase of a near-maximal lift where the speed of the barbell slows to a minimal velocity before accelerating again (9,10). Theoretically, if the sticking region is minimized, the force generated by muscles to lift the barbell must be more uniformly distributed. This means that a greater average muscle tension could be achieved throughout the range of movement and greater strength gains should be achieved.

To compensate for the perceived drawback with FWT, pneumatic training (PT) was created where by the resistance force is generated by air pressure. Hence, the inherent limitations of FWT may be avoided by providing a load/resistance that is not subject to inertia (14). Consequently, the forces generated should be more consistent during the entire concentric phase. Also, since the resistant load in PT comes from air pressure, PT allows athletes to generate greater acceleration and velocity due to its weightless resistant load. Forces generated during PT are more evenly distributed over the athlete's full range of motion than during FWT (12,14,18). Perhaps, this is why several studies (4,6,21,23) indicate that PT is often used with older subjects and patients with decreased lean muscle mass and with athletes who need muscular rehabilitation. However, regardless of the consistent resistance at any training speed, PT is not without drawbacks. Because of its weightless resistant load, PT cannot create the sticking region that is required to train for power.

Recent reports (1,13,26) have demonstrated an increase in strength, velocity, and power combination with FWT and other training techniques. But, they have not addressed the effects of a combination specifically between FWT and PT. Such a combination would appear to allow for the benefits of FWT and PT. After all, PT demands a greater amount of force generated over a longer range of motion while FWT requires a greater amount of force during the beginning of a lift. Combining FWT and PT allows the athlete to experience the sticking region during the beginning of the lift due to the effects of FWT and greater resisting force due to PT at the end of the lift. To the best of our knowledge, no studies have looked at combining FWT with PT. This paper attempts to answer whether an FWT or a combination of FWT and PT is more effective in increasing power endurance, peak power, and agility in tennis players during the sumo squats. We hypothesized that a combined training between FWT and PT would significantly improve power endurance, peak power, and agility when compared with FWT alone.

METHODS

Subjects

Thirty male competitive tennis players (20.1 ± 0.1 yrs; weight, 72.6 ± 4.3 kg; height, 173.3 ± 3.2 cm) volunteered to participate in this study. The inclusion criteria were: (a) subjects must be between 18 to 25 yrs of age; (b) subjects must be able to perform at least 1.5×bodyweight half squat; and (c) subjects' tennis proficiency must be better than 5.5 according to the USTA 1979 guideline. Exclusion criteria included no current musculoskeletal injuries or any other types of injury. Prior to the commencement of the research, the subjects read and signed an informed consent approved by the Ethics Review Committee for Research Involving Human Research participants, Health Science Group, Chulalongkorn University, Thailand.

Procedures

Before training, the subjects attended a laboratory familiarization visit to introduce the testing and training procedure used for the baseline measures. The subjects completed baseline tests for power endurance, peak power, and agility. Then, they were randomly placed into 1 of 3 training groups: CB (n = 10); WT (n = 10); and CO (n = 10). CB and WT completed training sessions 2 $d \cdot wk^{-1}$ for 8 wks. After 4 and 8 wks of training, mid- and post-training tests were conducted using the protocol as the pre-training test.

Experimental Protocol

Power Endurance and Peak Power

Power endurance (PE) and Peak power (PP) were performed using an FT 700 Power system (Fittech, Australia), which was used as a force plate (400 Series, Fittech, Adelaide, Australia) (Figure 1 A) and data collection tool. The system was connected to a laptop (Figure 1 B) installed with the Ballistic Measurement System software (BMS, Innervations, Adelaide, Australia). The sampling frequency was set at 200 Hz with sample period 40 sec in length for PE and 10 sec in length for PP. The subjects performed the standard warm-up and supervised warm-up that included dynamic stretching. After the warm-up, the subjects were asked to take a PP test that consisted of performing 6 continuous and dynamic jump squats on a force plate for 3 sets. There was a 3-min rest between sets to ensure that the subjects had enough recovery to perform the next set. The highest value of power of 18 squat jumps (6x3) reported from BMS was recorded as the subjects' peak power. After finishing the PP test, the subjects had a 10-min rest before performing 1 set of 30 continuous and dynamic jump squats on a force plate for PE test (2). The average power of the 30 jumps was recorded as the subjects' power endurance. The subjects were instructed to jump with their maximum effort, and verbal encouragement was given for both tests.

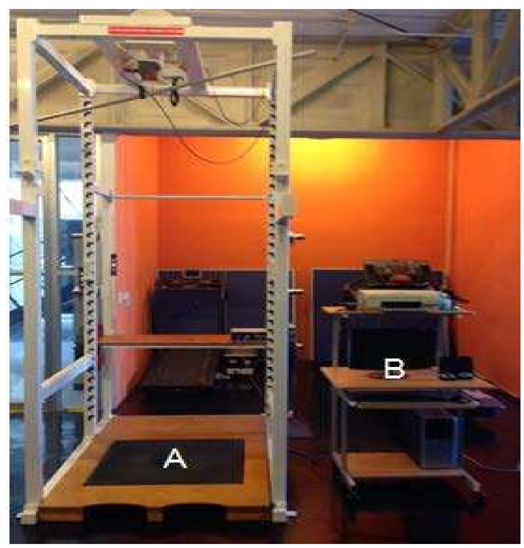

Figure 1. The Experimental Setup for the Power Endurance and Peak Power Test.

Agility

After finishing PE test, the subjects had a 30-min rest. The spider test (Figure 2) was used to assess the specific agility (AG) performance for tennis players, in which 5 balls were placed on a racket on the baseline at the center mark. The subjects were required to place the balls to the indicated sideline or baseline as fast as possible. The subjects started at the center mark and ran with the first ball to the sideline/baseline intersection and returned for the second ball. The subjects placed the second ball on the intersection of the service line and singles sideline, the third ball on the intersection of the service line and center service line, the fourth ball on the intersection of the opposite service line and single sideline, and the fifth ball on the intersection of the single sideline and baseline (20). The subjects were required to perform 3 sets of the agility test with a 4-min rest between sets. The minimum time (sec) of these values was kept.

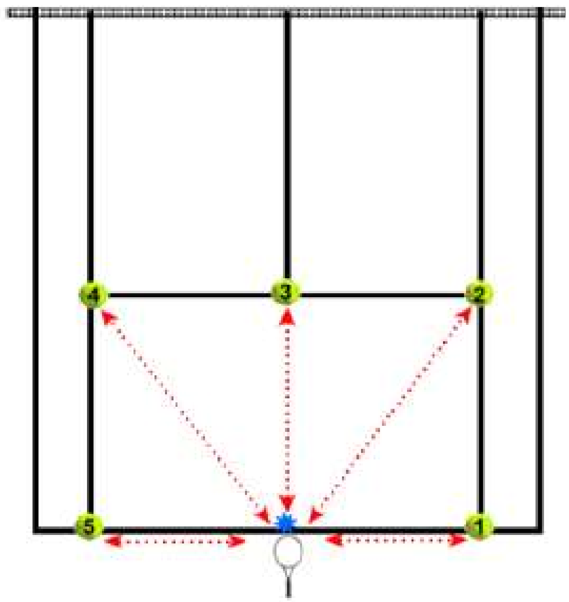

Figure 2. The Spider Test (**20**).

Instrumentation

A Keiser-equipment power rack, equipped with pneumatic technology (Power Rack, Keiser, Fresno, CA, USA) was used for the PT. Resistance, which was generated by an air compressor, could be adjusted by the pedal at the bottom of the rack (Figure 3 A, C). An Olympic barbell was attached to the rack by cables (Figure 3 A, D). The reported weight on the screen (Figure 3 A, E) was the combined resistance from the barbell and pneumatic system.

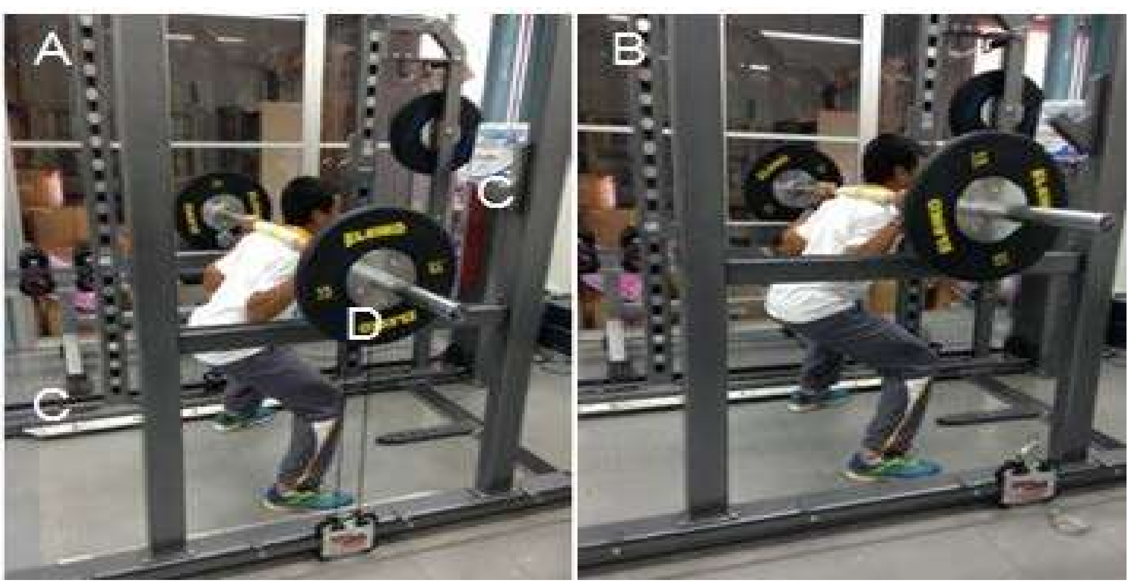

Figure 3. A: Combined Weight and Pneumatic Training, B: Weight Training.

Training Interventions
CB and WT were set to be equivalent in the intensity, which was 30% of 1RM in each subject during training

Combined Weight and Pneumatic Training (CB): A proportion between weight and pneumatic resistance was set at a weight resistance of 90%: pneumatic resistance 10% of 30% of 1RM. The subjects were required to perform 3 sets of 20 repetitions of sumo squat.

Weight Training (WT): Similar to CB group, the participants in WT group were also required to perform 3 sets of 20 repetitions of 30% of 1 RM of sumo squat. However in this group, the subjects were instructed to lift a free weight resistance which was 100% of weight resistance.

A 4-min rest between sets was imposed on both the WT and the CB groups to ensure adequate recovery of the phosphagen adenosine triphosphate (ATP) energy system (3,17). Moreover, the subjects in both groups were instructed to lift the barbell with their maximum effort. Verbal encouragement was given throughout their training. After training, both groups had a 1-hr rest before performing skill tennis training.

Control Group (CO): The subjects were required to perform skill tennis training

Statistical Analyses

All statistical analyses were performed using SPSS statistical software for Windows (Version 17.0, SPSS Inc., Chicago, IL, USA). Values are reported as mean ± SD. A 1-way ANOVA was used to compare PE, PP and AG. For all testing conditions, the level of significance was set at P<0.05.

RESULTS

Table 1 and Figures 4 graphically displayed the results for each dependent variable obtained from three conditions. The statistical analysis of power endurance showed that CB and WT were significantly different than CO groups (P<0.05) after 4 and 8 wks of training. After 8 wks of training, CB was significantly different than WT (P<0.05). With regard to peak power, CB and WT were significantly different than CO groups (P<0.05) after 4 and 8 wks of training. After 8 wks of training, CB was significantly different than WT (P<0.05). With regard to Agility, after 4 wks of training there were no significant differences (P>0.05) and after 8 wks of training CB and WT were significantly different than CO (P<0.05).

Table 1. Mean ± SD Values for Each Dependent Variable and Condition.

Conditions	Power Endurance (W·kg^{-1})			Peak Power (W·kg^{-1})			Agility (sec)		
	Pre-test	Mid-test	Post-test	Pre-test	Mid-test	Post-test	Pre-test	Mid-test	Post-test
Combined Weight and Pneumatic Training Group	51.29±2.47	56.47±1.90*	65.30±1.82*†	64.83±3.89	71.85±6.14*	81.32±5.39*†	17.39±0.60	16.81±0.56	16.11±0.68*
Weight Training Group	53.02±5.41	57.21±5.13*	60.90±4.33*	64.59±4.98	71.51±5.31*	75.02±4.12*	17.81±0.75	17.32±0.70	16.45±0.37*
Control Group	49.73±3.37	50.47±4.09	51.17±4.35	61.65±4.53	64.04±6.13	65.81±7.01	17.64±0.68	17.21±0.83	17.11±0.06

*Statistical difference from control group at P<0.05 †Statistical difference from weight training group at P<0.05

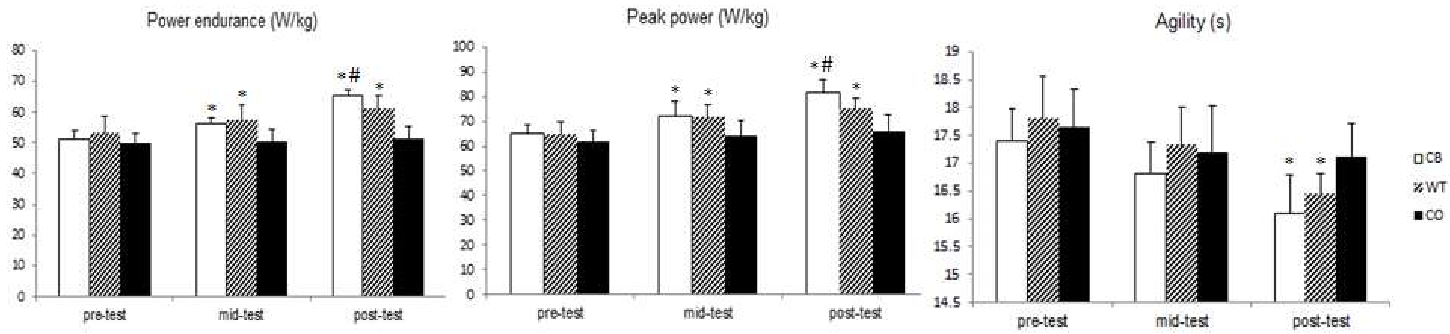

Figure 4. Average Change in Power Endurance, Peak Power and Agility after Training in Tennis Players. Data are mean ± SD. CB = Combined weight and pneumatic training group, WT = weight training group and CO = control group. *Statistical difference from control group at p<0.05 #Statistical difference from weight training group at P<0.05

DISCUSSION

The present study indicates that a combined weight and pneumatic training is an effective training program to improve power endurance and peak power in tennis players. Combined training is increasingly being used to enhance athletic ability and performance comparable to FWT (1,10,13,16). The combination of free weight and pneumatic resistance merges the benefits of both by allowing a greater amount of force to be generated over a longer range of motion.

A combined training of free weight and pneumatic improved peak power and power endurance more so than FWT alone due to the imposition of pneumatic resistance at the eccentric phase at sumo squat. In effect, then, the subjects developed stronger leg muscles (*i.e.,* gluteus maximus, quadriceps, hamstrings, and gastrocnemius), which are essential for power (7,25,27). Stronger eccentric-related leg muscles allows the subjects to have a better transition from muscle extension to a rapid contraction and/or explosive power (5,7,8,11,22).

As our testing procedure was similar to plyometric training, strong eccentric-related muscle was required in order to achieve greater test results. A combined training between free weight and pneumatic resistance training made muscles to work in both concentric and eccentric phase, while FWT provided resistant force only in concentric phase. As a result, the subjects in CB had a better peak power and power endurance than the participants in WT.

The results of the study illustrate that combined weight and pneumatic training significantly increases hip and thigh power production (i.e., as measured by the dynamic jump squats) than FWT alone. We believe that the combined weight and pneumatic training is highly effective in enhancing muscular efficiency. This, in turn, allows for excellent transfer of power to other biomechanically similar movement that requires a powerful thrust from the hip and thighs, such as running.

CONCLUSIONS

The current research has demonstrated the effects of combined weight and pneumatic training on power endurance of tennis players. The findings indicate that tennis players will benefit the most when trained with combined weight and pneumatic training for power endurance training because it will increase power endurance, peak power, and capacity to avoid a decrease in velocity at the end of longer sprint of the tennis players.

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