THE KINETIC CHAIN IN TENNIS

DO YOU PUSH OR PULL?

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DEFINING THE KINETIC CHAIN

The term 'kinetic chain' refers to a particular conceptual framework for understanding the mechanisms by which athletes accomplish the complex tasks required for function in sport. It is a co-ordinated sequencing of activation, mobilisation and stabilisation of body segments to generate and regulate force, produce motion and protect tissues from increased strain during an athletic activity[1].

The kinetic chain sequencing serves three purposes:

1. efficient generation and transfer of kinetic energy and force to the distal segment to move an object[1], accomplished by using the 'summation of speed' principle, in which the velocity and force developed in each segment are facilitated and augmented by the actions of proximal segments, similar to the occurrence of 'cracking a whip',
2. stabilisation and positioning of the body segments and joints to regulate and absorb the developed forces at the joints, accomplished by creating anticipatory postural adjustments that are integrated with the athletic activity pattern to maintain a stable base for activity[2,3],
3. stabilisation of body posture to counteract the eccentric loads and destabilising effects of the athletic movements, accomplished by integrating proximal and distal muscle activation to spread loads over the entire extremity[4], controlling eccentric and tension loads and placing joints in their most stable configuration in either upper or lower extremity[5].

THE KINETIC CHAIN IN THE TENNIS SERVE MOTION

The serve is considered by many to be the most important shot in tennis. It is a frequent activity, it can dictate the conditions under which each point is played and it is the only shot over which the player has control before the ball is hit. The serve has components of velocity, placement and spin, all of which are related to the effective development of an efficient kinetic chain. It should result in optimal placement of the racquet at the maximum velocity and the desired trajectory to go 'up and through' the ball. In order to do this, the body must go 'down and back' into a kinematic position of cocking and a kinetic position of loading, and then the arm must rapidly move forward and through ball impact. There are two ways to accomplish this motion: pushing the body and arm through ball impact, or pulling it through. These two kinetic chain patterns have observable differences in how the segments are activated and moved and have different physiological stresses and biomechanical results for serve performance.

PUSH-THROUGH AND PULL-THROUGH KINETIC CHAINS

The 'push-through' activation sequence uses knee flexion and back leg drive to maximise ground reaction forces that push the body upward from the cocking position into ball impact and create long axis rotation in the arm. In the normally operating kinetic chain, the legs and trunk segments are the engine for force development and the stable proximal base for distal mobility[3,6,7]. This link develops 51 to 55% of the kinetic energy and force delivered to the hand[7], creates the back leg to front leg angular momentum to drive the arm forward[8,9] and – because of its high cross-sectional area, large mass and high moment of inertia – creates an anchor, which allows centripetal motion to occur[2,3]. The functional result of this stable base is considered to represent core stability[10].

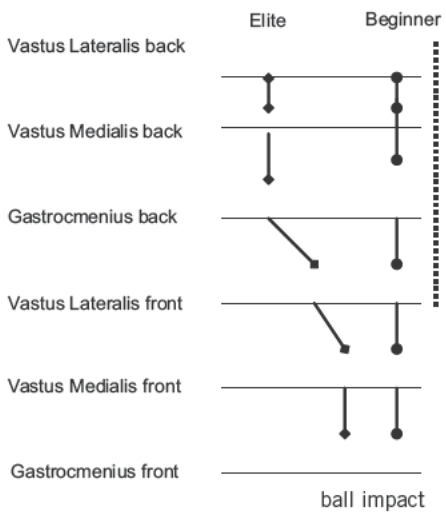

Figure 1: Differences between beginner and elite tennis players in lower extremity muscle activation during the tennis serve. Adapted from reference 14.

If the core stability and its force and torque generating capability are not used, other less efficient methods need to be used to maintain optimal performance. This is difficult because of the smaller size of the remaining muscles. Mathematical analysis has shown that a 20% decrease in trunk kinetic energy requires a 33% increase in shoulder velocity or a 70% increase in shoulder mass to maintain the same kinetic energy at the hand[7].

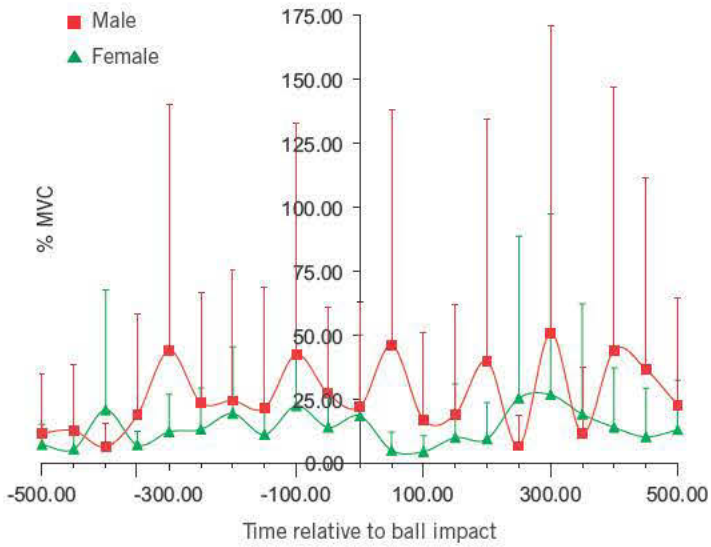

Figure 2: Hamstring activation of non-dominant leg during tennis serve.

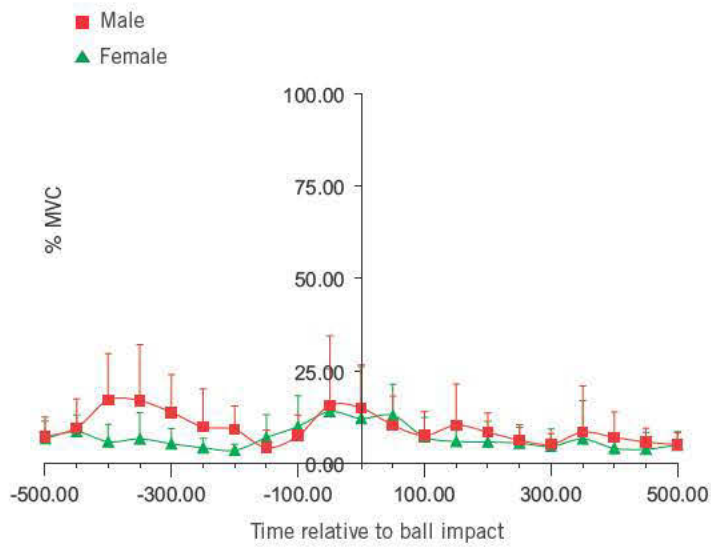

Figure 3: Gluteus medius activation of dominant leg during tennis serve.

Push-through utilises the large leg muscles to provide the majority of the power[8], decreases the internal rotation torques at the shoulder[11], produces greater muscle forces at the shoulder[8], allows higher degrees of shoulder abduction to produce top spin, decrease impingement[12] and generates greater racquet and ball velocities[13],[14]. This type of activation is the most efficient and is seen more frequently in elite male players. Figures 1 to 3 demonstrate electromyogram activation patterns in the lower extremity, which are characteristic of the push-through pattern. Figure 1 (elite player) demonstrates the back leg to front leg progression of activation in the gastrocnemius and quadriceps muscles before ball impact[14]; whereas Figures 2 and 3 demonstrate back leg hamstring and gluteus medius activation prior to ball impact[15]. Figure 4 demonstrates observational characteristics of push-through activations. The player's knees are bent, the back hip tilts down posteriorly and counter- rotates away from the court; the trunk does not hyperextend at cocking, and the arm is in line with the scapula and trunk.

'Pull-through' activation uses trunk muscles to pull the trunk and arm from cocking into ball impact and to create long axis rotation in the arm. Knee flexion and use of the legs is minimised. This activation increases internal rotation torques at the shoulder[8], creates increased scapular protraction and glenohumeral 'hyper-angulation'[16], decreases shoulder abduction and the ability to hit topspin[12] and is associated with lower ball velocities[14]. This type of activation results from a lack of the full use of the proximal kinetic chain segments and occurs more frequently in female elite players and recreational players. Figure 5 (over page) demonstrates electromyogram activation patterns in the trunk that are characteristic of the pull-through pattern, showing non-dominant external oblique activation to pull the trunk and arm into ball impact[15]. Figures 6 and 7 demonstrate observational characteristics of pull-through. The player's knees are less bent, the back hip tilts very little and does not counter rotate, the trunk extends and laterally tilts, the arm is in a position of hyperextension on the scapula and trunk, the trunk flexes forward as the arm goes towards ball impact, and the back hip is in a posteriorly displaced position at ball impact and follow-through.

Pull-through activation patterns are shown to develop less-stable kinematic patterns and higher force loads at the shoulder. An ongoing study of professional

Figure 4: Observable characteristics of the 'push-through' serve are scapular retraction and large degrees of knee flexion during cocking.

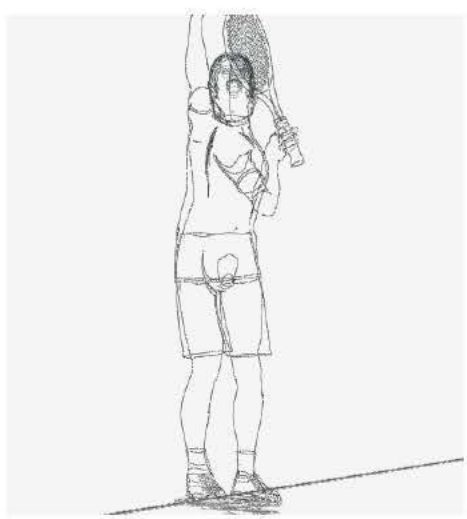

Figure 6: Observable characteristic of the 'pull-through' serve is the lack of knee flexion during cocking.

Figure 7: The 'hip-back' position during a pull-through serve

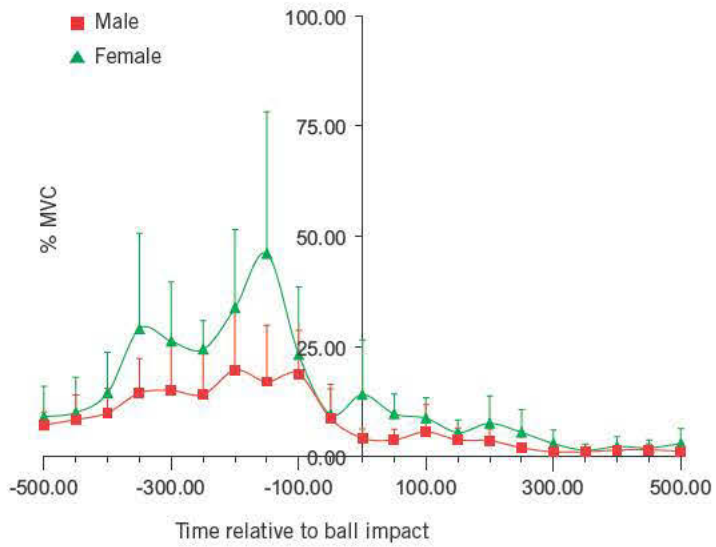

Figure 5: Non-dominant external oblique activation during tennis serve.

tennis players has demonstrated that 77% of female players and 21% of male players utilise the pull-through kinetic chain (Kibler, unpublished data). In addition, the different efficiencies of the two patterns could help to explain the differences in the performance results in the serve. Males win a significantly higher percentage of points and games on their serves. No epidemiological studies have looked at the correlation between shoulder injury and type of service motion. However, the kinematic pattern of glenohumeral hyperangulation and increased scapular protraction has been implicated in the generation of shoulder injury[16,17], and the pattern of decreased abduction is known to relate to impingement[18]. The inefficiency of the motion is shown by higher force loads but lower ball velocities.

Strategies for developing a more efficient push-through kinetic chain relate to physical and technical changes. Evaluation of hip and trunk flexibility, core strength and gluteal and hamstring strength will demonstrate any deficits that interfere with normal kinetic chain activation. Both the United States Tennis Association and the Women's Tennis Association have excellent kinetic chain evaluation programs. Technical modifications have included more emphasis on hip rotation and posterior tilting in cocking, serving with all weight on the back leg and touching the racquet back and down before throwing the ball up. These strategies are especially important in younger tennis players as they are found to use pull-through serve motions very frequently, and technical changes are more easily implemented at younger ages.

SUMMARY

Tennis players have to use their kinetic chains to move their body and arm through ball impact. The push-through technique is more efficient and is associated with better performance characteristics. Observation can differentiate push-through from pull-through, and strategies can be employed to improve the tennis player's capability of developing the push-through kinetic chain.

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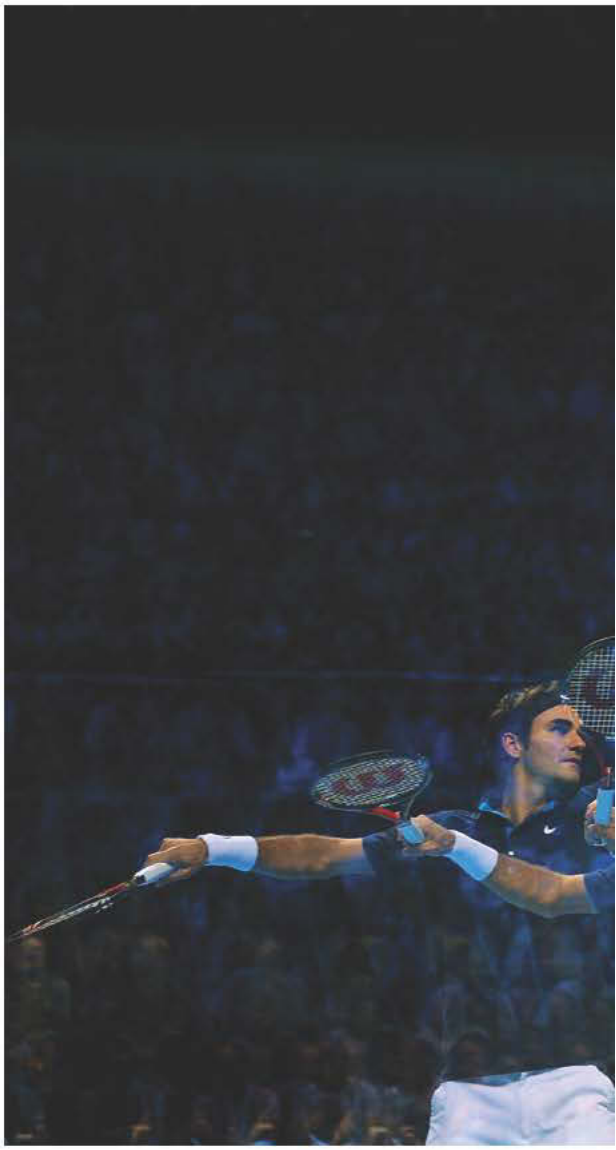

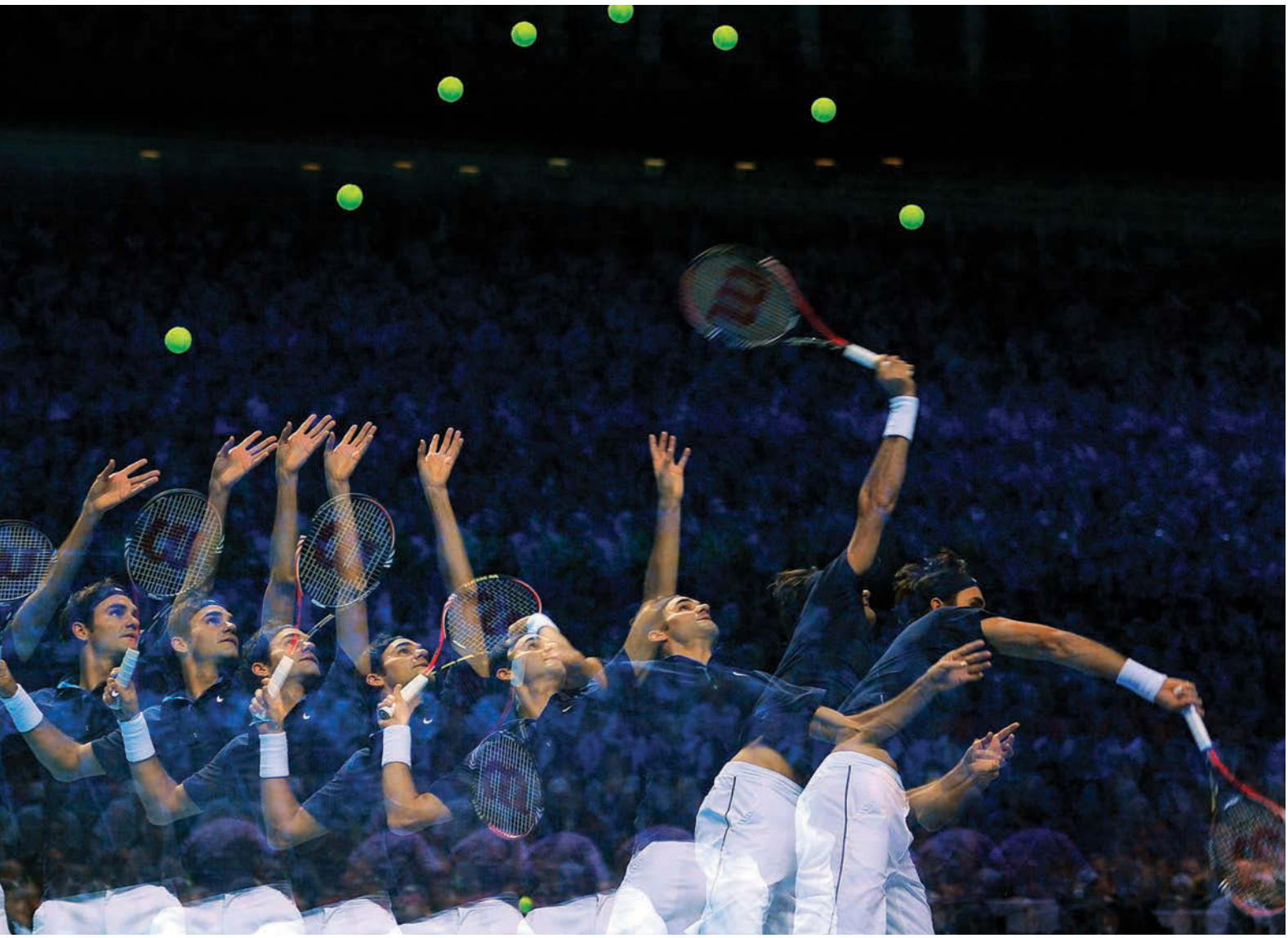

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