UPDATED MUSCULOSKELETAL SCREENING RESULTS OF MALE PROFESSIONAL TENNIS PLAYERS

THE ATP PERFORMANCE AND INJURY PREVENTION PROGRAMME

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INTRODUCTION

The use of a tennis specific musculoskeletal screening programme for elite level tennis players provides key information for both injury prevention and performance enhancement. Prior published reports[1,2] have outlined specific orthopaedic clinical tests applied for elite tennis players based on the understanding of the unique demands placed upon their musculoskeletal system[3].

The purpose of this updated article is to provide objective descriptive data highlighting the musculoskeletal adaptations and unique findings in male professional tennis players, obtained during the performance of screenings of 333 unique players over an 18 year period at ATP tournaments. The purpose of the ATP performance and injury prevention programme is to apply scientific and clinically valid and reliable screening tests to obtain objective descriptive information that can provide the framework for an exercise-based injury prevention programme. This programme targets areas of identified deficiency based on the descriptive data gathered during the screening session for the player. Not included in this report are findings from 245 follow-up screenings performed to provide longitudinal comparison and provide additional guidance beyond the initial screening session. To date, a total of over 600 tests have been performed on ATP players in this programme.

The sport of tennis produces significant repetitive demands on the entire body that can result in injury, primarily overuse, in the lower and upper body, as well as the trunk[4,5,6]. Table 1 outlines the clinical tests performed in the ATP Performance & Injury Prevention Programme. These

Table 1

Posture & Scapula:

Shoulder Height
Infraspinatus Atrophy Position (Hands on Hips View)
Kibler Scapular Dyskinesis Test

Shoulder:

Internal/External/Total Rotation ROM @ 90 Degrees Abduction
Horizontal Adduction (Cross ARM) ROM
Empty Can MMT with Hand Held Dynamometer (HHD)
Shoulder External Rotation at the side with HHD
Shoulder External Rotation with 90 degrees of Abduction with HHD

Elbow:

Elbow Extension ROM

Core Stability Tests:

Abdominal Bracing with Blood Pressure Cuff
Bridging with Unilateral Support
Ipsilateral Quadruped Test
One Leg Stability Test

Lower Extremity Flexibility Tests:

Straight Leg Raise ROM
Prone Knee Flexion ROM
Prone Hip Internal & External Rotation ROM
Thomas Test (Hip Flexors)
Dorsiflexion ROM (Knee straight/knee bent)

Table 1: Clinical Tests in the ATP Performance & Injury Prevention Programme.

Figure 1: Evaluation of shoulder height and visual observation of infraspinatus atrophy in the hands on hips resting position in an elite level tennis player.

specific tests measure range of motion, strength, and stability across the body, and are initially adapted and expanded from the USTA High Performance Profile (HPP)[3]. It is beyond the scope of this article to list in detail all tests and their diagnostic accuracy and methodology, however this can be found in prior published references[1,2]. The primary scope of this article is to present the latest clinical findings from the 333 musculoskeletal screenings. Additionally, it aims to summarize the significant and distinctive differences observed in male professional tennis players. The descriptive data provided in this article aims to aid sports medicine professionals in interpreting musculoskeletal testing results for the development of rehabilitation and injury prevention programs.

PLAYER DEMOGRAPHICS

Out of the 333 players in this sample, the majority were right-handed (85%) and predominantly used a two-handed backhand (76%). Additionally, 73% of players used a semi-western grip for their forehand. The players had an average age of 25.7±3.9 years and weighed 80.1±7.0 KG at the time of assessment.

POSTURE & SCAPULA

The typical shoulder posture observed in elite tennis players is characterised by the dominant shoulder being lower than the non-dominant shoulder[6]. This updated report confirms this observation, with 85% of players presenting with a lower dominant shoulder , while less than 5% presented with the non-dominant extremity lower. This suggests that a "lower" dominant shoulder, compared to bilateral height, is a normal finding in healthy uninjured players during clinical presentation. Infraspinatus atrophy, as agreed upon by two examiners based on significant concavity over the infraspinous fossa with visual observation, was detected in 73.5% of dominant shoulders and 6.16% of non-dominant shoulders (Figure 1). This finding aligns with a previous study by Ellenbecker et at[7], showing that infraspinatus atrophy correlated with external rotation weakness in professional tennis players. It indicates that dominant infraspinatus atrophy is prevalent in this population and may serve as an indicator of rotator cuff (external rotation) weakness requiring preventative intervention[1,7].

Figure 2: Measurement of shoulder internal rotation with scapular stabilization.

TABLE 2

Parameter	*Dominant Arm*	*Non-Dominant Arm*	*Difference*
Range of Motion (degrees)			
Shoulder ER	*100.0+8.5*	*95.1+10.3*	*4.8+9.8*
Shoulder IR	*38.7+8.0*	*49.5+7.3*	*-10.8+9.1*
Total Rotation	*138.6+10.3*	*145.2+9.7*	*-6.6+8.9*
X-arm Adduction	*31.6+6.5*	*40.1+7.3*	*-8.3+6.9*
Strength (KG/KG)			
Empty Can	*13.4+3.3*	*14.1+2.90*	*-0.66+2.34*
ER Neutral	*16.9+3.64*	*18.8+2.94*	*-1.92+3.1*
ER 90 ABD	*18.7+3.7*	*17.6+3.7*	*0.93+2.63*

Table 2: Shoulder ROM & strength data.

In this large study of male professional tennis players, the scapular dyskinesis test revealed observable scapular dysfunction, as per the classification and grading system of Kibler[8] in 54% of players on the dominant extremity and only 33% on the non-dominant extremity. These results underscore the necessity for preventative scapular stabilization exercises for a significant proportion of players in this population. During the test, a 2 kg ball was used in each hand to further provoke the scapular stabilizers during repeated arm elevation and controlled lowering. For players presenting with scapular dyskinesis, targeted scapular stabilization exercise focusing on the lower trapezius and serratus anterior force couple are advised and recommended.

SHOULDER

Testing shoulder range of motion (ROM) consisted of supine positioning with scapular stabilization as prior reported[1, 2,3] using a standard goniometer (Figure 2). Table 2 contains the mean±standard deviation of the dominant and non-dominant extremity as well as the average difference between extremities for the shoulder measurements from this study. The findings show 4.8±9.7 degrees greater external rotation ROM on the dominant extremity whilst internal rotation was 10.8±9.2 degrees less on the dominant extremity. This is consistent with many other reports on upper extremity overhead athletes[1,2,6,9].

Total rotation ROM which simply represents the summation of the external and internal rotation measurement was 6.6±8.9 degrees less on the dominant arm. This finding is clinically significant for interpretating shoulder rotational ROM in elite tennis players. It suggests that based on the descriptive data from this extensive population of professional males players, a loss of up to 6.6 degrees in total rotation ROM on the dominant arm is common. However, total rotation ROM losses exceeding 6-8 degrees indicate a pivotal threshold where interventions such as the sleeper and cross arm stretch are recommended and implemented to mitigate total rotation ROM loss on the dominant extremity[1,2,6,9].

Bilateral shoulder cross arm adduction ROM was assessed in a supine position, using scapular stabilization along the lateral scapular border with the examiners hand and an inclinometer (Figure 3). This test also measures posterior shoulder tightness in addition to the traditional measurement of internal rotation ROM at 90 degrees of shoulder abduction. The results indicate that the dominant extremity is 8.3±6.9 degrees tighter than the non-dominant extremity. This finding holds clinical relevance, emphasizing that approximately 8 degrees less horizontal adduction ROM is typically observed in the dominant extremity in the elite tennis player. When limitations exceed 8 degrees between extremities, it signals the need for posterior shoulder stretching performed on the dominant extremity both prior to and after tennis play to create a cross arm adduction profile with less than an 8-degree difference between extremities.

Results of shoulder strength testing are displayed in Table 2. The results of isometric strength data are presented in Kilograms (KG) of strength per KG of body weight (KG/KG) to allow for application of these ratios for clinical and performance cases. Tests were performed using a "make" test format to enhance reliability of the data acquisition. Normalization of strength data to body weight allows for application of descriptive

Figure 3: Measurement of shoulder horizontal adduction using an inclinometer with lateral scapular border stabilization.

Figure 4: Measurement of shoulder external rotation in 90 degrees of abduction in the seated position using a handheld dynamometer.

data profiles across players of various sizes and increases the utility of these measures.

The empty can test is used to best represent supraspinatus strength tested with a hand held dynamometer (HHD) in 90 degrees of elevation. Results of testing show the dominant extremity to be 0.66±2.34kg weaker than the non-dominant extremity. Concomitant testing of shoulder external rotation at the side, which primarily tests the infraspinatus, shows a mean deficit of 1.92±3.1 KG/KG on the dominant extremity in these players. Finally, testing the shoulder in 90 degrees of abduction for external rotation strength which primarily tests the teres minor and the infraspinatus secondarily showed 0.9±2.6 KG/KG greater strength on the dominant extremity compared to the non-dominant extremity (Figure 4). This creates a very abduction specific shoulder external rotation strength profile whereby external rotation strength measured at the side (infraspinatus) is slightly weaker on the dominant extremity whilst testing at 90 degrees of abduction (teres minor/infraspinatus) is actually stronger on the dominant extremity. Extensive support in the literature exists for the application of posterior rotator cuff strengthening using submaximal loading paradigms (low resistance, high repetition formatting) for both rehabilitation of shoulder pathology and injury prevention for overhead athletes[1,2,6]. These data can help guide clinicians evaluating high level tennis players with respect to normal shoulder strength characteristics based on this very large homogenous sample of male professional players.

ELBOW

The primary elbow test utilized was measuring elbow extension ROM with a standard goniometer in a seated position and 80-90 degrees of shoulder flexion and forearm supinated. Results of testing show a flexion contracture (loss of full elbow extension) of -2.7±6.7 degrees on the dominant arm with 4.6±6.4 degrees of hyperextension on the non-dominant extremity. This results in a bilateral difference of 7.1±6.2 degrees between extremities in elbow extension ROM. Players presenting with greater degrees of flexion contracture and bilateral difference may be candidates for interventions to improve elbow extension ROM through stretching and manual therapy/mobilization.

CORE STABILITY TESTING

Several tests are used to assess core stability in elite tennis players[1,2]. High levels of core muscle function are present during all tennis strokes and tennis specific functional movement patterns[4,10]. Loss of core muscle stabilization can increase spinal injury risk and inclusion of multiple tests of both anterior and posterior chain core muscle strength are important parts of a tennis specific musculoskeletal screening programme.

The abdominal bracing core stability test includes the use of a blood pressure cuff placed in the lumbar spine whilst alternatively lowering in a reciprocal fashion each lower extremity from a 90 degree hip and knee flexed starting position toward extension while maintaining a posterior pelvic tilt against the blood pressure cuff (Figure 5). An established requirement for passing this test is the ability to perform 10 repetitions with each lower extremity keeping an acceptable level of posteriorly directed pressure into the blood pressure cuff [1]. Achievement of 10 satisfactory repetitions was performed by 71% of the players tested in this investigation.

Concomitant bridging tests with alternating unilateral lower extremity support without rotational pelvic motion with arms crossed on the chest was achieved by 66% of the players in this study (ie 33% failed to perform the test correctly) (Figure 6). This pairing of abdominal bracing and posterior chain bridging is thought to encompass more of the core musculature in this population as compared to solely measuring the number of abdominal sit-ups in a designated time period[3].

Twenty-one% of players failed the ipsilateral quadruped test, also known as the rotatory stability test. They were unable to stabilize their core while moving the ipsilateral arm and leg pairings in the quadruped position. This is a more advanced core stability test requiring high levels of stabilization to allow ipsilateral extremity movements. The one leg stability test is used to assess both hip and core strength and stabilization[1]. The test is known to identify gluteus medius weakness through identification of contralateral hip drop (Trendelenburg Sign) during its execution, as well as excessive forward lean, and dynamic knee valgus[1] (Figure 7). In ATP players, 53% fail to perform the test without abnormal movement/substitution patterning (Trendelenburg Sign, Forward Lean or Dynamic Knee Valgus) on the dominant (same side as serving upper extremity) and a 48% failure rate was identified on the non-dominant lower extremity. Interventions to improve hip abduction strength and hip rotation (ER and IR) strength coupled with more traditional core stability exercises are given to players who fail these tests to address the insufficient core strength highlighted through failure of one or more of these core test procedures.

Figure 5: Abdominal bracing core stability test using a blood pressure cuff and reciprocal lower extremity lowering.

Figure 6: Bridging test with crossed arm to assess posterior chain core muscle function.

LOWER EXTREMITY FLEXIBILITY TESTS

Unlike the upper extremity (shoulder, elbow), where range of motion often reveals asymmetry, lower extremity flexibility tests consistently show bilateral symmetry. High levels of bilaterally symmetric hamstring (Straight leg raise) ROM were observed in these players (average 80 degrees), alongside comparable symmetry in prone knee flexion (quadriceps) flexibility (approximately 126-128 degrees). Prone hip rotation, measured with the hip in neutral 0 degrees of hip extension, displayed an average difference of approximately 1 degree bilaterally, showcasing remarkable consistency in hip rotational motion among these elite tennis players (Figure 8). This finding of bilateral symmetry in hip rotation ROM is consistent with a prior study of elite junior tennis players and professional baseball pitchers[11]. An average of 68 degrees of bilaterally symmetric total hip rotation ROM (adding hip ER and IR together) was measured.

However, one area of potential concern arises from the high failure rate of the hip flexor (Thomas) test, which stands at 59% for the dominant limb and 57% for the non-dominant limb. Tightness of the hip flexors can increase loading of the lumbar spine and limit hip extension range of motion required for optimal positioning during the cocking phase of the serve[10]. This loss of hip extension ROM can lead to compensation to achieve the extended position through lumbar spine hyperextension loading[12]. It is recommended to implement targeted exercises to improve hip flexor and rectus femoris flexibility after identifying a positive Thomas test result. This approach aims to improve hip extension range of motion.

Finally, distal ankle range of motion is measured in a non-weightbearing position, both with the knee extended (gastrocnemius) and knee flexed (soleus). The differences between the dominant and non-dominant lower extremity are negligible, aligning with the bilateral symmetry commonly observed in the lower extremities of tennis players (Table 3).

Figure 7: One leg stability test for hip and core stabilization.

Figure 8: Prone hip internal rotation measurement position and technique.

TABLE 3

Parameter	*Dominant Arm*	*Non-Dominant Arm*	*Difference*
Range of Motion (degrees)			
Straight Leg Raise	*80.2+8.5*	*80.6+8.6*	*-0.24+1.9*
Hip ER	*36.7+7.2*	*35.6+7.3*	*1.16+5.7*
Hip IR	*32.4+8.8*	*31.5+8.8*	*0.85+6.3*
Total Hip Rotation	*69.2+11.0*	*67.3+11.6*	*1.9+7.1*
Prone Knee Flexion	*127.5+5.9*	*125.8+6.0*	*2.1+3.9*
*Ankle Dorsiflexion **	*8.7+4.3*	*9.2+4.1*	*0.26+3.7*
*Ankle Dorsiflexion***	*14.7+4.8*	*13.3+4.4*	*1.3+3.9*

*Measured in knee extension; **Measured in knee flexion

Table 3: Lower extremity flexibility in professional male tennis players (degrees).

LIMITATIONS

Data from the ATP performance and injury prevention programme is collected from ATP players during ATP tournaments. Due to the tournament setting, players may exhibit varying levels of fatigue, and additionally we have no control over pre-measurement activity or rest. To minimise measurement variation, all measurements were conducted by a single physiotherapist. The programme aims to provide crucial information for players, coaches, physiotherapists, and doctors involved in player care, enabling the development of evidence-based preventive exercise programmes. To enhance compliance, players are equipped with portable exercise equipment (such as elastic bands, weighted balls, and balance platforms) and provided with written and video-based exercise descriptions. This support is essential given the extensive world-wide travel and time spent away from facility-based gyms by professional tennis players.

SUMMARY & CONCLUSION

The findings derived from the ATP performance and injury prevention programme provide objective descriptive data highlighting the musculoskeletal adaptations occurring in professional male tennis players due to repetitive elite play. This data set consistently highlights unique upper extremity range of motion characteristics, including reduced shoulder internal rotation, total shoulder rotation, cross arm adduction, and elbow extension ROM on the dominant extremity compared to the non-dominant extremity. Moreover, common findings of infraspinatus atrophy in the dominant arm, lower dominant shoulder posture, and scapular dyskinesis are indicative of postural variations among elite tennis players. Knowledge of these prevalent musculoskeletal findings is crucial for accurately interpreting clinical measurements in elite male professional tennis players. Regarding the lower body, symmetry in range of motion is notable, alongside robust core muscle function. However, frequent failures in the Thomas test and one leg stability test underscore areas of concern. These findings serve as valuable guidance for the designing and implementing both rehabilitation and prevention programs for elite tennis players.

Knowledge of these prevalent musculoskeletal findings is crucial for accurately interpreting clinical measurements in elite male professional tennis players.

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