Rotating for recovery

Meet the expert: Dr. Gary Windler

Tennis training

PRO U™ Player Orientation

Best serving strategy
Message from the President

Dear Members,

Babette Pluum, the founding and current editor of the STMS journal, has decided to step down after 13 years in office so this will be the last STMS journal she is editing. Once again, this issue demonstrates the very high standard our journal has reached as a result of her tireless efforts and we owe her a very big "Thank You!"

This edition has several original articles in all disciplines of tennis medicine and science. There are articles on the adolescent athlete, mental health and psychology, and optimisation of performance through the use of statistics. There are medicine papers on imaging of acromioclavicular and the prevention of ankle sprains, both important topics as the first is a bit of a controversial, but significant issue, and the other due to the great frequency of ankle sprains in tennis. There are tips for coaches, and information about what the professional players are learning, in the WTA article on the Players’ Pro University about professional life and life after tennis.

Continuing in the series of Meet the Expert, we have included an interview with Gary Windler, a member of the ATP Medical Team, clinician and active researcher of issues relating to the professional tennis player. Further, there are book and DVD reviews about tennis science and medicine to help our readership evaluate what they may want to use to further investigate areas of tennis medicine and science.

Lastly, a conference calendar of upcoming tennis related meetings (in addition to the most recent tennis science and technology meeting) is provided, including the two upcoming STMS meetings. There is the North American Regional Meeting being held August 1-2, 2008 in Cincinnati during the ATP tournament and hosted by Neeru Jayanthi and Robert Rhoades. Additionally, the World Congress of the STMS will be held in Tokyo, Japan during October 2-4, 2008, hosted by Moroe Beppu. The world congress promises to be a fantastic meeting, with three concurrent sessions, including work shops for trainers, debate sessions, current concepts and some of the newest, exciting original research in tennis medicine.

Once again, many thanks to Babette for all her hard work over the last 13 years. The STMS Journal is a magnificent legacy of her ongoing efforts to improve the delivery of sports medicine education to our tennis community.

I hope to see you in Cincinnati and Tokyo!

Sincerely,

Marc R. Safran, MD
President STMS
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Rolling for recovery

How fast your body recovers from the previous match or training session can ultimately determine your next performance, because if your body has not been able to repair and regenerate sufficiently, you simply will not perform to your maximum potential. I am a firm believer in the saying “Your next performance is only as good as your recovery from the last”. With this in mind, recovery and regeneration are treated with as much importance in the programmes I set for my athletes as movement, nutrition and mindset.

Tennis is a physically demanding sport. Players can experience muscle restriction (feeling stiff), which can alter joint motion and lead to poor movement patterns, a faster rate of fatigue and injury.

As a sports performance trainer working in tennis, I have discovered that the primary focus of many coaches and players is on training and competing, whilst recovery is often forgotten or given less attention. I often see athletes who put time and tremendous effort into their workouts, only to quickly rush through their cool down and stretching routines. They are missing one of the most important aspects of their pre-habilitation (preparing the body against injury) post performance body maintenance.

The best kept secret to maximising your performance is simple: “Recover better” according to tennis performance trainer Allistair McCaw. In this article Alistair explains his views on the potential benefits of using a simple piece of foam to optimise recovery and recommends eight specific foam-rolling exercises for players of all standards.

Recovery is probably one of the most overlooked aspects in an athletes’ program

Having a programme that incorporates good post training/match recovery techniques is critical for a player’s overall development and performance. It enables the player to perform the next time with less fatigue and in doing so, adapt to workloads faster.

The most common techniques used by players today are sports massage, aquatic therapy (pool running, movement exercises etc.), yoga and stretching. These all definitely contribute to the healing process, but the problem is the time that lapses between the end of the training session and when the massage, aquatic therapy or yoga happens. So what would be the best way to bridge this important gap between training and taking care of the recovery? One suggestion is to have your athletes rolling on a foam roller the minute they finish their workout.

Why foam rolling?
Hard exercise may lead to increased tension of our muscles and joints. Self-massage exercises (self-myofascial release) on this simple piece of foam can immediately reduce soft-tissue tension and speed up the recovery process. Using a foam roller can also provide similar benefits as a deep-tissue massage. By increasing flexibility and decreasing muscle tension, it can help to prevent injury, decrease muscle pain and improve function and performance. Your muscle resembles a rubber band and the further you stretch it, the further it will launch when you let it go. If you can increase the elasticity in the muscle by improving your flexibility, the result will be increased power and improved performance.

I believe that the foam roller is one of the most effective, all-around self-maintenance tools you will find, as it not only releases chronic muscular tension and pain (caused by playing or performing movement), but can actually restructure your skeletal system so that it aligns more positively with gravity. It is simple to use as you use your own body weight to roll on the round foam roll, massaging away restrictions to normal soft-tissue extensibility. Foam rolling is like getting a massage without the expense of a massage therapist. In fact it’s like having your own physical therapist, chiropractor, and masseuse at your beck and call. However, I definitely do not condone the services these practitioners offer as a good massage is always recommended.
There are many potential benefits of foam rolling - it
• can prevent joint stiffness and possibly reduce injury risk
• increases flexibility and joint function
• speeds up the recovery process
• is portable, light (weighs less than 500grams) and easy to travel with
• limits the costs of a regular massage

The better your recovery the faster your progress will be

Your turn!
I have put eight exercises together specifically for tennis players. These exercises cover all the major muscle groups involved in the game. Make these exercises part of your regular cool-down routine. Perform them directly after your training session or match (after a cool-down jog or spin on bike, but before stretching) to maximize their recovery time!

Place your body on the roller and slowly roll up and down (for about 30-45 seconds) along the muscle group you are targeting. If it hurts, it needs more attention. So if you find a particularly tight area, pause on that spot. Putting pressure on a tight area can help release the tissue.

Exercise 1.
Iliotibial band
Position yourself side lying on foam roll. Bottom leg is raised slightly off floor. Maintain head in neutral, with ears aligned with shoulders. Roll just below hip joint down the lateral thigh to the knee.

Exercise 2.
Gluteal muscles
Begin in position as shown with foot crossed to opposite knee. Roll on the posterior hip area. Increase the stretch by pulling the knee toward the opposite shoulder.
Exercise 3. 
**Hamstrings**
Place hamstring on the roll with hips unsupported. Opposite leg is bent to support this position. Roll from knee towards posterior hip while keeping quadriceps tightened.

Exercise 4. 
**Quadriceps**
Body is positioned prone with quadriceps on foam roll. It is very important to maintain proper core control (abdominal drawn-in position and tight gluteal muscles) to prevent low back compensations. Roll from pelvic bone to knee, emphasizing the lateral thigh.

Exercise 5. 
**Calves**
Place calf on the roll with hips supported. Have other knee bent to support a balanced position. Roll from below knee to Achilles tendon.

Exercise 6. 
**Adductors**
Extend the thigh and place foam roll in the groin region with body prone on the floor. Be cautious when rolling near the adductor complex origins at the pelvis.
Exercise 7.
Latissimus dorsi
Position yourself side lying with arm outstretched and foam roll placed in axillary area. Thumb is pointed up to pre-stretch the latissimus dorsi muscle. Movement during this technique is minimal.

Exercise 8.
Upper back
Cross arms to the opposite shoulder to clear the shoulder blades across the thoracic wall. While maintaining abdominal drawn-in position, raise hips until unsupported. Also stabilize the head in ‘neutral’. Roll mid-back area on the foam.

Summary
Whatever your level, foam rolling should be an integral part of your daily routine. It will aid injury prevention and recovery, and is one of the easiest and cheapest ways to improve recovery, alleviate aches and pains and improve flexibility. Use the roller directly after your workout prior to your cool-down stretch and remember that areas that hurt need more attention. A quicker recovery translates to a better performance the next time you play!

About the author
Tennis performance specialist Allistair McCaw is founder of Performance Tennis which specializes in tennis-specific conditioning training. Allistair has worked with no less than 6 top 20 tennis players including Jelena Dokic, Nathalie Dechy, Michaella Krajicek and Dinara Safina. He has also trained the world numbers one and two squash players Nicol David (world champion) and Natalie Grinham.

Address for correspondence www.performancetennis.com
Physiological and behavioural responses to thermal stresses in tennis

Background: Tennis is played year-round throughout the world in a wide variety of weather conditions. Often players in the Australian Open, held in the middle of summer, are faced with air temperatures exceeding 40°C. The current Extreme Heat Policy used at the Australian Open postpones play at an absolute air temperature ≥ 35°C and a Wet Bulb Globe Temperature ≥ 28°C. This is based on the American College of Sports Medicine’s Exertional Heat Illness Policy for distance running. Therefore, this policy may be inappropriate for tennis where activity is interspersed with rest periods which reduce the overall exercise intensity. Furthermore, there has been no known scientific evaluation of this policy. However, a review of its applicability to tennis using the current information base is difficult since there is no objective information about the effects of environmental conditions on players’ physiological responses, comfort and behaviour. Tennis players of all levels would benefit from objective and comprehensive information relating to how the thermal environment affects their health and safety. Such information enables them to make decisions about whether they choose to play tennis on a given day, the duration and intensity at which they play, the required fluid replacement, strategies to manage thermal comfort (e.g. wetting the skin, moving to the shade or fanning), and tactical modifications. These decisions enable players to minimise the risk of developing heat illness, and maximise comfort in adverse weather conditions.

Research objectives: The aim of this thesis was to obtain comprehensive data on environmental and metabolic heat stress, and body temperature regulation during competitive singles tennis matches over each of the seasons in Sydney, Australia. These data were then used to determine whether a steady-state core body temperature and thermal comfort are being achieved in tennis, in addition to the mechanisms responsible for their attainment (i.e. autonomic / physiological thermoregulation or behavioural / psychological thermoregulation?). These data were also used for the rational analysis of heat stress, which will enable prediction of all thermal exchanges and thus, tolerable environmental conditions for tennis. Finally, these data enabled an evaluation of the current Extreme Heat Policy and the suggestion of an alternative method for assessing heat stress in tennis (the Belding and Hatch Heat Stress Index).

Hypotheses: There is expected to be a range of environmental conditions (the prescriptive zone) in which thermoregulation is successful and body core temperature is maintained relative to the workload but independent of the environmental stress. Whilst environmental conditions within the prescriptive zone enable the maintenance of body core temperature, skin temperature is hypothesized to rise with increasing ambient temperature up to approximately 36°C in order to maintain convective heat dissipation. Since the thermal gradient for convective heat loss is reduced as air temperature approaches skin temperature, with heat being gained when skin temperature exceeds air temperature, the evaporation of sweat becomes the major if not sole method of heat dissipation. Therefore, sweat rate would be expected to increase with ambient temperature in order to maintain thermal equilibrium. Whilst core body temperature is maintained within tolerable levels during the prescriptive zone, players may subjectively rate conditions within the prescriptive zone as intolerable due to thermal discomfort that results from high core and skin temperatures and/or skin wettedness. In more stressful environmental conditions, or when players are experiencing physiological or subjective strain, players are expected to modify their behaviour to reduce the workload and heat production. This would be indicated by a reduction in effective playing time, point duration and stroke frequency. Within the prescriptive zone, it is anticipated that thermoregulatory responses will agree with previously published studies including: metabolic heat production of approximately 680 W, heart rate of around 145 beats. min⁻¹, body core (rectal) temperature of around 38.2°C, and sweat rate of approximately 0.93 L.h⁻¹. When conditions exceed the prescriptive zone, core body temperature is expected to be higher in response to the greater heat load that results in thermal equilibrium being achieved at a higher core body temperature. However, it is unknown whether the thermal environment and exercise intensity will represent a stress level above the upper threshold of the prescriptive zone during the experimental tennis matches within this study.

Methods: In the laboratory, the maximum aerobic power (VO₂max) and body composition for each subject was assessed. Experimental tennis matches were completed by men and women of varying standards in a range of thermal environments. Each of the six thermal stresses (air temperature, humidity, solar radiation, air movement, clothing and metabolic heat production) were measured or predicted for each tennis match and player. A whirling psychrometer was used to measure dry bulb (air) temperature and wet bulb temperature (for humidity) at 20 minute intervals throughout each tennis match and player. Mean radiant temperature (for solar radiation) was assessed by a globe thermometer, which recorded globe temperature each minute throughout matches. Air movement was also logged each minute.
throughout matches by a mechanical anemometer. An additional observation, natural wet bulb temperature, was measured at 20 minute intervals for the calculation of Wet Bulb Globe Temperature (WBGT). The thermal properties of clothing were predicted for normal tennis attire. Metabolic heat production was predicted from a known regression equation developed for the association between relative workload (% VO₂max) and rectal temperature. The regression equation determined for oxygen uptake (VO₂) and heart rate in the laboratory for each subject was also used to predict metabolic heat production. The thermal strains measured during tennis included rectal temperature, skin temperature, sweat rate, heart rate and subjective responses. Rectal temperature and four skin temperatures (arm, chest, thigh and leg) for each player were recorded every minute throughout matches by custom-built temperature loggers. Each player’s heart rate was recorded at 15 seconds intervals throughout play using a heart rate monitor. Body water loss for sweat rate was determined by weighing subjects fully clothed and equipped before play, after 30 minutes of play and at the completion of the match. Body mass changes would also include evaporative water loss from the respiratory tract and metabolic fuel used during activity. However, these changes are considered negligible and do not detract from the validity and reliability of this method of sweat loss assessment. Drink bottles were weighed at the same times to account for fluid intake. During the change of ends after every six games, players indicated subjective responses of perceived exertion, thermal comfort, sweatiness and a rating of conditions (thermal sensation). Notational analysis was conducted throughout matches to assess activity patterns and workload.

Results: Air temperature ranged from 14.5 to 38.4°C, relative humidity ranged from 21.8 to 73.7% and WBGT ranged between 13.5 and 29.2°C. Mean point duration was 5.8 ± 1.3 s and effective playing time (the proportion of the match spent in play) averaged 23.7 ± 5.2%. This equates to a work to rest ratio of approximately 1:3.5. Positive associations were found for the change in rectal temperature with both point duration (P < 0.001) and effective playing time (P < 0.05). Heart rate was also positively correlated with point duration (P < 0.0001) and effective playing time (P < 0.05). Rectal temperature averaged 38.5 ± 0.4°C (62% VO₂max) and mean heart rate was 136.8 ± 13.6 beats.min⁻¹ (66 % VO₂max). Both rectal temperature and heart rate were unaffected by the two components of the current Extreme Heat Policy (air temperature and Wet Bulb Globe Temperature), even in conditions exceeding the thresholds for each index (35°C and 28°C, respectively). Skin temperature demonstrated a positive association with air temperature (P < 0.0001). Sweat rate averaged 13.32 ± 5.56 mL.kg⁻¹.h⁻¹ or 0.92 ± 0.42 L.h⁻¹, and demonstrated positive relationships with air temperature (P < 0.0001), skin temperature (P < 0.0001) and rectal temperature (P < 0.03). Thermal comfort declined with increasing rectal temperature (P < 0.03) and skin temperature (P < 0.0001). Both point duration (P < 0.002) and effective playing time (P < 0.0002) were reduced as conditions were rated increasingly difficult. Oxygen uptake (VO₂) during tennis was 2.5 ± 0.5 L.min⁻¹ when predicted from rectal temperature and 2.6 ± 0.5 L.min⁻¹ when predicted from heart rate, which corresponds to metabolic heat production of 459.5 ± 76.3 W.m⁻² and 483.9 ± 95.4 W.m⁻², respectively. The required evaporation for thermal equilibrium (Eₗₑq) for the observations averaged 415.0 ± 104.5 W.m⁻² and was associated with the observed sweat rate (P < 0.0001). However, the relationship between the predicted Eₗₑq and the observed sweat rate was weaker than expected (R² = 0.33). Air temperature and relative humidity were modelled to predict conditions where Eₗₑq exceeded the maximum evaporative capacity of the environment (Eₘₐₓ), resulting in body heat storage.

Conclusions: Core body temperature remained controlled in environmental conditions at and a little beyond the two heat stress indices comprising the current Extreme Heat Policy. This suggests the current policy does not exceed the upper limit of the prescriptive zone and thereby endanger players. Both autonomic/physiological thermoregulation (increase in skin temperature and sweat rate) and behavioural/psychological thermoregulation (reduction in point duration and effective playing time) were involved in the control of core body temperature. The rational analysis of heat stress provides a more comprehensive approach to setting environmental limits. However, the prediction of thermal exchanges using standard equations was less accurate than expected, meaning these equations will need to be modified for improved prediction in tennis.

Sarah Morante has completed a Bachelors degree and a PhD (April 4th, 2008) in the School of Exercise and Sport Science at The University of Sydney. She currently operates a sport and fitness consultancy company that ranges from providing lecturing services to higher education providers including Sydney University and sporting/fitness organizations.
Introduction to PRO U™

Player Orientation

When women tennis players graduate to this elite professional level from the ITF circuits and/or juniors competitions, they become more than mere competitors on the Sony Ericsson WTA Tour; they are a part of the Sony Ericsson WTA Tour (the Tour). In order to take charge of their careers, players are responsible to make wise and informed decisions. PRO U™ helps players gain the knowledge and skills they need to make these professional decisions. It aims to guide players to minimize the stressors associated with women’s professional tennis and to promote their safety, career longevity and performance.

Rookie Phase eligibility

PRO U™ is divided into three phases to ensure that as players’ rankings and needs increase, so does the level of training and skill-building. The Rookie Phase is the introductory phase of PRO U™ and houses the Player Orientation, the focus of this article. The Rookie Phase begins when a player eighteen (18) years of age or younger participates:

- In two (2) or more WTA Tour main draw singles events in a 52 week period, or
- In a Grand Slam singles (main draw or qualifying).

History of PRO U™

PRO U™ programs came about as a result of the 1994 Age Eligibility Commission (now the PRO U™ Advisory Panel) report, which identified the major stressors in women’s professional tennis and made complementary recommendations. The 1994 Age Eligibility Commission report findings strongly indicated the need for developing skills and train these young athletes to succeed in the professional environment. Accordingly, the Player Orientation was expanded from a four-hour group session overview of the Tour to the system now in place. The current model is a comprehensive, skill-development process, divided into multiple phases, each of which is based on the needs of the player and business requirements of her particular career stage. In 2004, the Sony Ericsson WTA Tour invested in a 10-Year Review to determine the effectiveness of the PRO U™ programs, including the Age Eligibility Rule.¹ This review is considered to be the most comprehensive study of age-related programs in the history of professional sports and included a literature review and an analysis of quantitative, qualitative and statistical data. The 2004 review indicated that new stressors had emerged.

These were performance based, like injuries, length of season, competition and expectations; all stressors typically seen in professional sports. The reported stressors from 1994 (e.g., media, parents and family) were no longer at the top of the list. These changes in the main stressors, combined with the impressive statistical results: 24 % increase in career longevity (significance p<0.2), decrease in burnout from a rate of 7% to less than 1% (significance p=0.01), demonstrate that the PRO U™ programs in place between 1994 and 2004 did positively impact the career longevity, health and well-being of players on the women’s tour.¹ Consequently, the panel strongly recommended that these effective PRO U™ programs be made available to more athletes and at a younger age. With this aim, from 2008, the Rookie Phase of PRO U™ programs will be available to players online.

Introduction to the Player Orientation

The Player Orientation helps players learn the on-site realities and responsibilities of a professional Tour player. The key objectives of the Player Orientation are to optimize performance, enhance player health, and improve each player’s ability to make effective business decisions, ones that are beneficial to the individual and the Tour at-large.

The on-line modules are divided into three or more interactive lessons, to ensure the information is comprehensively covered in manageable doses. The on-line Player Orientation course includes audio, video, picture images and text. At the end of each lesson, players must pass an on-line quiz and evaluate the lesson content. Players must successfully complete each on-line course within 90 days of eligibility. The first modules to be launched in 2008 include:

- Human Development
- Tennis Development
- Business Development

PRO U™ is the Sony Ericsson WTA Tour’s umbrella institution for education. The PRO U™ staff is responsible for educating players and their support teams from the onset of their professional careers and covers development in three core domains:
An Intro to the Pros

- History of the WTA, structure of the Sony Ericsson WTA Tour, why PRO U™ exists, how the Tour and ITF/other tennis governing bodies work together, practical guidance on entry/withdrawal procedures, how the rankings work and the Age Eligibility Rule.2

Athlete Safety & Security

- Safety at home, safety during travel, safety at tournaments; Tour initiatives to promote safety (e.g., code of conduct for player support team members, athlete assistance programs and services) and the Tour's cumulative responsibility to promote a safe and healthy environment.

Rookie Hours

- An in-depth, interactive lesson reviewing individual Tour departments. Players learn: the purpose and role of each department; critical rules specific to that department; credentials, qualifications and licensure of staff members in departments; and practical skills related to the topic in each lesson. The goal is that players will develop the relevant professional skills necessary to succeed in the Tour environment.

The following departments are covered in the Rookie Hours:

- **Sport Sciences & Medicine** – players are introduced to the training (treatment) room; the physical therapy and massage therapy personnel; how and where to access health services on- and off-site; Tour rules pertaining to health (example: Extreme Heat Condition Rule);2 biomechanical services, nutrition and hydration services; and injury prevention practices, like the annual physical. Practical skills include: blister treatment and prevention, contents of a first aid kit, and proper dynamic warm-up and recovery techniques.

- **On-site Operations** – players are educated about the Tour supervisors' responsibilities, what it requires to run a successful event and consider the needs of the tournaments and players, and the enforcement of Tour rules (e.g., Patch Policy, Code of Conduct, Medical Time-Out).2 Practical skills include: the process of the draw and the daily schedule of play, and proper entry and withdrawal procedures.

- **Player Relations** – players are introduced to membership and benefits for members, the pension program, the importance of player meetings and the role of Player Council and the governance of the Tour and player news and information. Practical activities include: attendance at a player meeting and meeting with a Player Council representative.

- **Communications** – players learn how the media works as a business and how media grows the sport and helps to connect players with the fans, and influences the image of individual players, tournaments and the Tour. Practical skills include: review of advice from former players, attendance at a press conference and a review of interview techniques.

- **Marketing & Sponsorship** – players learn about the sponsorship agreements of the Sony Ericsson WTA Tour, players' roles with sponsors and the important relationship between players and the community, charities and fans. Practical activities include: important advice on self-promotion and marketing, meet the sponsors and participate in sponsor activities.

- **Athlete Assistance** – aims to enhance players' health, well-being and safety. Players learn about the services, resources and preventative strategies available to help manage the environmental and life stressors, improve overall coping skills and enhance performance. Practical activities include: an on-line tour of the Achieve Solutions website,3 the Athlete Assistance...
Kathy Martin

Kathy Martin graduated from the Lincoln Institute of Health Sciences with a Bachelor in Applied Sciences (Physiotherapy) in 1984. She was awarded the Australian Physiotherapy Association Sports Physiotherapist title in 1999. She received her Bachelor Arts (1991) and Graduate Diploma in Adolescent Health & Welfare (2004) from Melbourne University. She is currently completing her Masters in Counselling at Monash University. Kathy was the Australian Olympic Team Physiotherapist in 2000, the Australian Fed Cup Team Physiotherapist from 1998 to 2000, and Sports Medicine Consultant to Tennis Australia from 1998 to 2003. Prior to working in tennis, she ran her own physiotherapy clinic and was the physiotherapist to the Australian Ballet Company and School and the Victorian College of the Arts. She joined the Sony Ericsson WTA Tour as a Primary Health Care Provider in 1991. She is currently the Director, Athlete Assistance, Sony Ericsson WTA Tour.

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Ashley Keber

Ashley Keber graduated with a Bachelors of Arts in English from the University of Florida, Phi Beta Kappa. She has worked with the Tour since 1997, where she has been the PRO U™ department head, overseeing such programs as the Age Eligibility Rule, Player Orientation, media training and mentor program. She has served on the Women’s Sports Foundation Career Development task force, the Athlete Development steering committee and has been a featured speaker at coaching conferences and an invitee to the annual Board meeting and symposium for National Center for Human Performance. Prior to joining the Sony Ericsson WTA Tour, Ashley was a broadcast liaison for the 1996 Atlanta Olympic Broadcasting group, networks which included Eurosport, BBC, ZDF, Australia 7 and NBC. While attending university, she was an instructor and residence counselor for the UF-Nike Summer Tennis program.

Thomas Livengood

Thomas Livengood graduated with a Bachelors of Arts in Sociology and Russian Language and Literature from Kent State University. Tom joined the Sony Ericsson WTA Tour’s PRO U™ Department as Coordinator, in October 2003. Tom’s primary responsibilities as Coordinator, PRO U™ include development, tracking and maintenance of the Orientation program and monitoring the progress of players through the requirements of the Rookie Phase. His duties include working with players and their support teams (coaches, parents, agents) to help them learn about the professional tennis environment. He also assists with other Sony Ericsson WTA Tour educational initiatives such as the Coach Symposium and Junior forums.

Before joining the Tour, Tom’s past professional experiences include cross-cultural orientation and curriculum development and teaching international high school exchange students. He also lived in Russia for more than three years in the 1990s, and is fluent in conversational Russian.
At first sight “Tennis training” by Mark Kovacs, Britt Chandler and Jeff Chandler could be just one of the many books about tennis training. However, after studying it in more detail, it turns out to be a ‘must-have’ book for tennis medical and performance specialists.

Tennis is an individual and a technical sport. Because of the physiological and technical aspects of tennis, we must train the body in many areas. A player has to develop 4 sides: the player has to focus on physical training in the sport of tennis. In general it does not give any new information. It contains summaries of existing literature and references to known facts. However, what makes this book so good is the information about training principles, training laws, periodisation and experiences from the practices, with pictures the book is filled with tennis-specific exercises. “Tennis training” makes physical training in tennis easy to understand and to use by coaches, parents and athletes. For coaches it is a perfect reference book after their education/training to tennis coach. In practice, it is a book that can easily be used particularly because of the large number of specific exercises. Athletes gain in detail insight in what happens with their body during training, what exercises are really important and why physical training is such an important part of their development. Parents can also benefit from this information. They are usually further removed from the practice and this way they can better understand the technical explanations of the coaches, doctors and athletes.

As I am a physical trainer for the regional tennis squad and the Dutch National Paralympic Squad preparing for the Paralympic Games in Beijing, this book is definitely of interest for me. Additionally it is also useful for medical specialists, tennis coaches, athletes and parents.

Marijn Zaal
Physical trainer Royal Netherlands Lawn Tennis Association

This book has been written by three tennis experts who combine years of academic knowledge with real-world practical coaching to truly blend the art and science of tennis performance.

Dr. Mark Kovacs obtained a top 100 ITF junior ranking, won a US “gold-ball” and competed in many international tournaments including the US and Australian Open before attending Auburn University where he was an All-American and NCAA doubles champion. He has combined researched scientific evidence in his coaching profession both as a high-level tennis coach as well as a strength and conditioning specialist (CSCS) training hundreds of high school, collegiate, and professional athletes. In February of 2008, Dr. Kovacs was named the Manager of United States Tennis Association Sport Science in Boca Raton, Florida.

W. Britt Chandler has a master’s degree in exercise science from Auburn University and played collegiate tennis. He is certified as both a strength and conditioning specialist (CSCS) and certified personal trainer (NSCA-CPT). He also is a certified tennis coach through the USPTA. He currently works as both a tennis coach and strength conditioning specialist with some of the top juniors in the country. Britt is also the editorial assistant for the Strength and Conditioning Journal and has contributed book chapters and presentations on tennis specific research and training.

Dr. T. Jeff Chandler has over 20 years experience as a tennis researcher and sports science consultant, advisor, and author for many tennis organizations including the USTA, USPTA, ITE STMS and PTR. He has over 100 scientific publications, book chapters, and presentations relating to tennis training and performance. He is currently Department Head of Health, Physical Education & Recreation at Jacksonville State University, Jacksonville, Alabama, and is the Editor in Chief of the Strength and Conditioning Journal published through the National Strength and Conditioning Association. Dr. Chandler is certified with distinction as both a CSCS*D and NSCA-CPT*D. He is a Fellow in the American College of Sports Medicine (FACSM) and a Fellow in the National Strength and Conditioning Association (FNSCA).
Sports-related muscle injuries are frequent in adults and youngsters. The presentation of muscle and tendon trauma largely depends on the patient’s age: in youngsters the skeleton is weaker than in adults, whereas their ligaments and tendons can withstand more force. Therefore, skeletal lesions, more specifically those of the physis, are common in children. The type of sports activity determines the nature of the lesion. Most commonly apophyses of the hip and pelvis are subject to avulsion fractures in youngsters, and in tennis the pelvis is the most likely site to be affected. Lesions can be either acute or chronic.

Table 1. Most frequent sites of avulsion fractures, their corresponding muscle insertion and the most frequent athletic activities responsible for these lesions.

<table>
<thead>
<tr>
<th>Location (decreasing order of frequency)</th>
<th>Muscle insertion</th>
<th>Most frequent sports activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>ischial tuberosity</td>
<td>hamstrings</td>
<td>gymnastics, soccer, fencing, tennis, running</td>
</tr>
<tr>
<td>anterior inferior iliac spine</td>
<td>rectus femoris</td>
<td>soccer, athletics, tennis</td>
</tr>
<tr>
<td>anterior superior iliac spine</td>
<td>sartorius</td>
<td>soccer, athletics, gymnastics</td>
</tr>
<tr>
<td>superior corner of pubic symphysis</td>
<td>rectus abdominis</td>
<td>soccer, fencing</td>
</tr>
<tr>
<td>iliac crest</td>
<td>abdominal muscles</td>
<td>soccer, gymnastics, tennis</td>
</tr>
<tr>
<td>lesser trochanter</td>
<td>iliopsoas</td>
<td>athletics</td>
</tr>
</tbody>
</table>
Subacute and chronic avulsion fractures or insertional overuse lesions typically involve the proximal attachments of the gracilis (gracilis-adductor syndrome) and adductor muscles (chronic proximal adductor insertion avulsion syndrome) or distal adductor brevis muscle attachments (chronic distal adductor insertion avulsion syndrome or thigh splints).

Radiographic findings of the proximal gracilis-adductor syndrome consist of a mixture of bone rarefaction and reactive sclerosis that mimic normal variants, osteomyelitis or neoplasms (Figure 2). Periosteal bone apposition at the medial proximal third of the femur can be seen in thigh splints. Scintigraphy shows an elevated tracer uptake whereas MRI initially demonstrates bone marrow and soft tissue edema in all cases, and fatty replacement and sclerosis in the later stages of proximal gracilis and adductor injuries. Thus MRI may demonstrate a variable signal according to the reparative stage of the lesion (either due to edema, fatty reversion or sclerosis). Musculotendinous injuries are treated conservatively, although in acute avulsion fractures surgery may be necessary if displacements exceed 2 cm, or when malunited or hypertrophic fragments cause prolonged complaints.

Conclusions
1. In the adolescent, the physis is particularly susceptible to trauma.
2. The nature of the sport determines the pattern of injury. Lesions due to tennis usually involve the inferior and superior anterior iliac spine, the ischial tuberosity and the iliac crest, but other apophyses may be affected as well. Both the radiologist and the sports physician should be aware of these lesions.
3. During the healing phase the excessive callus formation of acute / avulsion lesions may simulate an osteosarcoma or exostosis.
4. The differential diagnosis of chronic overuse injuries in the immature skeleton includes normal variants, osteomyelitis and tumoral lesions.

References
The ITF Science & Technical Department hosted its 3rd International Congress on Tennis Science & Technology (TST) at Whitelands College at the University of Roehampton in London 10-12 September 2007. Over 90 of the world’s leading tennis science and technology researchers were present for three days of outstanding presentation and discussion.
Almost 50 presentations were given, the standard of which was extremely high. In addition to academics, the delegates included representatives from the equipment manufacturers, coaches, court constructors and national governing bodies. The congress was officially opened by ITF Vice President Geoff Pollard who commented that the Congress was a gathering of "the brains of tennis", and how understanding technology was crucial to the future of the game. In addition, he contributed to four scientific papers which focused on the probability of a player winning a match based on improving their level of play at different stages of the match.

Two keynote presentations were given: the first, by Dr Stuart Miller, ITF Head of Science & Technical, and which opened the Congress, discussed the role of the Science & Technical Department in the development of rules and regulations for tennis equipment. This presentation included an overview of the projects undertaken by the ITF Technical Centre, and their contribution to the understanding and protection of the nature of tennis. The second was presented by Professor Steve Haake of Sheffield Hallam University, Great Britain, who examined the evolution of the tennis racket and its effect on serve speed. To encourage debate amongst the delegates, a discussion panel, entitled 'Rules are made to be broken: where does tennis go from here?', addressed current issues with respect to the Rules of Tennis. As Chairman of the ITF Rules of Tennis Committee, Geoff Pollard played a major part on the distinguished panel, and was joined by Chris Bowers (journalist and broadcaster), Steven Martens (LTA Head of Technical Support), Angie Cunningham (Vice-President, Player Relations, Sony Ericsson WTA Tour), and Ralph Schwenger (Head Sport AG, R&D Director Racketsports). Among the many topics discussed during the discussion were electronic line-calling, equipment development, player physiology and coaching.

The quality of presentations was extremely high, and covered a variety of topics, including equipment technology, player development and analysis, and the environment. The second Howard Brody Award (sponsored by CISLunar Aerospace) for outstanding contributed paper, which was presented in person by Professor Brody, went to Simon Choppin of Sheffield University, Great Britain, for a paper on the three-dimensional analysis of racket and ball during play. Professor Brody commented that the 3rd TST Congress was thought-provoking, and generated more interaction between delegates than either of the two previous events.

Over 40 delegates took the opportunity to visit the ITF Technical Centre, which contains the world’s leading tennis-specific research and testing laboratory. Prior to the congress dinner being held at the All England Lawn Tennis Club, delegates also had the opportunity to tour the facility for a behind-the-scenes look at Wimbledon.

The congress dinner was attended by ITF President Francesco Ricci Bitti, who stressed the importance of technology in tennis, and the responsibility of the ITF to control the nature of the game through an understanding of equipment.

Proceedings, containing all the papers presented at the Congress, are available for purchase through the ITF Store https://store.itftennis.com.
Preventing ankle sprains and improving balance in tennis players

Introduction
Tennis is a popular sport, with an increasing number of active players.\(^1\) Although tennis is a non-contact sport, it is associated with a number of injuries.\(^2\) Most injuries in tennis occur in the lower extremities,\(^4\) consisting primarily of muscle strains and ligaments sprains in the ankle and knee,\(^2\) followed by the upper extremities and trunk area.\(^5\) Furthermore, tennis is a sport that requires speed, power, and functional strength movements for an extended period. Therefore, it is important to train the tennis player to maximise his performance while incorporating specific exercises to eliminate injury risk factors.\(^7\) More specifically, specialists propose strengthening exercise programmes to restore muscle imbalances, stretching exercise programmes to decrease muscle stiffness and balance exercise programmes to improve proprioception.\(^8\) Proprioception is especially important for tennis players, because tennis movement characteristics are complex, the footwork is demanding and a high level of balance is required.\(^18\,19\) Since balance is one of the fundamental qualities that tennis players must develop\(^20\) tennis-specific balance exercises should be included in a player’s daily training routine in order to maximise performance and minimise injury risk.\(^9\) The aim of the present paper was to present a structured programme of how to incorporate specific balance exercises for tennis players to improve balance and prevent lower limb injuries.

Specific characteristics of the balance exercise programme
According to the previous studies:
1. The content of the balance exercise programme should be incorporated into tennis training drills because all the exercises are designed to be a natural part of playing movements;\(^15\)
2. The tennis-specific balance exercises should be done on a tennis court or in a controlled environment (e.g. gym room) and allow the joints to move in the same way as they would in normal functional tennis activities;\(^17\)
3. The exercises may be progressed by changing from bilateral to unilateral standing in the first drill only;
4. The exercises performed on balance boards require a combination of balancing skills and certain tennis skills (e.g. dribbling, ground strokes and volleys);
5. The duration of each drill should be increased progressively.

The balance exercise programme
The combination of tennis drills and balance exercises make the training session more sport-specific and interesting. The specific balance exercise programme includes a closed-chain lower limb position. The proposed pieces of equipment are a mini-trampoline, balance boards with air and wooden balance boards. The use of a mini-trampoline can change the weight bearing surface from hard to soft and provide an element of instability, thus requiring more control in the weight-bearing lower extremity exercises for stability.\(^23\) With regard to the balance boards; the first is a balance board, 40 cm in diameter and filled with air flat side up and down. The second board is a flat wooden disk, 51 cm in diameter, and 1 cm high with a round hardwood block (9.5 cm diameter, 3.7 cm high) in the middle of its base. The board with the hemispherical bottom moves in all directions. With the use of these pieces of equipment, the balance exercise programme includes four different tennis drills (Table 1).
**Dribbling**

In this drill the tennis player stands with both feet on the mini-trampoline and dribbles the ball with the tennis racket (Figure 1). Then, the player does the same drill on the balance board with air and then, on the wooden balance board. The player then repeats all these exercises with a one-legged stance.

**Ground strokes**

In this drill, the tennis player stands in a closed position (sideways) with both feet on the mini-trampoline. The coach feeds the ball to the player who tries to hit a forehand drive and return the ball to the coach (Figure 2). The drill is then repeated on the backhand side. As the programme progresses the player does the same drill on two balance board with air (one foot on each board) and then, on the wooden balance boards.

**Ground stroke and volley**

In this drill the tennis player stands sideways with both feet on the mini-trampoline and tries to control the ball which the coach feeds before returning it with a forehand drive. The drill is then repeated using a backhand drive to return the ball. As the programme progresses the player does the same drill on two balance boards with air (one foot on each board) and then, on the wooden balance boards.

---

**Table 1. Recommendations for a tennis balance exercise programme**

<table>
<thead>
<tr>
<th>Drills performed on:</th>
<th>Training period</th>
<th>Rest period between each drill</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. trampoline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. balance board with air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. wooden balance board</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>First drill:</strong> Standing while dribbling (with the racket and tennis ball)</td>
<td>1st wk: 20s/drill (total 6mins)</td>
<td>20s (total 6mins)</td>
</tr>
<tr>
<td><strong>Second drill:</strong> Ground strokes</td>
<td>2nd wk: 30s/drill (total 10mins)</td>
<td>15s (total 5mins)</td>
</tr>
<tr>
<td><strong>Third drill:</strong> Ground stroke/volley</td>
<td>3rd and 4th wk: 40s/drill (total 12mins)</td>
<td>20s (total 6mins)</td>
</tr>
<tr>
<td><strong>Fourth drill:</strong> Control and ground stroke</td>
<td>5th and 6th wk: 60s/drill (total 12mins)</td>
<td>20s (total 4mins)</td>
</tr>
<tr>
<td>(Each drill performed 2 times)</td>
<td>7th and 8th wk: 60s/drill (total 14mins)</td>
<td>20s (total 4-5mins)</td>
</tr>
</tbody>
</table>

*Table 1. Recommendations for a tennis balance exercise programme*

**Mins, minutes; s, seconds; wk, week**
Address for correspondence: Vasiliki J. Malliou, Ph.D., Makrigianni 36, Ilissia, 1645, Athens, Greece.

Paraskerti Malliou, Ph.D. is Associate Professor and athletic trainer at the Democritus University of Thrace, Department of Physical Education and Sports Science in Komotini, Greece.

Vasiliki J. Malliou, Ph.D., is a physical education and tennis instructor at the National and Kapodistrian University of Athens, Department of Physical Education & Sports Science, in Athens, Greece.

Asimenia Gioftsidou, Ph.D. is a physical education teacher and athletic trainer at the Democritus University of Thrace, Department of Physical Education and Sports Science, in Komotini, Greece.

Stavros Douvis, Ph.D. is Associate Professor and Head of the tennis course at the University of Athens, Dept of Sports Science.

Alexandros Mavvidis, Ph.D. is Associate Professor and Head of the tennis course at the University of Thrace, Dept. of Sports Science.

Summary:
In conclusion, we recommend tennis coaches to include balance exercises in to their players’ daily tennis training programmes to improve proprioception and potentially reduce lower limb injuries. These balance exercises should be combined with tennis drills in order to be more sport-specific and interesting. The programme is intended to enhance hand-eye coordination and subconscious reaction. The duration of the recommended balance exercise programme should be eight weeks with a daily training duration that increases from 6 to 14 minutes (Table 1).

References
The Knee: Patient evaluation / Imaging / Therapy and Rehabilitation

This book about the knee joint is a manual for physicians, physical therapists and patients. It is written in a way patients can understand, but of sufficient medical interest to be useful to physicians such as orthopaedic surgeons and sports physicians. The book emphasizes the interaction between the physician, physical therapist and patient during the rehabilitation process. It explains how to make a successful return to sport and how to prevent injuries from re-occurring.

“The knee” is divided into three main sections. The first section includes general information in which the anatomy of the knee is explained and biomechanical information is provided for the different knee components during movement. The second section of the book describes common knee injuries in detail, and explains trauma mechanism, physical examination and injury-specific imaging. It also outlines conservative treatment and operative treatment techniques. To help the reader understand the recommended conservative treatment and specific rehabilitation phases, each chapter is supplied with drawings of the suggested exercises. The operative techniques are clarified by images as well, to explain the different phases of the operation. Schabus and Bosina particularly focus on the anterior cruciate ligament and gonarthrosis. They also discuss other common problems such as posterior cruciate ligament lesions, meniscal lesions, cartilage damage and patellar instability. The third section of the book explains the various exercises, using appropriate images, for stretching and strengthening the different muscles around the knee joint. There is the added bonus of a DVD showing all the exercises in the book which is provided with each copy. In summary, this book provides an excellent overview of the anatomy, injuries and rehabilitation techniques of the knee. It would be particularly useful for patients and coaches, and health care professionals starting a career in sports medicine.

Maarten Moen
sports physician

University Professor Dr. Rudolf Schabus was born in Hermagor/Kärnten in 1954 and studied medicine in Vienna (1973-1978). He went on to specialise in traumatology at the University Clinic for Traumatology, Vienna (1979-1985) and received certification as a sports physician in 1990. He is currently the Head of the Dept. of Traumatology and Sports Injuries in the Wiener Privatklinik.

Elisabeth (Lisi) Bosina was born in Vienna in 1959 and, after qualifying as a physiotherapist, she went on to specialise in sports physiotherapy. From 1988, she worked in private practice in Vienna. Shortly after the completion of this book, in 2005, she was tragically killed in an avalanche accident.
Loading and velocity generation in

The ‘why’
Shoulder injuries rank among the most prevalent and debilitating injuries sustained by professional tennis players. The loads endured by the tissues of the shoulder during stroke production, and more particularly the serve, are commonly implicated in shoulder joint injury. Indeed, past evidence points to these loads increasing along with serve velocity, as well as with varied segment use. The aim of this thesis was to therefore quantify how different types of serves (i.e., the flat serve and the kick serve) and how different service techniques (i.e., the foot-up) affected shoulder joint loading among high performance able-bodied and wheelchair players. Exciting in that it represented an opportunity for three-dimensional (3D) stereophotogrammetry – the gold standard in motion analysis – to evaluate a tennis stroke, and, challenging as the shoulder represents something of a ‘Holy Grail’ in upper-limb biomechanics.

The ‘where’, ‘who’ and ‘how’
The Vicon 612 (Oxford Metrics, Oxford, UK) system at the School of Sport Science, Exercise and Health was utilised to track retroreflective markers (UWA model) placed on twelve high performance able-bodied male tennis players and two top 30 professionally ranked male wheelchair tennis players executing serves of varying type (i.e., flat serve and kick serve) and technique. Twelve cameras, operating at 250 Hertz, minimised the prospect of marker occlusion and optimised marker reconstruction during data collection. Upper limb kinetics were calculated through inverse dynamics, where segmental masses and moments of inertia were provided from the data of De Leva and Clauser et al.

The challenges along the way (establishing the methodology)
In tennis, normative data describing the key mechanical characteristics of selected strokes is widespread, yet the number of strokes upon which these data should be based has rarely been documented. Consequently, verification of the repeatability of the tennis serve, and the minimum number of executions upon which representative observations could be made, needed to be established. In some agreement with theoretical models of performance analysis, reliable evaluation of the serve appeared to require at least three successful service trials. Determination of appropriate methods of data treatment, including an apposite smoothing technique to best represent higher-order kinematics both pre- and post-impact, saw a cubic spline interpolative procedure used.

Accurate 3D representation of segments requires at least three non-collinear markers, or points. Additional markers are required to define points of anatomical relevance. In the upper body, estimation of wrist and elbow movement is relatively simple as both joints can be represented by two degrees of freedom. However, biomechanical modelling of the shoulder is complicated by its three degrees of freedom as well as the high rotational velocities and large ranges of motion that punctuate its involvement in functional tasks. Further, gimbal lock (where angles become ill-defined as axes coincide) is of real interpretive concern when shoulder joint motion is determined via the Euler angle flexion-extension, abduction-adduction and internal-external rotation ZXY decomposition typically used to describe all other joint motion. Pilot work was thus undertaken to corroborate the ISB-recommended plane of elevation, elevation and internal-external rotation decomposition, and its accompanying spherical reference system, as preferable for computing more representative shoulder joint kinematics. Also, with soft tissue artefact considered the largest source of error in 3D motion analysis, a case study was needed to compare the coupling of different marker/triad positions (i.e., the technical coordinate systems) and the underlying humeral bone motion.

The analyses

Study 1: Similar shoulder joint kinetics developed dichotomous 3D racquet velocities in the high performance able-bodied flat serve and kick serve. Where higher peak horizontal, vertical and absolute racquet velocities were generated during the flat serve, higher lateral velocities characterised the kick serve. The comparable shoulder joint loading conditions nevertheless point to the repetitive, long-term performance of either serve as relevant in shoulder joint injury pathologies.

Study 2: Coordinative lower limb variation in the able-bodied serve, encapsulated by specific front and back lower limb joint kinematics was also shown to influence the development of flat serve racquet velocity. Aided by a leg drive, high-performance players generated similar absolute pre-impact racquet velocities from both foot-up and foot-back service stances. Conversely,
The high performance tennis serve

less dynamic engagement of their lower limbs (i.e. the ARM serve: flat serves hit with minimal active ankle, knee and hip joint flexion-extension) saw players unable to generate commensurate pre-impact absolute racquet velocities. Interestingly, comparable shoulder joint kinetics were inherent to the flat serve, irrespective of the noted lower limb kinematic variation. So, with differential absolute racquet velocities produced via similar shoulder joint loads but divergent ‘leg drives’, other links in the ‘kinetic chain’ may be more affected by variable lower limb involvement.

Study 3: In contrast to able-bodied serve performance, similar peak pre-impact absolute racquet velocities were generated during the wheelchair flat serve and kick serve. Wheelchair serve tactics still demanded the development of higher peak pre-impact horizontal and lateral racquet velocities during the flat serve and kick serve, respectively. Shoulder joint kinetics were consistent across wheelchair serve type, but specific to the individual players; likely varying with their level and severity of spinal cord injury. When expressed relative to absolute racquet velocity, both the high-performance able-bodied and wheelchair players tolerated comparable pre- and post-impact shoulder joint loading profiles such that related shoulder joint injury risk appears analogous between populations.

The ‘where to from here’ at the University of Western Australia
• Ongoing biomechanical examination to establish best marker positions and processes of shoulder joint estimation as well as most meaningful shoulder joint representation, to further enhance the calculation and interpretation of shoulder joint motion in all overhead motions.
• Examination of shoulder mechanics (inclusive of electromyography) in the flat, slice and kick serve performance of pre- and post-pubescent high performance male and female players.
• Derivation of ball spin rate and axis during the high performance serve of adult and junior players. Determination of the key kinematic characteristics that help produce ball rotation.

References

Machar is the Sport Science Manager for Tennis Australia. Previously, he worked as a Lecturer in Biomechanics at the University of Western Australia, where he continues to retain an Adjunct appointment. From 2000-2004, he was the Assistant Research Officer for the International Tennis Federation (ITF), based in Valencia, Spain. A Tennis Australia Level 3 Coach, Machar’s duties included coaching some of the world’s best juniors, conducting research on the game’s professional elite, creating and delivering the ITF Level 1 course, and co-authoring several ITF publications. During that period, Machar also filled the role of physical training advisor to former top 10 player, Greg Rusedski, and was contracted by the Chinese Tennis Association to work with and establish a strength and conditioning framework for the country’s female elite (Li Na and Jie Zheng).
Academically, Machar has completed a B.App.Sc. (Hons) in Human Movement [RMIT], PG Dip in Elite Sport Coaching (Canberra), and in December 2008, a PhD in Biomechanics [UWA].

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Introduction

There is a range of published material on the use of match statistics/probabilities to increase serving performance. Gale1 used a simple mathematical model to determine an optimal strategy for serving in tennis. Norman2 used dynamic programming to determine an optimal strategy of whether to use a slow or fast serve on the first and second serve. George3 used a simple probabilistic model to determine a serving strategy in tennis and stated that the usual serving strategy may not be optimal. Professional tennis matches were used as examples to support the claim. Gillman4 developed a similar analysis to serving strategies. Hannan5 also analysed different serving strategies, with the added complexity of the opponent returning the serve in such a way that the server countered with a strong shot or was forced to hit a weak shot. Pollard6 determined a method for finding the optimal risks that should be taken by the server on the first and second serves.

In the above papers the effect of the receiver’s receiving capacity on the probability that the server wins a point on the first serve and on the probability that he wins a point on the second serve, is typically handled implicitly. Nowadays, with the availability of substantial data on each player’s receiving capacity (as well as on each player’s serving capacity), it is possible to address the effect of the strength of the receiver on the server’s first and second serve probabilities explicitly rather than just implicitly. Thus, a player’s serving probabilities against one player can be different from his/her serving probabilities against another. Correspondingly, a player’s best serving strategy against one player can be different from the best serving strategy against another. Barnett and Clarke7 showed how to predict serving and receiving player statistics/probabilities prior to the start of a match. Their model can be used to evaluate the optimal serving strategy for a player against a particular opponent. Barnett and Pollard2 showed that players’ performances are affected by the court surface for both men and women. Thus, a player’s optimal serving strategy can vary from opponent to opponent and from surface to surface. In earlier studies, such variations were handled implicitly, and were not clearly identifiable to the reader.

Abstract

A large database of tennis statistics is used to calculate player match statistics for each court surface. Analysis is carried out to determine serving strategies to increase performance. The results of the analysis could be used by players and coaches to possibly increase serving performance.
As an example of a player’s optimal serving strategy varying from one opponent to another, we consider the following. Consider a typical professional man (player A) whose optimal serving strategy is typically a hard first serve and a softer second serve with spin. If this player’s opponent is equally as good at receiving a first serve as receiving a second serve, it is clear that player A may just as well serve a second serve as a first serve. On the other hand, if player A’s opponent is very much better at receiving a second serve than receiving a first serve, it may be better for player A to serve two first serves than to serve a fast first serve and a slower second serve. In this paper we see how the merits of this potential strategy of two fast serves can be assessed statistically by a player about to play a specific opponent.

This paper uses a large database as provided by KAN-soft (www.oncourt.info) to calculate player match statistics for each court surface. The methods of the analysis could be used by players and coaches to increase potential serving performance.

**OnCourt database**

The OnCourt database provides some match statistics since the 2003 French Open. Not all the match statistics for the ATP and WTA events are given. However the number of matches and tournaments included in the database has increased in recent years. The database is taken from the 6th August, 2007. The surfaces are categorized as grass, hard, indoor hard, clay, carpet and acrylic. For simplicity hard and indoor hard are considered as one surface. It is noted that acrylic will be played at the Australian Open from 2008. At August 2007, there are no match statistics recorded by the OnCourt database for matches played on acrylic.

A program was written in SAS to calculate the average serving and receiving statistics for each player on each surface. The serving and receiving statistics averaged across all matches on each surface was also calculated. Tables 1 and 2 below give these overall averages for men and women. The results indicate that women serve a higher percentage of 1st serves in play compared to men for all four surfaces. However, the results indicate that men win a higher percentage of points on the first and second serve compared to the women for all four surfaces. This agrees with the results of Barnett and Pollard. The difference between the percentage of wins on first serve for men and for women is 8.8%. The difference between the percentage of wins on second serve for men and women is 5.5%. As the former value is greater than the latter value, there is a suggestion or possibility that a fast first and fast second serve strategy is more likely to be a reasonable one in a men’s match than in a women’s match.
The players' serving and receiving statistics are defined as:

- \( a_{is} = \) percentage of first serves in play for player i on surface s,
- \( b_{is} = \) percentage of points won on first serve given that first serve is in for player i on surface s,
- \( c_{is} = \) percentage of points won on second serve for player i on surface s,
- \( d_{is} = \) percentage of points won on return of first serve for player i on surface s,
- \( e_{is} = \) percentage of points won on return of second serve for player i on surface s.

The surfaces are defined as: s=1 for grass, s=2 for carpet, s=3 for hard and s=4 for clay.

Combining player statistics is a common challenge in sport. While we would expect a good server to win a higher proportion of serves than average, this proportion would be reduced somewhat if his opponent is a good receiver. Using the method developed by Barnett and Clarke, we can calculate the combined percentage a player wins on his/her first and second serve for each surface. The equations are given as follows:

\[
\begin{align*}
fijs &= b_{is} - d_{is} + davs \quad (1) \\
ghi &= c_{is} - e_{is} + eavs \quad (2)
\end{align*}
\]

where:
- \( fijs = \) percentage of points won on first serve given that first serve is in when player i meets player j on surface s,
- \( ghi = \) percentage of points won on second serve when player i meets player j on surface s,
- davs represents the average percentage of points won on return of first serve on surface s,
- eavs represents the average percentage of points won on return of second serve on surface s.

A simple analysis can now be used to compare two serving strategies. The first strategy is where a player serves a fast serve on the first serve and a slow serve on the second serve. Using the method, the percentage of points won on serve is given by:

\[
ai s * fijs + (1- ai s) * gijs
\]

The second strategy is where a player serves a fast serve on both the first and second serve. Using this method, the percentage of points won on serve is given by:

\[
ai s * fijs + (1- ai s) * ai s * fijs
\]

Therefore, a player should use the second strategy if

\[
(1-ai s) * ai s * fijs > (1-ai s) * ghi
\]

which simplifies to

\[
ai s * fijs > ghi
\]

**Example: Andy Roddick versus Rafael Nadal**

Serving and receiving statistics for Andy Roddick and Rafael Nadal are given in Table 3. Equations 1 and 2 are used to calculate \( fijs \) and \( ghi \), where davs and eavs are obtained from Table 1. The lack of matches played on carpet by both players is noted. The results from Table 3 indicate that Roddick might be encouraged to serve fast on both the first and second serve when playing Nadal on grass. However he should use a fast first serve and slower second serve when playing Nadal on both hard court and clay. Nadal on the other hand should use a fast first serve and slower second serve when playing Roddick on grass, hard court and clay. This example illustrates the fact that it can be important for a player to identify the particular surface statistics for himself and his opponent.

The above analysis indicates that Roddick might do slightly better when playing Nadal on grass by using two first serves rather than using a first serve and a slower second serve. The effect however is not statistically significant. Nevertheless, Roddick might do well to mix his first and second serve when serving a second serve to Nadal. He would appear to have little to gain or lose sta-

### Table 1. Match statistics for men separated by court surface

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Grass</th>
<th>Carpet</th>
<th>Hard</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Win Percentage of 1st serves in play</td>
<td>61.9%</td>
<td>61.3%</td>
<td>60.0%</td>
<td>61.5%</td>
</tr>
<tr>
<td>Percentage of points won on first serve</td>
<td>74.1%</td>
<td>73.0%</td>
<td>71.0%</td>
<td>67.1%</td>
</tr>
<tr>
<td>Percentage of points won on second serve</td>
<td>51.8%</td>
<td>51.3%</td>
<td>50.9%</td>
<td>49.2%</td>
</tr>
<tr>
<td>Percentage of points won on serve</td>
<td>65.5%</td>
<td>64.6%</td>
<td>62.5%</td>
<td>60.2%</td>
</tr>
<tr>
<td>Percentage of points won on return on first serve</td>
<td>25.9%</td>
<td>27.0%</td>
<td>29.0%</td>
<td>32.9%</td>
</tr>
<tr>
<td>Percentage of points won on return on second serve</td>
<td>48.2%</td>
<td>48.7%</td>
<td>49.1%</td>
<td>50.8%</td>
</tr>
<tr>
<td>Percentage of points won on return of serve</td>
<td>34.5%</td>
<td>35.4%</td>
<td>37.5%</td>
<td>39.8%</td>
</tr>
<tr>
<td>Number of matches</td>
<td>928</td>
<td>304</td>
<td>4319</td>
<td>3331</td>
</tr>
</tbody>
</table>

### Table 2. Match statistics for women separated by court surface

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Grass</th>
<th>Carpet</th>
<th>Hard</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Win Percentage of 1st serves in play</td>
<td>63.1%</td>
<td>63.4%</td>
<td>62.1%</td>
<td>63.4%</td>
</tr>
<tr>
<td>Percentage of points won on first serve</td>
<td>65.4%</td>
<td>63.1%</td>
<td>62.0%</td>
<td>59.6%</td>
</tr>
<tr>
<td>Percentage of points won on second serve</td>
<td>46.1%</td>
<td>46.4%</td>
<td>45.3%</td>
<td>43.6%</td>
</tr>
<tr>
<td>Percentage of points won on serve</td>
<td>58.1%</td>
<td>57.0%</td>
<td>55.5%</td>
<td>53.5%</td>
</tr>
<tr>
<td>Percentage of points won on return on first serve</td>
<td>34.6%</td>
<td>36.9%</td>
<td>38.0%</td>
<td>40.4%</td>
</tr>
<tr>
<td>Percentage of points won on return on second serve</td>
<td>53.9%</td>
<td>53.6%</td>
<td>54.7%</td>
<td>56.4%</td>
</tr>
<tr>
<td>Percentage of points won on return of serve</td>
<td>41.9%</td>
<td>43.0%</td>
<td>44.5%</td>
<td>46.5%</td>
</tr>
<tr>
<td>Number of matches</td>
<td>881</td>
<td>199</td>
<td>3432</td>
<td>2293</td>
</tr>
</tbody>
</table>
Dr. Denny Meyer is a Senior Lecturer in Statistics at the Swinburne University of Technology. She has co-authored two books and has published upward of 50 articles in refereed journals. She is an applied statistician, working in areas such as sport statistics, management, tourism, mineral processing, advertising, agriculture and social research.

Dr. Tristan Barnett is an Adjunct Research Fellow in sports statistics at Swinburne University of Technology. He has written several published papers, given presentations at international conferences and has a PhD in tennis modelling. He has appeared on many occasions in the media including SEN sports radio and 3RRR sports segment “Run Like You Stole Something”. Tristan currently works as a gaming mathematician for Sportsbet21 Pty Ltd.

Emeritus Professor Graham Pollard is a former professor of applied statistics and pro-vice-chancellor of the University of Canberra, Australia. He is a former four grade tennis player and state squash champion, has a PhD in statistics from the Australian National University, and has international research publications in tennis, squash, theoretical statistics, maths education and physics.

About the authors

Acknowledgement
The authors would like to thank KAN-soft for providing the database for calculating serving and receiving statistics.

Table 3. Serving and receiving statistics for Andy Roddick and Rafael Nadal

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Andy Roddick</th>
<th>Rafael Nadal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grass</td>
<td>Carpet</td>
</tr>
<tr>
<td>(a_{is})</td>
<td>0.67</td>
<td>0.69</td>
</tr>
<tr>
<td>(b_{is})</td>
<td>0.82</td>
<td>0.78</td>
</tr>
<tr>
<td>(c_{is})</td>
<td>0.56</td>
<td>0.43</td>
</tr>
<tr>
<td>(d_{is})</td>
<td>0.28</td>
<td>0.23</td>
</tr>
<tr>
<td>(e_{is})</td>
<td>0.47</td>
<td>0.48</td>
</tr>
<tr>
<td>(f_{is})</td>
<td>0.799</td>
<td>0.790</td>
</tr>
<tr>
<td>(g_{is})</td>
<td>0.512</td>
<td>0.417</td>
</tr>
<tr>
<td>(a_{is} + b_{is})</td>
<td>0.535</td>
<td>0.545</td>
</tr>
<tr>
<td>Matches</td>
<td>37</td>
<td>3</td>
</tr>
</tbody>
</table>

Conclusions
The results indicate that separating player match statistics into different court surfaces can be useful (for some players against some other players on particular surfaces) in making decisions on serving strategies. An example where one player might benefit by serving two fast serves has been given. The method of analysis could be used by any player or coach to see whether serving performance might be enhanced during a forthcoming match. Thus, this approach could be quite a valuable tool for some players.

Player match statistics could be used in other applications. For example, match statistics separated by court surface could be used by television broadcasters as a guide to likely match outcomes and comments on strategies.

References
Australian elite tennis juniors’ perceptions of the importance of mental skills were investigated in a study commissioned by Tennis Victoria. Eight junior boys aged 13 to 17 years and seven girls aged 12 to 16 years comprising an elite training squad at Melbourne Park responded to a questionnaire. Responses to ratings of the importance of mental and physical factors, and key mental skills for success were recorded, together with the time devoted to mental preparation prior to important matches and explanations for match losses. While mental factors and skills were strongly endorsed, no gender differences were found in these endorsements or in the time devoted to mental preparation. Losses in important matches were generally attributed to mental factors. Results were interpreted in terms of the maturity of players and shared exposure to the State coach’s training methods and program. Future directions in tennis mental skills research are highlighted.

Introduction
In a recent publication, Weinberg\(^1\) suggests that the challenge for most tennis players is to identify, and adopt, key elements which facilitate playing at one’s best on a consistent basis. To this end, Weinberg\(^2\) suggests mental factors are paramount, citing: (a) Jimmy Connors’s contention that tennis is 95% mental at the professional level; and, (b) the results of a survey with coaches and players that found tennis success was considered at least 50% (and as high as 80-90%) mental. In further survey findings, Weinberg\(^2\) reports that, although players generally attributed losses to mental factors, players devote no time, or very little time (a few minutes), preparing themselves mentally for matches.

Key words:
elite tennis juniors, mental skills, mental skills training
In terms of teaching mental skills to players, Gould et al. suggest that tennis coaches should play a key role (as a player’s access to a sport psychologist may be restricted and coaches are generally the first, and most accessible, contact point for players). According to these authors, this role for coaches is proving to be a challenging one, with many coaches lacking requisite training in, and knowledge of, mental skills training. As concluded by these authors, “little is known about helping coaches develop mental skills in their athletes’ and more research on mental skills in tennis is warranted.

With few studies conducted to date to address mental skills development and training with children and young adolescents, the aim of this study was to examine elite tennis juniors’ perceptions of the importance of mental skills for success and, further, to examine for gender differences in these perceptions. As such, this study complements research with adult elite athletes and coaches as to their perceptions of the importance of mental skills. In these peak performance studies, a kaleidoscope of mental skills were found to be associated with success, with key skills embracing focused attention, feelings of confidence, ability to control nerves and anxiety, commitment and dedication.

In this exploratory investigation of elite juniors’ perceptions of the importance of mental skills for success it was hypothesised that:

1. Elite junior players would rate the importance of mental factors for success higher than the importance of physical factors and there would be no gender differences in these ratings;
2. Elite junior boys and girls would rate the same the importance of key mental skills for success;
3. Elite junior boys and girls would devote similar time to mental preparation prior to important matches, and, time devoted to mental preparation prior to matches would increase with a player’s age;
4. Elite junior players would attribute losses in important games to mental factors.

Method

Participants
An elite squad of eight boys aged 13 to 17 (mean 16.1) years and seven girls aged 12 to 16 (mean 14.8) years participated in the study. The juniors, who were the top two ranked players in their age groups in the State, trained twice weekly at Melbourne Park, Melbourne, Australia under the guidance of the State coach. The coaching program conducted by the State coach did not include any formal mental skills training sessions.

Materials
Participants completed a self-report instrument (questionnaire) that was developed for the purposes of this study and consisted of both quantitative (n = 7) and qualitative (n = 1) measures. The quantitative measures consisted of asking participants to rate the importance of the physical (e.g. fitness) and mental (mind, thinking) aspects of tennis for success on a 5-point Likert scale (anchored where 1 = not important at all to 5 = extremely important). Using the same 5-point Likert scale, and adapting Williams and Krane’s psychological profile of a sporting champion, participants were also asked to rate the importance for success of: (a) success of determination and commitment; (b) self-belief; (c) ability to control one’s nerves and anxiety; (d) concentration; and, (e) love and interest in tennis. In addition, participants reported on how much time they devoted to mental preparation before an important match. The qualitative measure in the questionnaire consisted of asking participants to nominate reasons for their losses in important matches.

Procedure

After receiving informed consent from players’ parents, the investigator met with participants prior to a training session at Melbourne Park. The investigator outlined the study’s purpose and advised participation in the study was voluntary; there was with no requirement for players to identify themselves in responding and there were no correct, or incorrect, answers. All participants completed the questionnaire within 20 to 30 minutes.

Data Analysis

To analyse the quantitative data, a number of inferential statistics was conducted. Specifically, a series of seven Mann-Whitney U-tests were conducted to examine for differences in: (a) ratings of importance of physical and mental factors; and, (b) ratings of five key mental skills by gender. An independent t-test and a Pearson’s product moment correlation were also conducted to examine for gender differences in the amount of time devoted to mental factors prior to matches and the relationship between the amount of time devoted to mental preparation and age of participants respectively.

To analyse the qualitative data, an inductive content analysis of participants’ accounts for their losses in important games was conducted. In a popular procedure adopted by qualitative researchers, key words, phrases or statements (referred to as ‘raw data themes’) were identified in participants’ narratives. Raw data themes sharing explicitly similar meaning were subsequently grouped into higher order (general) dimensions. In a final procedure, these general dimensions were classified as physical (e.g. physical fitness), mental (e.g. motivation) or other (e.g. weather, court conditions) factors in accord with Weinberg’s descriptions of these factors.
Results
Mental skills and success
Participants’ ratings of the importance of physical and mental factors for success are presented in Table 1.

Table 1. Mean ratings by elite juniors (by gender) of the importance of physical and mental factors for success in tennis on Likert scale

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean rating: junior boys</th>
<th>Mean rating: junior girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td>4.75</td>
<td>4.71</td>
</tr>
<tr>
<td>Mental</td>
<td>4.88</td>
<td>4.71</td>
</tr>
</tbody>
</table>

A Mann-Whitney U-test revealed no significant differences in participants’ ratings of the importance of physical and mental factors for success (Mann-Whitney U = 59.5, p>0.05).

Participants’ ratings of the importance of five mental skills and attributes for success are presented in Table 2.

Table 2. Mean ratings by elite juniors (by gender) of the importance of key mental skills and attributes for success*

<table>
<thead>
<tr>
<th>Mental skill and attribute</th>
<th>Mean rating: junior boy</th>
<th>Mean rating: junior girl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determination and commitment</td>
<td>4.75</td>
<td>4.86</td>
</tr>
<tr>
<td>Self confidence</td>
<td>4.88</td>
<td>4.71</td>
</tr>
<tr>
<td>Ability to control nerves and anxiety</td>
<td>4.50</td>
<td>4.57</td>
</tr>
<tr>
<td>Concentration</td>
<td>4.62</td>
<td>4.86</td>
</tr>
<tr>
<td>Love and interest in tennis</td>
<td>4.88</td>
<td>4.42</td>
</tr>
</tbody>
</table>

A series of five Mann-Whitney U-tests revealed no significant differences between junior boys’ and junior girls’ ratings of the importance of each of the five skills and attributes listed in Table 2.

Mental preparation time
In terms of time devoted to mental preparation before an important game, junior boys reported spending between 1 to 30 minutes (mean 12.5), compared with 10 to 20 minutes (mean 18.9) reported by junior girls. An independent t-test revealed no significant differences between junior boys and junior girls in terms of their mental preparation time (t (13) = -1.5, p>0.05) and a Pearson’s product moment correlation revealed no significant relationship between mental preparation time and age of player (Pearson’s product moment = -0.16, p>0.05).

Discussion
In summary, the study found that elite junior players:
1. Considered physical and mental factors to be equally important for success, with no gender differences in these perceptions evident;
2. Strongly endorsed the importance of key mental skills and attributes - determination and commitment, self confidence, ability to control nerves and anxiety, concentration, love and interest in tennis – with no gender differences in these perceptions evident;
3. Spent between 1-30 minutes mentally preparing prior to important matches, with no gender differences evident in the time devoted to mental preparation by players;
4. Nominated an array of factors (e.g. choking, attack of nerves, a lack of motivation and self confidence) to explain losses in important matches. The majority (78%) of nominated factors were mental ones, although a lack of physical skills was a shared general dimension of factors across elite junior boys and girls.

It was an aim of the study to examine for gender differences in elite juniors’ perceptions of mental skills, and it is noteworthy that no gender differences were found across a number of measures. This finding suggests there may have been a comparable level of maturity shared by the elite junior boys and girls in this study. It is also possible that the finding of no gender differences arises as a consequence of all players, as members of an elite training squad, sharing a common (or similar) training and coaching program conducted by the State coach.

As such, the study’s findings suggest that elite junior players possessed an acute awareness of the importance of mental skills and attributes for success. While this awareness of the importance of mental factors did not differ significantly from players’ perceptions of the importance of physical factors, a set of five
key mental skills and attributes were strongly endorsed and match losses were, in the main, attributed to mental factors. The importance attributed to mental skills by elite junior players was further strengthened in the reporting by all players of a set period of time devoted to mentally preparing for important matches. As such, this study’s findings are consistent with, and lend support to, findings from studies on adult athletes and coaches’ perceptions of the importance of mental skills and a mental skills profile linked with successful performance.

The implications of this study suggest it would be appropriate, and responsible, for coaches (qualified/trained in sport psychology) to integrate mental skill training into elite juniors’ normal training schedules. Mental skills training need not be deferred to post-junior or open coaching programs but could be introduced at an earlier stage of development for aspiring players. The juniors in this study (who received no formal mental skills training in the State coaching program) clearly demonstrated an awareness of the importance of mental factors and skills and had already adopted a key guideline of such a mental skills training program in setting aside specific time to mentally prepare for matches.

Several factors limit the validity of this study’s findings including the small sample size (albeit ‘an information rich’ group of participants) and a restricted number of questions adopted in the questionnaire. This study’s findings suggest much could be gained in adopting a qualitative approach in future research to further explore elite junior players’ perceptions on what it takes to be a champion and what suggestions they would offer for aspiring players to adopt to achieve excellence and enjoyment in competing.

As an exploratory investigation of elite juniors’ perception of mental skills, this study starts to address Gould et al. call for more knowledge about mental skills in junior tennis. If this were a tennis match, it would be appropriate for the umpire to now call the score at ‘advantage researcher’, being a time ripe for a fuller understanding of those elements underpinning success in junior tennis.

References

Dr Janet A Young, B.Com., BA (Hons), PhD, MAPS, is a lecturer in the School of Human Movement, Recreation and Performance at Victoria University and also conducts a sport psychology practice based in Melbourne, Australia. Her research interests include optimal performance and experiential states, talent development, mental toughness and retirement from sport.

Dr Young has had a long involvement in tennis both at a National and International level in roles including Head of Women’s Tennis at Tennis Australia, Tour Director for the Women’s Tennis Association, Australian Fed Cup Manager, Tournament Director of the Richard Laton Properties Canberra Women’s Classic and member of the ITF Women’s Pro Circuit Committee. As a former Australian representative, Dr Young was a member of two winning Fed Cup Teams. Tennis Australia and the International Hall of Fame recently honoured Dr Young for her contributions to Australian Tennis.

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Dr Janet Young, Sport, Recreation and Fitness, School of Sport and Science, Victoria University, PO Box 14428, Melbourne Vic 8001, Australia.
Meet the expert: Dr. Gary Windler

Dr. Gary Windler is an orthopaedic surgeon specializing in sports medicine in Charleston, South Carolina. Dr. Windler is a member of the ATP Medical Services Committee, and has served as a tournament physician for ATP and WTA tournaments. He is a team physician for professional soccer, ice hockey, and baseball teams in Charleston as well as Charleston Southern University.

I wanted to pursue a career in sports medicine. The fellowship in Long Beach prepared me most for developing my sports medicine practice. However, Dr. Jackson was a wonderful mentor who taught me much more than just orthopaedic sports medicine. The year I spent in Oxford provided a tremendous cultural experience – my wife Rhicky and I lived with orthopaedic fellows and their families from nine different countries. I gained an awareness of the similarities and differences in how medicine is practised in countries outside of the United States.

4. When did you first get involved in ‘tennis medicine’?

I attended a STMS meeting in Ponte Vedra Beach, Florida in the mid 90s. That is when I realised there were many talented people who shared an interest in tennis medicine and science.

5. You were an ATP Traveling Sports Medicine Fellow in 2000. How did that happen and what have you learned from it?

I was extremely fortunate to have been given the opportunity by Dr. David Altchek and Dr. Per Renström to step into that position. Most of the six months was spent travelling to tournaments in the U.S. and Europe as a representative of the ATP Medical Services. That experience helped me to better understand what the players go through on a physical and emotional level being on tour week in and week out for 11 months of the year. It also provided a unique insight into the challenges of providing medical care to professional tennis players on tour.

6. You have been a member of the ATP Medical Services Committee since 2000 and are currently one of the ATP Medical Directors. What is your main task?

1. What are your favourite sports and how did you become interested in tennis?

I played American football, basketball and lacrosse in high school and went on to play college lacrosse. I really didn’t play any tennis until college when I began playing recreationally. I’ve been hooked on it ever since. As I get older, and unfortunately a step slower, it’s still exciting to me to learn how to hit a new shot that I couldn’t hit before.

2. Why did you decide to pursue a career in orthopaedic surgery?

When we were going through our clinical rotations in medical school, I found that I related best to the orthopaedic residents. Also, since I was always involved in sports, orthopaedics seemed like a natural fit for me.

3. You did a fellowship in Knee and Sports Medicine under the direction of Dr. Douglas W. Jackson in Long Beach, California, and a second orthopaedic clinical and research fellowship at the Nuffield and John Radcliffe Hospitals in Oxford, England. Why did you do these fellowships and what did you learn from it?

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6. You have been a member of the ATP Medical Services Committee since 2000 and are currently one of the ATP Medical Directors. What is your main task?
The ATP Medical Services Committee is responsible for coordinating all aspects of player medical care at ATP tournaments around the world. This can be somewhat of a daunting task. Unlike taking care of a sports “team”, the professional tennis “tour” functions more like a travelling circus. We have players from many different countries with a variety of injuries and illnesses to contend with. Fortunately, over the years, we have been able to put together a very talented group of ATP Sports Medicine Trainers and Tournament Physicians to take on the responsibility of providing medical care at these events.

7. You have done many ‘physicals’ on ATP players with Todd Ellenbecker. What is the purpose of these physicals and what have you learned from them?

Todd and I started doing musculoskeletal screenings on the players during the 2006 season. The primary aim of these screenings is to identify muscle weakness, joint and muscle inflexibilities and muscle imbalances that may contribute to an increased risk of injury. By providing players with an individualised exercise programme to address any deficiencies that are found, we hope to be able to reduce the number and severity of injuries and perhaps improve performance as well.

8. In which areas of tennis medicine is further research needed?

Unfortunately, injury prevention is an area that is poorly understood in tennis and sports medicine in general. We hope that the musculoskeletal screenings we are doing will help us develop a profile of what a healthy professional tennis player looks like. By implementing more refined screening methods, I believe that better strategies for injury prevention can become a reality.

9. Every two years, the ATP organizes a Tournament Physician Conference for all the doctors working at ATP Tournament. What are the goals of these meetings and are those goals accomplished?

The ATP, through its support of the Tournament Physician’s Conference, provides the opportunity for the many dedicated people involved in providing medical care at ATP and Grand Slam tournaments to come together. The goals of the conference are to discuss tournament medical issues, present some of the latest information in tennis medicine and science, and promote collegiality and a sense of team building among the ATP Tournament Physicians. We have been very pleased with the feedback we have received from participants and so I think that our goals are being achieved.

10. You are currently involved in a joint project between the ATP and WTA in the development of a comprehensive medical documentation system. How do you envision this new system impacting the ATP and WTA players?

This collaborative project has been in the works for a couple of years now. It has proved to be quite an undertaking. Once implemented, it will improve communication among the ATP Sports Medicine Therapists, WTA Primary Health Care Providers and Tournament Physicians. They will have access to a more complete medical record. This will help to improve the care that the players receive at tournaments around the world. In addition, the system will ultimately enhance our ability to collect and analyse meaningful injury data.
What is the best serving strategy?

Abstract

A player can get a high percentage of first serves into court by taking a low risk on first service, or can get a lower percentage of first serves into court (with a higher probability of winning the resultant point if the serve goes into court) by taking a higher risk on service. This characteristic also applies to second serves.

In this paper the relationship between the risks taken (on first and second serves) and the probability of winning the point is considered.

Using Wimbledon Championships Men's Singles data, it is shown that the relationship between the risk taken on a serve and the probability of winning that point (if the serve goes into court), is typically not a linear one. It appears that for most players quadratic relationships are needed to model this type of data. Finally, some practical suggestions are made as to where the server might best focus his/her attention on how to increase the probability of winning a point on service.

Introduction

The problem outlined in this paper has been considered by several authors. Gale\(^1\) described a graphical method for identifying the best first serve and the best second serve from a set of serves. Redington\(^2\) concluded that in the 1971 Wimbledon final, John Newcombe would have done slightly better if he had repeated his first serve instead of using a softer second serve, and that his optimal second serve would have been somewhere between the two serves he used. George\(^3\) considered a typical player with a 'strong' and a 'weak' serve, and, under very general assumptions he identified the circumstances in which the 'strong followed by strong' and the 'weak followed by weak' service strategies are better than the usual 'strong-weak' strategy. He also showed that, given his assumptions, the 'weak-strong' option is always suboptimal. His limited data set for men’s singles supported the common practice that the 'strong-weak' option is typically best, and it indicated that the 'weak-weak' option is worst. King and Baker\(^4\) carried out the same analysis as George for a larger data set of women’s singles. For one player in their data set, the 'weak-weak' strategy was preferable, whilst for another the 'strong-strong' strategy was best, but for the remaining ten players in the analysis it appeared that the 'strong-weak' strategy was best. A rather similar approach to the above 'two-service (strong/weak) problem' was given by Hannah\(^5\) who also proposed a (rather impractical) game theory ap-

Keywords: Query, statistics, quadratic relationship, percentage, probability
proach. More recently, McMahon and de Mestre addressed this ‘two-service’ problem by analyzing 414 women’s and 444 men’s grand slam matches in the year 2000. They concluded that in a surprising number of matches, one or both players would have benefited from a departure from the ‘strong-weak’ strategy. The most common beneficial change for women was to a slow-safe strategy, and for men it was to a fast-fast strategy (in spite of the additional double faults).

It is clear that the server in tennis is faced with challenging decisions. On the first serve for example the server can serve a relatively safe serve which has a high probability of going into court, but the receiver is quite likely to be able to receive such a serve satisfactorily. Alternatively, the server can elect to play a faster serve aimed closer to the corners of the service area, with a higher probability of winning the point if the serve goes into court.

However, such a serve is more likely to be a fault. There is clearly a ‘balance’ between taking too small a risk and taking too large a risk on the first serve. There is also such a ‘balance’ on the second serve, although the penalty for not getting the second serve into the service court, with a higher probability of winning the point if the serve goes into court.

Thus, the server takes maximum risk (x=10), he/she serves a very ‘safe’ and slowish service often with spin and not directed to a corner of the service court, and it has a very high (assumed 1) probability of going into the service court.

They assumed that the probability the server wins the point given the service goes into the service court, increases as the level of risk, x, increases, and that this relationship was linear, and given by $P(w/i and x) = a + bx$.

where a + bx was assumed to take values between 0 and 1 (for the relevant values of x), a > 0 and b > 0.

Firstly analyzing the second service, they noted that the probability the server wins the point given a second serve with risk x2 was used, is given by $P_2(x_2) = (1 - 0.1x_2)(a + bx_2)$.

and that the associated optimal value of x2, x2*, is given by

$$x_2^* = \begin{cases} \frac{5 - 0.5r}{r} & \text{if } r \leq 10 \\ 0 & \text{if } r > 10 \end{cases}$$

where $r = a/b$. The probability that the server wins the point given a first service with risk x1 is used and a second service with risk x2 used (if required), is given by

$P_1(x_1, x_2) = (1 - 0.1x_1)(a + bx_1)(0.1x_1)(1 + 0.1x_2)$.

and the associated optimal value of x1, x1*, is given by

$$x_1^* = \begin{cases} 6.25 - 0.25r + 0.0125r^2 & \text{if } r \leq 10 \\ 5 & \text{if } r > 10 \end{cases}$$

For example, for a player who wins about 50% of points when x = 0 and the service goes into play, and about 80% of points when x = 6 and the service goes into play, a = 0.5 and b = 0.05. Thus, given a straight line relationship between the risk and the probability of winning the point if the serve goes in, the optimal risk on the first serve is 5 when r is greater or equal to 10 and is slightly greater than 5 when r is less than 10. Thus, the optimal risk on first service can never be less than 5 when the above relationship is linear. The optimal risk on first service can however be less than 5 when the above relationship is quadratic rather than linear.

The average risk taken by the players in the Wimbledon Men’s Singles Championships 1992-1995 on first service was 4.06.8.

The average risk taken by the players in the Wimbledon Men’s Singles Championships 1992-1995 on first service was 4.06.8. Thus, it would appear that for many men or even for most men the optimal risk on first service is less than 5, and a quadratic relationship can be used to model this situation.

Using the quadratic relationship $ax + bx + cx^2$ (rather than the linear one above) for $P(w/i and x)$, it can be shown that the optimal value of x for the second serve is given by

$$x_2^* = \frac{(c - 0.1b + \sqrt{b^2 + 0.1bc + 0.01(b^2 - 3ac) / 0.3c}}{0.3c}$$

if this expression is positive, and zero otherwise. The associated value of P2(x2*) is given by

$$P_2^*(x_2^*) = (1 - 0.1x_2^*)(a + bx_2^* + cx_2^*^2)$.

and the optimal value for the first serve is given by

$$x_1^* = \frac{(c - 0.1b + \sqrt{b^2 + 0.1bc + 0.01(b^2 - 3ac + 3cp_2^*(x_2^*)) / 0.3c}}{0.3c}$$

if this expression is positive, and zero otherwise.

The probability, $P$, that the server wins a point is given by

$$P = P_2P(w/i) + (1 - P_2)P_1P(w/i).$$
where $P_1$ is the probability that the first service is not a fault (i.e. is ‘in court’), $P_w$ is the probability that the server wins the point given the first serve is in court, $P_2$ is the probability that the second service is not a fault, and $P_{w2}$ is the probability that the server wins the point given the second service is not a fault. For the data on the 1992-1995 Wimbledon singles in the paper by Magnus and Klaassen, these probabilities have estimates of 0.594, 0.733, 0.864 and 0.594 respectively for men, and 0.608, 0.622, 0.860 and 0.541 respectively for women. For these men’s singles statistics the estimated probability of winning the point on the first serve is 0.733 when the estimated risk taken is $10^{4}(1-0.594) = 4.06$, and the estimated probability of winning the point on the second serve is 0.594 when the estimated risk taken is $10^{4}(1-0.864) = 1.36$. The overall probability of winning a point is 0.644. Norton and Clarke added service data from men’s and women’s singles at Wimbledon 2001, the French Open 2001, the Australian Open 2000-2002 plus doubles data from Australian Open 2001 to the 1992-1995 Wimbledon data utilized here. They noted the expected slight differences in service statistics between the three tournaments (surfaces).

We consider now an ‘average’ professional male tennis player with the above average statistical characteristics. Further, we assume that these five statistics (0.594, 0.733, 0.864, 0.594 and 0.644) are not far from their ‘optimal’ values for this ‘average’ player. This would appear to be a reasonable assumption as it seems unlikely that for such an ‘average’ professional player, any one of the statistics is a long way from optimal for him. The fact that the risk taken on first service is substantially less than 5 indicates that the above linear model is inappropriate, and that a quadratic one could be appropriate. Thus, fitting the above quadratic model, the estimates of $a$, $b$ and $c$ for professional male players are (to 3 significant figures) $0.491$, $0.0837$ and $-0.00591$ respectively. This fitted quadratic relationship is shown in figure 1. For professional female players, the corresponding estimates for $a$, $b$ and $c$ are (to 3 significant figures) $0.479$, $0.0487$ and $-0.00310$ respectively. In the remainder of this paper, for simplicity, the discussion is presented in terms of the data for male professional players. However, all of that discussion is directly relevant to female professional players as well.
We secondly consider increasing player improving (just) his second serve by increasing the probability of winning the point if the serve goes in. A quadratic expression, however, has been used above successfully. This conclusion is not to say that a (possibly small) percentage of players does in fact have a linear relationship rather than a quadratic one. Each player could experiment with his serve with the view to identifying the nature (linear or quadratic) of their own particular risk/winning relationship. Given the quality and sample size of the above Wimbledon data however, it would seem reasonable to believe that the relationship is a quadratic one for the majority of players.

As can be seen from the previous equation, there are four options for doing this. Increase $P_{1i}$, $P(w_{1i})$, $P_{2i}$ and/or $P(w_{2i})$. One or two of these options may be preferable to the others. To look at this, we consider the ‘average’ professional considered above.

We consider firstly, and simply as an example, the above ‘average’ player by increasing (just) his second serve by increasing $P_{2i}$ from 0.864 to (say) 1.0, whilst leaving the other three probability values unchanged. If this player can increase $P_{2i}$ from 0.864 to 1.0, whilst leaving the other three probabilities unchanged, his overall probability of winning the point increases from 0.644 to 0.677. The curve $C_2$ in figure 2 is a curve with various ($P_{2i}$, $P(w_{2i})$) values such that the player’s overall probability of winning the point remains constant at the original 0.644, whilst leaving $P_{1i}$ and $P(w_{1i})$ unchanged at 0.594 and 0.733 respectively. For comparative purposes, the curve $C_1$ in figure 2 is the curve of various ($P_{1i}$, $P(w_{1i})$) values such that the player’s overall probability of winning the point remains constant at the original 0.644, whilst leaving $P_{2i}$ and $P(w_{2i})$ unchanged at 0.864 and 0.594 respectively. Thus, it can be seen that the above player can lift his probability of winning a point from 0.644 to 0.677 by lifting $P_{1i}$ by 0.149 from 0.594 to 0.743, or by lifting $P_{2i}$ by 0.136 from 0.864 to 1.0, or by lifting $P(w_{2i})$ by 0.094 from 0.594 to 0.688, or by lifting $P(w_{1i})$ by 0.055 from 0.733 to 0.788. Thus, the above player with ‘average’ characteristics gets the greatest return by increasing $P_{1i}$ by (say) one percentage point, then the next biggest return by increasing $P(w_{2i})$ by (say) one percentage point, then the next biggest by increasing $P_{2i}$ by (say) one percentage point, and finally the smallest by increasing $P_{1i}$ by (say) one percentage point. Of course, it may be more difficult to increase $P_{1i}$ by one percentage point than to increase (say) $P_{2i}$ by the same amount, but it can still be useful to know the relative sizes of the various benefits achieved by such improvements in play. Thus, for the above player, increasing $P_{1i}$ by one percentage point has a benefit approximately 2.7 times greater than the benefit obtained by increasing $P_{2i}$ by the same amount (note $0.149/0.0.055 = 2.7$ approximately). Also, if the above player increased $P(w_{1i})$ by one percentage point and decreased $P_{1i}$ by one percentage point, his overall increase in the probability of winning the point would be about 1.65 (a little less than 1.7 due to a negative interaction between the two actions) times the increase he would have achieved by increasing just $P_{1i}$ by one percentage point. (Note that these factors of 2.7 and 1.65, and the general nature of the conclusion here, are not sensitive to the assumption that this player is an ‘average’ player rather than any player at all.) In practice this ‘average’ player would probably try to increase more than just one of these probabilities at a time, and in doing so try to move from a curve such as $C_1$ to one such as $C_2$ for the second serve, and/or from one such as $C_3$ to one such as $C_4$ for the first serve. The graphs in Figure 2 indicate that, for the ‘average’ professional player, there...
would appear to be greater scope for increasing the probability of winning a point by focusing (initially at least) on improving the first serve outcome (i.e. \( P(w_1/i) \), and possibly \( P(i/x) \), simultaneously) rather than on improving the second serve outcome. One aspect of there being greater scope on the first serve is that there is a greater (probability serve goes in) range for possible improvements in the first serve than there is for improvements in the second serve. Another aspect (as noted above) is that there is a greater overall return on the first serve (the curves C3 and C4 are closer together than are the curves C1 and C2 in figure 2).

Discussion
It would appear that for many or most professional men tennis players the relationship between the probability of winning the point and the risk taken on the serve is a quadratic one, and that it is best to serve more than 50% of first serves into court. For some players the relationship might be linear in the range (say) \( x = 3.5 \) to \( x = 5.5 \), in which case it can be optimal to serve only about 50% of serves into play. Thus, a player should acquire at least an approximate understanding of his/her own \( P(i/x) \) and \( P(w_1/i \text{ and } x) \) relationships, particularly in the domain of \( x \) near 4 and 5 for the first service, and correspondingly in the domain of \( x \) near 0 and 1 for the second service. This might be achievable over time by keeping some match statistics (even some match experimentation), as well as doing some service experiments on a practice court (possibly against an opponent).

For a player with an underlying quadratic relationship, it can be seen that the slope of this quadratic relationship near \( x = 5 \) is important/critical for the first serve, and the slope near \( x = 0 \) and \( x = 1 \) is important/critical for the second serve. As this slope near \( x = 5 \) decreases, \( x_1^* \) decreases, implying that the server should aim to get nearer 60% or even a higher percentage of first serves into play. Correspondingly, as the slope near \( x = 0.5 \) increases, it can be optimal to serve a higher percentage of double faults.

Conclusions
Data from the Wimbledon Men’s singles 1992-1995 Championships indicates that for many men the relationship between the probability of winning the point (if the serve goes in) and the risk taken on that serve is a quadratic one rather than a linear one. This is important as it indicates that for such players it is typically optimal to serve greater than 50% of first serves into play, and to serve a reasonably strong second serve even if it results in (say) 0-15% double faults. This is not to say that the relationship is not linear for some men, and if the relationship is linear for a player, it is optimal for that player to serve only 50% or even slightly less a percentage of first services into play.

In order to serve (close to) optimally it is useful for a player to know (at least approximately) the shape of the above relationship for his/her own services. Through experimentation and data collection this should be possible for a player.

In order to improve the probability of winning a point on service, it would appear that the server might focus firstly on improving his/her first serve outcome rather than his/her second serve outcome. In particular, he/she might focus attention on increasing the probability of winning the point when the first serve goes in, rather than on increasing the probability of the first serve going in.

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About the author
Geoff Pollard is the President of Tennis Australia, Vice President of the ITF and Chairman of the Technical Commission and Rules of Tennis Committee of the ITF. Prior to being elected President of Tennis Australia in 1989, he was Senior Lecturer in Statistics, Demography and Actuarial Studies at Macquarie University, Sydney. He is now undertaking a PhD at Swinburne University of Technology, Melbourne.

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Core stability is increasing in popularity as a conditioning tool for athletes. The relevance of trunk muscles for optimal performance in tennis has been well established. Dr. Ben Kübler (Past-President of the STMS) has stated that ‘core stability is the ability to control the position and motion of the trunk over the pelvis and leg to allow optimum production, transfer and control of force and motion to the terminal limbs in integrated kinetic chain activities.’

Carl Petersen and Nina Nittinger have launched a series of Fit to Play™ & Perform DVDs which demonstrates innovative and practical exercises for core stability training.

The first DVD Core Stability 1 focuses on “Basework & bridging” providing versatile exercises to enhance training of the core in three dimensions (3D) and multiple planes of movement. It delivers a variety of exercises in lying, supine, prone, quadruped and seated bridge positions. The authors show expert utilisation of balance equipment, elastic resistance and ‘physio-balls’.

The second DVD Core Stability 2, “Lower core & leg training”, shows how to improve 3D core stability by connecting the lower core and legs with functional exercises that work the muscle slings in closed and partially closed kinetic chain movements. The extended hip position for squatting as well as optimal recruitment, balance, timing and deceleration control are also emphasized.

The third DVD Core Stability 3, “Upper core & arm training”, is of particular importance for tennis players given the high demands that their strokes place on the dominant upper limb. The authors present multiple exercises for scapular stabilisation, and deceleration of posterior shoulder muscles using practical and portable equipment.

All the DVDs have an introductory “warm-up” and finish with a “cool-down” section. They also include information that the authors have edited from a video on “Agility, balance and coordination drills.” In my opinion these DVDs are of great value to doctors, therapists and coaches in their efforts to optimise athletic function and reduce injury in tennis players.

I would like to congratulate Carl and Nina for their original and practical contribution to Tennis Science!

Javier Maquirriain, MD, PhD
Welcome to Japan!
On the occasion of Japan being host to the 10th World Congress of the Society for Tennis Medicine and Science and on behalf of the Japan Tennis Association, I would like to extend a sincere welcome to everyone.

Tennis is one of the most popular sports in Japan. Even the Emperor and Empress have enjoyed playing tennis since the days of their youth. Tennis in Japan has a long history, and already over 100 years have passed since Japan started participating in international tournaments, attaining many achievements during this time. Recently, though, it seems Japan has been left behind by Europe, the US, and other countries. The Japan Tennis Association is doing all it can to improve our players, and I think everyone is well aware of the great efforts that our young players have made at international tournaments since the start of the New Year. Moreover, the Japanese National Training Center was completed this January. Now I think we will have further opportunities to strengthen our players and popularize tennis.

In improving players and preventing injuries, medical and scientific support is crucial. So this is an opportune time for the 10th World Congress of the Society for Tennis Medicine and Science to be held in Tokyo. The Japan Tennis Association offers its warmest appreciation for those participating in this congress, which is being held in Asia for the first time.

Autumn in Japan is a truly beautiful and breathtaking season. I hope that along with the meetings and the AIG Japan Open, you will have a chance to experience some of the beauty of Japan and the depth of its traditional culture.

I look forward to your participation.

Masaaki Morita, President, Japan Tennis Association

The Organizing Committee for the 10th World Congress of STMS
Congress Organizer: Moroe Beppu
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Secretary-General: Takayuki Sukegawa, Shoji Ishii
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Key information
Deadline for abstract submission: June 30, 2008
Abstract notification information: July 31, 2008
Deadline for hotel accommodation: August 31, 2008
Deadline for early registration: August 31, 2008

Scientific program
Friday, October 3
Morning
Instructional lecture
Symposium: injuries of the wrist
Symposium: Injuries of the elbow
Workshop: ultrasonography of the elbow
Workshop: ultrasonography of the shoulder

Afternoon
Symposium: injury prevention
Symposium: injuries of the shoulder
Symposium: medical care
Symposium: strengthening and conditioning for tennis
Symposium: wheelchair tennis
Debate

Saturday, October 4
Morning
Instructional lecture
Symposium: injuries of the knee
Symposium: Injuries of the foot and ankle
Workshop: arthroscopy of the elbow
Workshop: arthroscopy of the shoulder
Debate

Tennis playing, followed by welcome reception
Date: 6.00-8.00 pm, Thursday October 2
Venue: Takanawa tennis center
Price: included in registration fee

Gala dinner
Date: Friday evening, October 3
Venue: Sheraton Miyako Hotel Tokyo
Price: 10,000 Yen/12,000 Yen
* Gala dinner is limited to 100 persons by order of application

AIG Japan Open Tennis
Date: Saturday afternoon, October 4
Venue: Ariake Colosseum
Price: included in registration fee
* Tickets are limited to 100 persons

Hotel Accommodations
JTB Global Marketing and Travel Inc. (JTB GMT) has reserved rooms at the following hotels for Congress participants at special discount rates. Those persons who wish to apply for hotel reservation are requested to complete the application form no later than September 5th, 2008 by Online. Hotel assignment will be made on a first-come, first-served basis.

Sheraton Miyako Hotel Tokyo – Adjacent to the venue
Grand Prince Hotel Takanawa – 10 min by taxi
Hotel Princess Garden - 5 min. by free shuttle bus from Meguro Station

Chair
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Congress Organizer
Chairman & Professor
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