INTRODUCTION

The physiological demands of tennis as well as the complex biomechanics of the service motion and ground strokes make it imperative that tennis athletes are in top physical condition in order for performance to be maximised. However, both the physical demands and biomechanical requirements create a potential for injury to occur in tennis athletes who have sub-optimal anatomy, physiology and/or biomechanics. In the event injury does occur, clinicians routinely identify reversible physical impairments which can be addressed with musculoskeletal rehabilitation interventions. While clinicians commonly focus on physical impairments as part of the rehabilitation process, it has been suggested that other areas of athletic function and performance should also be considered.

Finding the influence or cause of injury (in the absence of trauma) can be difficult. Factors can be grouped into three primary groups:

- patient-specific factors,
- clinician specific factors and
- external factors.

First, patients may seek medical treatment for pain or anatomical dysfunction i.e. the inability to fully elevate an arm or extend a knee but they more often have a complaint related to performance such as lost velocity during a serve or hitting inaccurate ground strokes. If this patient-specific item is not accounted for during rehabilitation programme development, clinicians may struggle with applying the proper corrective regimen. Second, the clinician needs to properly identify causes of dysfunction during the physical

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examination. Clinician-specific items such as anatomical impairments or faulty biomechanics found during a routine injury evaluation may or may not be contributing to the overall dysfunction and/or cause of injury. It is the responsibility of the clinician to make correct judgments about the involvement of observed impairments on the injured state in order to apply the proper treatment. Finally, psychosocial influences such as interactions and influences from outside sources i.e. pressure to perform from coaches or administrators (external factor) could lead to injury by negatively altering the focus of the individual. Accounting for all of these factors increases the difficulty of developing appropriate rehabilitation protocols but is necessary so that each area of deficiency may be addressed.

This paper will describe interventions which can be applied directly to tennis athletes in a rehabilitation setting. The interventions will be categorised based on the three areas of injury influence and components of the optimal outcome model of rehabilitation (Figure 1). This allows a more individualised programme for rehabilitation.

**PATIENT-SPECIFIC REHABILITATION**

The clinician can use patient-directed assessment tools to categorise the injury in terms of the patient’s sport and expectations. Measuring patient expectation, resiliency and/or patient perceived function prior to the beginning of treatment can help provide insight to each individual patient’s specific concerns and potential goals. To assist clinicians with incorporating patient values into treatment plans, patient-reported outcome measures are routinely utilised in rehabilitation to establish a perceived level of function either in activities of daily living or athletic performance. While many different patient reported outcome instruments exist, selection of the appropriate instrument will be based on your athlete’s needs.

Two instruments which may be of use in tennis players are the Kerlan-Jobe Orthopaedic Center Shoulder and Elbow Score (KJOC)\(^2\) or the Patient-Specific Functional Scale\(^3\). The KJOC is comprised of 10 individual questions scored via visual analogue scales. The KJOC is scored by summing the results of the 10 questions with the total score being reported from 0 to 100 (with 100 indicating high level of function or ‘best’ score). This questionnaire has been found to be sensitive to overhead athletes.\(^4\) The Patient Specific Functional Scale questionnaire requires the patient to list three to five activities they have difficulty doing because of his or her shoulder problem and rate each item from 0 to 10 (0=cannot perform activity at all, 10=can perform activity at the same level as prior to the injury).\(^5\) Both instruments allow tennis athletes to grade their athletic performance from their personal view which should aid clinicians in establishing patient-specific rehabilitation goals thus accounting for the patient-specific rehabilitation factors.

**CLINICIAN-SPECIFIC REHABILITATION**

There are different rehabilitation approaches for treating overhead athletes including only targeting the site of symptoms (such as only performing therapeutic measures at or around the shoulder for complaints of shoulder pain) or targeting all potential regions or segments which could be contributing to the symptoms. The latter approach is known as the kinetic chain framework for rehabilitation which has been described in detail\(^6\) and is advocated as an ideal tactic for treating athletes with musculoskeletal injury because of its comprehensive treatment design. The kinetic chain framework describes five logically arranged key areas of focus to be addressed during the treatment process (proper motion, core stability and strength, stability of energy transfer links, closed chain exercise implementation and use of multiple planes). Similar to the kinetic chain description of functional performance, the rehabilitation philosophy specifically utilises global muscles to facilitate local muscle activation and function throughout the course of treatment. An understanding of kinetic chain function serves as the foundation for this treatment approach.

The kinetic chain is a co-ordinated sequencing of activation, mobilisation and stabilisation of body segments to produce a dynamic activity. The kinetic chain has several functions:\(^6\)

1. Using integrated programmes of muscle activation to temporarily link multiple body segments into one functional segment (the back leg in

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**Figure 1:** Optimal Outcome Model depicting the achievement of an optimal patient outcome by achieving balance between the patient-specific, clinician-specific and external factors. (Originally published in Sciascia A. Int J Athl Ther Trai 2013; 18:14-19.)
cocking stance and push-off, the arm in long axis rotation prior to ball impact) to decrease the degrees of freedom in the entire motion.

2. Providing a stable proximal base for distal arm mobility.

3. Maximising force development in the large muscles of the core and transferring it to the hand.

4. Producing interactive moments at distal joints that develop more force and energy than the joint itself could develop and decrease the magnitude of the applied loads at the distal joint.

5. Producing torques that decrease deceleration forces.

Each body part has specific roles in the entire motion of any dynamic task. The feet are contact points with the ground and allow maximum ground reaction force for proximal stability and force generation. The legs and core are the mass for the stable base and the engine for the largest amount of force generation. The shoulder is the funnel for force regulation and transmission and the fulcrum for stability during the rapid motion of the arm. The arm and hand is the rapidly moving delivery mechanism of the force to the ball or racquet.

A deficit within one or more of the individual anatomical segments can negatively affect performance and potentially lead to injury. Therefore, a clinician is encouraged to implement injury rehabilitation and prevention programmes which will initially eliminate physical deficits followed by a focus on increasing an athlete’s longevity while simultaneously decreasing the risk of injury. After restoration of any existing impairment or deficit, the clinician must assist the athlete in re-establishing functional patterns and sports-specific skills. This can be done with a logical, progressive rehabilitation approach which begins and ends with integrated muscle activation and movement.

Areas of deficiency

First, whether rehabilitating an upper or lower extremity injury, the athlete’s areas of deficiency and severity of impairment should drive the treatment. For example, if a tennis player is being treated for knee pain where both flexibility and strength deficits exist at the hip, it would be appropriate to alleviate the inflexibility in order to maximise the effects of future strengthening interventions. Attention should be directed towards improving flexibility of larger muscles responsible for both movement and force development including the hamstrings and hip flexors of the lower extremity and the latissimus dorsi of the upper extremity. In addition to the larger global muscle groups responsible for flexion and extension, the muscles responsible for extremity rotation and eccentric control should be targeted as well. In some instances deeper immobility issues may be present, requiring manual therapy techniques such as joint mobilisation. Manual therapy manoeuvres are advocated as long as it is physiologically safe to do so.

Core strength and stability

Next, core strength and stability should be improved. The core, being the central component of the kinetic chain, serves as the critical link between the development and transfer of energy. Recent literature has theorised and examined the link between core instability and athletic performance finding that deleterious effects occur in the presence of core instability. Therefore, enhancing local stabilisers and global movers of the trunk and pelvis would help overcome any foundational weakness and deficient stability within the core (Figure 2).

Energy transfer

The next area of progression would be improving the capability of the energy transfer links for the extremities. For the upper extremity, the energy transfer link between the core and arm is the scapula while the pelvis is the acting link between the core and the leg. The ankle also serves as a link of energy transfer between the ground and the leg which could affect both upper and lower extremity tasks. Improving the stability and function of the energy transfer links is performed through progressive integrated motions where the degrees of freedom are initially constrained through small movement and then facilitated through movement from larger kinetic chain segments. For example, correction of scapular position can be performed as an isolated exercise initially to begin restoration of scapular function.

Figure 2: Trunk rotations with a static lower extremity places focus on the trunk muscles to enhance core strength and stability.
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Tennis athlete for multiple reasons. First, these types of exercises are best suited for re-establishing the proximal stability and control in the links of the kinetic chain such as the pelvis and trunk. Second, the rationale behind the closed-chain framework is to maximise the ability of the inhibited muscles to activate. This involves placing the extremity in a closed-chain position, emphasising normal activation patterns and focusing on the muscle of interest by de-emphasising compensatory muscle activation. Third, athletes requiring rehabilitation typically must 'relearn' how to properly perform motor tasks to both maximise performance and decrease injury. Closed chain exercise encourages feedback from different mechanoreceptors through joint compression which enhances retraining of the motor system. For upper extremity focus, tasks such as the low row (Figure 3) and active inferior glide (Figure 6) which accentuate the scapular stability function of the lower trapezius and serratus anterior are suggested. Lower extremity manoeuvres such as lunging and squatting are helpful at providing feedback while taxing multiple segments.

Scapular motion can then be advanced with more functional manoeuvres such as scapular retraction with trunk rotation and hip extension where the rotary motion of the trunk and extension of the hips aids the performance of scapular retraction (Figure 3). A progression of this nature allows for muscle activation re-education and mimics functional tasks such as the trunk and hip motion that occurs during both phases of the service or ground stroke motions. A sample progression for improving pelvic stability would begin with pelvic neutral positioning manoeuvres which can then be advanced to hip counter rotation manoeuvres which such as those which parallel the hip motion during tennis activities (Figure 4).

**Closed chain exercise**
After improving the energy transfer link function of the scapula and pelvis, use of closed chain exercise is the next recommendation. Closed chain exercise is advantageous in the rehabilitation of the

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The final component of the kinetic chain framework is to have the athlete work in multiple planes of motion. Strengthening and stabilisation should begin by emphasising work in successful planes and then progress to deficient planes. Clinicians should avoid the use of single planar exercises which isolate specific muscles or specific joints. Greater isolation should be utilised in the later stages of the rehabilitation protocol. During the early phases, emphasis should be placed on achieving successful positions, motions and muscle activation sequences. In this manner, normal physiologic activations are restored, which lead to restoration of normal biomechanical motions.

ACCOUNTING FOR EXTERNAL FACTORS

The final consideration in the rehabilitation of a tennis player is to assess the magnitude of influence from external sources. Applicable objective measures tailored towards assessing external factors can be difficult to distribute and disseminate, however general demographic information can be captured (sport requirements including playing surface, current individual or team record, match schedule etc). Clinicians can reasonably provide applicable third parties i.e. coaches, complete diagnoses and/or prognoses with realistic time considerations. An adequate review of performance limitations and restrictions would decrease placing unnecessary pressure on an individual athlete to accelerate through the rehabilitation process before impairments have been adequately resolved.

One means of providing both the individual athlete and coaches with useful feedback about the athlete’s progress is the utilisation of sports-specific programmes and functional testing. Using dynamic measurements beyond traditional impairment testing may help reduce or eliminate premature return to activity (i.e. return prior to the optimisation of functional capability necessary to perform sport-specific tasks), however no standardised

Figure 5: Low row manoeuvre.
Figure 6: Active inferior glide.
method exists for assessing a tennis athlete. It has been suggested that a tennis-specific interval sports programme may be useful for re-establishing tennis skills and qualitatively assessing performance under controlled conditions\textsuperscript{13}. Periodic testing throughout the rehabilitation process may give all involved parties insight as to whether patient expectations are being met, biomechanical improvements are being made and if set goals are being reached.

Another method of improving the external factor considerations is to perform a biomechanical assessment of both the tennis serve and ground strokes. Mechanical nodes have been described where recommended service motions have been advocated for optimal performance and injury reduction\textsuperscript{7,14}. The assessment can be performed as part of the initial evaluation of the tennis athlete and should be also examined towards the completion of formal rehabilitation. The post-treatment mechanical examination is important because improvements in strength and/or flexibility may lead to altered performance initially because the athlete is not familiar with how to utilise the new gains. Clinicians should allot adequate time to retrain the motor system to perform under the new degrees of freedom or constraints.

SUMMARY

Rehabilitating tennis athletes can be challenging due to the demands and complexity of the sport. A multi-modal rehabilitation approach for the tennis athlete may assist clinicians in producing more optimal treatment outcomes. Clinicians should attempt to develop programmes based on patient-specific goals as well as known biomechanical and physiological requirements for tennis, which can be addressed with a kinetic chain-based regimen. Optimal outcomes can be achieved with a comprehensive treatment plan which accounts for the patient-specific and external influential factors in addition to traditional impairment factors.

\textbf{References}


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