EFFECT OF PLAYING TENNIS ON SHOULDER INTERNAL AND EXTERNAL ROTATION STRENGTH AND PROPRIOCEPTION

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ABSTRACT

The aim of the present study was to determine the effect of playing tennis on shoulder rotators strenght and proprioception.For this porpuse, ten beginner tennis players and 10 age matched sedentary controls voluntarily participated in this study. Shoulder internal and external rotators strength were evaluated by isokinetic dynamometer at a speed of 60°/sec. Shoulder proprioception was also determined by isokinetic dynamometer and assessed by measuring reproduction of passive positioning at 15º and 30º joint angles in direction of internal and external rotation. Measurements were taken before and immediately after a ten-week tennis program. According to results, after a 10-week period, neither trained group nor the control group demonstrated significant differences in proprioceptive sense evaluations ($p>0.05$). Result supported that tennis program which continued for ten weeks has strenghtening effect on internal rotators especially on dominant shoulder ($p< 0.05$) This may lead to a lowering of the strength ratio on dominant shoulder. Asymmetric sports like tennis would result in such adaptations in dominant shoulders. The decrement in strength ratio could be characterized as glenohumeral joint instability. As a result, there should be emphasis on supplemental external strengthening exercises in the training program such group of beginner tennis players to maintain the glenohumeral stability.

Key words: shoulder strength, isokinetics, proprioception, tennis

TENİS OYUNUNUN İNTERNAL & EKSTERNAL OMUZ PROPRİYOSEPSİYONUNA VE OMUZ KAS KUVVETİNE ETKİSİ

ÖZET

Bu çalışmanın amacı tenis oyununun internal ve eksternal omuz propriyosepsiyonuna ve kas kuvvetine etkisini araştırmaktır. Tenise yeni başlayan 10 oyuncu ve bu oyunculara yaşıt 10 gönüllü sedanter birey çalışmaya katılmıştır. Katılımcıların internal ve eksternal omuz kuvvet değerlendirmeleri izokinetik dinamometre ile 60°/sn hız ile ölçüldü. Propriyosepsiyon değerlendirmeleri yine izokinetik dinamometre ile ve pasif konumlandırmanın tekrarlanabilmesi esasına göre internal ve eksternal rotasyonda 15º ve 30º'lik eklem açılanmalarında ölçülmüştür. Bu değerlendirmeler 10 haftalık tenis eğitim programının öncesinde ve sonrasında gerçekleştirilmiştir. Sonuç olarak, 10 haftalık tenis programının propriyosepsiyon değerlendirmeleri açısından herhangi bir istatistiksel farklılık yaratmadığı bulunmuştur. Bu programın sonunda dominant kolda sadece internal rotasyon kuvvetinde anlamlı bir artış gözlemlenmiştir. Tenis gibi asimetrik olarak belirtilen sporlarda bu tür adaptasyonlar normal görünmekle birlikte omuz internal ve eksternal kuvvet oranın düşmesine sebep olmaktadır. Bu azalma glenohumeral eklem instabilitesi olarak algılanmalıdır. Başlangıç seviyesindeki tenis eğitim programlarına omuzun eksternal rotasyon kuvvetini destekleyen egzersizlerin eklenmesi önerilmektedir.

Anahtar kelimeler: omuz kuvveti, izokinetik, propriyosepsiyon, tenis

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INTRODUCTION

Tennis is a global sport with numerous health benefits for individuals of any age or sex (Pluim et al., 2007). Playing tennis regularly provides improved cardiovascular function, decreased risk of cardiovascular disease, increased muscle strength, improved balance, and proprioception (Groppel and DiNubile, 2009). A major concern in tennis is the ability to perform and repeat intermittently muscular force at high speed (Groppel and Roetert, 1992). The chain of actions causes the transfer of truncal torque to ultimate projectile velocity. The transfer of this torque depends on an explosive contraction of the shoulder muscles (Mont et al., 1994). Tennis mostly involves repeated forceful and quick arm actions (e.g., service, forehand, and backhand) with the extended forearms. These ballistic movements generate a lot of eccentric load on the shoulder joint. Thus, the ability to elevate the hand over the head and execute many forceful functional tasks requires well-coordinated and synchronized actions of the shoulder muscles (Chandler et al., 1992; Kablan et al., 2004).

The functional stability of the shoulder joint, which includes several bone and joint structures, is maintained through the collaborative effect of ligaments and the rotator cuff muscles, as well as other muscles (Pedersen et al., 1998). Rotator cuff muscles constitute one of the sources of proprioceptive signals, which play a primary role in timing and optimal muscular control in the shoulder joint (Carpenter et al., 1998; Janwantanakul et al., 2003; Kablan et al., 2004; Warner et al., 1996). Proprioception encompasses an awareness of joint position and joint motion. Proprioceptors are located in the joint and surrounding joint capsules, muscle spindle afferents, and tendons (Lephart et al., 1997). A number of studies (Lephart et al., 2002; Myers et al., 2002) have stated that stability of the glenohumeral joint is provided by different mechanisms such as muscular stabilizers, capsuloligamentous tissues, and intra-articular tissues. These structures may help with joint stability by providing afferent feedback for the muscular contraction of the shoulder mechanism. Muscles receive feedback through proprioceptors in order to work properly (Lephart et al., 2002). A previous study (Lephart et al., 2002) stated that proprioception plays a crucial role in the normal function of the shoulder muscles and in protecting the shoulder against potential instability.

The aim of this study was to determine the effect of playing tennis on shoulder rotators strength and proprioception of tennis players with age-matched sedentary controls.

MATERIALS and METHODS

Subjects

Ten beginner tennis players (mean age = 20.1 ± 0.99 years, body mass = 71.8 ± 7.10 kg, height =178.2 ± 6.04 cm) and 10 age-matched sedentary controls (mean age = 20.8 ± 1.03 years, body mass = 67.8 ± 7.05 kg, height =176.4 ± 5.10 cm) participated in this study. All participants were healthy and free of any upper extremity injuries. All participants were provided with written consent about the possible risks and benefits of the experimental procedure.

Pre-tests were performed before the tennis program began and post-tests were conducted following the 10-week program. However, only the experimental group underwent a tennis program that included two training sessions (each session required 60 minutes of exercise) each week. Through the tennis course, players were introduced to the game of tennis, learned fundamental tennis techniques (forehand and backhand strokes, volley, and serve), and played short matches (Table 1). Subjects returned for a post-test data collection session within one week of completing the tennis program.

Instrumentation & Experimental Procedures

Isokinetic muscle performance of the internal and external rotators was assessed in concentric mode at 60º/sec with the Biodex Isokinetic System 4 (Biodex Medical Systems, Inc., New York, USA). Arms were placed at 90º of shoulder abduction and elbow flexion. Subjects completed a warm-up period that consisted of three submaximum followed by 3 maximum repetitions (Lephart et al., 1997). The test began when the subject was ready to start. The test involved three maximum concentric contractions of internal and external rotation, with a predetermined range of motion from 0º to 90º of external rotation. Peak torque to body weight (PT/BW) and conventional strength ratio were chosen for strength analysis.

Shoulder proprioception was also evaluated using the Biodex isokinetic system 4 (Biodex Medical Systems, Inc., New York, USA). Shoulder proprioception was determined by measuring the subject’s perception of joint position. Participants were tested in a seated position. They were blindfolded and headsets were placed over their ears to eliminate external visual and auditory stimuli. To evaluate proprioceptive awareness, the shoulder joint was positioned at 90º abduction and 90º external rotation and internal rotation, and the elbow was flexed to 90º. The perception of joint position was assessed by measuring the reproduction of passive positioning at 15º and 30º joint angles in the direction of internal and external rotation (Kablan et al., 2004; Boyar et al., 2007). The dynamometer rotated the shoulder into the reference angles of 15º and 30º internal rotation. The speed of measurement was 2º/s.

The shoulder joint was tested from the starting position. When participants were ready, the limb was moved passively to the first angle of internal rotation at a rate of 30º or 15º. The shoulder was positioned at the angle for 10 seconds and the subjects were asked to concentrate on this position. The limb was then moved passively by the device either externally or internally at a constant speed of 2º/sec. The participants were then asked to reproduce the joint angles that were previously presented. The subjects manipulated the handheld on/off switch when they thought their joint had reached the previous position.

Statistical Analysis

The data were analyzed with a separate 2x2 (Group-by-Time; Side-by-Time) mixed model of repeated measures ANOVA design with the proprioception and isokinetic parameters as dependent measures. A separate ANOVA was chosen because all of the dependent variables were autonomous. Limbs were also analyzed separately. The level of significance was set at $p < 0.05$ for all tests.

Table 1. Ten-week tennis program details

	Week I		Week II		Week III		Week IV	
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**
10 min	Warm up*	Warm up*	Warm up*	Warm up*	Warm up*	Warm up*	Warm up*	Warm up*
20 min	Ball, racquet control, basic foot work drills, ready position	Forehand review drills, forehand practice with balls over the net	Introduction to backhand, the grip	Backhand review drills, backhand practice with balls	Coach feeds (3 balls x 2 sets) the players for forehand & backhand drives	Basic forehand rally with the coach on service line (1 min for each players)	Push the ball than racquet on opposite shoulder without running (15 balls x 2 sets)	Push the ball than racquet on opposite shoulder with running (15 balls x 2 sets)
20 min	Forehand contact & follow through Pre-strecth, contact & follow through	Stationary forehand drills with a partner Forehand practice with the coach (5 balls x 2 sets for each player)	Backhand contact & follow through Pre-strecth, contact & follow through	Stationary backhand drills with a partner Backhand practice with the coach (5 balls x 2 sets for each player)	Changing the grip from forehand to backhand and reverse with several games	Basic backhand rally with the coach on service line (1 min for each players)	Free rally with coach (2 min for each players (wall practice for inactive ones)	Free rally with coach (2 min for each players (wall practice for inactive ones)
10 min	Back swing, contact & follow through, put it all together	Learn to rally	Back swing, contact & follow through, put it all together	Learn to rally	Practice the forehand & backhand from service line	Free rally with a partner	Free rally with a partner from base-line	Free rally with a partner from base-line

	Week V		Week VI		Week VII		Week VIII	
	Day 9	**Day 10**	**Day 11**	**Day 12**	**Day 13**	**Day 14**	**Day 15**	**Day 16**
10 min	Warm up*	Warm up*	Warm up*	Warm up*	Warm up*	Warm up*	Warm up*	Warm up*
20 min	Exercise for hand-eye coordination, movement involving catching, tracking, throwing tennis ball	Serve review, service practice (5 balls x 5 different distances)	Coach feeds the player with 5 balls (8 meter running) x 2 sets (wall practice for inactive ones)	Free rally with partner (4 min x 4 sets x 1 min rest)	Foot work and movement drills, introduction to short, wide, low, high bouncing shots	Rally with coach (cross-court & down the-line-shots) 20 balls for each players	Forehand backhand "forever rally" from base-line	Rally with a partner, performing smach
20 min	Serve (spin & flat), toss the ball, holding the ball, arm extended, relaxed, release ball above eye level	1 partner serves basically (10 balls x 3 sets) other returns with forehand & backhand	Free rally with a partner from base-line	Forehand & backhand volley drills with a partner, small-sided serve and volley games	Forehand & backhand drives (coach delivers tha balls), short & wide shots, low & high bouncing shots	Continue to rally with coach (cross-court & down the-line-shots) 20 balls for each players	Introduction to single play, approach shots	Rally with a partner, the lobs, defensive & offensive shots
10 min	Toss practice	Serve game (targetting marked area)	Short matches	Short matches	Short double matches	Short double matches	Short matches	Short matches

Week IX		Week X	
Day 17	**Day 18**	**Day 19**	**Day 20**
Single Tounaments (double elimination tournament system)	Single Tounaments (double elimination tournament system)	Single Tounaments (double elimination tournament system)	Single Tounaments (double elimination tournament system)

5 minute jogging and 5 minute dynamic stretching

RESULTS

Significant group-by-time interactions for the concentric internal rotator PT/BW ($F_{1,18}$ = 4.60, P = 0.04) was observed for the dominant shoulder (Table 2). The dominant concentric internal rotator PT/BW ($F_{1,18}$ = 11.85, P = 0.003) increased significantly in the experimental group following training (pre: 0.70 ± 0.10 vs. post: 0.83 ± 0.08 N•m/kgbw; 95% CI -0.18 to -0.06), whereas the control group remained the same ($F_{1,18}$ = 0.17, P = 0.68; pre: 0.75 ± 0.13 vs. post: 0.76 ± 0.08 N•m/kgbw; 95% CI -0.11 to 0.08) (Table 2). However, there were no group-by-time interactions in the non-dominant concentric internal rotator PT/BW ($F_{1,18}$ = 0.03, P = 0.86), non-dominant concentric external rotator PT/BW ($F_{1,18}$ = 0.001, P = 0.97) and agonist/antagonist ratio of both limbs ($F_{1,18}$ = 1.66, P = 0.21; $F_{1,18}$ = 0.07, P = 0.78). Only the dominant concentric external rotator PT/BW demonstrated a time effect ($F_{1,18}$ = 6.27, P = 0.02) but not significant group-by-time interactions ($F_{1,18}$ = 0.78, P = 0.38) (Table 2).

Significant side-by-time interaction for the internal rotators of the experimental group was also observed ($F_{1,18}$ = 4.99, P = 0.03) (Table 2). The dominant shoulder significantly increased the internal rotators PT/BW ($F_{1,18}$ = 19.95, P = 0.00) after the training program, whereas the non-dominant shoulder remained the same ($F_{1,18}$ = 1.71, P = 0.21). Meanwhile, there was no side-by-time interaction for internal rotators PT/BW of the control group ($F_{1,18}$ = 0.08, P = 0.77).

Comparison of the dominant and non-dominant internal rotators PT/BW results demonstrated significant difference ($t_{(18)}$=2.70, p= 0.01) in posttest evaluations in the experimental group (Table 2). Pre-test evaluation of the same group for dominant and non-dominant internal rotators PT did not show any difference ($t_{(18)}$=0.97, p= 0.34). The statistical analysis also revealed no group-by-time interaction in the shoulder proprioception scores for both 30° and 15° ($F_{1,18}$ = 1.24, P = 0.27; $F_{1,18}$ = 0.24, P = 0.62) (Figure 1). The experimental group completed the tennis program with an 89% participation rate.

Table 2. Isokinetic shoulder external and internal rotation strength parameters.

	Experimental Group (n= 10)		Control Group n= (10)	
	Pre-test	Post-test	Pre-test	Post-test
		External rotation strength		
Peak Torque/BW				
Dominant	0.58 (0.07)	0.63 (0.07)	0.59 (0.06)	0.61 (0.07)
Non-dominant	0.57 (0.06)	0.57 (0.06)	0.55 (0.09)	0.54 (0.05)
		Internal rotation strength		
Peak Torque/BW				
Dominant	0.70 (0.10)*,†	0.83 (0.08)*†‡	0.75 (0.13)	0.76 (0.08)
Non-dominant	0.66 (0.07)	0.69 (0.12)	0.65 (0.08)	0.68 (0.13)
Agon/Antagon Ratio				
Dominant	0.83 (0.06)	0.76 (0.06)	0.80 (0.11)	0.81 (0.10)
Non-dominant	0.87 (0.10)	0.84 (0.16)	0.83 (0.12)	0.81 (0.11)

*Represents significant (p < 0.05) differences between pre- and post-tests (group by time)
†Represents significant (p < 0.05) differences between pre- and post-tests (side by time)
‡Represents significant (p < 0.05) differences between dominant and non-dominant shoulder

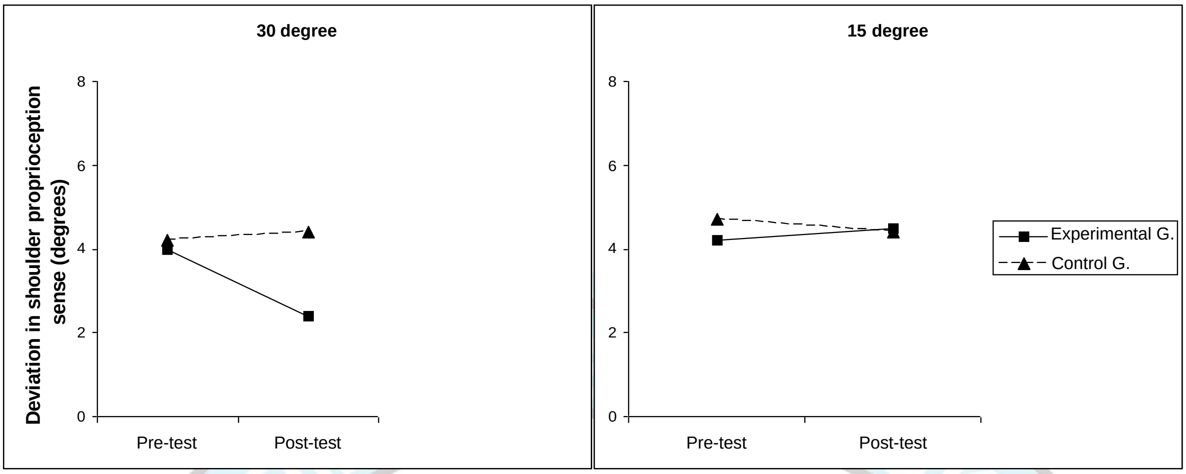

Figure 1. Training-induced changes in shoulder proprioception. The "y" axis indicates the deviation from the reference angles (30° & 15°).

DISCUSSION

The present study focused on whether playing tennis can have a positive effect on shoulder strength and shoulder proprioception. Playing tennis for a ten-week period only improved the internal rotational strength of the shoulder but not the positional sense of the participants.

The main finding of our study was that playing tennis for ten weeks resulted in significant improvement (17%) in the internal rotational strength of the dominant limb of the experimental group. This effect could be attributed to the training program that all subjects were required to participate in. This is consistent with the tennis training demands; the concentric internal rotation performed during the acceleration phase of the forehand and serve is thought to provide a stimulus for strength improvement of the shoulder internal rotators (Ellenbecker, 1991; Ellenbecker, 1992). Additionally, only the dominant shoulder internal rotation strength of the trained group was stronger than the non-dominant shoulder in post-test evaluations. The high impact on the dominant shoulder during tennis training is also an important characteristic of the game. Previous studies have demonstrated that repetitious movement with the dominant shoulder during performance may result in many anatomical and physiological adaptations (Colak et al., 2004). Therefore, asymmetric sports like tennis would result in such adaptations in dominant shoulders.

The recommended shoulder strength ratios for external and internal rotators range between 66% and 70% in healthy shoulders (Davies, 1992; Ellenbecker, 1995). Maintaining this ratio is crucial for glenohumeral stability. The current study revealed similar results as previous studies (Davies, 1992; Ellenbecker, 1995). The 10-week tennis program did not significantly change the external to internal ratio; however, the decrement was approximately 10% in the experimental group. The improvement of the internal rotator strength was discussed in a previous paragraph; however, without similar development of the external rotators, it leads to a lowering of the strength ratio on the dominant shoulder. The decrement in external/internal rotation ratio could be characterized as glenohumeral joint instability or muscular imbalance, which can lead to shoulder injury (Ellenbecker, 1995). For this reason, there should be emphasis on supplemental external strengthening exercises in the training program so the group of beginner tennis players maintains glenohumeral stability. It has been proposed that shoulder proprioceptive sense can be enhanced with training (Swanik et al., 2002). Giacomo and Ellenbecker (2009) reported that in order to improve the proprioceptive function of the shoulder, athletes should be encouraged to participate in rhythmic stabilization, closed kinetic chain exercises, and oscillation-based exercises. The present study, as shown in table 1, mainly focused on playing tennis for a ten-week period. Besides playing tennis, there were no proprioceptive-specific exercises. However, the nature of tennis, requiring dynamic balance exercises, improves the proprioceptive sense of tennis players (Groppel and DiNubile, 2009). In the present study, neither the trained group nor the control group demonstrated significant differences in proprioceptive sense evaluations. Boyar et al. (2006) examined shoulder proprioceptive sense differences in adolescent tennis players and their controls. The authors concluded that tennis players had better proprioceptive sense than their age-matched sedentary controls; therefore, it can be stated that tennis enhances overall shoulder proprioception. The absence of significant changes in proprioceptive sense during the ten-week period in this study is not thought to diminish its importance. In the present study, the ten-week training period may not have been long enough to observe measurable differences.

Some limitations of the present study need to be addressed. The small size of the study group decreases the statistical power of the findings. Although some parameters are significantly different, the parameters with low power have a high possibility for statistical errors. A larger sample size with more power is needed in future studies.

CONCLUSIONS

The results of this study support that playing tennis increases muscular strength in beginner tennis players, especially the internal rotators of the dominant shoulder. Besides the increased internal rotator strength, the absence of improvement of external rotator strength caused a decrement in the external/internal rotators strength ratio, which may lead to shoulder injury. Therefore, additional supplemental external rotator strengthening exercises are recommended to maintain the normal external/internal rotators strength ratio range. The current study could not support the positive role of playing tennis on shoulder proprioception. Nevertheless, future research is needed with longer time periods, as well as a prospective assessment of proprioceptive sense.

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