Common Injuries in Tennis Players: Exercises to Address Muscular Imbalances and Reduce Injury Risk

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SUMMARY

A TENNIS-SPECIFIC STRENGTH AND CONDITIONING PROGRAM CAN PLAY A KEY ROLE IN PREVENTING COMMON INJURIES IN TENNIS PLAYERS. THE INFORMATION PROVIDED IN THIS ARTICLE IDENTIFIES COMMON TENNIS INJURIES AND THE TENNIS DEMANDS AND MUSCULAR IMBALANCES THAT MAY PLAY A ROLE IN CAUSING THEM. SPECIFIC EXERCISES ARE SUGGESTED BASED ON THESE SPORT-SPECIFIC MUSCULAR IMBALANCES THAT HAVE A GOAL OF BOTH PREVENTING INJURIES AND ENHANCING A PLAYER'S PERFORMANCE.

INTRODUCTION

The demands of tennis on the elite players' body affect the upper and lower extremities as well as the trunk and can lead to characteristic injury patterns and musculoskeletal adaptations (19,31,52). The repetitive stressors and loading sequences create muscular imbalances specific to the sport that requires preventative interventions believed to lower injury risk. The focus of this article will be to overview common tennis injuries, also noting the rate and location at which they occur, and to highlight prevention strategies specifically focusing on key resistive exercises that can be applied for the elite player, which may prevent common tennis injuries. Research specifically linking the performance of specific exercises and injury prevention in tennis players is presently limited. Several studies and musculoskeletal descriptive profiles referenced in this article have identified alterations or changes in muscular strength or strength balance in elite-level tennis players, which differ from other athletes and the general public. These muscular imbalances and studies identifying specific muscle groups with altered performance form the basis for the exercise recommendations contained in this review. Additionally, several studies have linked specific resistive exercises with performance enhancement in elite tennis players (14,41,59). Further research is needed to establish the important role specific resistance exercises have in truly preventing tennis injuries and provide much needed evidence in this area.

COMMON TENNIS INJURIES

Tennis injuries have been reported throughout all regions of the body with more common areas being the shoulder, elbow, and knee. Table 1 lists some of the key epidemiologic studies that highlight the anatomical regions of the body and the frequency of where tennis injuries most commonly occur. Of note is the fact that musculoskeletal injuries in tennis occur in nearly all regions of the body. Most of the injuries in tennis can be defined as overuse injuries coming from the repetitive microtrauma inherent in the sport (30,47).

Identification of the most commonly injured anatomical sites in tennis is an important indication of areas that should be targeted for preventative training for the strength and conditioning professional. A percentage comparison of injury location of reported studies in tennis players is shown in Table 1. A review of these studies shows that the lower extremity is the most frequently injured region in tennis players (range 39–65%), followed

KEY WORDS:
tennis; strength; muscle balance; shoulder; elbow; back; hip

Table 1
Analysis of injury location in tennis players

Study type author/reference	P Oldenziel and Stam (46)	P Veijgen (60)	P Kühne et al. (38)	P Sallis et al. (56)	P Safran et al. (55)	P Hutchinson et al. (25)	P Winge et al. (62)	R Jayanthi et al. (26)	R Krause and Pöttinger (37)	R Chard and Lachmann (9)	R Reece et al. (48)	R Biener and Caluori (3)
"N"	2,331	283	335	1,874 (all sports)	233	304	46	299	88	131	176	15
Head/trunk	11	10	11.3	7.9	19.9	22	11	10	19.3	20	19.3	8
Head/neck	9	1.1			4.2	7				2	2.8	6
Back					12.1	12		10				2
Upper back/chest	1	1.1	11.3	7.9			11		19.3	16	2.3	
Lower back	1	7.8									10.2	
Abdomen					3.6	3					4	
Upper extremity	29	36.7	24.9	23.9	27.7	27	45.8	41	36.2	35	19.9	43.4
Shoulder	4	12	11.8	13.9	10.7	9	17.4	15	27.2	9	9.1	
Arm	<1	2.8		5.9	5.0		4.4					
Elbow	2	13.1	4.4		8.5	8	10.9	20	4.5	14.5	7.4	
Forearm	1	2.8	5.1				2.2				1.1	
Wrist/hand	21	6.0	3.6	4.1	3.5	10	10.9	6	4.5	7	2.3	
Lower extremity	60	53.3	63.6	65.2	52.5	51	39	39	39.8	45	60.8	48.6
Pelvis/hip	<1	3.5	27.1		6.4	8			5.7		5.7	
Thigh/groin	2	8.5		13.9	9.9	21	4.3	5	3.4		9.7	
Knee	10	12.7	7.8	12.0	5.0	2	6.5	12	9.1	19	13	
Lower leg	10	18.0	14.6	13.2		2	4.3	1			4.5	
Calf/Achilles	7				9.2		4.3	5	2.3	4	5.7	
Ankle	25	8.5	6.9	16.7	8.5	7	10.9	8	19.3	5.5	14.2	
Foot/toes	5	2.1	7.2	9.4	13.5	11	8.7	8		4	8	
Other	<1			3.0			4.3	3	4.5	(19)*		
Total	100	100	99.8	100	100.1	100	100.1	93	99.8	100	100	100

All values are expressed in percent.

Study type: P = prospective; R = retrospective. *"N"* = subject population.

*The total number of overuse injuries.

by the upper extremity (range 24–46%) and the head/trunk (range 8–22%). The retrospective data show a fairly similar distribution over the lower extremity (range 31–61%), upper extremity (range 22–48%), and head/trunk (range 8–20%).

The most frequently injured parts of the lower body were the lower leg, ankle, and thigh (upper leg), with the ankle sprain and thigh muscle strain (hamstring, quadriceps, and adductors) as most frequent injuries. Upper extremity injuries were most frequently located in the elbow and shoulder regions, with tendon injuries of the shoulder and tennis elbow (humeral epicondylitis) as most frequent injuries. For the purposes of this review and due to the space available, the primary injuries for which tennis-specific preventative exercise interventions will be presented are the shoulder, elbow, lower back, and hip.

Shoulder

Overuse injuries in the shoulder typically involve rotator cuff and biceps tendon pathology (61) often secondary to not only the repetitive concentric and eccentric demands on the rotator cuff but also the underlying hypermobility and excessive laxity of the glenohumeral joint. The high levels of muscular control required to maintain stability of the shoulder joint during tennis strokes have been reported by Ryu et al. (51). This study reported high levels of normalized concentric and eccentric muscular activity using electromyography (EMG) for the rotator cuff and scapular stabilizers during virtually all strokes. For example, during the cocking phase of the tennis serve, muscular activities of the supraspinatus (53%), infraspinatus (41%), and serratus anterior (70%) function to position the scapula and stabilize the glenohumeral joint, while during the follow-through phase, eccentric activation of the rotator cuff (40%) and serratus anterior (53%) assists with further stabilization and deceleration of the shoulder (51). The fact that the modern game of tennis is characterized by over 75% forehands and serves, which inherently require powerful concentric internal shoulder rotation for power generation, is consistent with the common finding of muscular imbalance between the posterior rotator cuff (external rotators) when compared with the internal rotators (27,51). Additionally, isokinetic testing (8,11,12,17,19) of the shoulder has repeatedly shown either equal or decreased dominant arm external rotation strength and 15 to 30% increases in dominant arm internal rotation strength compared with the nondominant arm in elite-level players. This finding coupled with reports of scapular dysfunction and muscular weakness in the upper back and thorax among experts who routinely evaluate elite tennis players (29) has led to the recommendation of the preventative exercises (Figures 1–5) to increase posterior rotator cuff and scapular stabilization.

Ellenbecker and Roetert (18) measured isokinetic internal and external rotation strength before and after a 4-month season of college tennis in elite female players. This study did not show any significant change in rotator cuff strength despite daily tennis play and competition over the 4-month season. This has led to the recommendation for the performance of preventative supplemental exercise for the rotator cuff and scapular muscles as an essential base in the exercise program for the elite player (Table 2). These exercises are based on EMG research, which has identified high levels of rotator cuff and scapular muscle activity, and inherently use arm positioning that minimizes impingement and loading of the shoulder's noncontractile stabilizing structures (2,5,16,32,42,49,58). These exercises should be performed using a multiple-set paradigm (2-3 sets) and high repetition base (15-20 repetitions per set) to promote local muscular endurance (22,36). Exercise programs that contain multiple exercises using the low resistance high-repetition format have been used in both tennis players and overhead athletes, resulting in modification of

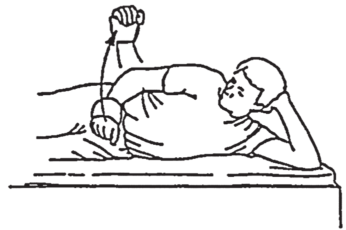
Figure 1. External rotation at 90 abduction with elastic tubing. a) start position; b) end position.

the external to internal rotation ratio, improved strength, and endurance of the rotator cuff and performance enhancement (7,14,41,43,59) Finally, recent research has highlighted the importance of using moderate exercise intensities (approximately 40% of maximum voluntary isometric contraction levels) during rotator cuff exercise to enhance and facilitate the contribution from the rotator cuff and minimize deltoid activation and compensatory shearing during external rotation strengthening exercises (4). While it is not practical for the strength and conditioning professional to monitor electrical activity levels of specific muscles during exercise, the key point of this important research is to use and apply exercises for the rotator cuff that are at submaximal intensity levels to more optimally allow for rotator cuff activation with lower overall levels of deltoid muscular activation.

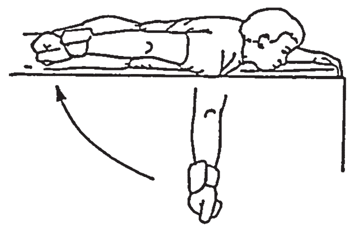
Elbow

Injuries to the elbow region in elite tennis players primarily involve repetitive overuse and center on the tendonous structures inserting at the medial and lateral humeral epicondyle (44). The reported injury rates for

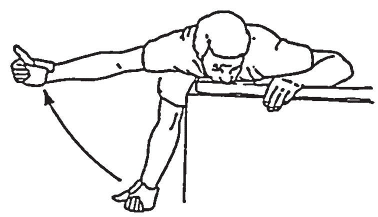
1. SIDELYING EXTERNAL ROTATION:
Lie on uninvolved side, with involved arm at side, with a small pillow between arm and body. Keeping elbow of involved arm bent and fixed to side, raise arm into external rotation. Slowly lower to starting position and repeat.



2. SHOULDER EXTENSION:
Lie on table on stomach, with involved arm hanging straight to the floor. With thumb pointed outward, raise arm straight back into extension toward your hip. Slowly lower arm and repeat.



3. PRONE HORIZONTAL ABDUCTION:
Lie on table on stomach, with involved arm hanging straight to the floor. With thumb pointed outward, raise arm out to the side, parallel to the floor. Slowly lower arm, and repeat.



4. 90/90 EXTERNAL ROTATION:
Lie on table on stomach, with shoulder abducted to 90 degrees and arm supported on table, with elbow bent at 90 degrees. Keeping the shoulder and elbow fixed, rotate arm into external rotation, slowly lower to start position, and repeat.

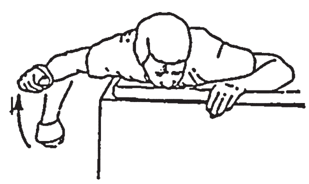


Figure 2. Isotonic rotator cuff exercise program.

Figure 5. Seated row on stability ball.

Exercises recommended for prevention of elbow injury focus on increasing the strength and particularly the muscular endurance of the wrist and forearm musculature (Table 3). In addition to the standard flexor and extensor wrist curls and forearm pronation and supination, the use of a counterbalanced weight or gripping the dumbbell at one end during the isolated performance of radial and ulnar deviation of the wrist is recommended. It is important to note that contrary to common beliefs among coaches, players, and tennis elbow are quite high, with percentages ranging from 37 to 57% in elite and recreational players (Table 1). These studies also show higher rates of incidence in elite players on the medial side of the elbow from overload on the serve and forehand strokes compared with higher rates of lateral humeral epicondylitis in lower level recreational players from the overload on the backhand ground stroke (45).

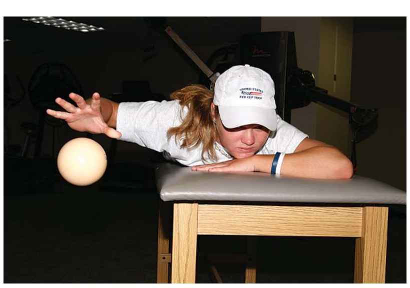


Figure 3. External rotation 90/90 prone plyometric exercise.

Figure 4. External rotation with scapular retraction (bilateral shoulder external rotation with maximal effort bilateral scapular retraction).

Table 2
Recommended tennis-specific injury prevention exercises for the shoulder

Jobe rotator cuff exercises
Sidelying external rotation
Prone extension
Prone horizontal abduction
Prone external rotation
Shoulder external rotation (neutral) (tubing)
Shoulder external rotation 90 abduction (tubing)
Shoulder 90/90 prone plyometrics
Shoulder retro toss plyometrics
External rotation with retraction (tubing)
Seated rowing on stability ball (tubing)
Serratus step-up
Serratus punch

Table 3 Recommended tennis-specific exercises for the elbow and wrist
Wrist curls (flexion)
Wrist curls (extension)
Radial deviation curls
Ulnar deviation curls
Forearm pronation/supination
Ball dribbles off wall
Wrist snaps
Wrist flips

even medical professionals, power generation does not come from the wrist and forearm in properly executed tennis strokes (21,28). Instead, the summation of forces from the entire body or kinetic chain produces the power that is transferred through the wrist, forearm, and ultimately to the racquet head to generate power (21,28). Reliance on the forearm musculature for power generation is a common clinical hypothesis for the origin of elbow pathology in tennis players due to nonoptimal contributions from other segments of the kinetic chain and poor overall stroke biomechanics and whole body fitness (13).

Additional higher level wrist and forearm strength and conditioning exercises for tennis players include ball dribbling (Figure 6) and plyometric wrist snaps with a medicine ball (Figure 7). These drills provide additional overload to the wrist and

Figure 6. Ball dribbling on wall.

Figure 7. Plyometric wrist snaps.

forearm muscles to further develop both dynamic strength and muscular endurance for this important region. Ball dribbling can be performed using sets of 30 seconds or more to create significant forearm fatigue and improve endurance.

Lower Back

The motions required in tennis include repeated flexion, extension, lateral flexion, and rotation of the spine, and intense tennis play is generally held to be a risk factor for low back pain (24). One of the motions that can particularly stress the spine in the elite player is the combined movements of extension, lateral flexion, and rotation that are inherent in the cocking or loading phase of the tennis serve. These combined repetitive motions have been shown to stress the lumbar spine and are believed to be a causative factor for spondylolysis (fracture of a specific region of the vertebrae termed the pars interarticularis) and spondylolisthesis (pars fracture with graded anterior migration of the vertebral body) identified in many athletes in sports with repetitive extension-based movement requirements (1,23,40). Tennis is no exception. Alyas et al. (1) studied the spine of 33 asymptomatic, elite, adolescent tennis players (mean age 17.3 ± 1.7 years). Five players (15.2%) had a normal magnetic resonance imaging examination, and 28 (84.8%) had an abnormal examination. Nine players showed 10 pars lesions (3 complete fractures), and 23 patients showed signs of early facet arthropathy. This study shows the impact of repetitive loading on the adolescent spine even in asymptomatic elite-level players. Tennis players can suffer from lumbar disc disease, sciatica, and facet syndromes secondary to the excessive repetitive loading as well (24).

To combat the effects of this loading, preventative conditioning strategies for tennis players include extensive core stability training. Similar to research on the shoulder, isokinetic profiling studies of elite tennis players show characteristic muscle development likely induced from the sport-specific demands imparted to the tennis players' body (50,54). Roetert et al. (54) tested elite junior players and found the trunk extension to flexion ratio to be <100, indicating greater actual strength in the abdominals and trunk flexors compared with the back extensors in these elite players. Research on normal populations (nonathletes and nontennis players) typically produces ratios >100 in the extension to flexion ratio whereby the low back extensor strength exceeds trunk flexor strength (57). Ellenbecker and Roetert (20) tested elite junior players and found symmetrical torso rotation strength using an isokinetic dynamometer, indicating that healthy uninjured players should have symmetrical strength development in the directions of both left and right rotation. These data provide insight into the training strategy for core stabilization in tennis players. Emphasis on both the flexors and extensors must be given to ensure that balanced extensor and flexor muscular development occurs as well as an emphasis on rotational exercise due to the predominance of trunk rotation inherent in all tennis strokes. Table 4 lists a sample of core stabilization exercises recommended for tennis

Table 4
Recommended core program for tennis players

Sit-ups on stability ball
Plyometric sit-ups with partner
Plyometric sit-ups with partner w/rotation
Quadruped pointer
Russian twist
Supermans (prone extension)
TV watching (prone plank)
Side plank
Side plank with unilateral row
Knee to chest on stability ball
Knee to chest with rotation on stability ball (*W*'s)
Unilateral knee to chest tuck with rotation on stability ball
Dead bug (abdominal bracing with alternate leg/arm lowering)

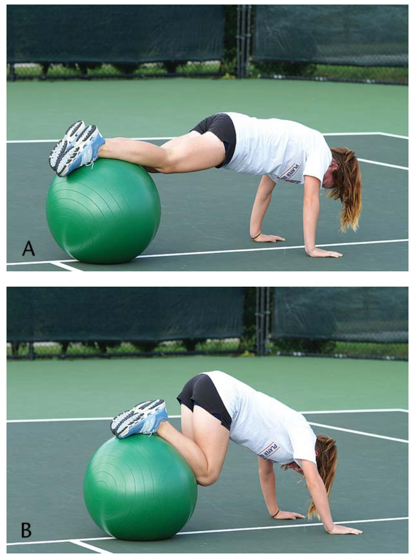


Figure 9. Knee to chest on stability ball with rotation. (a) Start position. (b) End position.

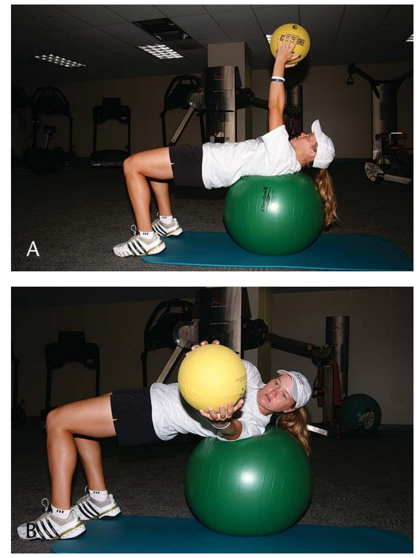


Figure 11. Russian twist. (a) Start position. (b) End position.

players that load and stress the core musculature in all 3 planes (sagittal, frontal, and transverse).

Figures 8–13 show core stabilization exercises used with tennis players. The quadruped pointer exercise can be made more difficult by placing a stability ball under the player to create an unstable surface and further challenge the player as alternate arm and leg extension pairs are performed. Careful monitoring of spinal position and maintenance of a neutral spinal posture during unilateral leg extension are critically important. Many players will excessively hyperextend their spine during leg extension and do not have engagement of the core musculature to optimally stabilize and obtain full benefit from this important exercise. The player's racquet can be placed across the lower back during the exercise to further stress the stabilization concept to the player during performance of this exercise. Figures 11–13 show variations of core stabilization exercises using a stability ball coupling core stabilization with rotation. Each of these exercises can be used to challenge core stabilization in all 3 planes and provide a focused program for core stabilization for tennis players.

Hip

Historically, injuries to the hip region were thought to focus on the powerful muscles that spanned not only the hip joint but also the knee joint (rectus femoris and hamstrings). An increased understanding of the evaluation and diagnosis of the hip has led to the identification of other forms of hip pathology in tennis due to the impact

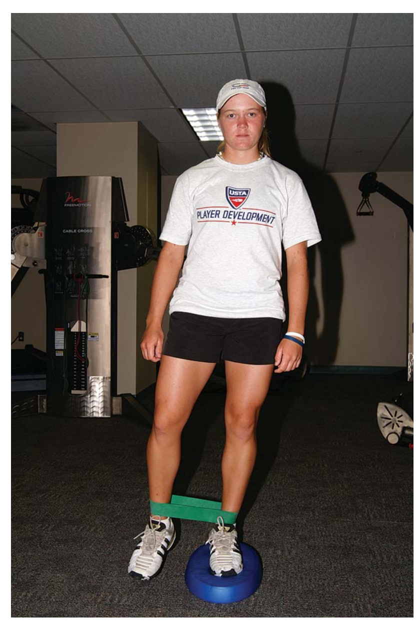


Figure 12. Elastic tubing kicks.

Figure 8. Pointer exercise for core stabilization training.

Figure 10. Unilateral knee to chest on stability ball.

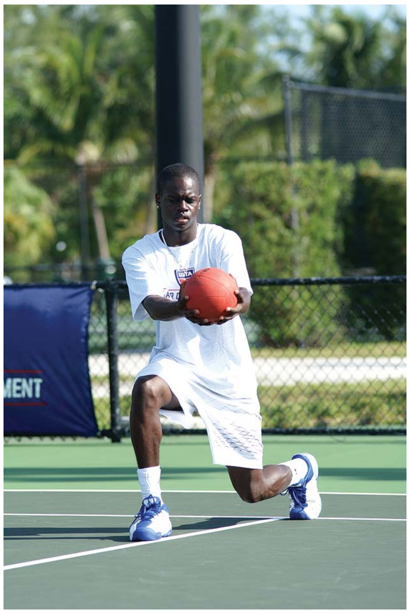


Figure 13. Lunge with rotation.

loading and multidirectional movement patterns and abrupt stopping, starting, cutting, and twisting that occur in the lower extremities during tennis (33). Injuries to the hip including femoroacetabular impingement and labral tears can occur in elite tennis players and require surgical treatment in some cases (6). In addition to ensuring that proper flexibility exists around the hip and pelvic girdle, exercises to provide greater stabilization to the hip joint and core are recommended to potentially decrease hip injury risk. Ellenbecker et al. (15) measured hip rotation range of motion and found no side-to-side differences in hip internal or external rotation range of motion in healthy uninjured elite tennis players. No additional present data are available on normal muscular strength and range of motion relationships in the hip and pelvis to guide strength and conditioning programming at this time.

Several exercises in addition to many of the exercise listed in the core training section can be used (Table 5) to improve muscular strength and endurance of the muscle groups supporting the hip in an effort to provide additional muscular stabilization to this

Table 5 Recommended hip stabilization program for tennis players
Clamshells
Reverse clamshells
Hip abduction/adduction
Plyometric lateral step overs
Elastic tubing kicks
Monster walks
Lunge with rotation

joint during on-court loading. Figure 12 shows the elastic tubing kick exercise that focuses significantly on hip abduction strength and muscular co-contraction in a closed chain environment using a balance platform to increase muscular stabilization. This exercise is most effective in producing significant muscular fatigue in the weight bearing limb, despite the athlete's typical perception that the moving limb is performing most of the work. Multiple sets of 30 seconds or more are used with the rubber tubing kick exercise to provide a more endurance-oriented load to the both the stance and moving lower extremity. The lunge with rotation (Figure 13) mimics joint angles and movement patterns used during tennis ground strokes with additional emphasis on balance and maintenance of an effective upright posture during the bilateral rotation movement performed from the effectively executed and maintained forward lunge position.

Finally, Figures 14 and 15 show the clamshell and reverse clamshell exercise used to improve hip internal and external rotation strength. An elastic loop can be used to provide resistance in the directions of hip abduction with external and internal rotation during hip adduction. It is important for the player to perform this exercise while lying on both sides to foster symmetrical hip rotation strength development in both lower extremities.

Figure 14. Clamshell.

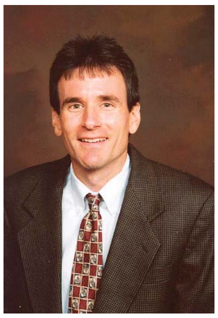
While it is beyond the scope of this review to provide exercise recommendations for all regions of the body for the elite tennis player, the reader is directed to previously published articles and reviews from journals and books that provide tennis-specific resistive exercise recommendations and provide information on periodized training formats and additional details (10,34,35,39,52,53). It is hoped that future research will focus on establishing the important role resistive exercise plays in directly preventing injuries in tennis, as well as continue to provide descriptive musculoskeletal profiles of elite players.

SUMMARY

A tennis-specific strength and conditioning program can play a key role in preventing common injuries in tennis players. The information provided in this article identifies common tennis injuries and the tennis demands and muscular imbalances that may play a role in causing them. Specific exercises are suggested in this review based on these sport-specific muscular

Figure 15. Reverse clamshell.

imbalances, which are designed to attempt to prevent injuries and enhance a player's performance. Further research is needed to provide evidence for the effectiveness of these exercises in overall injury prevention in tennis players.



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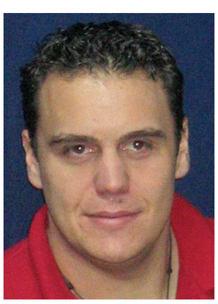

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