THEORY INTO PRACTICE: THE KEY TO ACCEPTANCE OF SPORT BIOMECHANICS

Bruce Elliott
School of Sport Science, Exercise and Health
The University of Western Australia, Perth, Western Australia, Australia

‘A legacy of a scientific approach to coaching excellence, with a particular love and talent for badminton coaching’

Acceptance by administrators, coaches and players alike requires sport science research to be valid, repeatable and to meet the perceived needs of the specific sport. David Waddell certainly worked towards these goals in badminton. In this paper I will provide a three stage approach (flow from basic to applied research followed then by research dissemination) that has been shown to be successful in tennis and cricket. Basic research is essential to establish testing and data analysis protocols that are valid, repeatable and answer questions of interest. Applied research then needs to be of sufficient depth to make a difference to coaching philosophy. Applied findings must then be interpreted for coaches in a meaningful manner. In this paper I will focus on the tennis serve to show the depth of understanding required to ‘make a difference’. Finally a brief discussion will be included on areas of current research, within the framework of this topic.

KEY WORDS: Tennis, racket sports, applied biomechanics

INTRODUCTION: In thinking about how to present a tribute to David Waddell, it may have seemed logical to review biomechanics research related to badminton. However, to be accepted by coaches, players and administrators requires a greater ‘body of knowledge’ than is currently available in badminton. For that reason I will focus this paper on the biomechanics of the tennis serve (Figure 1), so that young scientists can see, at least in my opinion, the research process that needs to be followed to ‘make a difference’. This needs to happen in much the same way as clinical biomechanics has influenced so many aspects of medical and para-medical practice.

Figure 1: High performance tennis service action

THE START POINT - BASIC RESEARCH

The following three basic research examples, while not exhaustive with reference to the racket sport literature, have in different ways enabled applied studies to be designed and conducted with far greater surety than would have been possible without their input.

- *Impact smoothing*: While racket velocities, pre- and post-impact, have been a problem for many decades, Knudson and Bahamonde (2001) brought this issue to prominence in tennis research. The question that needs to be addressed is; ‘do you need to use a different ‘data filtering’ approach for situations where the oncoming ball has a large amount of momentum (forehand as studied by Knudson and Bahamonde, 2001), compared with the situation where the ball has minimal momentum (tennis serve).

The question is even more important in kicking studies where you have much longer contact periods between the ball and the swinging limb (~5 ms in tennis compared with ~15 ms in kicking). Currently linear and polynomial extrapolation conditions have been shown to produce accurate angular position and velocity estimates for tennis impacts.

- *Segment contributions to velocity generation*: A number of 2D papers have reported percentage contributions to pre-impact racket velocity (in the sagittal plane). I know I always wondered when one followed this procedure, why the wrist flexion was so dominant with reference to percentage contribution to service velocity. Sprigings et al. (1994), published an algorithm that addressed the percentage contribution of various segment movements to final racket velocity (including long axis rotation, such as shoulder internal rotation) This enabled Elliott et al. (1995) to apply this procedure to the service action of high performance players, and it all became clear - shoulder internal rotation occurred late in the swing to impact, at a similar time to wrist flexion (it did not follow the kinetic or kinematic chain). This movement rotation was also identified as a key factor in the development of racket speed.

- *Role of muscle pre-contraction in enhancing performance*: While papers by Walshe et al. (1998) go a long way to explaining the contributions of muscle-pre-stretch, athletes are typically only concerned with ‘end results’. For that reason many sport scientists have combined the influences of muscle pre-stretch and elastic energy storage under the title ‘contributions to performance following a pre-stretch’. While this is not theoretically correct it certainly permits athletes to focus on the influence of technique on performance outcome. This was the approach we took when investigating the role of ‘pause’ between back swing (external rotation at the shoulder) and forwardswing (internal rotation at the shoulder) phases of the tennis serve (Elliott et al., 1999)

THE NEXT STEP - APPLIED RESEARCH

The applied research studies reviewed represent a spectrum of research into different aspects of service technique.

- *Lower limb drive and trunk rotations:* Initial work on the forces with the court produced by different serving techniques (Elliott and Wood, 1983), when linked with a paper on trunk angular momentum during the high performance serve (Bahamonde, 2000) provide a clear theoretical construct for understanding and therefore teaching the ‘undercarriage’ for an effective serve. More recent work (Sweeney et al., in review) has taken this research further by demonstrating the importance of ‘back-hip’ elevation in this process.

- Velocity generation
    a. Upper limb movements: Research has clearly shown the importance of shoulder internal rotation and wrist flexion to the generation of racket speed in the service action (Elliott et al., 1995). Suddenly coaching and physical preparation of athletes could be structured to create optimal conditions to produce high levels of shoulder internal rotation.

b. Impact locations: Very practical research by Chow and colleagues (2003) at the Atlanta Olympics provided ball impact locations for professional players under tournament conditions. Impact for both male and female players was marginally to the left of the front toe for the power serve as shown in Figure 2. This information then linked the research on leg drive, hip and trunk rotations with impact location. This position also produced an almost ideal situation for shoulder internal rotation to play its role in the service action. The miss-alignment of the racket and the forearm (observe this angle in Figure 2) further demonstrates the ability to internally rotate at the shoulder, such that the racket is assisted in its forward movement through impact.

Figure 2: High performance tennis service action at impact

THE FINAL STEP - DISSEMINATION AND APPLICATION OF RESEARCH FINDINGS

This can obviously take a number of different approaches. In the early days (less academic pressure) I tried to write practical articles to complement papers published in the research literature. A typical flow of these papers is listed below.

- A 3-D kinematic method for determining the effectiveness of arm segment rotations in producing racquet-head speed. Journal of Biomechanics, 27(3): 245-254, 1994.

⇩

- Contributions of upper limb segment rotations during the power serve in tennis, Journal of Applied Biomechanics. 11 (4): 433-442, 1995.

⇩

- The super servers: Pete Sampras and Goran Ivanisevic. Australian Tennis, June: 46-47, 1996

While this is a far more difficult task in today's academic climate that demands research grants and high quality publications, it is important that we do not lose sight of the need to impart knowledge. Books, applied articles and presentations at Sport Specific Conferences all go a long way to enhancing your profile in the world of sport biomechanics. Where possible complement your research papers with review articles such as: *'Biomechanics of the serve in tennis. A biomechanical perspective. Sports Medicine, 6: 285-294, 1998',* and books '*Biomechanics of Advanced Tennis. International Tennis Federation Press, London, 2003'* that permit you to disseminate your research findings to an even larger population (this book was also published into Spanish and French).

CURRENT RESEARCH

Our current work is similarly based around both basic and applied approaches.

- Basic Science - *3D modelling of the shoulder joint*: More recent work on the modelling process has attempted to better define the shoulder joint - the centre of rotation - to improve reporting upper limb angles during fast rotations, as in the tennis serve. An in-vivo approach using an MRI to establish the glenohumeral joint centre compared a number of commonly used protocols along with a new regression approach (Campbell et al. a, in press). This regression, combining: 3D distance between the *Clavicle, C7* an *Acromion lateral ridge* markers and *the virtual location* between C7 and the sternal notch, subject *height and mass*, was shown to better calculate the 'centre of rotation' during dynamic movements than previously established methods (Meskers et al., 1998). This work further elucidated that a single centre of rotation can be assumed to occur throughout large ranging, high velocity upper limb movements, such as the tennis serve (Cambell et al., b, in press).

- Applied science - Development sequences in stroke production with a particular interest in differences between male and female players are also a current interest. When does service power become influenced by shoulder internal rotation and do contributions to racket velocity follow a linear increase with chronological age?

CONCLUDING REMARKS: When talking with young clinical biomechanists my advice is always to develop a research theme and build a research reputation in that area. You may take a neuromuscular approach; to working with various populations (e.g. cerebral palsy or children), or with specific areas of the body (e.g. the shoulder). In sport biomechanics the temptation has always been, at least for me, to allow my focus to become a little blurred. However, I have always tried to retain a focus on tennis and cricket research, either from a technique development or from an injury reduction perspective. You need a team to achieve the goals I have promoted in this paper, so do not be afraid to collaborate with your colleagues - I would encourage you to do so. I openly acknowledge the tremendous role that fellow colleagues and graduate students have played in my research endeavours.

REFERENCES:

Bahamonde, R. (2000). Changes in angular momentum during the tennis serve. Journal of Sports Sciences, 18: 579-592.

Campbell, A., Lloyd, D., Alderson, J., Elliott, B. (in press - a) MRI development and validation of a two new predictive methods of glenohumeral joint centre location identification and comparison with established techniques. Journal of Biomechanics.

Campbell, A., Lloyd, D., Alderson, J. & Elliott, B. (in press - b). Effects of different technical coordinate system definitions on the three dimensional representation of the glenohumeral joint centre. Medical and Biological Engineering and Computing**.**

Chow, J., Carlton, L., Lim, Y., Chae, W., Shim, J., Kuenster, A & Kokubun, K. (2003). Comparing the pre- and post-impact ball and racquet kinematics of elite tennis players' first and second serves: A preliminary study. Journal of Sports Sciences, 21: 529-537.

Elliott, B. (1996). The super severs: Pete Sampras and Goran Ivanisevic. Australian Tennis, June: 46-47.

Elliott, B. (1998). Biomechanics of the tennis serve: A biomechanical perspective. Sports Medicine, 6: 285-294.

Elliott, B. & Wood, G. (1983). The biomechanics of the foot-up and foot-back tennis service techniques. Australian Journal of Sports Sciences, 3:3-6.

Elliott, B., Marshall, R. & Noffal, G. (1995). Contributions of upper limb segment rotations during the power serve in tennis. Journal of Applied Biomechanics, 11: 433-442.

Elliott, B., Baxter, K. & Besier, T. (1999). Internal rotation of upper-arm segment during a stretch-shorten cycle movement. Journal of Applied Biomechanics, 15: 381-395.

Elliott, B., Reid, M. & Crespo, M. (Eds) Biomechanics of Advanced Tennis. International Tennis Federation Press, London, 2003. Knudson, D. & Bahamonde, R. (2001). Effect of endpoint conditions on position and velocity near impact in tennis. Journal of Sports Sciences, 19: 839-844.

Meskers, C. G., van der Helm, F. C., Rozendaal, L. A. and Rozing, P. M., 1998. In vivo estimation of the glenohumeral joint rotation center from scapular bony landmarks by linear regression. Journal of Biomechanics 31(1), 93-96.

Sprigings, E., Marshall, R., Elliott, B. & Jennings, L. (1994). A 3-D kinematic method for determining the effectiveness of arm segment rotations in producing racquet-head speed. Journal of Biomechanics, 27: 245-254, 1994.

Sweeney, M., Reid, M., Alderson, & Elliott, B. (submitted). Lower limb and trunk function in the high performance tennis serve. Journal of Sports Sciences.

Walshe, A. Wison, G. & Ettema, G. (1998). Stretch-shorten cycle compared with isometric preload: Contributors to enhanced muscular performance. Journal of Applied Physiology, 18: 97-106.