## Influence of Playing a Prolonged Tennis Match on Shoulder Internal Range of Motion


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# Influence of Playing a Prolonged Tennis Match on Shoulder Internal Range of Motion

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**Background:** Shoulder range of motion (ROM) deficits have been identified as an injury risk factor among tennis players. It is well known that shoulder internal rotation deficit increases with age and years of play, but there is a lack of knowledge regarding the influence of a prolonged tennis match on shoulder ROM.

**Purpose:** To examine changes in shoulder ROM during a prolonged tennis match.

**Study Design:** Descriptive laboratory study.

**Methods:** Shoulder passive internal and external rotation ROM were measured on 8 male tennis players before, every 30 minutes during, and just after a 3-hour tennis match. Total ROM was calculated as the combination of shoulder internal and external rotations. Ball velocity on the serve was measured with a radar gun before, at midmatch, and just after the match.

**Results:** Decreases in shoulder internal rotation (–20.8°; $P = .005$), total ROM (–24.6°; $P = .001$), and serve velocity (–1.8 m/s; $P = .002$) were observed at the end of the match. No statistically significant difference was observed for shoulder external rotation after the match ($P = .460$).

**Conclusion:** Passive shoulder internal rotation and total ROM are significantly decreased during a 3-hour tennis match.

**Clinical Relevance:** The results show that a prolonged tennis match play can modify values of shoulder ROM.

**Keywords:** tennis serve; shoulder; range of motion; performance

Objective measurement of range of motion (ROM) of the shoulder joint is important for tennis performance as well as rehabilitation and prevention of shoulder injury.[7] Chandler et al[3] were the first to compare active internal and external rotation ROM for the shoulder with 90° of abduction in junior elite tennis players. They found significantly less mean internal rotation range in the dominant arm compared with the nondominant arm (–11°). Conversely, greater external rotation was reported on the dominant shoulder compared with the nondominant one (+3°). Ellenbecker et al[5,7] found similar results in later studies. Kibler et al[11] reported that dominant internal rotation of the shoulder decreased and the difference between the dominant and nondominant internal rotation increased with both age and years of tournament play. This deficit in shoulder internal rotation ROM of approximately 10° between dominant and nondominant arm is currently considered as a physiological adaptation that occurs normally in tennis players.[8]

The concept of shoulder total rotation ROM was introduced by Wilk et al.[24] It involves adding the internal and external rotation ROM at 90° of abduction together. In elite junior tennis players, significantly less dominant shoulder total rotation ROM was identified (149.1° vs 158.2°).[6] Pathologic shoulder internal rotation is identified when there is a loss of shoulder internal rotation greater than 18° to 20° associated with a corresponding loss of total ROM greater than 5° when compared bilaterally.[14] Indeed, recent findings support that a loss of total shoulder ROM is predictive of future shoulder injury in professional overhead throwing athletes.[23] In baseball, it has been shown that pitchers whose total ROM comparison was greater than 5° exhibited a 2.5 times greater risk of sustaining a shoulder injury.[23] In tennis, a statistically significant correlation was observed between dominant shoulder internal rotation deficits and shoulder pain.[21] Moreover, a significant relationship between serve velocity and increased dominant shoulder internal rotation at 0° of abduction has been found in expert tennis players.[4]

To our knowledge, no study has analyzed the acute effect of prolonged tennis match play on shoulder ROM, as all previous studies have been limited to chronic adaptations.[2,5,7,11] It is still unknown whether a prolonged tennis match decreases shoulder internal rotation and total ROM.

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Determining the acute effect of a prolonged tennis match on shoulder ROM may be insightful for understanding shoulder injury potential and serve performance. Consequently, the aim of this work was to analyze the influence of playing a prolonged tennis match on ball velocity during the serve as well as on shoulder ROM.

## METHODS

### Participants

Eight male tennis players (mean ± SD: age, 20.4 ± 2.8 years; height, 1.80 ± 0.05 m; weight, 69.4 ± 9.8 kg) with an International Tennis Number between 3 and 4 participated voluntarily in this study.

### Experimental Protocol

This study was approved by the local ethics committee and was conducted in accordance with the 1975 Declaration of Helsinki. Before experimentation, the participants were fully informed of the experimental procedures, and written consent was obtained from each player. The prolonged exercise was a 3-hour standardized competitive tennis match. All participants played against an opponent of similar level. Four matches involving the 8 players were performed. Each tennis match was preceded by a standard warm-up, as practiced during tennis tournaments. With the exception of the measurement of shoulder ROM and ball velocity during the serve, the matches were played according to the rules of the International Tennis Federation (ITF). The resting times allowed were 20 seconds between points, 90 seconds between change-overs, and 120 seconds between sets. The participants were asked to play at their best level, as in an official tournament.

### Shoulder ROM

For assessment of shoulder ROM, the players were placed supine with the shoulder at 90° of abduction in the plane of the scapula with the elbow flexed to 90°. One examiner assessed shoulder passive internal and external rotation ROM with a standard goniometer. During this assessment, the other examiner stabilized the scapula.[23,24] For shoulder internal rotation, a combination of end feel, palpation of the coracoid process, and visualization of compensatory movement was used to determine the end ROM.[23] The extremity was rotated until the participant's coracoid was felt rising into the examiner's thumb; motion was stopped when this movement occurred. To avoid altering the normal shoulder kinematics, the humeral head was not manually stabilized.[23,24] For all of the measurements, the axis of the goniometer was positioned over the olecranon process, with the stationary arm of the device perpendicular to the ground and with the moveable arm aligned along the ulna to the ulnar styloid process.[23,24] These shoulder measurements were conducted before any warm-up (T0), during brief interruptions (30, 60, 90, 120, and 150 minutes: T30, T60, T90, T120, and T150, respectively), and immediately after a 3-hour standardized tennis match (T180). During the match, the testing periods were included during the resting time of change-overs. Consequently, they did not disrupt the intervals allowed by the ITF between games. The same examiners assessed shoulder ROM for each match. The total shoulder ROM was the sum of the shoulder internal and external rotations.

### Serve Velocity

To measure the evolution of serve velocity during the match, each player performed sessions of 5 successful "flat" serves from the right service court to the "deuce" service box. These sessions for ball velocity measurements were conducted before the match (T0), during an interruption at midmatch (T90), and immediately after the tennis match (T180). Postimpact ball velocity was measured for each trial with a radar gun (Stalker Professional Sports Radar; Stalker Radar; precision, ±1.6 km/h; frequency, 34.7 GHz; target acquisition time, 0.01 seconds) fixed on a 2.5-m–high tripod, 2 m behind the players in the direction of the serve.

### Statistical Analyses

Means and standard deviations (5 trials for each player) were calculated for all variables. Data (serve velocity and shoulder ROM) were tested using a 1-factor (time) analysis of variance for repeated measures on ranks. When significant main effects were found, the Student-Newman-Keuls method post hoc test was used. Statistical significance was accepted at $P < .05$. The statistical analyses were undertaken by using SigmaStat software (Jandel Corp).

## RESULTS

### Shoulder ROM

The mean values of shoulder internal and external rotations and total ROM measured before and every 30 minutes during the match are presented in Figures 1 to 3. The results reveal significant reductions in dominant shoulder internal rotation ROM (–20.8°; –41%; $P = .005$) and in dominant total shoulder ROM (–24.6°; –15%; $P = .001$) between the beginning (T0) and the end of the match (T180). The mean shoulder internal rotation ROM became significantly lower after 90 minutes (–14.8°; $P < .01$) (Figure 1). Concerning the total shoulder ROM, the mean value was significantly reduced after the first 30 minutes of the match (–8.2° at T30; $P < .05$) (Figure 2).

No statistically significant differences were observed for external rotation in the dominant shoulder between T0 and T180 ($P = .460$) (Figure 3).

### Number of Strokes

During the tennis matches, the participants played 5 sets and 46 ± 1 games. Moreover, they hit 547 ± 93 groundstrokes

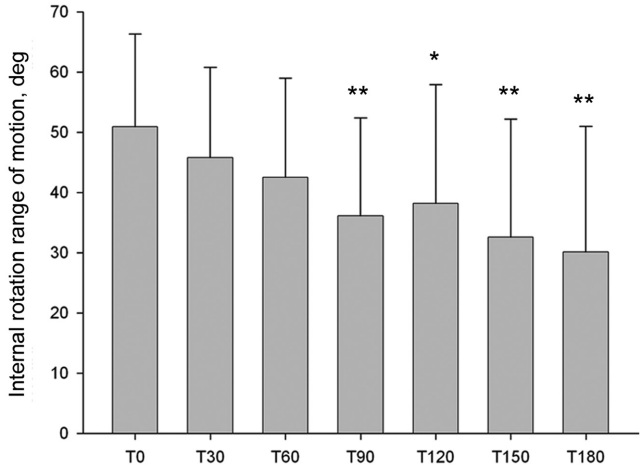


**Figure 1.** Shoulder internal range of motion before (T0), during (T30, T60, T90, T120, and T150), and immediately after the match (T180). Values are means ± SD. *$P < .05$; **$P < .01$ (significantly different from T0).

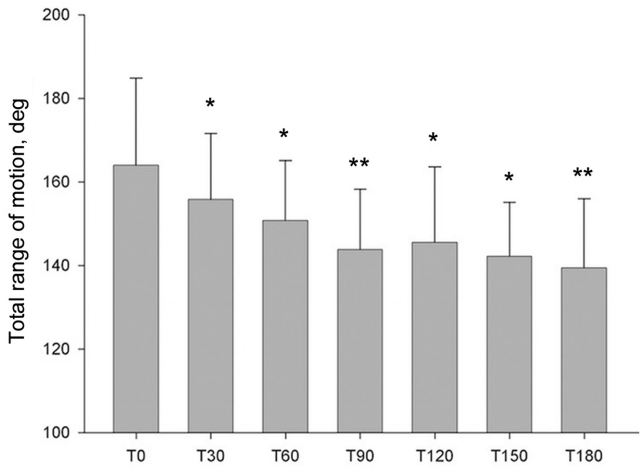


**Figure 2.** Shoulder total range of motion before (T0), during (T30, T60, T90, T120, and T150), and immediately after the match (T180). Values are means ± SD. *$P < .05$; **$P < .01$ (significantly different from T0).

and 253 ± 25 serves. The decrease in shoulder internal rotation ROM was significantly correlated with the increase of the number of strokes performed by the players (serves plus groundstrokes) during the match ($r = -0.97$; $P < .001$).

### Serve Velocity

The results show that serve velocity at the end of the match (T180) was significantly reduced in comparison with T0 (–1.8 m/s; –3.9%; $P = .002$) and T90 (–0.8 m/s; $P = .002$). On the contrary, no statistically significant difference was observed for the ball velocity between T0 and T90 ($P = .125$) (Figure 4).

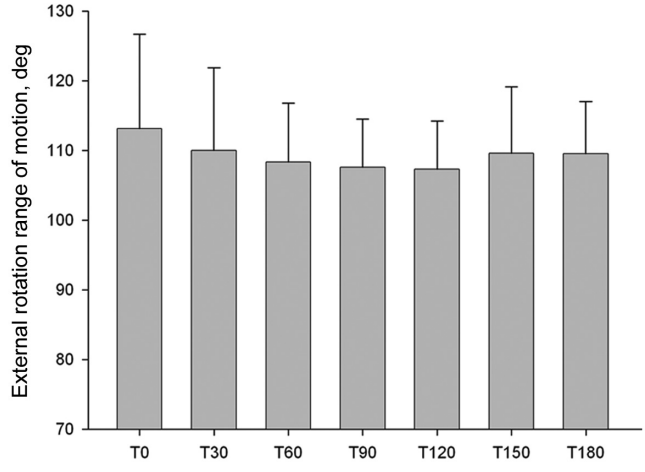


**Figure 3.** Shoulder external range of motion before (T0), during (T30, T60, T90, T120, and T150), and immediately after the match (T180). Values are means ± SD.

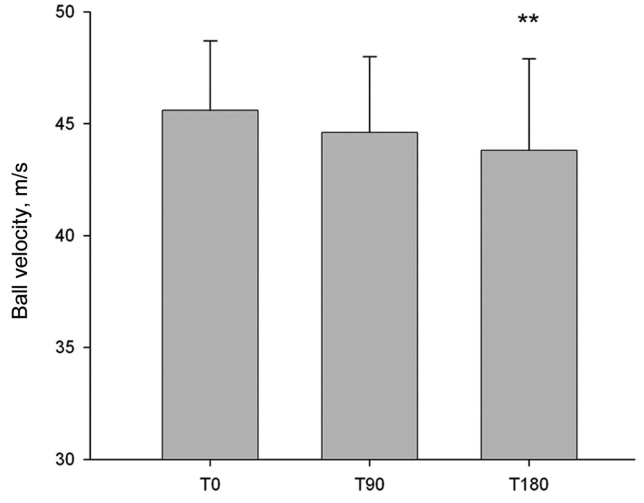


**Figure 4.** Serve velocity before (T0), during (T90), and immediately after the match (T180). Values are means ± SD. **$P < .05$ (significantly different from T0 and T90).

## DISCUSSION

The purpose of this study was to analyze the acute influence of prolonged match play on shoulder ROM in tennis players. Our results show that shoulder internal rotation and total ROM significantly decreased between T0 and T180, whereas shoulder external rotation was not significantly altered during the match. These results are in accordance with previous findings that demonstrated significant decreases in shoulder internal rotation and total ROM immediately after baseball pitching in the dominant shoulder but no difference in shoulder external rotation.[12,19] However, the deficits observed in the current study (−20.8° and −24.6° for shoulder internal rotation and total ROM, respectively) are higher than those measured by

Reinold et al[19] (−9.5° and −10.7°) and Kibler et al[12] (−7° and −2°). These discrepancies are probably the result of differences in the experimental design. Reinold et al[19] and Kibler et al[12] evaluated the acute effect of a "normal" baseball throwing game (the total numbers of pitches thrown were between 50 and 72), whereas the current study aimed to analyze the acute effect of a prolonged tennis match during which players hit approximately 250 serves and 547 groundstrokes. These numbers are largely higher than those reported for 90-minute tennis matches during which players hit between 50 and 150 serves.[16]

According to Manske et al,[14] pathologic shoulder internal rotation is identified when there is a loss of shoulder internal rotation greater than 18° to 20°, with a corresponding loss of total ROM greater than 5° when compared bilaterally. For Burkhart et al,[1] a nonacceptable level of shoulder internal rotation deficit is defined as (1) more than 20° loss of shoulder internal rotation or (2) greater than a 10% loss of the total ROM. In the current study, the mean loss of shoulder internal rotation reached 20.8° and the mean loss of total ROM approximated 25° (ie, 15%) after the match. Although our study did not compare dominant and nondominant shoulders, the results show that prolonged tennis match play can bring the dominant shoulder to a risky situation when compared with the beginning of the match.

The decreases in shoulder internal rotation and total ROM measured in this study could be the result of repetitive eccentric contractions[18] caused by the numerous powerful serves hit by the players through the 3-hour match. Indeed, the muscles responsible for external rotation of the shoulder (supraspinatus, infraspinatus, teres minor) exhibit moderate eccentric activity in the posterior rotator cuff during the serving motion[20] since the shoulder internally rotates between 2090 and 5580 deg/s.[9,22] Repetitive eccentric contractions can cause posterior muscle tendon unit and capsular tightness that has been shown to create abnormal shoulder biomechanics.[15] Indeed, it has been reported that posterior capsule tightness of the shoulder causes subsequent anterior and superior translations of the humeral head.[10] As a consequence, this phenomenon could reduce subacromial space and lead to soft tissue impingement. Moreover, Muraki et al[17] reported increased peak subacromial pressure and increased contact area on the coracoacromial ligament in the follow-through position of overhead throwing after modifying the posteroinferior shoulder capsule. Further support for posterior shoulder tightness as a risk factor of shoulder injuries comes from Wilk et al[23] and Vad et al,[21] who observed decreased shoulder internal rotation in baseball and tennis players with shoulder impingement symptoms. Consequently, one may argue that shoulder ROM changes caused by a prolonged tennis match could increase the risk of shoulder injuries.

In tennis, serve velocity depends on many factors, one of which is dominant shoulder ROM.[4] Indeed, high ball velocity in serve motion requires the shoulder to be forcefully propelled forward from a position of full external rotation to near full internal rotation. In fact, during the cocking phase of the serve, the internal rotators are stretched by the movement of shoulder external rotation to store elastic energy, which is reused as the internal rotators begin to shorten during the acceleration phase of the serve. In expert tennis players, the relationship between shoulder flexibility and serve performance has been confirmed by Cohen et al,[4] who reported that serve velocity is significantly correlated with increased dominant passive shoulder internal rotation measured at 0° of abduction. In this study, the results show decreases both in shoulder ROM and in serve velocity from T0 to T180. It is possible that the fatigue of the rotator cuff muscles induced by a 3-hour tennis match has reduced the ROM traveled by the shoulder during the serve. This could result in a less effective use of the stretch shortening cycle in the shoulder rotators during the cocking and acceleration phases and consequently to a decrease in serve performance from T0 to T180.

Even though the evolution of shoulder ROM during the recovery after the prolonged tennis match play was not measured in the current study, we can hypothesize that these changes last several days. Indeed, it has been reported that the decreases in shoulder ROM continue to be present 24, 48, and 72 hours after an acute baseball pitching episode.[12,19] This phenomenon is problematic for tennis players who regularly play 1 or 2 matches per day during tournaments. One may hypothesize that many tennis players play one tennis match after another while their shoulder ROM does not return to baseline. Like Reinold et al,[19] we believe that although an acute decrease in shoulder ROM may be a normal physiological response, tennis players may be more vulnerable to shoulder injury if they continue to play with decreased shoulder internal rotation and total ROM. Consequently, it appears necessary to restore the tennis player's normal shoulder ROM before having to play the next match. Throughout a prolonged tennis match (especially during a "best of 5 sets" format used in men's tennis during Grand Slam tournaments), tennis players could take advantage of changing ends for practicing cross-body stretches and pendulum exercises to limit loss of shoulder ROM. After the match, stretching (cross-body and sleeper stretches),[10,15] joint mobilization,[15] ice, and instrument-assisted soft tissue mobilization[13] are recommended for tennis players because these techniques have been studied and found to be beneficial for increasing shoulder ROM.

There are several limitations in this study that should be considered. First, this study only evaluated changes in internal, external, and total rotations in the dominant shoulder to evaluate the acute changes resulting from a prolonged tennis match. Side-to-side differences were not measured. Moreover, the sample size is somewhat small because we only included expert tennis players and their participation was voluntary. Making analyses on expert players generally leads to a small sample size because of the difficulty in recruiting them.

## CONCLUSION

This study shows that dominant shoulder internal rotation and total ROM were significantly decreased during a 3-hour tennis match. These alterations in shoulder ROM

have the potential to increase shoulder injury risk and to negatively influence the serve performance during tennis match play. However, no significant difference for the shoulder external rotation was noticed. Consequently, tennis players are encouraged to restore their normal shoulder internal and total ROM with stretching and recovery techniques before having to play the next match to avoid shoulder pathologic conditions and to maintain performance.

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