Biomechanics of the Serve in Tennis
A Biomedical Perspective

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Summary

Epidemiological studies have indicated that the serve, arguably the most important facet of the game of tennis, is also the most likely stroke to cause injury, particularly to the elbow and back. A review of the kinematic and kinetic studies on the service action fails to clearly identify the reason(s) for these injuries. Data from these studies does, however, allow possible causes of injury to be postulated. Electromyographic data from the prime mover muscles involved in the serve have shown that muscle action was greater for beginners, whose muscles were active for longer periods than those of advanced players. Ground reaction forces associated with different serving techniques were small compared to those recorded from activities involving running or jumping. The potential to cause injury seems to be related to high internal forces (combination of muscle and joint reaction forces), particularly where these forces are associated with poor technique and high segment accelerations. These situations occur when the racket moves behind the body and the vertebral column is laterally flexed and hyperextended. The pronation of the forearm and the forces associated with the swing to the ball, the impact and the early follow through are also factors that have the potential to cause injury. The action of serving induces strains and pressures upon the body. A sensible approach to the number of serves, particularly when practising (overuse), appropriate physical preparation and a technique that does not introduce excessive forces to selected body parts (misuse) will greatly reduce the potential for injury from this activity.

Tennis is a game enjoyed by players of all standards and ages. While it is imperative to master a number of strokes to be successful at any level, the serve is arguably the most important facet of the game. As the serve is controlled by the player (closed skill) it should be relatively easy to master. However, the complex movements requiring both the upper and lower limbs to coordinate to pro-
duce a fluent serving action create many problems of technique, some of which may have the potential to cause injury.

It is reasonable to hypothesise that back pain (an injury reported by tennis players) is discogenic and has a mechanical cause (Schultz et al. 1979). While the aetiology of most lower back pain is unknown, it is accepted that mechanical stress can aggravate this pain (Voloshin & Wosk 1982). These researchers further highlighted the seriousness of lower back injuries when they showed that the attenuation of ground reaction forces of healthy subjects or subjects with knee injuries was 20% higher than for those subjects suffering from low back pain. A study of 2481 tennis players over 3 years by Nigg and Denoth (1980) reported that 52.6% of all players interviewed had experienced an injury, while 17.7% of this sample had injuries to the back, which may possibly be attributed to the service action.

Epidemiological studies certainly indicate that other injuries also occur in tennis. Priest et al. (1980a,b) reported that 31% of a sample of 2633 average players had suffered elbow pain at some time during their careers. Frequency of play had a direct relationship with pain, as the more frequently a person played the greater was the incidence of pain (Carroll 1981; Priest et al. 1980a). Those players with a history of elbow pain, or who currently had pain, had played tennis longer than those without pain (Priest et al. 1980a,b). It was then a natural conclusion that Priest et al. (1980a,b) found a trend for players of higher ability (played longer, practised more) to have a history of elbow pain. 45% of participants in the study by Priest et al. (1980b) identified the serve as being associated with elbow pain, while 25% of players from the same study identified the serve as the most painful tennis stroke. Ryan (1977) reported that 29% of players experiencing elbow pain attributed this pain to overhead strokes, particularly the serve. Allman et al. (1975) further identified the serve as a stroke that may cause elbow injury.

A 4-year study by Fricker and Maguire (1986) at the Australian Institute of Sport reported that of the 176 injuries treated from the tennis group, 104 were to the lower limbs, 34 to the upper limbs and 37 to the trunk. Of these 176 injuries, 109 were intrinsic (e.g. ankle ligament strain), 7 were extrinsic (e.g. falls producing bruising) and 60 were overuse (e.g. stress fractures). It can be surmised from this study that the service action was responsible for only a small percentage of the total injuries sustained by this group of high performance juniors. Epidemiological studies have therefore clearly linked the service action with injuries to the elbow and back (Allman et al. 1975; Carroll 1981; Maguire 1986; Nigg & Denoth 1980; Priest et al. 1980 a,b; Ryan 1977).

The critical variable in the study of the aetiology of pain and injuries is load (Nigg et al. 1986). A schematic description of the factors influencing load in the tennis serve is illustrated in figure 1.

This review paper discusses the biomechanics of the service action in 3 sections in an attempt to identify variables which may be linked to the injuries identified by the epidemiological studies: the research directed at the general kinematics and kinetics of the serve (the external movement), the muscular activity associated with this action (internal movement) and finally a brief review of the influences of selected boundary conditions (anthropometry and racket) in the service action as a potential cause of injury.

1. The Kinematics and Kinetics of the Serve

The primary consideration in serving is rhythm. The coordination of the body segments must occur in a sequence referred to as the 'kinetic chain' (Braden & Bruns 1977; Elliott & Kilderry 1983) so that an optimal racket position, trajectory and velocity are apparent at impact. Interruption to this flow will not only reduce the effectiveness of the serve, but will increase the possibility of injury.

The position of the ball at the peak of the toss is a major factor that may disrupt the rhythm of the serve. Beerman and Sher (1981) used Newtonian mechanics (ignoring the influence of air resistance) to show that a player has 8 times as long to contact the ball when it is thrown to the height of the 'sweet spot' of the racket as when the ball is thrown 1.2m above this point. When the ball is