

IMPACT: The Modern Game of Tennis and Physical Requirements.

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## ***The Modern Game of Tennis & Physical Requirements***

**Presented By**

**David H Robinson USPTA, NSPA, ACSM, ACE, IDEA  
Owner**



**2005 USPTA MID-ATLANTIC CONVENTION  
McCormack-Nagelsen Tennis Center  
Williamsburg, VA. March 4-6**

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**2005 USPTA Mid-Atlantic Convention**  
**Williamsburg, VA. March 4<sup>th</sup> 8:45am-12 noon**

### **Course Overview**

Three hour workshops designed to train and inform USPTA members in the practical application of tennis-specific sport sciences. Attendees will learn how to increase business via the health/fitness market and implement fitness into tennis programming for fun, profit and skill development. Important principles and techniques will be demonstrated to improve performance, health and prevent or rehabilitate common tennis injuries.

### **Format**

The first hour will be a hands-on classroom session followed by two hours on-court training. Please bring your racquets and wear tennis attire.

### **Why This Is Course Unique**

Many sport science seminars tend to be overly technical and challenging to apply. David Robinson has a 25 year USPTA tennis professional background and 15 years as a tennis-specific fitness specialist. He has competed and coached at all levels, including juniors, collegiate, professional and senior divisions. This combination of skills allows the technical information and training to be presented in an easily understood and readily applied manner for the USPTA professional.

### **Objectives**

The course material is extensive, encompassing and designed to:

- 1.** Clarify the most common and often confusing areas of sport science that are of the highest priority to the USPTA professional.
- 2.** Present the latest and most significant research and training developments.
- 3.** Demonstrate practical and highly useful concepts and techniques in utilizing tennis-specific fitness training and methods to; market, recruit and retain fitness seekers as tennis players increasing your business and “Grow the Game.”
- 4.** Teach techniques that enable the attendees to incorporate fitness training as part of their privates, clinics and camp programs for fun, skill development and profit.
- 5.** Help the teaching pro prevent and rehabilitate injuries to themselves and their students.
- 6.** Identify methods and principles to enhance performance for any player.
- 7.** Offer USPTA members resources, reference material, motivation and direction in furthering their career development.

**Additional areas or inquiry may be identified during the course presentation as needed.**

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## **Brief Biography**

### **David H Robinson USPTA, NSPA, ACSM, ACE, IDEA**

David Robinson founded *TenniStrength & Fitness* in 1990. He has a 25+ year career in the tennis profession and 15 year background as a tennis-specific fitness specialist. He was certified by the USPTA in 1980 and the National Sports Performance Association (NSPA) in 1990, where he was named to the faculty in 1993. He is a member of the American College of Sports Medicine (ACSM), American Council on Exercise (ACE) and IDEA (a consortium of health and fitness organizations). He is currently working on his accreditation as a Clinical Exercise Specialist for sports medicine applications.

David competed and held rankings, including juniors, collegiate, professional and senior divisions. He was a touring coach on the WTA tour for three years with former world top ten ranked, Barbara Potter, and has coached numerous elite players and varsity teams. He taught tennis at five star resorts and prestigious clubs during his tennis career. He has worked for the USTA (Coaches Workshops, Schools Programs) and is the Fitness Director for the USTA Mid-Atlantic CTC.

David served on the USPTA Mid-Atlantic board as Public Relations Director and Director of *USPTA Tennis Across America*. He was the Tennis Chairman for the Lafayette Spring Fair/USPTA Tennis Across America from 1990-2001 and remains a consultant. This event has drawn as many as 6,000 people and the ABC WJLA television coverage of this was featured at USPTA National conventions.

As a fitness expert for *Tennis Magazine* since 1994, he has published articles in the “*Fit Player*” section of the magazine and is often quoted. He has presented at many health and fitness conventions to educate and train the fitness professional regarding tennis-specific conditioning and injury prevention/rehab. He conducts clinics at special events, including the ATP Legg Mason tournament for the USPTA and Wilson Racquet Sports. He has been on the Wilson Advisory Staff since 1985. He also consults and trains the staff for fitness programs and facilities at tennis academies, clubs and resorts.

David Robinson has a uniquely dynamic hands-on combination of in depth and diversified professional tennis background along with sport science skills. This allows him to convey and impart tangible information in a manner that tennis players, coaches and fitness trainers can easily understand and utilize for fun, function and profit.

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## ***The Modern Game of Tennis and Physical Requirements***

**Friday March 4<sup>th</sup> 2005**  
**8:45am-9:55am: Classroom**

### **1. Evolution of the Game**

***Brief overview: rules, equipment, strategies, surfaces, strokes and stances:***

- ***First and foremost, all*** of these elements are interrelated. The principles of “cause and effect” dictate dynamic changes in response to the interaction of these components.
- ***An excellent example*** of a significantly effecting physiological, psychological and game altering change is related to a lesser known, former foot fault rule.
- ***Players were once required*** to service while maintaining one foot to court contact until *after* striking the ball.
- ***This prohibited full utilization*** of (closed chain kinetic) ground reaction forces.
- ***Many believe the racquet technology*** to be the major contributor to the modern men’s “ace fest” dilemma.
- ***However, studies regarding the prominently noticed “jumping effect,” have shown the powerful effect upon upper body loading.*** This is in addition to the 10 percent of total racquet speed directly generated by the legs. This demonstrates the power potential and consequence of ground reaction forces.
- ***Foot fault rule change created the current “jumping effect”*** on serves which can allow for a safer yet more forceful service. The reduced stress (as factored output) to the rotator cuff and elbow was a result of the superior kinetics. This is created by the increased forward knee flexion (bending) during the loading phase.
- ***All service kinetics can be enhanced*** when greater than 10 degrees of forward knee flexion is applied. Achieving maximum safe output and efficiency, requires optimized lower body **kinetics** (the linking system or coupling of movements) and **kinematics** (the segmental joint velocities within each of these movements) to be properly integrated with the core and upper body “**kin-kin.**”
- ***Improved kinetics can offset stressful kinematics.*** It has been reported that the less functional the kinetics; the more compensatory kinematics are imposed as segmental joint velocities increase during kinetic breakdown.
- ***Sequential requirements*** for development are; functional **strength, flexibility** for full Range Of Motion (ROM), correct **biomechanics** and plyometric

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exercises for **power**. Proper biomechanics are impossible without necessary strength and ROM. Once these components are acquired, power training can be incorporated safely and effectively.

- **Observe the “old” service motion;** the rear foot was the first to make contact with the court after hitting the ball and the shoulder angle at ball contact was higher ( $> 90$  degrees abduction) than shoulder girdle (Scapula.)
- **Currently, elite players land front foot first** as a result of the optimized closed kinetic chain ground reaction force effects and the shoulder angle at ball contact is in line with the Scapula (90 degrees abduction).
- **Former rule was physically prohibitive** of this type of force production. Another major component of the greater flexion of the forward knee is the ability to safely integrate power in the form of core, scapular, and shoulder/arm loading movements.
- **Compare shoulder to scapular orientation** in serve “trophy poses.” The “forward knee flexed serve” allows the scapula to load “down and around.” Unloading the scapula shows the resulting upward rotation, placing the shoulder at a decreased 90 degree angle that is in line with the scapular plane.
- **The “old rule” motion shows an increased shoulder to scapular angle,** between 110 and 130 degrees of abduction, or 20-50 degrees of abduction above the scapular plane. This reduces power and places the vulnerable shoulder at a more injury prone angle while forcing the shoulder and tennis arm into stressful compensatory kinematics (increased segmental joint velocities). This demonstrates a problem when teaching recreational players to serve with an over-simplified methodology such as isolating the arm movements.
- **Modern players during their initial warm up serves will land on the rear foot first** until they are warmed up enough for increased ground reaction forces to be created and tolerated.
- **Then the front foot starts landing first** and the vertical jumping increases as an effect of increased closed chain kinetic ground reactions initiated by forward knee flexion.
- **Increase in core and scapular loading:** the position of the scapula begins to “go vertical” as more forward knee flexion occurs.
- **No study has shown a clear advantage between the abbreviated, semi-abbreviated and full backswing on the serve.** However, there is some reduction in kinematic stress imposed upon the anterior shoulder with the abbreviated variation. The appropriate kinetics for either backswing is thought to be the causative factor between the qualities of the serve and injury potential.

### The Kinetic Links of the Serve

- **Leg drive: ground reaction initiation.** Everything begins by flexing the hips and knees to accentuate pushing off the surface. Every proper ground based closed chain movement requires hip and knee flexion.
- **Trunk rotation: utilization and transfer** of lower body unloading movements.
- **Upper arm elevation: transition** from the cocking phase.
- **Forearm extension: “Onward and Upward.”** Full extension should occur as demonstrated when the racquet, both lower and upper arm, the scapula are in a straight line to the contact point. Recreational players, who have an inaccurate contact point due to misplacing the toss and/or poor timing, can not achieve full extension.
- **Upper arm internal rotation: generates 50 percent of the racquet head speed.** External rotators and adductors (3 of the 4 rotator cuff muscles) bear the burden of deceleration and stabilization. Rapid internal rotation is more stressful as the degree of upper arm (humerus) abduction increases. This is due to both joint angle stress and kinematic compensation.
- **Forearm pronation: functions more as a steering wheel** than accelerator. The pronation determines the placement of the serve and can add some racquet speed. Medial tennis elbow is typically caused by this segment. The key to prevention and improved performance **requires optimized equipment, biomechanics, strengthening, flexibility and safe practicing.**
- **Wrist flexion: the tip of the whip.** The wrist should be thought of as the final conduit for all stroke force production and ball control. When a player is nervous, this conduit loses fluidity and proprioception (feel). This can produce an effect of “driving with one foot on the gas and the other on the brakes. Repetitively, this stress will “burn up the brakes.”

***Learning proper gripping techniques are essential in performance enhancement and injury prevention.*** This involves the loosening and tightening of appropriate grips between each stroke and contact. A volley usually requires the firmest grip (except for touch volleys) and serves/smashes the loosest grip. Learning to squeeze just prior to contact, how tightly, which fingers, on what strokes, are key differences between elite players and novices, who often tend to squeeze continuously and/or incorrectly.

Also, observe how every elite player will take their dominant hand off the racquet handle, as soon as a point is over. They either switch the racquet to the non-dominant hand or slide the dominant hand up to the throat of the racquet. This is a muscular recovery and relaxation technique, to prevent forearm fatigue and potential tennis elbow, which is integrated with psychological transitioning.

## 2. Changes Inversely Effecting Today's Injury Epidemic

- **Tally up**; the inception of the match shortening tie break, fewer best of five set men's matches, more aces/non-returnable serves, shorter baseline rallies and a reduction in doubles competition by the top players. This amounts to less total time in competition.
- **Irony** is; despite reduced play, injury rates have soared to epidemic proportions. Certainly, the modern power game and racquets are significant. However, the shift to hard courts appears to just as, or more an injurious factor, particularly in conjunction with today's game style and equipment.
- **Three of the four "Slams" were played on grass** courts until the US Open changed to clay for a number of years, before changing again to Decoturf and the Australian Open switching to Rebound ACE.. While there are some slipping incidents on the grass courts, most of the slipping is at the beginning of the event when the courts are "greasy" or were after a rain delay in the "pre tarp" Wimbledon era. There were still fewer grass court injuries then.
- **Grass courts then** had a faster, lower and less predictable bounce. They were no tarps pulled over during rain delays and the courts played slick when damp.
- **These factors made the serve volley game the most effective style.** A current player like Roger Federer has the ideal all court playing style for winning on any surfaces in today's game. Another benefit of his diversified game is the disbursement of physical stresses.
- **Players in that era could wear spikes** (current grass court shoes have "nubs") and Rod Laver was known for once having defeated Ken Rosewall at Wimbledon because he switched to spikes after a rain delay and Rosewall did not.
- **Interesting surface to shoe interaction side note**; regards Andre Agassi's choice when competing on clay, to wear "nubbed" grass court shoes. This is to increase the level of traction to **his** personal preference. Andre, like most American players, was never that comfortable sliding on clay and wanted more a positive footing and pattern of movement similar to his biomechanics on the hard courts. Guillermo Coria is a clay court specialist who is also known to wear grass court shoes on clay.
- **Agassi is also known for preparing on hard courts before the French Open.** Sounds strange and is atypical, but Andre felt that when he practiced too much on clay prior to the French Open, he lost much of his aggressiveness and found himself disadvantaged by rallying too much.
- **Moral to these examples are** that experienced players can and will make more individualized adjustments to playing variables regardless of "mythological" norms.

### 3. Hard on Hard Courts

- ***Hard courts are now the most dominant surface*** since the US Open changed to Decoturf and the Australian Open switched to Rebound Ace. These are “rubberized” hard courts designed to produce a higher, slower bounce and to absorb shock. Also, the “tune up” tournaments needed to be played on similar surfaces as well. This vastly increased the total number of hard court events and the consecutive weeks of hard court play and practice.
- ***The Rebound Ace surface has the most positive traction*** of any surface. While this may sound good on paper; more shock absorbing and surer footing, the first year on Rebound Ace, many players were having old or negative traction shoes overnight shipped to them. Most notably was the immediate epidemic of ankle and knee injuries and currently, hip injuries from this extremely tacky surface.
- ***When players attempted to change directions on Rebound Ace***, their shoes would stick like glue and the ankles were subjected to extreme rollover stress (inversion/eversion). The knees and hips were subjected to an increase in side to side (lateral/medial) stress as well as rotational stress (torsion.)
- ***When using angular momentum***, the knees and hip were subjected to additional torsion. The lumbar spine is at increased risk from the axial forces (rotation applied to the spine).
- ***The clay courts best allow for the physical stress*** of directional change and rotational stresses to be reduced as well as having natural shock absorbing properties.
- ***Current injury phenomenon is the onslaught of hip injuries*** among the pro ranks. This is directly related to hard courts, new powerful racquets, the explosive use of angular momentum and the subsequent ultra aggressive modern game. Modern players hit far more offensive shots from defensive situations, which place the greatest amount of physical stress of any type of shot-making.
- ***Hip injuries in tennis were once reserved for the super seniors*** as an effect of osteo-arthritic aging. Hip injuries in non-senior players are typically due to powerful rotation, over-stretching and impact.
- ***Professional tennis organizations were forced to respond*** to the hard and grass court men’s game becoming an “ace fest.” In effort to slow the ball down as to produce rallies worth watching on the newly prominent hard courts, more “grit” was added to the top coat. This made the traction even more positive.
- ***Grass courts and balls have been tweaked*** to produce a higher, truer bounce which contributed significantly to the shift from serve/volley tactics to the current baseline dominant style. Despite this, the few serve volley players still find the grass courts and indoors to be their optimal surfaces.

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- ***Clay court balls have become livelier:*** Clay court tennis was historically a game of attrition and unforced errors were the primary match determining factor. Spectators were often bored watching “moon-ball” rallies that could exceed 50 shots per point. This was only partially due to the surface speed as the balls used to be pressureless as well. To make the clay court game more aggressive and exciting, the balls were changed the pressured type. Also, the courts have been rolled for greater firmness to speed up the bounce.
- ***The reason pressureless balls were used in Europe*** and other countries were due to the much higher cost for a can of balls than in the USA. Basically, pressureless balls don't go dead (they come dead) and the clay courts won't wear down the nap. This allowed recreational players' several matches with the same can of balls.

#### 4. Shoe to Surface Interaction and Injuries

- ***Unless the traction stresses are alleviated,*** the USTA adage: “**Tennis, the Sport for a Lifetime**” may need to be prefaced or have a caveat; “**On Clay Courts.**”
- ***Anyone who can continue to play injury free tennis*** throughout life will reap tremendous benefits that few other activities can compete.
- ***Studies are underway to research the “shoe to surface interaction” effect*** and I suspect the shoe manufacturers will be the first marketing force to adjust due to their ever changing product line. However, it will take years for the court surfacing companies to make appropriate adjustments.
- ***Tennis ball manufacturers react*** to whatever surface is played on. It would be interesting if they could produce a “posi-traction” ball for hard courts that would bounce higher and slower without having to add more grit to the surface top coat. Perhaps a bounce controlled, gummy, nap-less tennis ball may evolve. Just a thought that squash ball technology may be applied to tennis.
- ***Ideally, a tri-interaction adjustment of ball speed/bounce, surface traction/bounce and shoe traction changes*** would work best.
- ***The game has been adjusting the surface to ball speed ratios*** for some time, making the slow red clay faster and the fast grass slower with a truer, higher bounce.
- ***There have always been surface specific shoes made,*** but the hard court shoes have focused on shock absorbing and stabilization, rather than reducing the joint killing, ultra-traction. Only a few players, such as Michael Chang and some of the clay court specialists wearing reduced traction shoes can actually slide on hard courts. Elite players “in the know” select hard court shoes to match the surface traction. Some have even been known to have another manufacturer's shoe soles custom built onto their endorsed footwear.
- ***My shoe to surface injury occurred in the early 1980's as a result of a new shoe product.*** I had just signed with New Balance and was sent their latest

creation; the CT 500, a shoe with a gum rubber outer-sole for extra traction and a soft half inch polyurethane mid-sole for shock absorbing. The shoe did not have the lateral stabilization of current hard court shoes and this combination created a disastrous result on a dark colored, freshly resurfaced hard court that had been under the summer heat and sun. While making a routine recovery movement, the left shoe stopped on a dime, but I needed at least a silver dollar to stop on and went down, tearing ligaments from inverting my left ankle.

- ***Good news was that I discovered the power of an aggressive rehab program.*** Under my insurance plan, I found a physiotherapist who had been an athletic trainer (ATC) for a pro soccer team. Certainly, he had solid experience with ankle injured athletes and I benefited from that.

## 5. Closed Chain Biomechanics on Ground Strokes

- ***Staying current with information, being observant and open minded is the key to being a successful teaching pro, coach or trainer.*** Today's players need to learn "multi-stance" footwork patterns and strokes to accommodate the different types of oncoming balls, tactics and court positions. This is based upon; bounce height/width, running speed/distance/direction, and shot selection; **all in an integrated manner.**
- ***"Swing step squared" and open/semi-open stances have replaced the old closed stance*** on ground strokes except for wide one handed backhands.
- ***The difficulty in using angular momentum*** (rotational forces accentuated by the open and semi-open stances) while the feet are glued to the ground. Rotation is reduced and stress is induced when there is a binding effect of the feet upon the surface.
- ***A "jumping effect" is needed even without actually becoming airborne;*** this vertical movement reduces a player's body weight induced friction upon the court surface enough for angular momentum to be optimized, yet less stressful to the rotationally sensitive knee, hip and lumbar components. With the exception of the serve and overhead, jumping does not directly produce power, rather it allows for increased angular momentum.
- ***Today's players need to flex their knees and hips*** during any closed chain loading phase on ground strokes and overhead shots to maximize safe, powerful and effective shot making. Without the extension of these joints during the unloading phase, force production is stifled and injurious stress increases.
- ***The power of the new racquets*** combined with truer, higher bouncing surfaces has made it much more viable to "unload on the ball." In the wood racquet days, you had to create or simply have a better opening to hit winners or forcing shots and the ball often needed to be around net height or above to allow for high percentage capitalization. This might be considered an effect of "supply and demand."

- ***Overuse of the big power shot with a wood racquet typically only increased fatigue and unforced errors*** rather than the converse. Basically, the “Vegas odds” have swung towards the power game from the controlled game due to this transition and the biomechanics have evolved in that respect. It was once rare to have match statistics that had more winners to errors, but in today’s top level, that stat is often reversed.
- ***Players use the open/semi-open stances to increase angular momentum, allow for varied ball height/width contact and to help save two steps on most strokes.*** One of the main benefits of the open stances is the ability to aggressively play high balls. This allows a player to hit more strokes on the rise and above net level. This stance has the widest range of ball height and width contact points, except for one handed backhand slices (the most under rated stroke in tennis!) The harder the ball is struck, the sooner it can come back. This has produced more sprinting and quick directional changes and less of the smoother, gliding running style of yesteryear. This raises the value of saving steps and more aggressive shot selection.
- ***Many two handed backhands are now hit open, semi-open or square*** except on low/short/wide balls. Most players still have an ingrained footwork pattern that correlates to their stroke biomechanics. However, trying to exclusively use the same stance for every shot is extremely limiting, energy consuming, potentially injurious and easily exploitable.
- ***Open stance was a teaching taboo for many years*** and instructors were known for chastising students for “hitting off their back foot.” The open stance gradually became accepted, even on backhands. Historically, teaching pros have passed on old biomechanics as “gospel.” It is often difficult to admit that we had taught incorrect technique and principles. However, just as in health and medicine, there are sometimes major reversals in informational doctrine.
- ***Open stance frees the body to rotate and allows a player to remain closer to the center of the court after contact.*** Unless having run with great speed and distance to the ball, a player will not move beyond the point of contact, other than a small “stutter stop step” or two.
- ***Swing step always brings the player’s body beyond the point of contact*** and the open stance can allow the player to remain a full step closer to the center of the court. This equals a two step savings in movement to and from most strokes.
- ***Swing step is dominantly used by players with one or two handed backhand,*** whose footwork style and stroke mechanics are based upon square to closed type hitting stances. The swing step is used to allow rotation and recovery. The forehand will often swing step on short low balls that are better hit from a square stance.
- ***Since Monica Seles demonstrated the effectiveness of open stance two-handed strokes,*** more players as evidenced by the Williams sisters, have switched. Davenport is an example of a top woman who prefers the swing step but uses the open/semi-open stances when required.

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- ***All players need to be able to use multiple footwork patterns.*** High bouncing balls, particularly when wide are best hit open and the shorter low balls are best suited to the swing step. A player like a Williams' sister will remain open on all except the necessary and Davenport or Hewitt will do the opposite. This is a result of their trained biomechanical patterns.
- ***Maria Sharapova is a good example of modern mixed stance strokes.*** She clearly prefers the swing step on her backhand as taught impeccably by Robert Lansdorp, however, readily rather than reluctantly, she opens up as needed.
- ***Many players were taught "mono-stances."*** The old principle and still needed in some preferred biomechanics are; to create the "ideal" ball contact position such as "knee to waist height." Unfortunately, a smart opponent will make a "mono-stancer" either hit out of their preferred zone or make them work very hard to jockey for the "ideal" hitting position and contact point.
- ***Ball bounce height to width relationship;*** the new emphasis is teaching players to correctly align themselves in relation to how high or low the oncoming ball bounces. A shoulder height ball will be struck further from the body than any other height. As the ball height raises or lowers from the shoulder level; the contact point becomes closer to the body.
- ***Any decent instructor can teach proper stroke technique WITHOUT THE BALL.*** However, the techniques will breakdown if the contact point is too close or far away from the students' body or if the timing is off. Essentially, the shift in ball contact positioning skills has shifted from an "up/back jockeying" emphasis to "width jockeying."
- ***Up/back positioning is now more a tactical element*** such as taking balls earlier, above net height or on the rise, rather than creating an ideal contact position based upon players stroke style preferences and restrictions.
- ***Biomechanical changes:*** Initially and for many years, a ball control oriented, "straight back" closed stance stroke was used. This was the mainstay of grass court strokes. The grips were either eastern or continental which allowed for the low, quick and unpredictable bounces on the early days of grass and easy volleying.
- ***This evolved into the "large looping topspin" open stance.*** The heavy topspin game became the driving factor, as these were the days from Borg and Vilas to Thomas Muster. Gabriella Sabatini and Anna Kournikova were the most notable females to play this style.
- ***Modern compact loop:*** this stroke style is explosive and versatile. The open, semi-open stance or square stance used generates high racquet speeds that can be hit with any degree of topspin or can be flattened out for penetration. Ivan Lendl's forehand might be considered the "father" of this stroke, Andre Agassi or Pete Sampras the "prodigal sons" and Roger Federer, the "contemporary offspring" of current forehand stroke biomechanics.

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The modern strokes allow players to take the ball earlier as being more compact, facilitating quicker timing. Hitting on the rise was best demonstrated by Jimmy Connors flat/slice strokes and then was contemporarily refined by Andre Agassi. The women tend to be less compact as many need a larger backswing for pace.

- ***Current techniques use angular momentum to “kick start”*** the rotation of the upper arm, coupled with rapid pronation in the forearm. The follow through is usually wrapped over the neck to allow for the added deceleration requirements rather than the old “above the shoulder height and point to the court follow through,” used in the antiquated “turn, step and hit” pattern.
- ***Many players, particularly the men on short low balls,*** will “**fan the forehand,**” accentuating rapid forearm pronation and internal upper arm rotation. The follow through tends to be only about waist to shoulder height and the racquet face finishes closed. Roger Federer and others use this technique on most forehands. This technique requires greater forearm strength and flexibility, hence the “male pattern.”
- ***Varied stroke follow through:*** The movement path and length of any follow through will be a result of a player's preferred biomechanics in relationship to shot selection. Often when hitting a topspin lob or a late forehand; the racquet will finish high on the same side rather than crossing the body's' mid-line. A larger backswing and/or faster swing will result in a longer follow through.
- ***Tennis arm injuries from ground strokes*** have shifted into the medial elbow; particularly the more western (supinated) the grip. Previously, lateral forearm injuries were more common. Lateral tennis elbow is still mainly a “hackers” one-handed backhand problem due to repetitively positioning too close to the ball, late contact and/or having a “lazy continental” grip.
- ***Initiating forearm movement with a supinated (full western grip) or semi-supinated (semi-western) grip*** produces greater degrees of rotation during pronation, which increases deceleration stress and over-stretching of the attachments.
- ***Problems with the full western grip include;*** difficulty in flattening out a shot to penetrate the court, the huge grip change to the backhand, and limitation on ball contact position and the added stress to both the elbow and wrist joints from the fully supinated grip.
- ***NOTE: the #1 cause of medial tennis elbow*** is from the serve due to rapid elbow extension and forearm pronation.

## 6. Injury Consideration and Summation

- ***Most long term players at any level*** have been sidelined at least once with some type of injury.
- ***Majority of top 200 pros retire from competition*** or drop significantly in rankings due to injuries.

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- ***Prioritize the playing schedule and training design*** to prevent injuries and if needed, rehabilitating them promptly, aggressively, and without exacerbation.
- ***Creating an off season and other breaks*** from competition are essential to progress and longevity.
- ***The Female Athlete Triad***: is a very serious medical condition resulting from a combination of three interrelated conditions that are associated with athletic training: disordered eating (anorexia and/or bulimia), amenorrhea (absence of at least three consecutive menstrual cycles) and osteoporosis (weakening of the bones.) Premature osteoporotic fractures can occur, and lost bone mineral density may never be regained.

Women with disordered eating may engage in a wide range of harmful behaviors, from food restriction to bingeing and purging, to lose weight or maintain a thin physique. Many athletes do not meet the strict criteria for anorexia nervosa or bulimia nervosa, but will manifest similar disordered eating behaviors as part of the triad syndrome.

Even non-elite athletes can develop the condition. Effort needs to be made to promote a healthy perspective from women on their bodies form and function. No studies have shown any improved performance from women at below baseline body fat levels, only the perils. There are men with disordered eating conditions, however, due to their biological make-up; men have a much lower risk of premature osteoporosis.

## 7. Biomechanics: Kinetics and Kinematics

- ***Kinetics*** refers to the linkage or organization of movements.
- ***Kinematics*** refers to the segmental joint velocities within the kinetic link system as a rate of reactions.
- ***Kinematic stress*** produces most overuse injuries and are directly related to and resultant of kinetic flaws or deficits.
- ***Open versus closed chain kinetic*** biomechanics fundamentally refers to whether surface reaction forces (closed) are available and utilized ***or not*** (open.)
- ***Practical difference in closed versus open chain*** is demonstrated very well in the force production changes that occur when a player is properly setup (closed chain) to hit a groundstroke or hitting on the dead run (open chain.)
- ***Dead run strokes requires the hitting arm and shoulder*** to have adequate strength, flexibility, proper open chain “kin-kin” optimization and proprioception (fine motor skills) to produce desired force and feel.
- ***Kinematics; the complete definition***: Tennis coaches are generally familiar with the kinetic link system, however rarely understand the nature and

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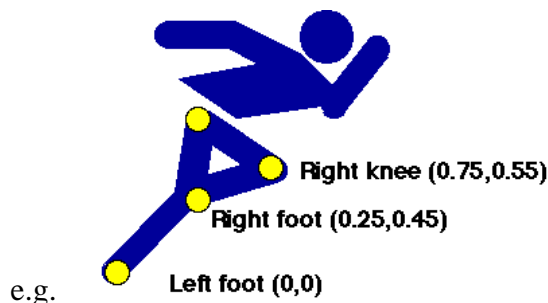
significance that kinematics plays. For those wishing to understand this science, please read the following in depth definitions:

- ***Kinematics is the science of motion.*** In human movement, it is the study of the positions, angles, velocities, and accelerations of body segments and joints during motion.

Body **segments** are considered to be rigid bodies for the purposes of describing the motion of the body. They include the foot, shank (leg), thigh, pelvis, thorax, hand, forearm, upper-arm and head.

**Joints** between adjacent segments include the ankle (talocrural plus subtalar joints), knee, hip, wrist, elbow and shoulder.

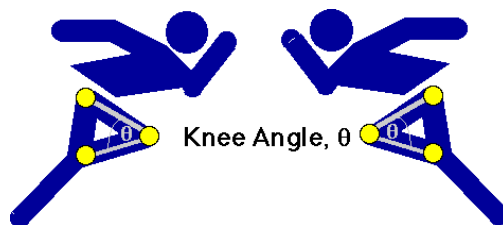
**Position** describes the location of a body segment or joint in space, measured in meters. A related measure called **displacement** refers to the position with respect to a starting position. In two dimensions, the position is given in Cartesian co-ordinates, with horizontal followed by vertical position.



In three dimensions all three directions must be defined:

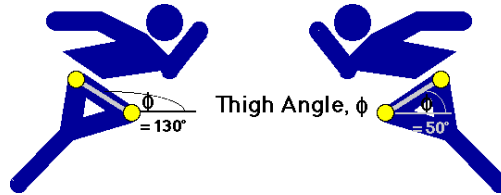
e.g. (1.5, 6.2, 3.2), (2.8, 9.6, 7.8) etc.

**Joint angle** (also called inter-segmental angle) is simply the angle between the two segments on either side of the joint, usually measured in degrees and often converted to clinical notation. Since joint angles are relative to the segment angles, they don't change with the body orientation.



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**Segment angle** is quite different. It is the angle of the segment with respect to the right-hand horizontal. Note that it is an absolute measure, meaning that it changes according to the orientation of the body.



**Velocity** is another word for speed. Velocity may be **linear** (change in position) measured in meters per second (m/s or ms<sup>-1</sup>), or **angular** (change in angle), measured in degrees per second (deg./s or deg.s<sup>-1</sup>). Normally, velocity is derived from position or angle data by the process of **differentiation**.

Velocity = distance moved / time taken

Thus if the knee moves from a horizontal position of 1.5 m to a position of 1.6 m in 1/50 of a second, it has a velocity of

$$\text{Velocity} = (1.6 - 1.5) / (1/50)$$

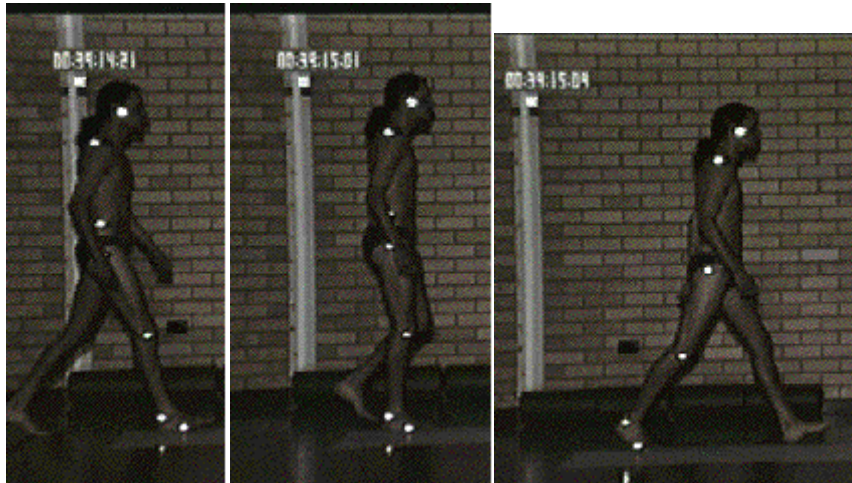
$$= 0.1 \times 50 = 5 \text{ ms}^{-1}.$$

**Acceleration** is change in velocity. Again, it may be **linear** (change in linear velocity) measured in meters per second per second (m/s<sup>2</sup> or ms<sup>-2</sup>), or **angular** (change in angular velocity), measured in degrees per second per second (deg./s<sup>2</sup> or deg.s<sup>-2</sup>). Acceleration, too, is usually calculated from the position data by differentiating twice. It can also be measured directly by an instrument called an **accelerometer**.

Kinematic measurements are limited in what they can tell us about the causes of motion is - for this we need to look at the **kinetics**. However, they do provide a **description** of the motion which can be valuable for certain purposes.

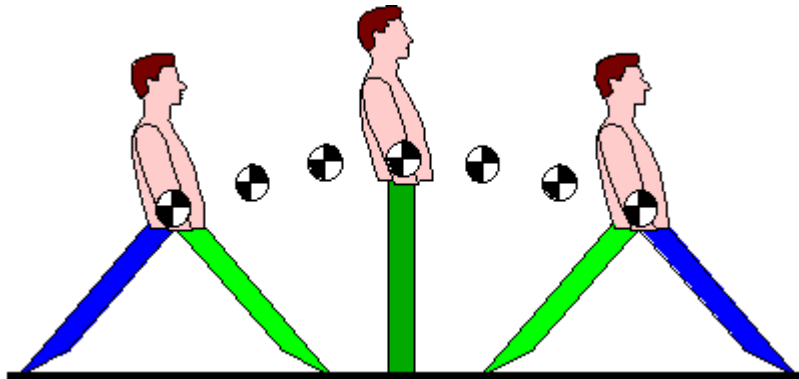
**Stance-phase kinematics:** One important observation we can make from looking at the kinematics is the amount of up-down and sideways motion. In actions such as walking and running, the body is attempting to move horizontally across the ground - any other motion, especially vertical, does not help this objective, and uses up precious energy.

If the body had wheels it could avoid vertical motion all together, but since we have legs, there must be some vertical motion. The reason for this is that at heel-strike and toe-off the two legs make up the sides of a triangle, while during mid-stance the stance leg is vertical:



**Heel-strike -----> Mid-stance -----> Toe-off**

This has the effect of lowering the upper-body (often called the HAT segment for Head-Arms-Trunk) at heel-strike and toe-off (which together make up the phase known as **double stance**, when both feet are in contact with the ground), and raising it during **mid-stance**:



**Heel-strike -----> Mid-stance -----> Toe-off**

By the way, the funny cross-like sign means the body centre of mass (CoM), which is located in the HAT segment (in the pelvis). In order for the CoM to rise up between heel-strike and mid-stance, energy must be expended, which is not gotten back when it drops back down again at toe-off. This up-down motion of the CoM is therefore inefficient, and we will see the locomotor system has several methods to try to reduce its amplitude.

### **The Determinants of Gait**

After the second-world war, there were a large number of limbless ex-servicemen in the United States. The Government realized that a major effort

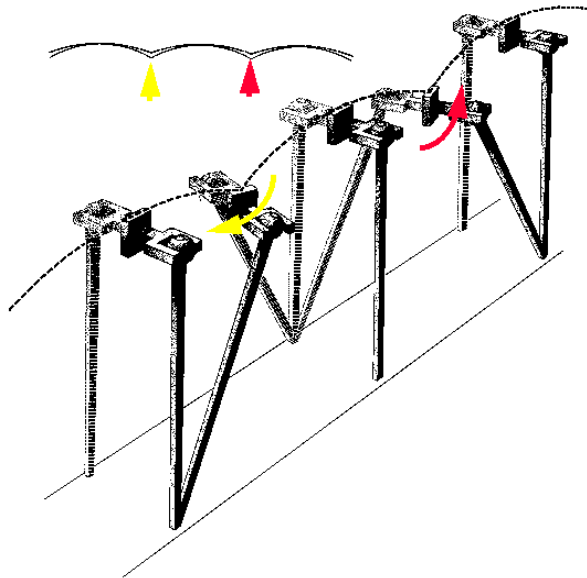
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was needed to develop improved prostheses, particularly lower-limb prostheses, to get these people walking again. As part of this large research project, the University of California at Berkely was requested to perform comprehensive studies on normal and disordered locomotion. Out of this research came much of our present understanding of the biomechanical mechanisms used in walking and running.

Several of these key mechanisms relate to the methods used by the body to reduce the up-down and side-to-side motion of the body CoM, and because of their fundamental importance to walking biomechanics, they have been called the Determinants of Gait. The determinants have two main goals: to reduce the maximum height of the body CoM during mid-stance and to increase the minimum height of the body CoM at heel-strike and toe-off.

### a) Pelvic rotation

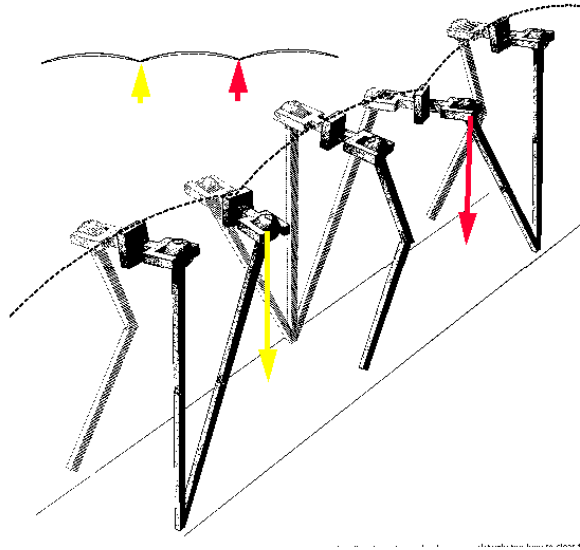
The pelvis rotates anteriorly at heel-strike, and posteriorly at toe-off to increase the effective leg-length at these times:



### b) Pelvic list

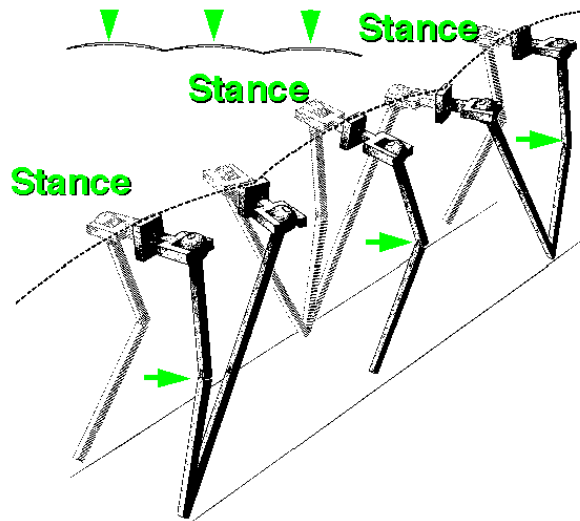
The pelvis lists downward (obliquity) to increase the effective leg length at toe-off and heel-strike:

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### c) Stance Phase knee flexion

A slight flexion of the knee lowers the CoM during stance:



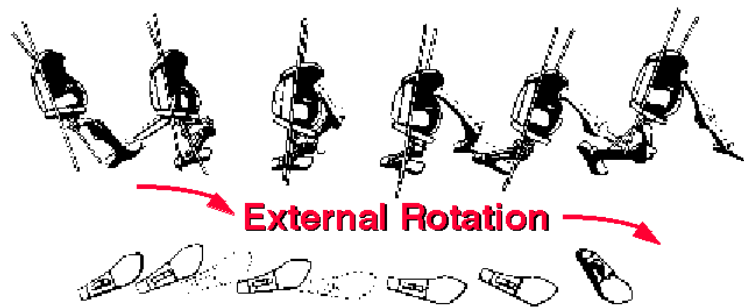
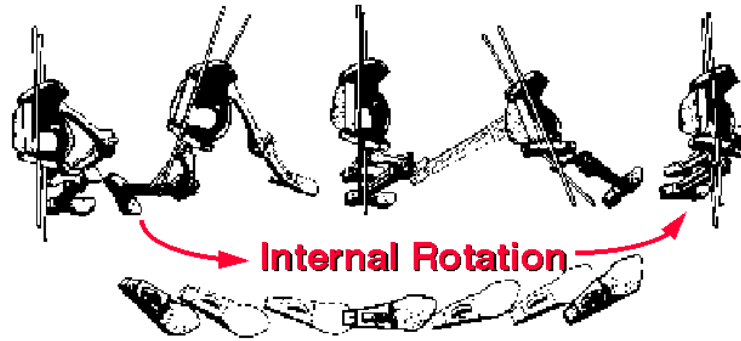
### d) Ankle rockers

The ankle is dorsiflexed at heel-strike and plantar-flexed at toe-off. Both these actions increase the length of the leg (see pictures above).

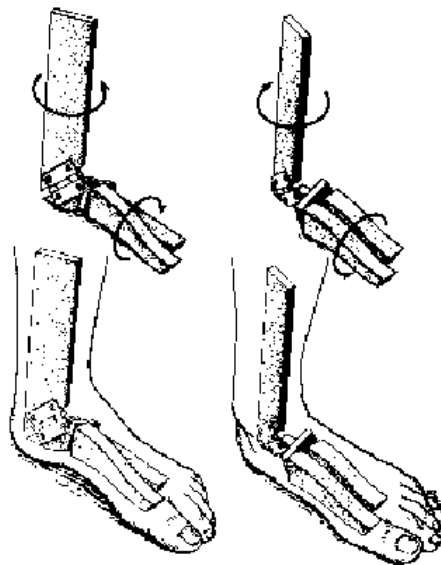
### e) Transverse rotation of leg segments

The lower-limb is lengthened by external rotation, and shortened by internal rotation.

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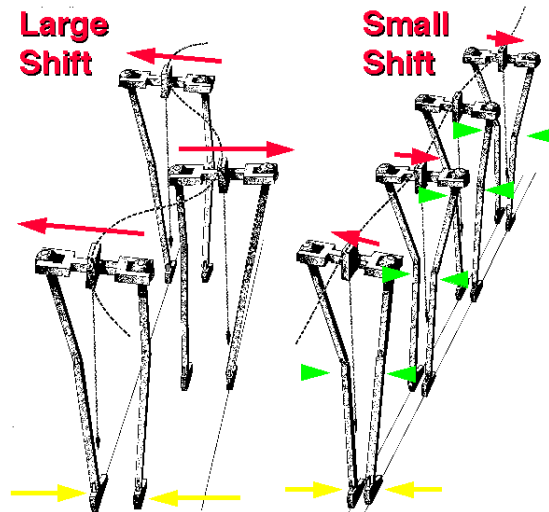


In the foot, these rotations are facilitated by the **torque-converter** effect, whereby pronation at heel-strike is converted to internal tibial (and subsequently femoral) rotation, and external rotation of the femur at toe-off is converted into supination of the foot. These actions are a consequence of the axes of the talo-crural and talo-calcaneal (subtalar) joints:



f) **Genu valgum** The anatomical valgus at the knee permits a narrower walking

base, and thus a smaller lateral shift, than would otherwise be necessary:



All these actions in themselves contribute very small reductions in the amplitude of the CoM (pelvis) motion, but added together, they reduce it considerably, to around 50 mm (up-down and side-to-side) in normal gait.

### Swing-phase kinematics

An essential pre-requisite for gait is to be able to **shorten the swing leg** before propelling it forward. The main way this is achieved is by flexion of the knee. This amount of swing-phase knee-flexion is proportional to the stride length, and thus the gait velocity (Kirtley et al, 1985):

Many gait pathologies (e.g hemiplegia, diplegia, knee osteoarthritis) impair swing-phase knee flexion, causing **compensatory mechanisms** to be used, such as **hip-hiking, lateral-tilting** and **circumduction**.

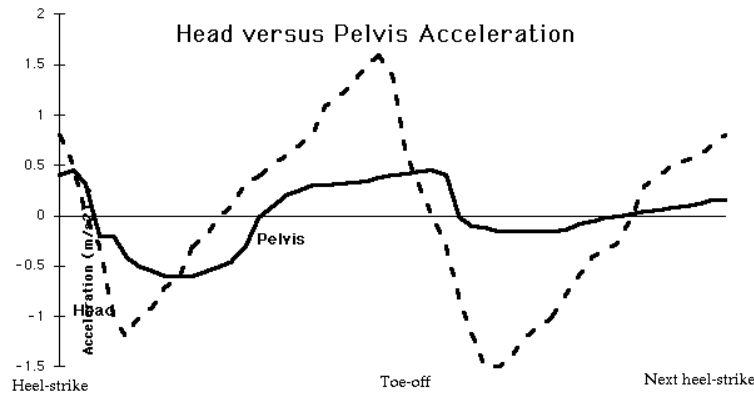
### Summary of sagittal-plane joint angles

So, basically, you can think of the actions of the knee and ankle joints as compensating for the flexion-extension motion of the hip. At extreme flexion of the hip (at heel-strike and toe-off) the knee is extended, while during stance knee flexion and ankle dorsiflexion help to reduce the effective height of the body.

### Other useful kinematic measures

Other useful kinematic measures relate to the **risk of falling**. In general, there are two types of fall: the **trip**, and the **skid**. The former is a result of the low **foot clearance** during mid-swing, typically about 1.5 cm, while the latter is caused by a high forward **velocity at heel-strike**. Moreover, it is possible that

the vestibular organ may be disorientated by high accelerations from the lower-limbs if they are not (as is usually the case) attenuated by the spine. Thus, the **head to hip forward acceleration ratio** has been used to gauge the efficiency of this **spinal damping** mechanism.



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## 8. Fundamentals of Joints for Tennis Applications

### *Joint Types*

- **Hinge:** Bi-directional extension/flexion such as knee and elbow
- **Ball/Socket:** Multi-directional allowing for all movements of the hip and shoulder. Flexion, extension, adduction, abduction, horizontal flexion/extension, internal/external rotation and circumduction.
- **Scapular:** Multi-directional shoulder girdle complex interacts directly with the shoulder and thoracic spine. Retraction, protraction, elevation, depression and circumduction.
- **Pelvic:** Multi-directional complex interacts directly with hips and lumbar spine. Extension, forward flexion, R/L lateral flexions are controlled by the lumbar spine, transverse abdominals, oblique abdominals and are directly influenced by hip and spinal movements.
- **Spinal:** Multi-directional foundation for all movement and posture. Flexion, extension, R/L lateral flexion and axial rotation (rotation applied to the spine).
- **Wrist:** Multi-directional; flexion, extension, ulnar flexion, radial flexion and circumduction.
- **Ankle:** plantar flexion, dorsiflexion, eversion, inversion and circumduction.
- **Foot:** Pronated (flat-footed) and supinated (high arched).

## 9. The “Ins, Outs, Ups, Downs, To and Aways”

### Tennis Related Movements

- **Internal/External Rotation:** movements used by the upper arms and hips to rotate inwards or outwards. Rapid internal rotation of the upper arm during service can injure the decelerating external rotators (teres minor and infraspinatus).
- **Eversion/Inversion:** the ankles outward (lateral ankle stress) or inward movements (medial ankle stress.) Acute eversion is the most common ankle injury and overuse injuries are rare. Inversion is used to help stretch out and maintain quality center of balance for the low wide balls and best demonstrated by the very limber, Kim Clijsters.

The most common overuse injuries of the foot are; plantar fasciitis (overstretching of the heel during ankle dorsiflexion, particularly in a pronated (flat footed) player. Stress fractures are the other common overuse foot injury. Stress fractures are an increased risk factor for females. This is largely due to the effect of osteoporosis as a result of having too low a body fat percentage, which is a determining factor in the **Female Athlete Triad**.

- **Supination/Pronation:** the forearms inward or outwards rotation. Foot types; high arch is supinated and flat footed is pronated. Forearm is a movement and foot type is a genetic description. Pronated (flat) feet are more vulnerable to movement injuries due to forcing a greater ankle ROM during plantar flexion and dorsiflexion. Supinated (high arched) feet are more vulnerable to stress fractures due to reduced dispersal of surface to foot contact stress.

Players should wear a straight lasted shoe for pronated feet and curved last for supinated feet. Orthodic shoe inserts can also help significantly.

- **Adduction/Abduction:** Typical example; to bring a ball/socket joint laterally towards (**adduction**) or away (**abduction**) from the spine. The rapid adduction of the serving arm places great stress upon the decelerating rotator cuff adductor (supraspinatus). Hip adduction/abduction are primary movers in side shuffling recovery movements.
- **Flexion(s)/Extension(s):** hinge and ball/socket joints, spinal column, pelvis, wrist and ankle movements. Sometimes confusing due to special terminologies describing certain joint functions such as wrist movements which have three types of flexion; **flexion** such as; the wrist snap on a serve, **radial flexion**, used on a dead run and/or “hook-spin” forehand and **ulnar flexion**; used on some slice backhands/backhand volleys.
- **Circumduction:** Multi-directional joints have abilities to combine movements into a circular path. Best demonstrated by the shoulder, hips ankles and wrists. Circumduction in tennis is never isolated and is a segmental movement within the kinetic structure.

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- **Scapular (Shoulder Girdle) Movements:** Retraction (backwards), protraction (forward,) elevation (upward,) depression (downward) and the orientation to the Gleno-Humeral (GH) joint (shoulder ball & socket). Elbow/upper arm height, movement and alignment during any of these movements dictate the muscular organization.

**Examples:** “High elbowed” scapular retraction will place more emphasis the posterior deltoid area (part of upper back and shoulder musculature) needed for high backhands and overhead strokes. A low elbow retraction will shift the emphasis to the latissimus dorsi (“lats”) and is a stronger (advantaged) movement. Both elbow heights will strengthen the middle trapezoids (“traps”). However, the “lat row” will develop more retractile strength due to the increased load capability. Adding depression during retraction will help strengthen the typically weak, lower trapezoids needed for serving or smashes. Elevation strengthening is accomplished by exercises such as shrugs and overhead presses. **Any overhead movement requires caution among tennis players due to shoulder stresses.**

- **Closed and open chain scapulo- thoracic biomechanics:** the interaction of the shoulder girdle to the thoracic (mid-spine) spine. Proper posture is essential as most tennis players and white collar workers tend to be kyphotic (stoop shouldered). This is a result of posterior muscles being over-stretched and weak, while the anterior muscles are short and too strong.

Postural strengthening exercises, such as rows are needed for the posterior, while flexibility exercises are more required for the anterior area to correct this imbalance. Whether or not ground reaction forces are available and utilized, will determine the opening or closing of the kinetic chain.

## 10. Individualized Tennis-Specific Physiological Structuring

- **Foundational development of the strength base:** is required for all safe and effective training. This is accomplished best in the weight room using basic compound (multi-joint) exercises.
- **The strength base develops best when weight lifting at 70- 90 percent of an estimated one rep maximum.** Untrained individuals will need to progress up to these loads. Naturally strong players will focus more on equalizing strength patterns, but everyone should seek to eliminate imbalances between both agonist and antagonistic muscle groups.
- **The exercise selection and variations should be both individual and tennis specific.** Body types are very significant factors in training design. The three phenotypes are; ectomorph (long boned, lanky and lean), endomorph (short boned and stocky) and mesomorph (the perfect middle ground that the other phenotypes work towards).

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Building muscle on the longer bones of ectomorphs takes more time and they often have high metabolisms, making them “hard gainers.” It may take considerable time, effort and extra calories for an ectomorph to acquire an appropriate strength base. Caloric quantity is typically more important than quality as not enough calories is worse than “bad calories.” Heavy weight lifting is a cornerstone in ectomorphic training design.

The endomorphs usually have natural strength, but the strength is often very imbalanced. Endos have a propensity for easy weight gain and particularly in females; body fat may be a problem. Endo weight training is more high rep oriented, but heavier weights are needed to correct weak areas. Smart nutrition plays a major role in acquiring their optimal body composition.

A challenge for endomorphs is trying to stay lean by increasing aerobic exercise, while not slowing neuromuscular function and still remaining fresh for tennis. The aerobics should be heavily cross-trained and remain interval in nature. Variety can be implemented during an individual workout and/or changed from workout to workout. Still, nutrition plays the most important role as tennis is energy hungry and too much off-court training can result in over-training.

- ***Once the strength base is achieved, maintenance is easy.*** Typically one or two 30-60 minute sessions per week will maintain strength if the load is at or near peak training loads. Overloading techniques and high volume training are not required and may impair performance if used within the week of a match.
- ***Very few people should be concerned with becoming “bulky”*** from the heavier lifts. Even those who want to bulk up, find it easier said than done. There are heavy lifting modalities, to increase strength without adding size and weight to the individual, if desired. This type of modality utilizes heavy loading while lowering intensity, volume and frequency. People seeking to reduce body fat, can use this modality to maintain their metabolically active muscle tissue during caloric restrictions.
- ***Power*** is developed via biomechanics and neuromuscular training such as plyometrics. This requires adequate strength and flexibility for effectiveness and safety.
- ***Plyometric training is unsafe*** without an adequate strength base and functional ROM.
- ***Use entry level plyometrics to teach technique*** until the player has begun to develop an acceptable strength base.
- ***Gradually increase plyo-forces*** as the strength base increases.
- ***Flexibility:*** The big news in stretching to make serious note of; has been the recent discovery that static and Proprioceptive Neuro-Facilitation (PNF) **stretching is counter productive prior to and during activity.** Studies have shown that **pre-activity static stretching does not reduce injuries**, while newer studies demonstrate an **increased injury potential and performance hindrance.**

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- ***Should a player needs to increase ROM*** due to inflexibilities, these stretches are done **after** exercise as part of muscular recovery/cool down.
- ***Muscular endurance:*** This is acquired through interval movement drills using **longer** work to rest ratios, high rep weight lifting and repetitive stroke drills such as; hitting 50 consecutive high backhands.
- ***Cardio-pulmonary endurance:*** This is developed the same way as muscular endurance, minus the weight lifting. Interval training is the mainstay of this tennis specific conditioning. VO2 max is considered the benchmark of aerobic fitness and determines ones' lactate threshold (the point in increasing exercise intensity that the body must begin using the finite anaerobic energy system).

Oxygen must be brought into the lungs, extracted by the lungs, pumped to and from the heart, then be extracted and utilized by the muscles. The bottleneck is the hearts' ability to meet the muscles demands.

VO2 max is the maximum amount of oxygen in milliliters, one can use in one minute per kilogram of body weight. Those who are fit have higher VO2 max values and can exercise more intensely than those who are not as well conditioned. Numerous studies show that you can increase your VO2 max by working out at an intensity that raises your heart rate to between 65 and 85 per cent of its maximum for at least 20 minutes three to five times a week. A mean value of VO2 max for male athletes is about 3.5 liters/minute and for female athletes it is about 2.7 liters/minute.

- ***Don't use extended steady (heart rate) state aerobics*** as this will make the tennis player move **slower**. The end result of extended steady state aerobic training is the player will be less tired after they lose! Stick with interval training for tennis players.
- ***Between point recoveries:*** Interval training incorporating work to rest ratios designed to produce a rapid decrease in heart rate after strenuous activity. This utilizes **higher work intensity** and a **shorter rest ratio**. The best barometer of between point recovery related to cardio-pulmonary abilities are measured by how quickly a players' heart rate can drop in 25 seconds (the time allowed between points) after reaching >65 percent of their V02 max. (maximal oxygen consumption).
- ***Post activity recovery:*** requires a proper cool down (light aerobics followed by static and/or PNF stretching), and can include a massage treatment. The light exercise is needed to prevent blood pooling and to flush exercise waste chemicals from the muscle tissues, while pumping in the healing blood supply.

Re-hydration, adequate macro/micronutrient replenishment is essential in recovery. Other factors including: efficiency of a players' game style, how hard and long they were "worked over," other pre-activities or rest. Last but not least, overall physical condition and age. The first physical problem experienced by the over 30 player, is age related recovery diminishment. High levels of conditioning

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can offset age related recovery to a degree. Andre Agassi is a good example of offsetting age by training and making his opponents work harder than himself.

- **Vision training: *The body can only respond to what the senses perceive.*** Vision is by far the #1 sense (taste, touch, sound and sight) required for tennis. #2 is touch, which is completely influenced by sight. #3 is sound to help differentiate ball speed/spin. Taste and smell are only factors in nutrition with the exception of “the sweet smell of victory.”

***The five muscles that control eye movements are the first muscles to fatigue in a long match.*** This may cause inefficient movement patterns and biomechanical stroke breakdown, which can result in “late stage fatigue injuries.”

**Practical on-court drills** for coaches and players of all skill levels includes: Colored balls, number balls, cue or trigger words, location tests, focus lights, juggle sticks, glow balls, special racquets, peripheral awareness training, etc.

Lefties use more of their “right mind” where peripheral awareness is drawn from. Peripheral awareness allows a player to focus on the moving ball while not “losing sight” of an opponents often subtle, tell-tale movements.

***Eyewear for everyone:*** Eye strain from squinting is the major causative factor in the ocular fatigue described above. Appropriate eyewear is the most effective counter measure and prevents exposure damage.

- ***Proprioception:*** the fine motor skills involved in balance and “feel.” Balance and touch exercises can be integrated in on-court or off-court workouts.
- ***Ball feel*** can be practiced on court with precise placement drills. Ball control drills such as running drop volleys are excellent. A good base of strength, stability and flexibility, facilitates this development.
- ***Detraining:*** is specific to the physical component. The first skills to detrain are the fine motor skills, followed by flexibility, endurance, power and lastly, strength.
- ***Maintenance:*** a plan to prevent detraining of acquired physical skills. Strength base maintenance training reduces the intensity, volume, duration and frequency, **but not the load!** The same principles apply to each physical component in reductions without decreasing or changing the basic goal of the training.
- ***General Parameters*** are; **intensity** (how hard the exercise, factored by; how short the rest between bouts), **volume** (total work in a session), **duration** (length of the workout) and **frequency** (time/days between repeated training).
- ***These variables in the parameters need to be individually adjusted,*** to each segment within physiological training.

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- ***It is unhealthy to exercise with high levels of all*** of these parameters simultaneously. Something has to give, as working out hard and long every day will catch up negatively sooner rather than later.

### 11. Basic Principles: Agonistic and Antagonistic Muscular Function.

- ***Balancing*** the accelerators, decelerators and stabilizers is the essence of this function.
- ***For every action, there is a reaction.*** When this is not balanced, injuries and poor performance occur.
- ***The decelerator and the stabilizer muscles*** are the source of most overuse injuries. They require eccentric or negative strength to endure and absorb the accelerators/primary movers' forces.
- ***Eccentric overloading*** can result in injuries and/or **Delayed Onset Muscle Soreness (DOMS)**; this delayed soreness is a calcium chemical reaction not lactic acid as was once thought. DOMS can be avoided by; incremental progressions, easy introduction of new exercises and repeating the exercises(s) within 7-10 days.
- ***Well applied eccentric*** strength training of vulnerable decelerators and stabilizers will help protect them from injury and allow for safer, more aggressive performance enhancing plyometric training.

### 12. The Overhead Athletes Considerations

- ***Precautions: Protecting the shoulder, elbow, wrist and lumbar spine.*** Limit and space practice serves as a baseball pitcher might, especially after a biomechanical change or post rehab condition. A technical change can induce a great stress on newly recruited and untrained muscles. Every player needs an individual progression to adjust safely and effectively.
- ***Biomechanical requirements:*** technique is critical in both force production and injury prevention. The concept is to efficiently develop force production via proper kinetics.
- ***Common mistakes and corrections:*** Teaching complex biomechanics; over-simplifications versus functional techniques and progressions. It has been a common and generally positive teaching progression to utilize KISS (Keep It Simple Stupid) methodologies. However, incorrect use of segmental breakdown/reconstruction can be counter productive and injurious.
- ***Understanding the need for “prehab”*** (injury prevention) exercises. This is something everyone who participates in any physical activity should engage. All forms of physical activities and individuals have their inherent injury potential. Most prehab exercises are simple, consume little time and often improve performance via corrections to the “weak link principle.”

### 13. Upper Body and Arm Development

- ***Strength can often be a simple observation*** of musculature or using the 60 second push-up test (modified on knees for weaker individuals, who of course are in need of strength development or are carrying too much body fat). Bench pressing goals for a male tennis player are a 1.0 bodyweight 1RM and .75 for women. The USTA has published the **High Performance Profile 9** (found on the Resource CDROM) for physical therapists to evaluate weak and inflexible areas.
- ***Women generally have only 60 percent of the upper body strength*** compared to men and are prone to shoulder and neck injuries. They have six times the rate of whiplash than men because of this disparity. Resistance training at 70-90 percent 1RM will correct this most effectively.
- ***Women tend to have greater ROM, but can also suffer more*** from joint laxity (especially pre or post-natal), impingement syndromes or instability injuries. Scapulo-thoracic spine (interaction between the scapula and mid-spine) deficiencies are more prominent as well.
- ***In the gym, female non-elite athletes*** tend to prioritize their cosmetic desires by over emphasizing thigh and gluteal exercises, while under-training their upper body other than triceps extensions to firm up a flabby upper arm.
- ***Men tend to over focus*** on upper body “mirror exercises” such as bench pressing, abdominal crunches and biceps curls when in fact they need to emphasize posterior strengthening. This is particularly true for the hamstrings, lumbar spine including the transverse abdominals (TA; deep lower abs required for pelvic/lumbar stability) and the upper back musculature.
- ***If the player does not present with a pre-existing injury or medical condition (always ask!);*** strengthening exercises can be implemented as part of an on court program using bands, body weight and partner assisted exercises, or optimally; in a gym setting.
- ***The most simple and beneficial tennis specific compound (multi-joint) exercises are:*** supported rowing variations (retraction), supinating dumbbell chest press plus (protraction), pronating dumbbell shoulder presses (elevation) and narrow neutral gripped pulley lat pulldowns (depression.)
- ***Pulldowns should never be “behind the neck” or wider than shoulder width grips.*** The only grips used are either neutral or semi-supinated. The failure to adhere to these points may cause serious shoulder or arm injury to an active tennis player! These “risky” variations are common in bodybuilding style programs, but are contraindicated for overhead athletes and most general populations.
- ***NOTE: most physiotherapists discourage overhead pressing movements*** due to the stresses involved. However, many activities in life and especially tennis involve overhead movement and rotator cuff foundation exercises are often inadequate in complete overhead development.
- ***Most tennis specific and least stressful variation of the overhead (shoulder) press*** is known as “Arnolds.” Schwarzeneger created a movement variation that

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begins in a supinated grip and pronates during the elevation phase. This lends itself to the forearm pronation strengthening required in serving biomechanics, while easing rotator cuff stresses.

- ***Prehab rotator cuff foundation exercises are essential*** for all overhead athletes. These are very simple and require only light dumbbells and/or bands.
- ***Rotator cuff is comprised of four muscles*** often called “SITS” for the Supraspinatus (abductor), Infraspinatus (external rotator), Teres Minor (external rotator) and the Subscapularis (internal rotator).
- ***Subscapularis is rarely injured***, while the others, particularly the supraspinatus and infraspinatus are.
- ***An emphasis on eccentric (negative) strengthening of the external rotators and adductors*** are most significant as they represent the “brakes and stabilizers” for the rapid internal rotation and adduction.
- ***An injured rotator cuff can not tolerate eccentric resistance*** and must be preconditioned by a physiotherapist with concentric resistance from either an isokinetic machine or manual resistance.
- ***Most of the racquet head speed in serving and smashing is generated by rapid internal rotation.*** This places tremendous stress on the decelerators and stabilizers in the rotator cuff group.

### **Three basic rotator cuff foundation exercises are commonly used:**

- ***Scaption:*** a circular dumbbell movement that begins at the waistline and moves upward until the bells touch over head. The circular pattern is 30 degrees forward and utilizes a “thumbs up” grip.
- ***Internal and external rotation*** of the upper arm (humerus) with an emphasis on external rotation is recommended.
- ***There are two basic variations of rotation;*** adducted (elbows at waist level) and abducted (elbows at shoulder level.) The abducted is the most tennis specific and the adducted is used to precondition prior the abducted variation. The abducted variation often uses dumbbells and the adducted is best with bands or pulleys and can be executed with dumbbells in a side lying position. Often a 45 degree abducted position is used as a stepping stone to the 90 degree variation.
- ***Most useful, is a manually or dumbbell resisted compound movement*** that properly involves concentric and/or eccentric resistance during simultaneous abduction and external rotation followed by adduction and internal rotation.
- ***A good analogy in general is to think of the body as a car,*** or for elite players; a race car. There has to be a balanced ratio between horsepower (primary movers), suspension (stabilizers) and the brakes (decelerators.) Any weak link in this equation will result in some form of decreased performance, or worse, an accident (injury).

- **Other good shoulder stabilizing and endurance exercises include:** assuming the appropriate (full or knees down) push up position and to place a six to eight inch platform such as a thick telephone book between the arms. The movements are to alternately place each hand on the platform.
- **A great variation of this uses the Stairmaster** machine by placing the hands on the foot plates to execute the movements.
- **Use the large (exact size should be individualized) physio-ball** or also called “Swiss stability ball” to perform prone walk-outs and/or “hands on the ball, push ups.”

#### 14. Principles of Periodization and the Tennis Challenge

1. **Biomechanical changes and focused physical conditioning.** This is the opportunity to make stroke changes that would be difficult during a competitive phase. Repetitive stroke drills to refine technical adjustments are employed. Developing the strength base in the gym is a key area at this phase. A pre-conditioning weight program precedes the heavier lifts, followed by increasing loads from between 70 and 90 percent of an estimated one rep max.
  - **High versus low repetition resistance training:** The most common tennis-specific modality is high repetitions to train the muscles to prepare the repeated muscular contractions involved in a long match. However, this type of training does not properly build the strength base and heavier, low repetition will. High rep training is best applied during pre-match periodization and pre-conditioning phases.
  - **Most common mistake** in all tennis and general training is not developing an adequate strength base **first**, as it is the physical foundation for **all** training.
  - **A properly periodized strength program** will incorporate both high and low repetition training. This is critical in allowing the greatest benefits from other training techniques while reducing the risk of injury.
  - **A perfect example is the reversal of position in the fitness industry** regarding how a sedentary person should initiate a fitness program. Originally, it was recommended to begin with cardio then add strength training. The results were many over-use injuries due to the highly repetitious nature of aerobic training.
  - **Current recommendation is to build a safe, progressive strength base first;** such that aerobics can be safely implemented and that a varied selection of low impact aerobics is prudent. Example: jogging is high impact and swimming is low. Variety disperses injurious stresses, while engaging the positive adaptive mechanisms.
2. **Pre-competition:** Play pattern drills and point play gradually becomes more of the on-court emphasis. Weight training tapers into a strength maintenance phase and higher rep endurance training is introduced.
3. **Competition:** Everything is about trying to peak at the most important upcoming tournaments or team matches. The strength maintenance program can be continued in a low intensity, volume and frequency modality, when the player is fresh. Nutrition, rest and match preparation are focused and adjusted to needs.
4. **Active rest:** Cross training and low intensity activities are used as per the individual.

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- ***The low intensity, volume and frequency strength maintenance program can be continued.***
- ***My personal choice is a two days on, one day off*** of an hour or two of activity. Day one I like to cross-train. Some players choose basketball or soccer, while I play squash. Squash??? Yes, another myth of detriment. I play mostly with other tennis pros and barter some tennis lessons with the squash pros.
- ***Another myth debunked:*** The consensus among squash playing tennis pros is a tremendous benefit of the ever-lunging workout and from “wrist education.” 45 minutes of squash feels like an hour and a half of singles and the ability to lunge for low wide balls is developed better than any other activity.
- ***“Squash arm” open chain kinetics*** is often used by players like Andy Roddick for emergency shot making. The tennis observation that squash dominant players were too “wristy.” While there is much biomechanical difference between the two sports strokes, squash improvements upon the mobility, strength, power and function of the wrist and forearm ***are*** transferable to tennis. This cross transfer is best utilized in dead run type situations that force late contact shot-making.
- ***NOTE: Recreational players/novices, particularly those lacking “natural racket skills.”*** Anyone still trying to differentiate volley technique from ground strokes can easily become muscularly confused and that originated the myth that squash is bad for tennis. They should stick to tennis and do not usually play enough tennis to warrant a true active rest period.
- ***Even elite tennis players will suffer some temporary muscle confusion*** if tennis immediately follows squash. Better to play tennis first if both sports are played in the same day.
- ***On my other training day;*** I do my strength maintenance program followed by a muscle recovering, swimming medley for 20-45 minutes.
- ***Day three is pure rest.*** A deep tissue massage is my favorite additive.
- ***If a player needs more rest,*** a “one on, one off” training split may be more appropriate. Several days to a week or two of very low activity may initially be required after longer, hard periods of activity.
- ***Macro or micro cycles:*** Due to the lack of a true off season for many elite players and short reprieves from competition. Rather than a one to three month macro-cycle, one to three week micro-cycles are employed. This is not as optimal, but “there is the way it ought to be and the way it is.”
- ***The Limited off-season dilemma:*** Tennis pros are the only professional athletes that do not have a formal off season. Additionally, they travel more and further than any other sport. This makes injury and burnout more likely.
- ***Planning peak performance:*** This boils down to prioritizing which events are most important and planning backwards from that point. The top players always prioritize the key Grand Slams.
- ***Understanding limitations and decision making:*** Becoming an accurate realist takes experience, but an experienced coach can help a player from making many mistakes. Just like in many matches, sometimes reducing errors is a winning formula.

## 15. Rules of Injury Prevention and Rehab

**Rule #1; “Do No Harm.”** Know injuries caused by common biomechanical errors and the corresponding corrections. Avoid over-simplification errors and learn methods to teach proper biomechanics without undue complexity.

**Rule #2:** Replace “*No Pain, No Gain,*” with “*Stimulate, Don’t Annihilate*” and “*Train Smarter, Not Harder*” to enhance development and avoid over-training. Quality over quantity is the essence of this change. Everyone has their limits and understanding the bell curve nature of training allows maximal effect with minimal risk.

**Rule #3: “Get in Shape to Play a Sport, Don’t Play a Sport to Get in Shape”** and modifying this “Golden Rule” for recreational players while enhancing your business. This is the fundamental sport science flaw or obstacle in tennis for health concepts. This is an important reason to implement conditioning into tennis programming.

The single most common denominator in training for sport or health is resistance training. Many years ago, even in football non-linemen, few athletes lifted weights other than wrestlers and competitive weight lifters. Now, every sport including golf and bowling has sport specific resistance training incorporated. Weight training is now universally recommended for almost anyone from preadolescents to senior citizens.

**Rule #4: Know and Use Available Medical Resources:** a “win-win-win” proposition. Developing synergistic relationships with orthopedists, physiotherapists and fitness specialists can provide a team approach to cultivating a healthy athlete or student while the bi-directional referrals promotes business.

**Rule #5: When Rehabilitating Injuries: PROGRESS GRADUALLY:** from **PRICES** (Protect, Rest, Ice, Compression, Elevation & SUPPORT) to **MICE** (Modifications + ICE,) to “Rolling the **DICE**” (Dynamic Activity Resumption) + **ICE** as needed.

- **Use caution applying ice to a nerve plexus.** The three common plexus points are; medial elbow, posterior knee and lateral ankle. A paper “buffer” can be used with a shortened application (10-15 minutes) **NOTE:** seniors, the fair skinned and individuals with other dermatologic problems should use the “shortened-buffer” technique.
- **Rule of thumb:** Emphasize ice whenever swelling and/or pain is present.
- **Many injuries respond better to alternating cold/hot treatments** as icing alone can result in less productive recovery and joint stiffening. Whether to end with cold or heat is an individual matter. Heat is generally not used during the acute injury phase and is added when pain/inflammation is controlled.

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- ***It was standard to finish cold until recently***, when athletic trainers reported many of their athletes responded better when ending with heat.
- ***The heat increases the repairing and chemical waste clearing blood supply to the injury and prevents the muscle stiffness after icing.*** Alternating heat and cold creates a pumping effect by dilating and constricting the blood vessels. This brings healing nutrients and removes the metabolic waste chemicals that exercise and injuries create. These wastes need to be flushed from the area for enhanced recovery and are a primary function of the cool down procedure in athletes.
- ***Bottom line:*** if you can end with a little heat and don't find increased inflammation or pain...end with heat.

### **Rule #6: Understand Drug Basics: Non-Steroidal Anti-Inflammatory Medications (NSAIDs):**

- ***There is much public and professional confusion on COX 2 NSAIDs.*** The FDA has done a poor job in evaluating the risk/benefits and presenting the findings. Many feel that the FDA is too linked to the pharmaceutical industry and that truly independent research is needed.
- ***Regarding the controversy surrounding COX 2 selective NSAIDs (Vioxx, Celebrex & Bextra)*** that were being pulled from the market due to studies showing them 2 ½ -3 times more likely to cause strokes.
- ***First, they are NOT more powerful than traditional mixed COX 1 & 2 Non-Specific (NS) NSAIDs*** (effect is DOSE dependant) as the COX 2 NSAIDs ***only*** reduce the risk of ulceration. The reason one COX 2 NSAID appears to be safer or more effective than another is related to the available dosages of the individual drugs. The stroke risk is a **drug class reaction**; therefore, any COX 2 NSAID can prove dangerous, especially at higher dosages. The risk is evident in the first 30 days of COX 2 NSAID use, thus dosage is more a concern than length of use. There is some debate whether Celebrex may be safer than Vioxx due to the sulfone/sulfonamide difference, but I suspect this theory is propagated by the manufacturers of Celebrex. Time will tell and until then it may be wise to avoid any COX 2 NSAID without a strong recommendation from a trustworthy MD.
- ***COX 2 NSAIDs were originally designed for people at high ulceration risk***, such as elderly GI impaired osteo-arthritics, who would need to stay on high doses for the rest of their lives and/or take other GI irritating medications. The latest guidelines are "black boxed" (highest level of FDA safety warning) contraindicating anyone at risk of cardio-vascular disease (CVD). These CVD risk patients and anyone might/could/should/will take an over-the-counter (OTC) adjunct, such as Prilosec (a proton pump inhibitor) or an old fashioned antacid like Zantac/Tagament to offset ulceration risks with regular NS NSAIDs.
- ***Personal NS NSAID choice is Relafen.*** This drug is prescription only and has the least GI irritant effect of any NS NSAID. This allows for higher dosing over longer periods of time. It is prudent to take OTC Prilosec or an antacid with any high dose/long term NS NSAID. OTC NS NSAIDs considerations towards Advil/Motrin vs. Aleve are mostly the duration of the medication. Aleve

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(naproxen sodium) is a twice per day (bid) 12 hour dosing and therefore should be less irritating to the GI tract than Motrin/Advil (ibuprofen) which has a 4-6 hour scheduling (tid/qid). Naprosyn (naproxen) is the prescription strength version of Aleve. Aleve is 225mg while Naprosyn is available at 375 and 500mg Rx dosages. There are quite a number of prescription NS NSAIDs available and your physician is the best to advise on selection, but look for a long acting version to help reduce GI problems.

- ***Of course, the pharmaceutical companies didn't waste a second or a dollar, marketing these high profits COX 2 NSAIDs drugs*** to the general population and try hard to extend their presence on the market. All NS NSAIDs are available generically and Prilosec is too. The pharmaceutical companies make much more profit on the newer, non-generically available medications and their marketing reflects this.
- ***Remember; ice is a very effective anti-inflammatory without any GI or CVD risks.*** Compression and elevation are also safe, effective treatment techniques.

### 16. Considerations and Proper NS NSAID Usage in Tennis:

- ***The “when, why, which and how” are individual*** and while the OTC versions such as, Advil or Aleve are handy, it is better to get a physicians guidance.
- ***There are some NS NSAID sports basics:*** if you take them prior to exercise, take it two hours prior with food to avoid stomach upset. This also applies to slowly digested foods (protein, fat and fiber filled carbs) as the blood that the stomach needs to digest, is shunted or diverted to the active muscles.
- ***Whatever is not digested will just “bounce around” during activity.*** One of the famous Pete Sampras “puking incidents” was related to taking an NS NSAID too soon before competition.
- ***Pre-match nerves can slow digestion*** as well and needs to be allowed for.
- ***If taken after activity, allow at least 30-60 minutes after the cool-down.*** The digestive system, based on factors such as exercise intensity, duration and heat, may be slowed to digest post-activity.
- ***The fundamental goal in preventing stomach upset*** is to consume NS NSAIDs with some food to insulate the stomach lining and to have them passed from the upper GI tract ASAP.
- ***A 20 minute “icing” immediately after play,*** will get any inflammation under more rapid control anyway.
- ***All NSAIDs from the biochemical position actually impair the healing process.*** The body's inflammation response is a mechanism of the healing process.
- ***However, if the use of them allows for earlier and/or more aggressive rehab,*** then this can outweigh the biochemical detriments.

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- *To take NSAIDs simply to play without a rehab program is generally considered a mistake.* Often the initial pain is from tendonitis, a mild injury that can turn into severe chronic tendinosis without proper treatment.

### 17. The Risk Versus Benefit of Cortico-Steroid Injections:

- *Cortisone injections are administered by an orthopedist, usually as a last resort short of surgical intervention.*
- *Patients are typically limited to three injections per year* because of the tendon damage (necrosis) around the injection site caused by the nature of this ultra powerful anti-inflammatory, steroidal class of medication.
- *Unless you know and trust your orthopedist or surgeon, it is wise to get a second opinion* before committing to surgery or cortico-steroid injections.

### 18. Anabolic (to build) Steroids:

- *Have been abused in many sports for decades.* Interesting discovery (ref?) was that benefits derived were more due to their anti-catabolic effects.
- *Muscle tissue is always “turning over”* or being broken down and rebuilt.
- *The effect is a much improved ratio of breakdown (catabolism) to rebuilding (anabolism)* due to the anti-catabolic effects.
- *In medical purposes, steroids are typically used* to counter the effects of muscle wasting conditions such as for burn, AIDS or other “wasting” patients.
- *Essentially, steroids allow an athlete to over-train* and get away with it.
- *Any muscle gained without training is dysfunctional.*
- *To keep this turnover balance in a non-steroid using player’s favor,* the athlete must develop a proper nutrition plan, understand and work within their limits of exercise intensity, duration and frequency to match their recovery capabilities.
- *The first problem with aging is the reduced rate of recovery.* Andre Agassi is a perfect example of “maintaining through quality training” and “playing within himself.”

### 19. Caffeine:

- *Main problem with caffeine,* aside from being illegal in some sports, is its diuretic effects.
- *If consumed too far before activity,* dehydration can occur.
- *If taken shortly before exercise the diuretic effect is shut down* and the benefits of caffeine can be utilized.

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- *Essentially, better mental alertness* from the stimulant effect and improved endurance from increased oxidation can occur. **Note:** increased oxidation also causes inflammation.
- **NOTE: if a player is subject to pre-match jitters** and coffee jitters, a very embarrassing, “choke-like” performance can occur.

## 20. Supplements:

- *Macro and micronutrients supplements* are generally safe as long as you read and understand the label, and don't mega-dose.
- *Energy bars and shakes* versus “real foods.” These supplements ARE real foods and designed for pre, during or post activity nutrition.
- *Mega-dosing of micronutrients can happen when using multiple supplements* as many macronutrient supplements are heavily fortified with vitamins and minerals.
- *Other individual supplements* such as creatine, “andro” and others have not shown much, if any benefit for the tennis player.
- *DHEA* is popular with the over 40 population.
- *Glucosamine, Chondroitin and MSM (Methyl Sufonyl Methane) for anti-inflammatory uses:* glucosamine is the most popular and documented supplement for inflammation, but cases of elevated blood sugar have been reported. Often these three supplements are combined into a “super supplement.”
- *Ephedrine has been banned* and is replaced temporarily, by similar “cold medicine” stimulants to evade the law.
- *This is comparable to the “Bayco, clear steroid scandal.”* The chemist involved designed a modified steroid that was designed to test negative on random checks, hence the nickname; “clear.” The illicit ergogenic (performance enhancing) and androgenic (muscle building) drug manufacturers are like computer hackers; staying one step ahead of the officials. Drug testing varies from one sport to another, as well as country to country. The International Olympic Committee (IOC) are international regulators, but much more stringent than the ITF, ATP and WTA.

## 21. Nutrition Needs

### Pre-exercise:

- *An opportunity to “top off” the fuel and water tanks.* As noted before in NSAID use, care needs to be taken to ensure the food is digested before activity.

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- ***Easily digested foods are recommended.*** These are lower fiber, glucose based carbohydrates, plus a small amount of complete protein.
- ***The protein should preferably be rich*** in glutamine and Branched Chain Amino Acids (BCAA).
- ***These are the key amino acids*** that are converted into blood sugar via the Glucose-Alanine Cycle and both prevent muscle breakdown (catabolism) and aid in muscle repair (anabolism).
- ***Pre-digested Whey protein*** is #1 in the protein supplement industry. Whey is lactose free milk protein isolate. It is naturally rich and often fortified with BCAAs' and glutamine.
- ***Note: lactose is milk sugar, the least digestible form of sugar*** for adults. **Bottom line:** if you like a bowl of cereal before activity; use the "LactAid" brand or take the lactose enzyme tablets.
- ***Drinking water until*** the need to "go" is a sign of hydration. Having to go every 20 minutes can be a sign of hyponatremia or a diuretic effect of caffeine or alcohol.
- ***Becoming over-zealous in water consumption can be dangerous*** due to the kidneys limited hourly ability to process water. Resulting hyponatremia can be fatal, but is rare in tennis players. Most cases have been "charity walkers" or non-elite race walkers who over indulge in the water opportunities along the way without actually losing much fluid.

### During Exercise:

- ***An electrolyte type sports hydration drink*** is a good choice in the hour before, during, or immediately after activity.
- ***New studies are showing the benefit of adding six grams (<30 kcal) of BCAA rich protein*** to the carb/electrolyte/fluid hydration drinks. The studies are showing two benefits: The increase in time to exhaustion (>150 kcal output from only < 30 kcal of intake) and reduced catabolism. It will be a while before they are widely marketed, but it is easy to create a personalized version by adding six grams of pre-digested whey protein isolate to the hydration drink.
- ***While bananas seem the food of choice during a match*** due to their high potassium content and an easier form of fructose (fruit sugar) to digest. Fructose is not as easily digested as the glucose or sucrose form of carbohydrates. The practice of eating bananas during activity should be replaced with an electrolyte, glucose based beverage.
- ***The 7% Solution:*** The high tech sports hydration beverages are designed to be specifically no stronger than seven percent carbohydrates, while soft drinks are 12 percent. Having too strong a concentration, including fruit juice, creates an osmotic effect (prevents water in the stomach from being absorbed).

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- ***Glucose replenishes muscle glycogen*** (carbohydrates stored in muscles cells) most efficiently and fructose replenishes liver glycogen best (carbohydrates stored in the liver for release during hypoglycemic conditions).
- ***Typical high tech carbohydrate hydration drinks usually breakdown as;*** 3% glucose polymers often labeled as maltodextrin (a high glycemic complex carb for steady blood sugar), 2% simple glucose (for quick energy release) and 2% crystalline pure fructose (the easiest form of fructose to digest) for liver glycogen replacement.

### Post Exercise:

- ***Once again, the above hydration beverage is best*** immediately after activity.
- ***A note on electrolyte requirements;*** electrolyte loss is not necessarily directly related to the quantity of water loss. A player, who has been in a cool, low sweat environment that suddenly plays in a hot humid climate, may have 10 times the electrolyte loss per ounce of fluid lost to that of an acclimated player. Sodium intake is the most important electrolyte requirement.
- ***Simple “salt tests,”*** such as tasting your sweat for saltiness and seeing if the dried sweat on your shirt leaves mineral lines indicates significant electrolyte losses.
- ***Water loss is simply measured by*** the bodyweight in a fully hydrated condition, minus the dehydrated weight. The weight difference is converted into liquid measure (ounce or liters) and replaced gradually over 1-12 hours. Depending on the degree of loss, rapid intravenous (IV) method (physician required) is used when dehydration is life threatening. **Trying to replace too much fluid too quickly can result in extremely dangerous hyponatremia.**
- ***In some tennis cases, the IV method is used for the “upcoming match dehydration threat.”*** This was first used by Jimmy Connors at the US Open and is mainly used by the men in hot Grand Slam conditions after winning a long five set match and having to play again in the next 24 hours. Losers don't need rapid hydration, although the rate and quality of recovery from a glucose/electrolyte IV is amazing...makes you think...maybe add a little protein?
- ***Nutrition and re-hydration with electrolytes are vital elements,*** particularly in the first 30-90 minutes after activity.
- ***Replenishing muscle glycogen*** (stored carbohydrates for energy) is opportunistic during this 90 minute window of time to capitalize on an exercise biochemistry phenomenon known as “insulin independent glycogen re-synthesis.”
- ***Normally, muscles require the insulin transport mechanism*** to uptake blood sugar and amino acids into the muscle cells. However, the greater glycogen depletion from exercise, the more the body super-compensates for this by the

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muscles acting like “dry sponges.” Thus, allowing the bypass of the insulin receptor bottleneck. This is critical in both exercise recovery and preparation for the next match or bout of exercise.

- ***Exercising specific muscles increases each of their insulin receptors sensitivity*** or ability to uptake. This is a primary reason why persons with diabetes are prescribed exercise, which helps clear blood sugar before the pancreas (the organ that secretes insulin) becomes chronically over stressed; producing type 2 diabetes.
- ***Amino acids from protein*** are also uptaken by insulin transport mechanism to repair the micro-traumas induced by exercise overload, assisting in tissue remodeling/adaptation. Protein should always be eaten with carbohydrates, as the insulin secreted from the digestion of carbohydrates, will transport the amino acids to the muscles cells. **NOTE:** players with any type of kidney (renal) dysfunction should consult with their physician regarding protein intake. Protein metabolites (urea) is cleared via the kidneys and measured as Blood Urea Nitrogen (BUN) in lab results.
- ***This explains the shift from the old technique of pre-activity carbohydrate loading*** by high carbohydrate intake four hours prior to activity to the current recommendation and knowledge, which post exercise nutrition, is the most important method in replenishment and preparation for the next bout of activity.
- ***This is to capitalize on the insulin independent glycogen re-synthesis***, by the intake of high glycemic carbohydrates, immediately after exercise. This is one of the few occasions when table sugar is better than broccoli as a carbohydrate source.
- ***If you played of singles or practiced hard for two hours***, the average energy expenditure to be replaced is 1200-1600 kcal.
- ***Most of this is needs to be replaced with 80 percent carbohydrates and 20 Percent protein*** representing the 15 percent protein used by intense activity plus five percent for tissue repair.
- ***This equates to 300-400 grams of carbohydrates, plus 60-80 grams of protein.*** This represents a large plate of pasta with a couple of chicken breasts or a post workout sports beverage with those numbers. A combination is often preferred; an average plate of pasta with one chicken breast after consuming a sport shake to make up the first half.
- ***After the 90 minute post activity replenishment***, the athlete continues replace lost glycogen with carbohydrates for up to 24 hours (Coyle, 1991). Once replenished, the athlete can begin adjusting into their normal Basal Metabolic Rate (BMR) based nutrition.
- ***BMR has a linear relationship*** to how much muscle mass (lean tissue) anyone carries (approx. 30-50 kcal per pound of lean tissue.) An example of BMR nutrition is a 55/30/15 percent carb/protein/fat mix.

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- ***Adjust macronutrient intake to exercise demands:*** In an athletes' nutritional plan, the quantity and type of carbs are most widely varied to meet demands. It is better to think of macronutrient consumption in two parts; exercise and resting nutrition. Exercise nutrition will have a much higher ratio of carbs than resting. Carb intake may change from 45% during rest to 90% shortly before, during and after exercise. Total consumption in protein intake may rise to 20% of total intake around exercise. Up to 15% of energy during intense exercise may be protein converted to glucose via the glucose-alanine cycle and the other five percent is needed for tissue repair/protection. If the body does not have protein available from nutrition, it may breakdown whole muscle tissue to acquire the key amino acids needed for the glucose-alanine cycle.. Players who lose significant weight during exercise (not counting fluid) will have higher protein needs to protect muscles from catabolism. Fat intake should be low quantity/high quality around the exercise session and will rise during rest. The body has large stores of fat to draw from when needed, however, requires Essential Fatty Acids (EFAs') for bodily functions.
- ***For athletes who are underweight;*** adding 250-500 kcal/day of protein and "healthy" fat can help gain body weight. Extra carb intake is used around exercise, but is less essential during rest phases. Protein is needed both to gain muscle and prevent loss. Extra fat is very helpful during rest as fat has twice the calories of carbs and protein per gram (4 kcal/gram carbs, 5 kcal/gram protein and 9kcal/gram fat). Note: alcohol is 7 kcal/gram, but is nutritionally void and a diuretic.
- ***If the player does not gain half to one pound in a week,*** increase intake another 250-500 kcal/day until a gain of a half to one pound per week is attained.
- ***Putting on 10 lbs of muscle can take a year*** and gaining weight in many cases is slower and more difficult than losing weight.
- ***Ultra rapid weight gain is a result of*** too much body fat accumulations, steroid use or freaky genetics.
- ***Sometimes a "bulking phase" is used to enhance muscle development*** in shorter time allotments. This requires high caloric intake and heavy weight training. The athlete then tries to shed the extra body fat while maintaining the new muscle. While this is rarely used in tennis except in the extremely under weight individual, it is however, the fastest way to put on muscle.
- ***Subtract 250-500 kcal/day for someone who is overweight.*** Note: one pound of body fat equals 3500 kcal, thus a loss of one pound per week is best.
- ***Trying to lose faster*** will increase muscle loss and decrease energy/performance, while increasing the risk of regaining fat.
- ***Any calorie restricted diet*** should pay close attention to micronutrients and the quality of the macronutrients to assure proper nutrition. Extra BCAA rich protein is needed to help protect the muscle from catabolism.

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- ***A moderate intensity/low volume/high frequency*** total muscle strength training program will also help maintain the highly metabolic muscle tissue and force the body to burn stored fat for energy. This is a function of the “use it or lose it” principle.
- ***Qualities of the amino acid profile in protein sources are important*** in protecting the muscles from catabolic muscle breakdown. Branched Chain Amino Acids and glutamine are the key amino acids needed.
- ***Protein quality is too often judged only*** by its’ leanness or whether it is a complete or incomplete protein, rather than the amino acid profile.
- ***Training or playing athletes need more protein*** and protein that is rich in BCAAs and glutamine. These are the key amino acids in the usage for energy and tissue repair.
- ***Avoid alcohol:*** Not only is alcohol void of nutrition, calorie dense and a diuretic; it is oxidized (burned with oxygen) preferentially. Fat is also metabolized via oxidation, thus when alcohol and fat are consumed together, the caloric intake is high and the fats are easily stored, rather than oxidized. The body chooses to burn the alcohol and store the fat because it perceives alcohol to be a toxin for immediate elimination.
- ***Note; those who prioritize loss of body fat over performance:*** The during and post exercise nutrition should be the consumption of a non or very low carb based electrolyte beverages. This forces the body to burn stored fat for energy during the post exercise metabolic burn. Individualized adjustments will need to be determined and performance/recovery may be impaired.

### **Bedtime:**

- ***Low glycemic carbohydrates with high quality protein and “healthy fat.”*** Low glycemic carbs help prevent the typical morning hypoglycemia (low blood sugar). A great bedtime source of protein is milk and turkey breast. Both of these are rich in L-Tryptophan, an amino that promotes quality sleep. EFA’s from healthy fats are needed for biochemical processes during sleep and the quantity will adjust whether the player is trying to gain, maintain or lose weight.

### **Waking up:**

- ***Hypoglycemia;*** known as low blood sugar. This is common in the morning. Therefore some fruit juice or fruit is a nice starter. After that, much depends on the upcoming activity and time until the next meal.

### **Low carb diets:**

- These diets have been popular with the obese. However, an athlete, even an obese one, will suffer performance drop off. Obese athletes should look to make an even reduction in macronutrient intake. The use of low glycemic

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carbs, two hours post exercise up until two hours pre-activity, is the most appropriate adjustment in carbohydrate intake.

### **Anti-inflammatory diet: Give yourself an “oil change”**

#### **1. Eliminate pro-inflammatory foods**

- ***Red Meats and Peanuts:*** These foods contain high levels of arachidonic acid, a type of fatty acid that converts into inflammatory mediators. Removing these foods from the diet decreases the levels of arachidonic acid in the body and reduces the occurrence of inflammation.
- ***Caffeine, fried foods, and carbonated drinks or alcohol:*** These foods greatly increase oxidation and free radicals, both of which initiate the inflammatory process, and makes one prone towards inflammation.
- ***Food allergies:*** Foods that do not agree with us can produce metabolites that interfere with normal bodily function and impair expedient healing of inflamed tissues. Many people experience long-term relief of pain with the simple elimination of food allergens such as wheat and dairy, especially those with long-term intestinal disorders.

#### **2. Implement a plant-based diet**

- ***Vegetables and fruits:*** These foods are rich in carotenoids and bioflavonoids that are powerful antioxidants, preventing free radical production and reducing the occurrence of inflammation. The more richly colored the fruit or vegetable, the more antioxidants it contains. Make sure every meal contains a healthy serving of fruits or vegetables
- ***Cold water fish:*** Salmon, halibut, mackerel, tuna, trout and other cold water fish contain lots of omega-3 fatty acids. These fatty acids offset the production of arachidonic acid, as well as favor the production of mediators that inhibit inflammation. Eat at least 3 servings of fish every week.
- ***Flax oil:*** This is rich in omega-3 and omega-6 fatty acids which work similarly to fish oils to help reduce inflammation. Use it in salads or in fruit smoothies, but never cook with it because of its strong tendency towards being oxidized.
- ***Ginger:*** Ginger has been shown to be a powerful anti-inflammatory agent. Use it freely in your cooking or make a tea with it. It also helps reduce nausea and some forms of abdominal distress.
- ***Turmeric:*** a curry like spice that has anti-inflammatory properties
- ***Whole grains, legumes, soy products:*** These foods are great sources for protein without the pro-inflammatory arachidonic acid. Skinless chicken breasts may also be added since most of the fat is found in the skin. Flank steak is the leanest beef and game meat such as venison is very lean as well, but can be tough if not prepared properly.

### 3. Nutritional supplements

- ***Correct nutritional deficiencies:*** Nutritional deficiencies can exacerbate pain and inflammation by slowing down the healing process of injured tissues. It is well established that deficiencies in zinc and vitamins C and A can delay wound healing. Deficiencies in minerals, such as calcium and magnesium, can also aggravate muscular pain.
- ***Antioxidants:*** Powerful antioxidants include vitamins A, C and E, carotenoids and bioflavonoids, along with selenium and glutathione.
- ***Exercise:*** Not only is exercise a great way to relieve stress and tension, but it promotes circulation, allowing vital nutrients to diffuse throughout the body, while flushing out metabolic waste. Exercise does not have to be strenuous. Daily walking or yoga is adequate enough to get the blood moving.
- ***Healthy fats versus bad fats*** are a major issue in inflammation.
- ***The healthy fats are either*** mono (MUFA) or polyunsaturated (PUFA) and can not be **hydrogenated** versions.
- ***The bad fat is saturated and the ugly fat is trans-fat,*** a result of hydrogenation.

#### Essential Fatty Acids (EFA):

- ***This represents the other quality of a specific fat source.*** Omega 3 fatty acids are best known for positive effects. The best sources are from cold water fish such as wild caught salmon (farm raised salmon, such as all Atlantic salmon, have less Omega 3's due to their unnatural diet). Flax seed and the oil from flax is the best plant source of omega 3 fatty acids.
- ***Eat wild salmon*** on to three times per week or take fish oil supplements.
- ***Make salad dressing from flax seed oil*** and raspberry balsamic vinegar for a “super salad dressing.”
- ***Add a tablespoon (15 grams) of flax oil to shakes*** (makes it creamy tasting).

### 22. Physical Training & Nutrition Effects Upon Systemic Remodeling

- ***Balanced nutrition with training and rest:*** is the health pyramid formula for everyone. Physical activity is only a stimulus and will be limited in effect and even deleterious, without nutrition and rest to allow the stimulus to be adapted upon. Repeating intense bouts of activity without adequate nutrition and rest is a recipe for over-training.
- ***Exercise biochemistry:*** Exercise has a profound effect upon the metabolism and alters biochemical reactions. Much of this is acquired through training specificity and genetic make up. Nutrition can either facilitate these effects or stymie them, based upon need and intake.

- ***Significance of nutrition for development, performance, recovery, healing and overall health*** can not be underestimated. After imposed demands are made upon the body, **most** of the beneficial adaptation occurs during sleep **if** proper nutrients are available. From a purely health viewpoint, nutrition and rest are the most important elements and exercise follows them.

### 23. Energy Systems: Anaerobic and Aerobic

- ***Aerobic:*** (with oxygen) uses the red, type one muscle fibers (Slow Twitch) needed for prolonged low intensity activity. Type 1 fibers do not hypertrophy (grow in size), rather their adaptation is more biochemical and to develop new capillaries that allow efficient fuel/oxygen transport and utilization.

Cardio-pulmonary training improves the oxidative energy system needed for quick recovery between points, overall endurance and sparing the limited high energy glycogen stores. Steady State training for prolonged periods is contraindicated for tennis due to power reduction (loss of speed). Light aerobic exercise for 10-20 minutes is used for cooling down and 5-15 minutes of preferably tennis specific exercise for warming up.

***Anaerobic: The nature of tennis;*** uses the white, type 2 (Fast Twitch) muscle fiber groups (subtypes A-C). These muscle fibers can hypertrophy readily upon proper stimulation and nourishment. Type 2 fibers are known to atrophy with disuse and aging. They are also directly related to metabolism and bone density. The Type 2A fibers are intermediaries or bridges between the aerobic and anaerobic needs, while the B subtype is the typical anaerobic muscle type. Ratios of Type 1 to Type 2 fiber domination is a genetic trait, but can be accentuated by training specificity. The Fast Glycolysis energy mechanism is used for intense activity such as the quick movements in tennis and has finite reserves.

**The ATP/CP mechanism of energy:** Adenosine Tri-Phosphate/Creatine Phosphate is the highest energy fuel system used for quick sprints, jumping, plyometrics and heavy weight lifts. It is also the most finite energy system and struggles to re-synthesize.

### 24. The Psycho-Physiological Connection

- ***Improved fitness mentally enhances and empowers:*** sport psychologists often speak about the benefits of physical conditioning.
- ***Self esteem:*** The simple act of hard work can produce dramatic increases in self esteem.
- ***Presence:*** Opponents can be intimidated by a more physically fit player.
- ***Intestinal fortitude:*** After periods of dedicated physical conditioning, a player will be willing to dig deeper during a difficult match. This is often the result of a stubbornness to lose after having paid their dues.

### Psycho-physiological dynamics in injuries

- **Turning liabilities into assets:** It is common for an athlete to take advantage of an injury layoff to develop other aspects that may not have had the opportunity prior to the injury.
- **Working around injuries:** a player and the coach will need to have a knowledgeable sense of creativity. This is to minimize the effect of an injury layoff and is essential in turning liabilities into assets.
- **Appreciation for the game:** When coming off an injury, a player who may have taken the game for granted will find new love for the game.
- **A new work ethic evolves:** Players that may have once been lazy regarding off-court conditioning will frequently develop a powerful, new work ethic.
- **Denial:** It is common, for a mentally tough athlete to hide their injury from not only their competitors, but from friends, family and themselves. This is usually to deny vulnerability and protect their on-court presence, not giving an opponent the thought that they may have a better chance to win.
- **Back door tanking:** Often, the mentally “un-tough” allow their injury to be publicly known to protect their self esteem and match credibility in the event of losing. This gives them an excuse for poor performance, typically to prepare for a “premature evacuation.”
- **Relief of pressure:** Coming back after an injury often relieves performance anxieties, although confidence will still be the main obstacle. The players’ self esteem is less at risk and the subsequent relief can allow an mentally unrestrained performance.
- **Self doubt:** a quandary whether or not to continue the pursuit of tennis excellence. Depending on the injury and previous potential, this doubt may be overcome or succumbed to.

### 25. Other Basic Variables:

- **Juniors:** weight-lifting is approved for preadolescents. Anyone at any age can develop muscle tissue (hypertrophy,) bone density and body composition. The obesity epidemic has created a new demand for physical activity, so take advantage and promote tennis for health!
- **Seniors:** Seniors are the #1 growth segment in the fitness industry. Tennis has the best age tiered structure of any sport, allowing a senior to be come the “new kid on the block” every five years.
- **Male:** ego actions are driven by competition and the need for acceptance. A strong ego is healthy and a big ego is unhealthy. Men tend to bond better than women in competitive arenas. This is thought to be nurtured response, not an act of nature, much like men vs. women in math and sciences (the recent William Summers/Harvard U. flap).

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- **Female:** “Female Athlete Triad,” is the strongest concern with women athletes. Also, the younger age of elite female athletes represents a challenge for the player, coaches and parents. Females can peak physically much earlier than men; 15-20 years old as opposed to 18-28 for men. Women usually need more upper body strengthening than men to compensate for gender strength variation.
- **Novices:** tennis for fitness versus fitness for tennis. Tapping the fitness seeker for new players; with fitness being the #1 growth sector recreational activities, the growth of tennis will need to play to this market.
- **Elite players: everything counts and nobody has a lock on knowledge.** Coaches often become threatened by other coaches’ input. However, a coach with a strong (not big) ego will seek out other opinions in the best interest of their players. Some speculate that the next generation of elite coaches will be specialists, like in medicine. We already see many top players using touring fitness trainers, some instead of a tennis coach, such as Roger Federer. Martina Navratilova (always ahead of her time) was the first to use a specialized coaching staff. She once had Billie Jean King as her formal tennis coach, Nancy Lieberman for conditioning and mental toughness, and Renee Richards for sport psychology. All three contributed to her mental skills, which were abysmal early in her career.
- **Teaching pros:** fitness can keep you on the court: even a slightly injured tennis instructor may be forced from their primary source of income, thus injury prevention is paramount! Integrating fitness into tennis clinics/camps for fun & profit: This may be the biggest element in the growth of tennis and the teaching pro can capitalize or succumb to the fitness seeker. Be proactive and develop a tennis program for health and fitness. The Tennis Industry Assn. (TIA) has a new program called “Cardio Tennis Workout” which they are pushing with the help of the USPTA, USTA and PTR. The TIA/USTA will match \$500-\$5,000 in funding (application on Resource CDROM) available to promote this and any “Grow the Game” program.
- **Natural athletes:** Use more progressions for rapid development. Use their abilities for match performance: sometimes the gifted ones are the hardest to coach as they often get away with tactical errors by running faster. A fast tennis player should learn to use their speed as part of their game, NOT as an act of compensation. Shot-makers also need to use this concept: often too large a shot selection is more ways to lose a point, rather than ways to win. Teaching these athletes court positioning and tactics is the best way to harness their skills. Their natural speed and strength should be turned into weapons, not ignored as a low priority development, remember; game development is as much about turning strengths into weapons, as it is to correct weakness/vulnerability.
- **Non-athletes:** simplifying the complex is the challenge. Using an appropriate methodology and progressions are the best road to training and retaining these people. **Patience is for student, not the teacher!** A good teacher really does not need patience, rather good technical and interpersonal skills are required. Remember; you know how to hit a backhand and it is the student that is struggling. If you know your “P’s & Q’s,” a successful progression will occur.

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- ***Privates:*** one on one conditioning drills and exercises. This can be a hybrid personal training session and tennis instruction. Also can be used to reduce rained-out sessions if you have a small indoor area or gym available.
- ***Clinics:*** adding the fitness station. “Drills for thrills without spills.” The station can be independent of the hitting drills or integrated. Typically, fitness training follows tennis practice. However, using stations during a group the program can handle a higher ratio of students to courts/instructors. This equates to keeping everyone active and increasing your profit margins.
- ***Camps:*** the conditioning coach as another instructor. Fitness training has become almost standard in the camp format. The difference lies in whether the players are benefiting from and enjoying the fitness aspect. A good conditioning program does not mean a “torture session.” Exercise tolerance is a very individual aspect and while tolerance can be improved with anyone, there are genetic factors as well. Since the decoding of the human genome, exercise tolerance markers have been discovered. It can be difficult for the untrained coach to differentiate between the unconditioned, the lazy and the low tolerant individual.
- ***Making it profitable:*** selling tennis for health benefits and using cost effective conditioning station concepts. The ways in which fitness can be integrated with tennis instruction are only limited by your imagination and knowledge. When I design a fitness program for group tennis, the logistics are my first priority, not the exercises. The logistics are time, courts, number of players and instructors cross referenced by student demographics (i.e.; age, sex and skill level) and facilities/equipment available. Most on-court fitness aids are very inexpensive, quickly transportable and weather resistant.

### **Classroom Discussion/Break**

**On Court: 10 am-12 noon**

**11. The Modern Dynamic Warm-Up**

- **Increase core body temperature by two degrees** in a manner to bring blood to the working muscles, synovial fluid (lubrication) to the joints, while gradually increasing functional ROM for flexibility. This should be done in a tennis-specific modality.
- *My favorite technique* is to gradually intensify walking alternating forehand and backhand stroke, short ball lunges. The lunges gradually progress from “waist height” stroking to “low ball” deepening lunges. Movements such as cariocas are excellent for part of this dynamic warm up.
- *This can be followed by* alternating low push-back and side lunges.
- *Using an accessory to add weight and/or air resistance to slow the racquet*, such as the **Swing Sock** will enhance the upper body and tennis arm(s) warm up. Do not try to accelerate a weighted racquet; keep the movements fluid and slow to moderate in pace
- *Then gradually start reproducing the service motion.*
- *This should take 3-10 minutes* until a light sweat is achieved.
- **Static stretching IS NOT NEEDED and is reserved for the cool down phase!**
- *Latest research* shows impaired performance and nil injury prevention. Increased injury potential is now associated with pre/during-activity static stretching.
- *A dynamic warm up such as “stroke lunge” progressions* should replace static stretching for activity preparation.
- *Importance and use of the Myotactic Stretch Reflex (stretch-shortening cycle)* as the function of the **Golgi Tendon Organs (GTO.)** The GTO neurologically delivers explosive, elastic energy return when a muscle or groups of muscles are pre-stretched rapidly and immediately contracted. The term “stretch shortening cycle” is the common buzzword for this effect.
- *Plyometrics (power developing exercises) utilize the GTO* for this very reason. Therefore, the converse can occur: when a muscle is static or “slow-stretched,” it can deactivate the GTO, thereby inhibiting performance for up to one hour and may actually cause injury as a result of neurological deficit. The primary function of the GTO is to protect the muscles from over-stretching. This is the fundamental reason that static stretching is now contraindicated prior to and during exercise.
- *The traditional warm-up gradations* of hitting and moving to hit or conditioning exercises are the next sequence.

## 2. Quickly Assessing Physical Abilities and Needs

### Legs, Core, Upper Body, Tennis Arm(s) and Simple Tests

- *The USTA Sport Science Department has a list of testing protocols* including the 60 second sit-up and push-up tests, 20 yard dash, a vertical jump test and others such as barbell bench pressing and squatting for a more elaborate set of evaluations.
- *These are well suited to advanced players and those with strong athletic skills.* However, these tests are contraindicated for populations that do not have baseline fitness or medical conditions. This represents most recreational players, especially seniors and obese individuals.
- *The USTA High Performance Lab* has produced a clinical evaluation guideline for physical therapists, called **High Performance Profile 9** (included on your “Resource CDROM”).

### The Quick Split-Squat, Legs and Core Test

- *This can readily reveal the functional status* of most players’ strength, flexibility and stability in these regions specific to tennis function.
- *The split squat* is similar to a lunge, only the forward lunge position is assumed and vertical movement (up/down) replaces any forward, backward or lateral lunging movements.

### What to look for:

- *Position the player(s) legs* into a wide enough up/back position such that at the lowest possible decent, the forward knee is positioned **DIRECTLY** over the ankle with the knee and toes pointing in **EXACTLY** the same direction.
- *The rear foot heel will rise* and surface contact will come up onto the ball of the fore-foot. Variation: the rear leg may be externally rotated 90 degrees and the ankle will be everted such that only the inside edge of the shoe is making direct contact to the surface. The difference in these variations applies to different directional footwork patterns and whether the player has greater rear leg flexibility in the hip flexors or adductors. This allows for a better center of balance on low and reaching strokes.

### Assessing:

- *Have the player(s)* try move up and down through **their** complete **Range of Motion (ROM)** a well developed player will descend and rise repeatedly with the rear knee near or lightly touching the surface and maintain a true vertical plane of movement without wobbling.
- *Without this ability a player can not* assume a proper low or reaching ball hitting stance and will bend at the waist or stoop rather than lunge for the ball.

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- ***These flaws create*** a poor center of balance; disrupt proper stroke biomechanics which places undue stress upon the knees, hips, lumbar spine and over-compensation of the hitting arm(s).
- ***Telling a student to simply “bend their knees”*** is a teaching error.

### Identifying the weak link(s):

- ***Should a player tend to move forward or bend forward from the waist***, this indicates inflexibility in the rear leg.
- ***Placing a hand on the forward thigh indicates*** lack of strength in the core and leg.
- ***Wobbliness indicates core instability*** and possibly weak leg strength.
- ***Inability to descend to 90/90 degree*** forward knee and hip flexion can be a combination of inflexibility and weakness.
- ***IF a player can assume a static 90/90 position***, test their stability by gently to moderately pushing them randomly from all directions at their shoulder height. Don't let them anticipate which direction the push is coming from by using the pushes in a rapid and random manner. More advanced players can tolerate stronger pushes.

### Correcting weak links:

- ***Having the player work on split-squats and various lunges*** is a very simple approach.
- ***Players with greater deficits*** will need to further address this in the gym with an individualized strength, stability and flexibility training program to acquire these skills.

## Upper Body/Tennis Arm Assessment and Development

- ***A development program is best achieved*** via an accurate assessment.
- ***This is difficult for a tennis or fitness coach*** and is best left to a physiotherapist with formal sports/tennis training.
- ***Core and lower body assessments*** are also greatly enhanced by using this type of therapist.

### 3. Getting “Loaded” for Tennis

#### Differences in linear and angular momentum in various strokes: Three typical kinetic link errors:

- ***omission***: a non-used link such as swinging from the shoulder without hip/trunk rotation
- ***improper sequence***: a link that is out of order, such as allowing the arm to get ahead of the hip/trunk rotation

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- **Weak link.** A link that bottlenecks the transfer of forces between segments(s.) Weak links can be technical and/or physical. Physical examples are the rotator cuff muscles during serve and overhead smashes or the core muscles during any running or hitting movement. Technical examples such as “late cocking” on the serve or any lateness in preparation to initiate any running and hitting pattern.

### 4. Plyometrics

- **Power developing exercises** utilize the GTO (stretch shortening cycle.)
- **Bounding exercises** for the legs.
- **Core training** with medicine balls.
- **Ground strokes** with medicine balls.
- **Serves and smashes:** isolated and full functional exercises.

### 5. Simple Remedies for Common Stroke and Movement Flaws

- **Essentially all areas must** efficiently and effectively generate force from the “ground up” for closed chain kinetics.
- **Open chain movements are undesirable, but crucial** in producing force when the closed chain ground reactions are not available. These typically occur when the player is in defensive situation, regardless of whether the chosen shot is offensive, defensive or neutral. The more offensive the shot selection from a non-setup stroke, the greater the physical demand and injury potential. Ball positioning and timing skills are required to allow any form of biomechanics to be executed correctly.

## Strokes

### Forehand and two handed backhand:

- **Organizing the kinetic loading phase** to allow for maximal angular and linear momentum.
- **Use coiling (rotation) and hip/knee flexion preparation** to generate angular momentum. This may be called “getting down and around.”
- **Linear momentum requires** moving the bodyweight and racquet in a forward plane to generate force. Oncoming ball speed is always the first source of power and is usually linear.

### One handed backhand drive:

- **Loading the upper body** is preceded by flexing and rotating the hips and torso, while flexing the knees.
- **Pre-stretching the rear deltoid:** is initiated during the shoulder turn and increased just prior to the foreswing.

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- ***Protracting the scapula***
- ***Flexing the elbow*** to load the triceps
- ***Pronating the forearm*** to load the supinators
- ***Flexing the wrist*** to load the extensors.
- ***This complex combination*** will produce force without the much larger angular momentum used in the forehand or two handed backhand.

### **One handed backhand slice:**

- ***Uses the least amount of angular momentum*** of any stroke except the non-swinging volleys.
- ***The stroke is loaded*** the same way as the drive.
- ***Because of the minimal use of angular momentum***, the slice does not require the more exacting ball position skills of the other ground strokes.
- ***A Major advantage of the slice is it conserves energy.*** A perfect example was when Mats Wilander defeated Ivan Lendl at the (*date?*) US Open. Mats used a two handed backhand, but had an excellent one handed slice.
- ***Most two handed players only slice when*** defensive or as an auxiliary shot, however Mats (who known as having the “best mind in tennis”) hit more slices than two handed backhands during that match.
- ***The reasons were simple;*** he conserved more energy than Ivan, didn’t need to hit many drives because Ivan “only came to the net to shake hands,” and didn’t give the more powerful Lendl the pace he prefers. Now, that’s smart tennis when Mats knew and could deviate from his preferred stroke to one that better fits the given situation.

### **Serve:**

- ***The most complex stroke*** in tennis.
- ***The serve requires more muscles to be loaded*** as well as a very complex kinetic and kinematic unloading phase. This significantly exposes any biomechanical flaw as reduction in power and greater injurious stress.
- ***The main techniques for the loading/unloading phases*** are described in the overhead smash below.
- ***Racquet head speeds*** (USTA Sport Science) are divided and calculated as follows:

<b>Movement</b>	<b>Percent of Racket Speed</b>
Leg Drive & Trunk Rotation	10%
Upper Arm Movement	50%
Forearm Extension & Pronation	None
Upper Arm Inward Rotation	50%
Hand Flexion	30%

### **Overhead smash:**

- ***While very similar to the serve, the positioning movements and timing become more critical and the placement, less.*** This is primarily due to the difference between tossing the ball for a serve and having to respond to a great variety of lob types, while having more than just a service box to aim towards.
- ***The loading phase has an abbreviated backswing*** to reduce the time needed for preparation. Many of the strongest servers use the abbreviated backswing, such as Andy Roddick, Goran, Roscoe Tanner to name just a few.
- ***Studies have not demonstrated any clear advantage*** to either length of take back during serves. The quality is directly related to the biomechanics.
- ***The main loading involves*** hip and trunk rotation for angular momentum, knee and hip flexion to increase vertical jump height and supply linear momentum and mildly hyper-extend the spine to add power and orient the scapula into a rotated, 45-90 degree vertical position.
- ***The unit turn*** on a deep lob will have the dominant side leg moving back and around. A short lob will use a non-dominant leg moving forward and around. This to simultaneously begin loading while moving a step in the correct direction
- ***Keeping the non-dominant shoulder up high until the unloading phase*** is equally important on both serves and smashes. The well known premature forward shoulder drop flaw can be easily corrected by focusing on keeping that shoulder up all the way until the unloading phase. Hence, the old overhead training techniques; “point at the ball” or “keep the chin up.”
- ***Back pedaling requires*** side shuffles on the short lobs and crossovers for the deeper lobs. There are two jumping styles; the traditional scissors kick or the Sampras/Roddick “slam dunk.”

### **Volley; forehand, backhand and swinging:**

- ***The swing volley is technically like*** any high bounced topspin ground stroke.
- ***Both conventional forehand and backhand volleys’ utilize linear momentum*** and very little angular momentum. Most of the loading occurs in the upper body.

### **Backhand volley:**

- ***Loading is similar*** to the one handed backhand slice.
- ***Becomes a more compact version as a player gets closer to the net*** or is dealing with a high pace passing shot/return of serve.
- ***One of the most commonly taught flaws*** is teaching a universally no-backswing racquet preparation. This ultra compact technique error limits the volley to close in volleying or high speed passing shots. Typically, this type of technique produces the notorious “push volley.”

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- ***Without a short backswing, the player attempts to add pace by shoving at the ball.***  
An adjustable backswing allows a player to add the appropriate pop to the volley efficiently and smoothly.

### **Forehand volley:**

- ***Often the “Achilles heal”*** for many players as it is the most technically different stroke from any other.
- ***Like the backhand volley, most of the loading is upper body oriented*** and linear momentum is the primary force generator. The linear momentum is created by forward body and racquet movement combined with oncoming ball speed.
- ***To prepare for a forehand volley***, a shoulder turn is initiated and the loading phase involves retracting the scapula while pre-stretching the anterior deltoid. The upper arm is externally rotated, the elbow is flexed 30-45 degrees, the forearm is semi-supinated and the wrist laid back.
- ***The unloading phase requires*** all of these loaded muscles to produce a coordinated kin-kin application.
- ***Like any stroke, only more essential, is forward body movement*** to all volleys. The forward movement is coupled with oncoming ball speed produce excellent linear momentum.
- ***A common teaching error*** is to have a student stop completely before contact. This produces a reduction in force that can be thought of as “driving a car with one foot on the brakes and the other foot on the gas.”
- ***It is important*** to try to be moving forward ***during*** contact.

## **6. Running: Footwork Patterns and Sequences**

### **First step:**

- ***Various ways to push off*** depending on stroke type, directional needs and time available.
- ***The integration of the recovery movement*** from the previous shot and positioning into the hopping split step.

### **Footwork techniques, patterns and differences between the first step and split/stutter steps:**

- ***Different strokes, the direction and time required*** to get into hitting preparation.
- ***Timing controlled movement to transition*** into the split/stutter step and the relationship of shot selection.

**Timing and techniques for split and stutter steps:**

- *The key concept* is timing these movements to the opponent's ball contact.
- *The deceleration movements' transition* into an explosive split step utilizes a few small side shuffles or stutter steps preceding the large hop into a dynamic split step.
- *The dynamic hop split step* affords the explosiveness created by the **Stretch Shortening Cycle** which also allows for a multi-directional first step.

**Footwork/movement from the split and stutter steps to the ball:**

- *Begins by watching the opponent's preparation and the ball* coming into and off their racquet. This affords the player an accurate "read" and subsequent movement pattern to court positioning and shot selection.
- *A typical teaching error* is giving the student a particular location to split step such as the service line on volleys or the center of the baseline on ground strokes.
- *Acquiring the correct geometric alignment and timing* the split step with the opponent's contact are the most critical factors
- *Unit Turn* preparation occurs immediately after the split step. This allows movement towards the appropriate stroke and court position. Examples such as trying to get in as close to the net as possible before the opponent makes contact.
- *Fine positioning skills.* These are the moments that bring the player into the optimal stroke and court specific location. An example is the close out volley: after the split step, a unit turn and first step, the player then moves diagonally forward with volley specific preparation to bisect the angle of the passing shot. A few "shrinking steps" then lead the prepared player into the ideal contact position.

**Recovery movements and techniques**

- *Open stance versus square/closed stance with swing step.* The open stance can save two full steps between movements. The swing step added to a laterally moving shot will force the player to move their body beyond the point of contact. The open stance will usually keep the player "inside of the contact zone" on most wide balls. When running fast at longer distance the open stance may require one or two small lateral stutter steps to end momentum and allow recovery footwork patterns.
- *When/how/why to use forward/backpedaling* and how to combine direct running, crossovers and side shuffles to arrive in the appropriate court position and to time an explosive split step are essential.
- *The more distance needed to return to a desired point of repositioning* in relation to the amount of time available and the direction of movement are the determining factors.
- *Players may use three stages of technique in lateral recovery sequence.* Example: when recovering from a wide position, a player may turn and initially run like a sprinter to quickly regain basic court position. As the player becomes closer to the

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time when the opponent is going to strike the ball, the second fastest recovery technique is employed; the crossover shuffle. The final movement requires a standard side shuffle or two. This is the only technique that can be converted to a split step. Try it for yourself!

- ***Essentially on lateral recovery movements;*** the side shuffle is used when recovering a short distance in a time allowing situation. The crossover technique allows for intermediate distance/time and requires a conversion to the side shuffle before the hop split step.
- ***Up/back recovery or repositioning*** is related to the players' desire to move forward towards the net or return to the baseline and the options allowed by the situation.
- ***In defensive repositioning, guise and guesswork are essential.*** Trying to make the opponent guess where you are going, rather than guessing where they will hit to, are major psycho-tactical elements. This allows for the often match altering effect of defensive play and transition into offense.
- ***Players, who are known to anticipate well,*** will influence their opponents shot selection by creating "false openings." This is often utilized by players who like the inverse forehand. They will shade the backhand side of the court to give the opponent a poor choice of either hitting toward the covered backhand side to avoid the killer forehand or to hit to the open court and allow the big forehand a swing. At the net, an experienced net player will often "shade & shoot; traditionally this meant covering or taking away the down the line pass to force and anticipate a crosscourt pass.
- ***Correct geometric alignment*** is related to both players court position, shot selection and shot tendencies. This and ***timing*** the split step with the opponent's contact are the most critical factors.

### 7. Exercise Biochemistry 101

#### The law of what is SAID (Specific Adaptation to Imposed Demands)

- ***This long standing golden rule*** governs all responses to stimulus.
- ***A tennis player wants to develop a complete plan*** to apply this rule to the specifics of tennis and their physical needs.
- ***On court tennis specificity training is a very simple formula;*** create a tennis situation that exceeds or **overloads** actual match conditions and then get used to it and then some!

#### Timeless SAID hitting drills, modernized:

- ***Harry Hopman, the famous Aussie Davis Cup knew what he was doing*** when it came to hitting drills for fitness. The legendary "Australian two on one drill's" are a perfect example of **tennis specific overload training**.
- ***The fundamentals of current work to rest ratio interval training*** guidelines can be perfectly applied.

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- ***These are basic set ups to allow the player in the “hot seat” to repetitively overload four positional situations.*** “Two up, one back” to develop passing shots, “two back, one up” for working the net game, “all up” for reflexive quick volley skills and “all back” to improve the baseline game.
- ***Dynamic combinations can simulate real match conditions*** and the variations. In any “two on one” set up, other than “all up,” the backcourt player(s) can transition to the net.
- ***The solo player*** is always being more physically stressed than actual match conditions.
- ***For a duet practice:*** begin with five minutes of “each corner to corner” semi-stationary drills. Then follow this by the killer “crosscourt/down the line drill.” One player hits every shot down the line and the other player hits everything cross court. The bottom line: both players are challenged to run side to side over and over while constantly reversing ball direction (especially the poor down the line player!)

### SAID Conclusions:

- ***All non-hitting tennis specific movements,*** training aids and techniques can be productive
- ***Human tennis resources are finite*** and any way that productive hitting drills can be used for interval training is an excellent way to be efficient.

### 8. Tools Not Toys, for Skill Development

- ***Tools:*** Medicine balls, weighted throwing balls, plyometric bounding aids, the physio-ball, stability cushion, movement ladders, hurdles, power shoots, Swing Sock, bands, weights, machines, body weight exercises partner exercises.
- ***Interval training is better for tennis than steady state training.*** Over-speed training techniques and aids. It is critical in selecting the correct individualized selection of these tools and exercises to optimize the risk/benefit ratio.

### 9. Top On-Court Fitness Drills for 1 to 20 Players

- ***Low and high intensity exercises*** versus low and high impact exercises.
- ***Avoid high impact drills*** with recreational or unfit players.
- ***Children benefit most from higher impact*** due to the bone density building effects.
- ***Weight lifting is the only low impact exercises that are bone building.*** This effect occurs best when at least 70-80+ percent one rep estimated maximum loads (Est.1RM) are utilized.
- ***Elite players need to avoid over-training*** stress by being judicious with high impact training.

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- ***All plyometric bounding IS high impact by nature*** and is required for elite training benefits. The key is to plan, adapt and modify based on individual needs.
- ***Intensity is the most broadly useful training variable*** that can be applied to all players.
- ***An individualized tennis specific “work to rest ratio”*** is the required formula.
- ***Training tricks*** for optimal skill and program development.
- ***Using the fitness station as an extra court*** for fun, profit and rainy day salvage.
- ***Line, mini-hurdles and ladder drills.***
- ***Footwork: patterns and development techniques.***
- ***Hitting drills for conditioning:*** Backcourt, mid-court transition and forecourt.

### 10. The Cool Down and Recovery

- ***Progression from activity to rest:*** first, a low level progressive aerobic cool down is followed by appropriate static stretching and/or Proprioceptive Neuro-Facilitation (PNF) techniques to can increase flexibility and recovery.
- ***PNF techniques increase flexibility and recovery*** by deactivating the GTO which allows for greater ROM during stretching.
- ***Nutrition and re-hydration*** including electrolytes are vital elements, particularly in the first 30-90 minutes after activity.
- ***Replenishing muscle and liver glycogen*** storage are opportunistic in this time frame to capitalize on a phenomenon known as “insulin independent glycogen resynthesis.”
- ***Normally, muscles require the insulin transport mechanism*** to uptake blood sugar and amino acids into the muscle cells. However, the greater glycogen depletion from exercise, the more the body super-compensates for this with the muscles acting like “dry sponges,” allowing the bypass of the insulin receptor bottleneck. This is critical in both exercise recovery and preparation for the next match or bout of exercise.
- ***Exercising specific muscles increases each of their insulin receptors sensitivity or ability to uptake.*** This is why persons with diabetes are prescribed exercise which helps clear blood sugar before the pancreas (the organ that secretes insulin) becomes chronically over stressed, producing type 2 diabetes.
- ***Amino acids from protein*** are also uptaked by insulin transport mechanism to repair the micro-traumas induced by exercise overload and assist in the tissue remodeling/adaptation.
- ***This explains the shift from the old technique*** of pre-activity carbohydrate loading of high carbohydrate intake four hours prior to activity to the current recommendation and knowledge for the most important method in replenishment and preparation for the next bout of activity.

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- ***Capitalize on insulin independent glycogen resynthesis***, by the intake of high glycemic carbohydrates immediately after exercise. This is one of the few occasions when table sugar is better than broccoli as a carbohydrate source.
- ***The qualities of the amino acid profile in protein sources*** are important in protecting the muscles from catabolic muscle breakdown

### Conclusions & Questions