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The USTA Newsletter for Tennis Coaches

High-Performance Coaching

The Relationship between Stroke Mechanics and Injuries in Tennis

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Introduction

Many of the injuries that occur in elite tennis players can be classified as "overuse" injuries. The repetitive demands placed upon the human body from countless hours of training and competition can gradually lead to muscle and/or tendon breakdown. As an example, serves and forehands make up 75% of all strokes during a typical match. Couple this with the fact that players hit with incredible power from virtually anywhere on the court and it is easy to see how players could develop muscular imbalances and experience forces that could ultimately lead to injury.

There are a number of factors that can increase a player's risk of injury, including overtraining, inadequate muscular strength and/or endurance, inflexibility, improper equipment and poor aerobic fitness level. While all of these factors are important to consider when attempting to minimize the risk of injury in elite tennis players, arguably the most important is understanding the role proper stroke mechanics plays in injury prevention. Before looking at specific tennis injuries and their relation to stroke mechanics in the accompanying photo series, it is necessary to review how a player develops power in properly executed tennis strokes.

Kinetic Link Principle

For many years sport scientists have understood that the body functions as a series of interconnected links, a concept known as the "kinetic link" principle. The energy or force generated by one link (or part of the body) can be transferred successively to the next link. The most effective tennis strokes begin with leg drive generating ground reaction forces that can be transferred up the segments of the kinetic chain to the racket.

The optimum coordination (timing) of these body segments and their movements will allow for the efficient transfer of energy and power up through the body, moving from one body segment to the next. Each movement in the sequence builds upon the previous motion and they all contribute to the generation of racket speed.

This transfer of energy in sequential coordination also is enhanced by the stretch-shortening cycle of muscle. The stretch-shortening cycle involves the active stretching of a muscle (e.g. a countermovement in which the muscle is activated but is being lengthened) immediately followed by a more forceful shortening of the muscle. In the forehand, for example, the chest and shoulder muscles are actively stretched (coaches often use the cue "loading" here) as the trunk rotates into the shot. This process

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Jack Guez/AFP/Getty Images

2005 and 2006 French Open champion Rafael Nadal shows how the kinetic chain can be used to generate tremendous power.

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USTA High Performance Coaching Program

Program Applications

The USTA Coaching Education Department is accepting applications for the High Performance Coaching Program. This educational program is intended specifically for the coach who is working with players striving for excellence in competitive tennis (i.e., sectional and national ranked junior players to collegiate and young professionals). The application for the program is available by emailing us at Coaching@USTA.com. or by going to the USTA Player Development Website (www.playerdevelopment.usta.com) and downloading the program application.

USTA High Performance Coaching Program Attendance

The following list of coaches successfully completed the USTA High Performance Coaching Program conducted at the USTA Player Development Headquarters, January 7-12, 2006 in Key Biscayne, Florida. Congratulations to each coach for their time and commitment to being the best coach they can be.

Brad Armfield
Lexington, SC

Teresa A. Boylan
Bay Village, OH

Page J. Buck
Palm Harbor, FL

Kathy Burke
Raleigh, NC

Alejandro Ciffoni
Weston, FL

Andy Gladstone
Daytona Beach, FL

Julio Godreau
Madison, MS

Jim Grabb
Manhattan Beach, CA

Jim Harp
Cumming, GA

Jim Markin
Beaverton, OR

Mark Merklein
Coral Springs, FL

Michael Milhouse
Homewood, IL

Allen Miller
Athens, GA

Joanne Moore
Lexington, KY

Pintu Patel
Midland, MI

Brad Pearce
Provo, UT

Martin Perry
Chicago, IL

Toby Simpson
Charleston, SC

Joseph Stafford
Orion Township, MI

Jeri Stewart
Columbus, GA

Harold Toussaint
Jefferson Valley, NY

Phillip Williamson
Yonkers, NY

USTA Player Development Update

E. Paul Roetert, Ph.D., Managing Director, USTA Player Development and **Paul Lubbers, Ph.D.**, Director, Coaching Education, USTA Player Development

This issue of the newsletter is dedicated to examining the link between technique and injury. Although many coaches prefer to focus on performance enhancement, injury prevention is equally important—especially when it relates to the well-being of young, developing players. Injuries can occur because of a number of different factors and can be categorized as "acute" or "chronic." Acute injuries, such as spraining an ankle or pulling a muscle, are sometimes difficult to avoid (although we certainly make sure there are no stray balls on the court). But hopefully, we can make a difference in avoiding some of the more chronic injuries that occur in our sport. So, what do we in Player Development do to create an environment where we can offset the potential for chronic injuries? More importantly, what can you do as a coach to keep your players injury free?

Testing, training and tracking

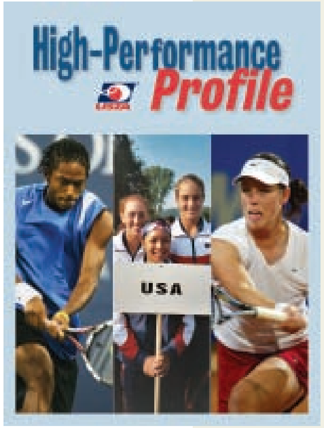
To ensure that elite level tennis players perform at their highest levels requires extensive practice, physical training and grueling competition. Maintaining this high level of performance while meeting the demands of training, however, can ultimately lead to overuse injury. Regular physical testing, to identify areas of weakness, is an important part of optimizing performance and preventing injury.

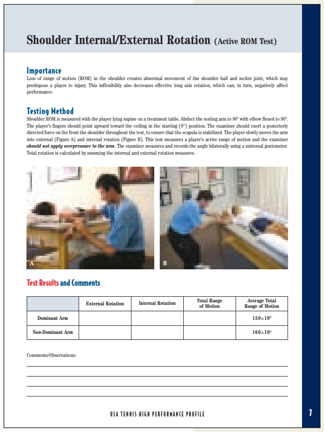
Players who come through our two National Training Centers are tested to establish both their fitness levels and their potential for injuries. Based on these testing results, our strength and conditioning staff designs training programs geared to the players' individual needs. Of course, we are interested in improvement, so we also track these players over time. We have some excellent equipment and very qualified staff members at our National Training Centers, but you can do a lot of this same sort of testing, tracking and training yourself and/or identify an expert in your area of the country to help you out. Start by printing a copy of the *High Performance Profile* at www.playerdevelopment.usta.com.

The USA Tennis High Performance Profile (HPP) is a series of musculoskeletal tests that has been assembled for the purpose of identifying muscular imbalances and pinpointing areas on which tennis players should focus their physical training. The information obtained from the HPP can be used to prevent injury and optimize on-court performance. The HPP targets areas of the body that are frequently injured in tennis players and includes strength and flexibility tests for the upper body, lower body and the core. A local certified strength and conditioning specialist, physical therapist, or athletic trainer will be able to help you administer these tests to set a baseline fitness level as well as a training program. Additional information on the *High Performance Profile* can be obtained by contacting the USTA Sport Science Department by e-mail at sportscience@usta.com.

Designing a proper training and competitive schedule

An important component of a properly-designed training program is "rest." Making sure that your players take a break at the right time can help them consistently play at their peak and help prevent overuse injuries as well as burn-out. When Kim Clijsters was growing up, she would play two tournaments in a row before taking a week off. When she started playing the juniors internationally, she played a maximum of three tournaments followed by a break. Of course, taking a longer break at the end of the tennis season is just as important. This concept is called "Periodization Training" and is widely used in many other sports. Our National Coaching staff spends a significant amount of time with our young prospects on their playing and training schedules. As a coach, one of the best things you can do is to sit down for a planning session with your players at the beginning of the year to develop a periodized plan for training and competition.




Shoulder Internal/External Rotation (Active ROM Test)

Importance
Loss of range of motion (ROM) in the shoulder creates abnormal movement of the shoulder ball and socket joint, which may predispose a player to injury. This inflexibility also decreases effective long axis rotation, which can, in turn, negatively affect performance.

Testing Method
Shoulder ROM is measured with the player lying supine on a treatment table. Abduct the testing arm to 90° with elbow flexed to 90°. The player's fingers should point upward toward the ceiling in the starting (0°) position. The examiner should exert a posteriorly directed force on the front the shoulder throughout the test, to ensure that the scapula is stabilized. The player slowly moves the arm into external (Figure A) and internal rotation (Figure B). This test measures a player's active range of motion and the examiner ***should not apply overpressure to the arm***. The examiner measures and records the angle bilaterally using a universal goniometer. Total rotation is calculated by summing the internal and external rotation measures.

A B

Test Results and Comments

	External Rotation	Internal Rotation	Total Range of Motion	Average Total Range of Motion
Dominant Arm				150±10°
Non-Dominant Arm				160±10°

Comments/Observations:

USA TENNIS HIGH PERFORMANCE PROFILE 7

Choosing the right equipment

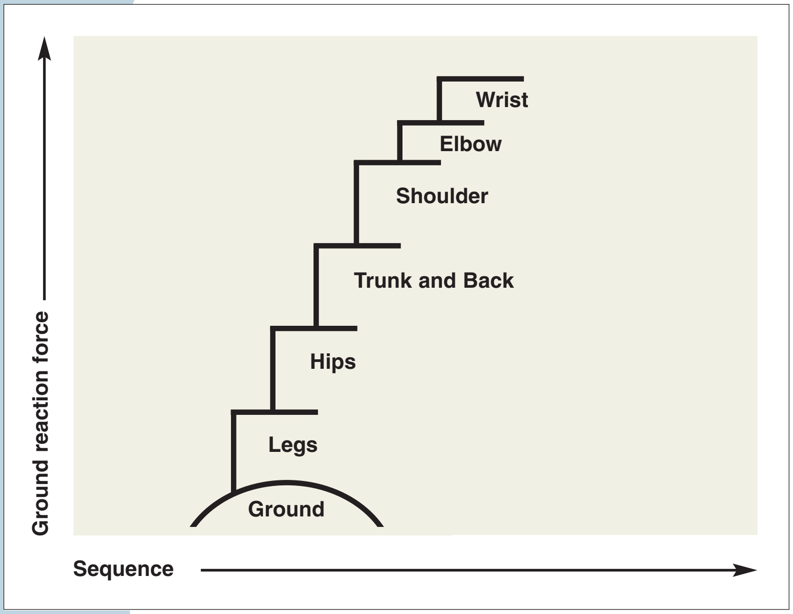
This is a very interesting topic because matching the best equipment to each individual player is an inexact science at best. You, as a coach, are probably the best person to help players make these decisions. However, many times racquets are purchased in a store without your input. Trying out different racquets (with different grips and strings) is a good idea before purchasing. Another area where other countries are spending a lot of time is on modified equipment for very young players. Not only are courts smaller, racquets shorter and lighter, and balls softer, but many of these countries have an elaborate system of competition formats set up. We hope to see a lot more of this in the United States in the near future.

Summary

As you can see, there are many ways in which you as a coach can have a major impact on keeping players injury-free. By following some of the above ideas, you will create an environment where your players can improve their performance and at the same time prevent injury. In the end they will have a better chance to reach their potential and continue to play and compete. This indeed is a winning formula.

continued from page 1

The Relationship between Stroke Mechanics and Injuries in Tennis



Power development in the kinetic chain starts with the ground and flows through the body through a series of coordinated movements.

stores energy which is returned as the muscle begins to shorten. This sequence of muscular coordination tends to be chosen naturally by the brain, but sometimes this must be coached in players who develop pauses that in turn lead to missed segment rotations or problems in sequencing movements.

Proper timing of the segments in the kinetic chain, which uses the stretch-shortening cycle, will maximize the transfer of energy to generate the greatest racket speed.

Mathematical estimates state that up to 54% of the power generated in the serve, for example, is produced by the legs and trunk. Many developing players may not use their legs and trunk adequately to generate this power, and consequently place increased demands on the smaller muscles in the kinetic chain. This, in turn, can lead to injury. Additionally, due to the reliance on angular momentum in many of the open stance shots, mis-timing the intricate series of segmental rotations (i.e., opening up too soon on the serve or forehand) can lead to the ineffective power transfer through the kinetic link system resulting in musculoskeletal injury.

In the following photo series, we profile several common tennis injuries and identify techniques and the underlying mechanics that could contribute to these injuries. Our goal is to look at the technique of some of today's top players and point out the specific stresses placed on their bodies. The players highlighted in the photo series are all elite-level players possessing tremendous skill and this analysis is not a critique of deficiencies in their technique. Some of the players have, in fact, had an injury that can be related to technique while others have not. However, it is important to realize that even though these players may be injury free, there are specific aspects of the strokes they hit that could subject a developing player (who may not have the strength or timing shown by these professional players) to an increased risk of injury.

This newsletter also contains specific exercises (see pages 10-11) that can be used to strengthen weak links in the kinetic chain and help protect the developing player against the injuries highlighted in the photo series. As an example, exercises for the rotator cuff and scapular areas are critically important for stabilizing and protecting the shoulder. Additionally, exercises for the core and hip region play a vital role in absorbing and dissipating the repetitive loading that occurs in the lower extremities, even during optimal stroke performance. Optimal stroke mechanics and muscular balance are key ingredients to an injury prevention program. It is essential that developing players be monitored closely in their stroke mechanics (by a certified coach or teaching professional) and undergo regular testing to assess their muscular strength, endurance and flexibility.

Resources

USTA Player Development website (www.playerdevelopment.usta.com): The USTA Player Development website includes several articles on technique and injury, including a white paper from the USTA Sport Science Committee on this topic. This information can be found under the Sport Science heading by clicking on *Knowledge Areas*, then clicking *Technique*.

Biomechanics of Advanced Tennis: This book, published by the ITF and edited by Bruce Elliott, Machar Reid and Miguel Crespo, is presented in a "coach friendly" way and takes an in-depth look at tennis technique and the biomechanics of stroke production (ISBN: 1-903013-23-2, ITF, www.itftennis.com).

World-Class Tennis Technique: This book, edited by Paul Roetert and Jack Groppel, looks at the sport science that underlies proper technique. The book examines each stroke individually and addresses topics such as using the kinetic chain, maintaining technique under pressure, and using strength and conditioning to enhance technique. (ISBN: 0-7360-3747-0, Human Kinetics, www.humankinetics.com).

Coaches' Infoservice website (www.coachesinfo.com): This website contains information on many sports, but has a large section devoted to tennis and provides many interesting articles on technique and technology in tennis. Current articles include the "Biomechanics of the forehand," "Biomechanics of the volley," "The serve in tennis" and "Racket technology and tennis strokes."

Photos by Lance Jeffrey

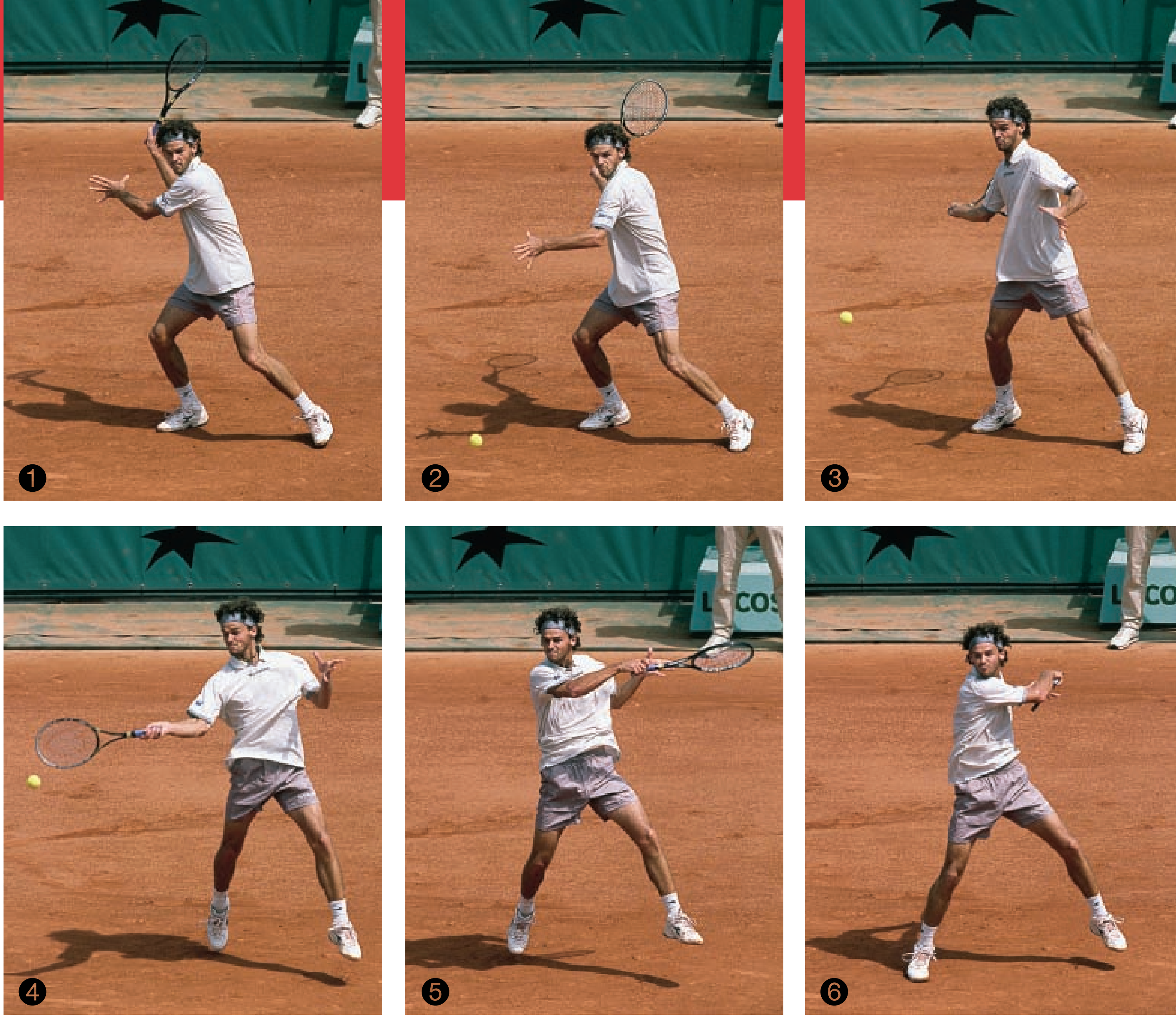
Upper Body Injuries and the Open Stance Forehand

Potential Problem

As Kim Clijsters hits this open stance forehand, pay particular attention to picture #4. In this picture, you see that her body is positioned so it is virtually parallel to the baseline. To achieve this position she has opened up her hips and trunk, causing a “lag” in which the right arm trails behind the plane of the body.

Implications for Injury

The early opening of the body and the resulting arm lag during the forehand can place excessive stress on the shoulder, particularly the rotator cuff and stabilizing structures, and the elbow. Initially, this can lead to tendonitis in the shoulder. It also places the shoulder at further risk for becoming unstable, making it more susceptible to serious injury as the structures are repetitively loaded in this lengthened position. Failure to use the entire kinetic chain properly to generate power and assist the arm when the ball is contacted late can place additional stress on the inside of the elbow, particularly when the player compensates by using the wrist and forearm excessively.



Photos by Lance Jeffrey

Hip Injury and the Open Stance Forehand

Potential Problem

As Gustavo Kuerten performs an open stance forehand, pay attention to pictures 2-4 as he loads and subsequently hits off the right leg and hip. In the open stance forehand, the muscles and structures spanning the right hip are required to absorb large forces (pictures 1-2). This is followed by explosive concentric contraction of the same muscles (pictures 3 and 4), producing the power that is needed from the first links of the kinetic chain. The forces generated by the legs and trunk are ultimately transferred through the kinetic chain to the upper body. Interestingly, most would argue that this is a properly-executed stroke. However, even when performed properly, the loading of the dominant side hip is an inherent characteristic of the open stance forehand and must be considered when preventing and/or treating injuries in the lower body.

Implications for Injury

The repetitive loading of the right hip in a right-handed player can lead to injury to the hip joint itself as well as the hip's stabilizing structures: the joint capsule, labrum, and the muscles and ligaments that support this joint. Players who repetitively load the hip can develop an injury to these structures, especially when strength imbalances and poor flexibility exist in this region. Research has shown that repetitive tennis play can create loss of motion in the hip joint. Players need excellent strength and flexibility in the hip to execute this shot properly. The exercises and stretches detailed in this newsletter can help prepare the player to handle the loads while decreasing the risk of hip injury.

Photos by Lance Jeffrey

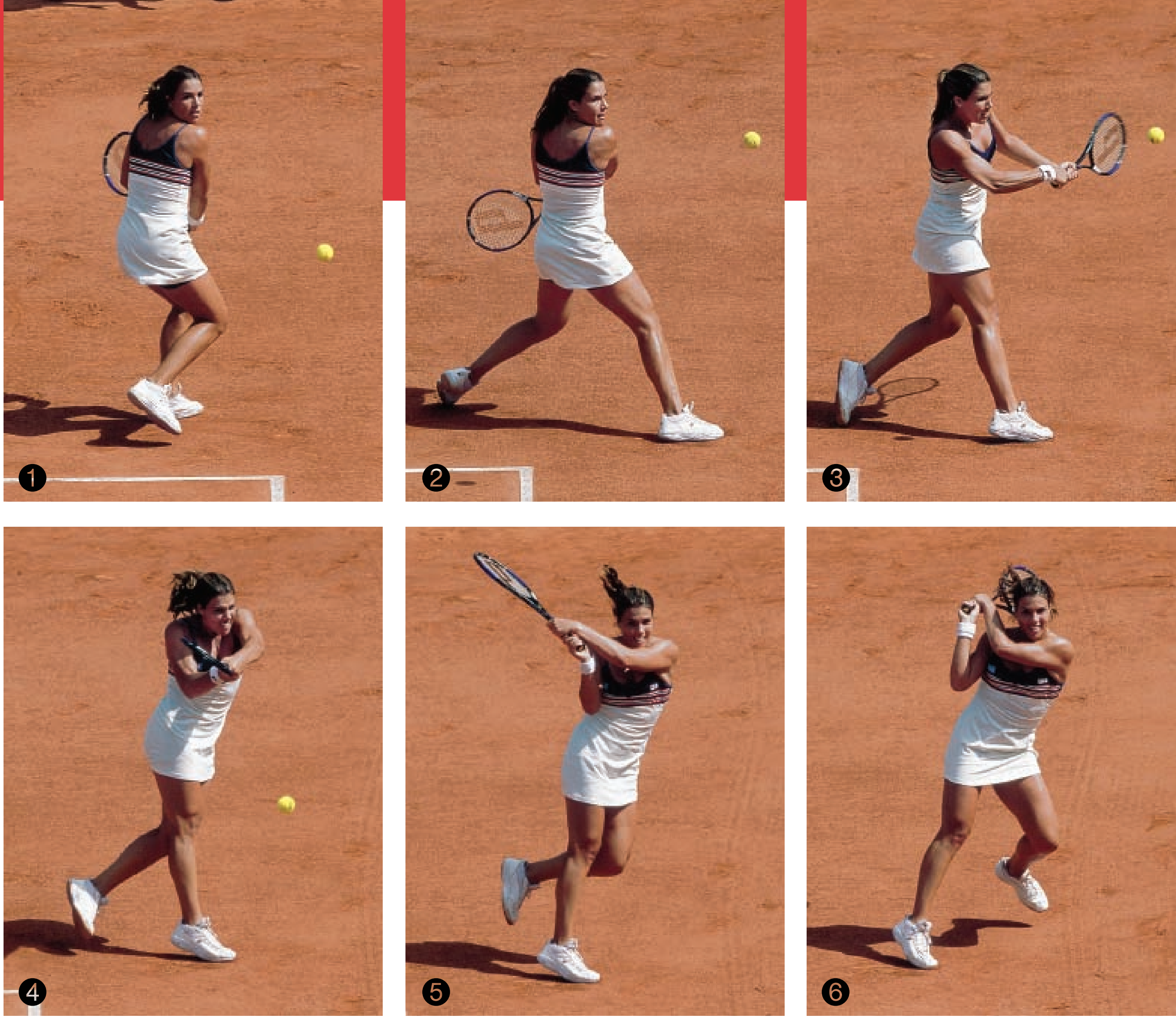
Shoulder and Abdominal Injuries and the Serve

Potential Problem

In the first few photos of the series, Venus Williams prepares to hit the serve using what most would consider normal technique. Please note that there is not much torso/shoulder rotation, even during the preparation phase. As the stroke continues, Venus begins to further open her body and does not drive with the legs as forcefully as she could (pictures 4–6). As a result, Venus must pull her body through the service motion using her abdominal muscles rather than push through the serve using her leg drive. Having to pull her arm through the hitting zone places added stress on her abdominal muscles and shoulder, as these areas are forced to make up for the break in the kinetic chain that results from the lack of rotation and leg drive.

Implications for Injury

In addition to placing increased stress on the abdominal muscles, which can lead to abdominal muscle pulls, the "arm lag" position created by the premature opening up of the body can place additional loads on the front of the right shoulder as well as the inside of the right elbow joint. Rotator cuff tendonitis and labral tears in the shoulder can result from the excess loading in the shoulder during this arm-lag type positioning on the service motion. Research has shown there are significant reductions in the shoulder and elbow load when a greater leg drive is achieved.



Photos by Lance Jeffrey

Knee Injuries and the Two-Handed Backhand

Potential Problem

As Jennifer Capriati executes a two-handed backhand in which she is pulled wide off the court, we want to look at the load experienced by the right knee, looking specifically at picture 2. The potential problem we see in this picture relates to the position of her front (right) foot. The placement of the front foot is very closed and is actually parallel to the baseline. As Jennifer begins to transfer her body weight forward onto the front foot, she will attempt to rotate her hip and pelvis over a very closed leg/foot position.

Implications for Injury

As the body rotates on a fixed or planted limb, rotation must be absorbed or taken care of by the hip and knee joints of that limb. In this example, the closed position of the foot actually serves to block or inhibit the rotation of the player's hips and trunk, thereby placing a great deal of stress on the knee. Placement of the front foot in a more open position (approximately a 45 degree angle relative to the baseline) would help to facilitate additional body rotation and decrease the stress on the hip and knee joints of the front leg.

Photos by Lance Jeffrey

Wrist Injuries and the Two-Handed Backhand

Potential Problem

Wrist injuries appear to be on the rise in tennis and Nadia Petrova shows one potential reason why this may be so. In picture 4, you can see the extreme position and downward bending (ulnar deviation) of the right wrist as she prepares to accelerate the racquet forward to ball contact. This position is often incorporated as part of the two-handed backhand technique as players attempt to drop the racquet head further below the path of incoming ball to produce greater topspin.

Implications for Injury

Injuries to the wrist are becoming more and more common in junior and professional tennis players and they can occur on either the thumb (radial) side or the little finger (ulnar) side of the wrist. The repetitive use and the forces experienced at the extreme ends of the wrist's range of motion (as seen in this backhand) place greater stress on the tendons that cross this joint. Extreme grips also can contribute to the apparent rise in wrist injuries. There also is a piece of cartilage on the ulnar side of the wrist (the triangular fibro-cartilage complex, or TFCC) that is loaded when the wrist is put into a position of extreme extension and/or ulnar deviation. When put in this position repeatedly, the TFCC can actually tear away from the end of the ulna bone. When this happens players may experience a clicking feeling in the wrist and/or pain. This type of injury often requires surgery to correct. As an additional note, the backwards movement of Petrova's body, as she strikes the ball, limits the linear momentum she can generate and therefore places a greater demand on the upper body segments.

Strength and Conditioning for Injury Prevention

USTA Sport Science and Strength and Conditioning Staff

In many instances, properly designed strength and conditioning programs can be used to help prevent the injuries that were discussed in the photo series. In some instances, the injury prevention centers on building strength in certain areas of the body. In others, it is a matter of improving flexibility or learning how to use the entire kinetic chain. In this article, we describe two exercises that can be used to prevent each injury that was profiled. While many of the exercises can be performed with little or no special equipment, several of the exercises require equipment that you would find in a weight room. On these pages we specifically address exercises that can be used in the prevention of hip and shoulder injuries. However, additional information and exercise descriptions related to the prevention of knee, wrist and abdominal injuries can be found on the USTA Player Development website, at www.playerdevelopment.usta.com, on the front page and under the Strength and Conditioning—Injury Prevention link.

Prevention of hip injuries

The loading and rotation associated with the open stance forehand places the hip at risk for injury. Maintaining strength and flexibility in the muscles surrounding this joint can help to minimize this risk.

Monster walks: This exercise builds strength in the muscles on the outside of the hip—muscles that provide stability and help with lateral movement. With a piece of elastic tubing around the ankles, start at the left doubles sideline facing the net. Get into a good athletic position—knees bent slightly, body upright and facing forward, and feet slightly wider than shoulder width apart. Maintaining this position, slowly step laterally 6 inches with the right foot. While controlling the band, lift the left foot and step in toward the right foot 6 inches. Continue this pattern while "walking" to the other doubles sideline. Repeat this exercise twice in each direction across the court.

"Figure-4" stretch: Maintaining flexibility as you externally rotate the hip is essential for being able to load and unload the hip without injury. The Figure-4 stretch is performed by crossing the right ankle over the left knee. Grab behind the left knee with both hands and pull it towards your chest. You will feel a stretch deep in the right hip. Perform 2-3 times daily on both sides, holding each stretch for 20-30 seconds.

Additional exercises on the Player Development website: Medicine ball squats and throws, medicine ball rotation drills, low to high pulls, hamstring stretch, quadriceps stretch, hip flexor stretch.

"FIGURE 4" STRETCH

Photos by Scott Riewald

MONSTER WALKS

Prevention of shoulder and elbow injuries

Proper timing and coordination of the kinetic chain is critical for avoiding the types of injuries that can occur in the upper body when hitting an open stance forehand. Additionally, having adequate strength in the rotator cuff and upper back can help stabilize the shoulder and prevent injury.

Low-to-high pull described for a right-handed player: The low-to-high pull is a multi-planar exercise that uses rotational movement patterns and integrates the entire kinetic chain. To perform this exercise, adjust a cable column weight machine so the handle starts approximately one foot off the ground. Position your body so you will have to rotate your torso to reach the handle in its starting position while also being able to bring the cable up and across your body during the lift. Using a low to moderate weight, grasp the handle with both hands at the starting position while flexing the knees and loading the right leg. Drive off the right leg while first pulling and then pushing the cable across the body so that the movement ends with both hands over the left shoulder with the arms fully extended. Perform this exercise explosively and lower the weight in a controlled manner between each repetition. Perform three sets of 15-20 repetitions.

Straight arm rowing: This exercise trains the muscles that stabilize the shoulder blades and help protect the rotator cuff from injury. Loop a piece of elastic tubing through a fence, or around another stationary object, at about hip level. Standing in an athletic position and holding an end of the tubing with each hand, elevate the arms so they are at an angle of roughly 45 degrees relative to the body. Step back so there is tension in the band. Squeeze the shoulder blades together and perform a rowing action by pulling the handles back towards the hips while keeping the arms straight. Return to the starting position with the body and tension in the tubing under control, and repeat. Perform 1-3 sets of 15 repetitions.

Additional exercises on the Player Development website: Shoulder external rotation exercises, wrist flexion and extension exercises, wrist pronation and supination.

LOW-TO-HIGH PULL (RIGHT-HANDED PLAYER)

Photos by Scott Riewald

STRAIGHT ARM ROWING

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USTA High Performance Coaching Program Dates

Program Dates for 2006 and 2007

Date	Location	Application Deadline
August 15-20, 2006	USTA Training Center, Carson, CA	Program Full
January 9-14, 2007	USTA Training Center, Key Biscayne, FL	October 15, 2006

Applications for the above program dates are available by contacting 305-365-USTA or e-mailing us at Coaching@USTA.com. We encourage all interested coaches to apply as soon as possible.