Nerve conduction studies of upper extremities in tennis players

T Çolak, B Bamaç, A Özbek, F Budak, Y S Bamaç

Objectives: The influence of regular and intense practice of an asymmetric sport such as tennis on nerves in the dominant extremity was examined.

Methods: The study included 21 male elite tennis players with a mean (SD) age of 27.5 (1.7) years and 21 male non-active controls aged 26.4 (1.9) years. Anthropometric measurements (height, weight, limb length, and perimeters of arm and forearm) were determined for each subject, and range of motion assessment and radiographic examination carried out. Standard nerve conduction techniques using constant measured distances were applied to evaluate the median, ulnar, and radial nerves in the dominant and non-dominant limb of each individual.

Results: The sensory and motor conduction velocities of the radial nerve and the sensory conduction velocity of the ulnar nerve were significantly delayed in the dominant arms of tennis players compared with their non-dominant arms and normal subjects. There were no statistical differences in the latencies, conduction velocities, or amplitudes of the median motor and sensory nerves between controls and tennis players in either the dominant or non-dominant arms. However, the range of motion of the upper extremity was significantly increased in tennis players when compared with control subjects. Tennis players were taller and heavier than control subjects and their dominant upper limb lengths were longer, and arm and forearm circumferences greater, than those of the control subjects.

Conclusions: Many of the asymptomatic tennis players with abnormal nerve conduction tests in the present study may have presymptomatic or asymptomatic neuropathy similar to subclinical entrapment nerve neuropathy.
to stimulate the radial nerve. Recording was carried out over the brachioradialis muscle using surface disc electrodes.

In the present study, the following median and radial nerve measures were used: (i) baseline to peak amplitude of the sensory nerve action potential (Amp-S); (ii) distal peak latency of the sensory nerve action potential (DL-S); (iii) conduction velocity of the sensory nerve fibres (CV-S); (iv) baseline to peak amplitude of the compound muscle action potential (Amp-M); (v) distal onset latency of the compound muscle action potential (DL-M); and (vi) conduction velocity of the motor nerve fibres (CV-M).

The mean nerve conduction parameters of this population were compared with existing literature values.

Simple biometric measurements were also carried out. The groups were matched according to weight, height, and limb lengths. We measured the length of the upper limbs as the distance between the acromial angle and the tip of the third digit of the hand, when the shoulder was flexed to 90° with the elbow extended. Perimeters of arm and forearm were measured to allow comparison between the dominant side and the non-dominant side. Using a tape measure, we obtained the perimeter of the forearm 10 cm proximal to the styloid process of the ulna and the perimeter of the arm 10 cm proximal to the medial epicondyle of humerus.

The range of motion of the upper extremities was evaluated by using a Biodex System 3 (Biodex Medical Systems, Shirley, NY, USA). Comparative plain films of both elbows were obtained from players in an anteroposterior projection to determine the radiographic manifestations of musculoskeletal stress at the elbow associated with tennis.

All subjects were informed of the study purposes, procedures, and known risks, and all gave their informed consent. This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the ethics committee of our faculty.

When performing nerve conduction studies, and during the assessment of movement and radiological findings, the observers were not blinded to the subjects’ tennis playing habits.

The results are presented as means (SD). Differences between the groups were calculated using a non-parametric test for independent samples (Mann-Whitney U test). The SPSS package (SPSS for Windows v 11.0, SPSS, Chicago, IL, USA) for personal computers was used for the statistical analyses. A p value of <0.05 was considered significant.

RESULTS

Two groups of subjects were examined. Their biometric characteristics are given in table 1. The tennis players were slightly larger and heavier, but as the difference was small this is not significant. The perimeters of the arm and forearm were chiefly influenced by muscle mass. A very marked hypertrophy was observed in all the tennis players in the dominant arm and forearm.

In the present study, the following median and radial nerve measures were used: (i) baseline to peak amplitude of the sensory nerve action potential (Amp-S); (ii) distal peak latency of the sensory nerve action potential (DL-S); (iii) conduction velocity of the sensory nerve fibres (CV-S); (iv) baseline to peak amplitude of the compound muscle action potential (Amp-M); (v) distal onset latency of the compound muscle action potential (DL-M); and (vi) conduction velocity of the motor nerve fibres (CV-M).

We observed significant differences in upper extremity length between the two arms in the tennis players. Anteroposterior roentgenograms of the elbows of tennis players showed a highly significant hypertrophy of bone in response to exercise. Visual inspection of the radiographs of tennis players revealed an obvious difference in bone structure between the stroke arm and the non-dominant arm; bone development was clearly greatly increased in the dominant extremity. There were no bony changes such as callus formation, arthritic spurs, fracture fragments, or changes in carrying angle.

In this study the range of motion of the upper extremities of the tennis players was clearly increased except for elbow flexion. Measurements showed significant differences in hyperextension, adduction, internal and external rotation degree of the shoulder, and pronation and supination of the forearm, and in flexion, extension, and ulnar and radial deviation of the wrist between tennis players and control subjects in the dominant extremity. Ranges of motion values of the upper extremity are shown in table 2.

There were no statistical differences in conduction velocities, latencies, or amplitudes of the median motor and sensory nerves between the control group and tennis players in both dominant and non-dominant arms (table 3).

The sensory and motor conduction velocities of the radial nerve were significantly delayed in the dominant arms of tennis players compared with their non-dominant arms and with normal subjects (table 4).

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**Table 1** Comparison of the biometric data of professional tennis players and sedentary non-athletic subjects

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Normal</th>
<th>Tennis</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>26.46 (0.5)</td>
<td>27.56 (0.7)</td>
<td>0.123</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>174.9 (0.3)</td>
<td>176.1 (0.6)</td>
<td>0.095</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>72.26 (1.2)</td>
<td>74.65 (1.4)</td>
<td>0.057</td>
</tr>
<tr>
<td>Perimeter forearm (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant</td>
<td>25.5 (1.4)</td>
<td>28.7 (1.3)</td>
<td>0.03</td>
</tr>
<tr>
<td>Non-dominant</td>
<td>24.9 (1.3)</td>
<td>25.1 (1.4)</td>
<td>0.255</td>
</tr>
<tr>
<td>p</td>
<td>0.06</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Perimeter arm (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant</td>
<td>29.4 (2.0)</td>
<td>31.9 (1.2)</td>
<td>0.02</td>
</tr>
<tr>
<td>Non-dominant</td>
<td>28.4 (1.9)</td>
<td>28.2 (1.0)</td>
<td>0.349</td>
</tr>
<tr>
<td>p</td>
<td>0.06</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Length upper extremity (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant</td>
<td>72.63 (0.8)</td>
<td>73.03 (0.9)</td>
<td>0.491</td>
</tr>
<tr>
<td>Non-dominant</td>
<td>72.50 (1.8)</td>
<td>71.92 (0.7)</td>
<td>0.552</td>
</tr>
<tr>
<td>p</td>
<td>0.627</td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>

Values are given as mean (SD). Significant p values are shown in bold.

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**Table 2** Range of motion of upper extremity (dominant arm)

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Tennis</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder flexion</td>
<td>180.0 (0.0)</td>
<td>180.0 (0.0)</td>
<td>1.000</td>
</tr>
<tr>
<td>Shoulder hyperextension</td>
<td>54.1 (4.1)</td>
<td>57.5 (6.1)</td>
<td>0.000</td>
</tr>
<tr>
<td>Shoulder abduction</td>
<td>179.8 (2.4)</td>
<td>180.0 (0.0)</td>
<td>0.317</td>
</tr>
<tr>
<td>Shoulder adduction</td>
<td>38.9 (7.7)</td>
<td>43.3 (13.8)</td>
<td>0.01</td>
</tr>
<tr>
<td>Shoulder internal rotation</td>
<td>64.4 (7.6)</td>
<td>70.6 (2.9)</td>
<td>0.000</td>
</tr>
<tr>
<td>Shoulder external rotation</td>
<td>84.2 (6.6)</td>
<td>89.9 (3.1)</td>
<td>0.000</td>
</tr>
<tr>
<td>Elbow flexion</td>
<td>144.1 (4.5)</td>
<td>133.4 (5.3)</td>
<td>0.000</td>
</tr>
<tr>
<td>Forearm supination</td>
<td>78.3 (9.7)</td>
<td>84.3 (3.0)</td>
<td>0.000</td>
</tr>
<tr>
<td>Forearm pronation</td>
<td>78.8 (9.3)</td>
<td>84.3 (3.0)</td>
<td>0.000</td>
</tr>
<tr>
<td>Wrist flexion</td>
<td>85.8 (4.4)</td>
<td>89.7 (1.7)</td>
<td>0.000</td>
</tr>
<tr>
<td>Wrist extension</td>
<td>64.6 (5.3)</td>
<td>68.9 (4.8)</td>
<td>0.01</td>
</tr>
<tr>
<td>Wrist ulnar deviation</td>
<td>27.6 (3.2)</td>
<td>29.2 (6.9)</td>
<td>0.009</td>
</tr>
<tr>
<td>Wrist radial deviation</td>
<td>18.8 (1.3)</td>
<td>20.0 (0.0)</td>
<td>0.006</td>
</tr>
</tbody>
</table>

Values are given as mean (SD). Significant p values are shown in bold.
The distal latencies (motor and sensory) of the radial nerve in the tennis players were significantly prolonged compared with control subjects (p<0.05) (table 4).

Latencies of the ulnar sensory nerve potential were considerably greater and conduction velocities were smaller in the tennis players’ dominant arms compared with the controls (p<0.05) (table 5).

Although reaching statistical significance between the groups, nerve conduction values within the tennis playing population fell within the normal range.

**DISCUSSION**

Retrospective studies indicate that muscles, tendons, bones, and nerves tend to adapt in response to high training loads. However, these particular adaptations are not beneficial to performance and may be associated with increased injury risk. Several authors have discussed the effect of regular and intense practice of an asymmetric sport, such as tennis, on performance and may be associated with increased injury risk. Several authors have discussed the effect of regular and intense practice of an asymmetric sport, such as tennis, on performance and may be associated with increased injury risk. Several authors have discussed the effect of regular and intense practice of an asymmetric sport, such as tennis, on performance and may be associated with increased injury risk. Several authors have discussed the effect of regular and intense practice of an asymmetric sport, such as tennis, on performance and may be associated with increased injury risk. Several authors have discussed the effect of regular and intense practice of an asymmetric sport, such as tennis, on performance and may be associated with increased injury risk. Several authors have discussed the effect of regular and intense practice of an asymmetric sport, such as tennis, on performance and may be associated with increased injury risk. Several authors have discussed the effect of regular and intense practice of an asymmetric sport, such as tennis, on performance and may be associated with increased injury risk.

In this study, ulnar nerve conduction velocity and amplitude were significantly higher in the tennis players’ dominant arms compared to the non-dominant arms and controls. These findings support previous studies that have shown increased muscle strength and size in tennis players compared to non-tennis players.

Physical exercise causes hypertrophy in the muscles involved. The perimeters of the arm and forearm were principally influenced by muscle hypertrophy in this study. A very marked hypertrophy was measured in all the tennis players in the dominant forearm and arm. We were surprised to find a significant range of motion decrease in elbow flexion in tennis players and suggest that hypertrophy of the elbow flexors was the possible reason. In the tennis players, the range of motion of other upper extremity joints was clearly increased in the dominant limb.

Nerve entrapment syndromes can occur in athletes. Many neurological injuries remain subclinical and are not recognised before neurological damage is permanent. Our results demonstrated that the sensory and motor conduction velocities of the radial nerve were significantly delayed in the dominant arms of tennis players compared with their non-dominant arms and with control subjects. We suggest that repetitive motion and overload of wrist extensors and the supinator muscle are major etiological factors in the delayed radial nerve motor and sensory conduction velocity. Forceful repetitive movements may cause stretching or impingement of the radial nerve within unyielding musculotendinous compartments followed by fascial thickening.

From an anatomical point of view, the inseparable origin of the wrist extensors and supinator muscle seems to link tennis elbow with radial tunnel syndrome. Compression of the deep branch of the radial nerve during its passage through Frohse’s arcade in the supinator muscle is one of the classical explanations advanced for epicondylalgia.9–10

Rath et al defined the anatomy of the deep branch of the radial nerve and indicated that it is most affected during its passage through the supinator muscle because of the marked fibrous thickening of the perineurium and the interstitial connective tissue. They found that the nerve is also closely related to the radial head around which it winds in supination and extension. Safran indicated that radial nerve entrapment is aggravated by active supination and passive pronation as well as by resisted extension of the long finger while the elbow is extended depending on the site of entrapment.10–12

Studies show that wrist extensors are highly involved in all strokes in tennis.13–14 In our opinion if the extensor group and supinator muscle are at near maximum contraction, stiffness and overload of the muscles can cause repeated microtrauma to the radial nerve during its course. Repetitive motion and overuse of the upper extremity make the tennis player vulnerable to radial nerve disorders.

Spontaneous entrapment of the superficial radial nerve in the forearm in the region where the nerve passes to a subcutaneous position has occasionally been reported. In 15 of the tennis players, the radial sensory and motor conduction velocities were slower than in the control subject in this study. These results show that competitive tennis players have a tendency to radial nerve damage although they were asymptomatic. We think that dynamic pressure on the radial nerve causes microtrauma, leading to repetitive entrapment of the superficial radial nerve, which is why it is more common in tennis players.15
nerve is the result of delayed motor and sensory nerve conduction velocity.

The elbow is also the most common site for ulnar nerve compression. Potential compressive sites include the arcade or ligament of Struthers, the medial intermuscular septum, the cubital tunnel, and the medial head of the triceps. Normally, the ulnar nerve is subjected to stretch and compression forces that are moderated by its ability to glide in its anatomic path around the elbow. When normal excursion is restricted, irritation ensues. This results in a cycle of perineural scarring, further loss of excursion, and progressive nerve damage. The peripheral location of the motor and the sensory fibres may explain the usual clinical presentation in cases of early compression.15–18

In this study, we found that the sensory conduction velocity of the ulnar nerve was significantly delayed in the tennis players’ dominant arms. In the tennis players the elbow is subjected to valgus stresses during the throwing motion which cause increased force to the medial elbow. We suggest that the valgus extension overload leads to possible subclinical pathologies in the ulnar nerve.

Another factor leading to dynamic compression of the ulnar nerve is elbow flexion. In clinical studies, increased cubital tunnel pressures with elbow flexion have been reported. The decrease in canal volume with elbow flexion is consistent with findings of increased intraneurial and extraneural pressures within the canal. On flexing the elbow, ulnar nerve traction and excursion occurs because the course of the nerve is behind the axis of rotation of the elbow (nerve compression in this region explains why so many patients with ulnar nerve lesions at the elbow have no abnormality of the joint itself and no history of injury). Excursion of the nerve at the elbow is further increased when the shoulder is placed in abduction and the wrist in extension. These traction forces on the ulnar nerve are increased in situations where there are valgus forces, as in throwing.19–21 We propose that because of the superficial location of the ulnar nerve, excursion of the nerve at the elbow with repetitive motion, abnormal elbow mechanics, and overuse of the triceps muscle in playing tennis may initiate the injury. Sensory fibres may be affected earlier than motor fibres so sensory conduction studies using ulnar neuropathy might be more useful than motor studies in early diagnosis. The high prevalence of decreased ulnar nerve conduction without corresponding symptoms may suggest subclinical entrapment neuropathy.

In this study we did not find statistical differences in conduction velocities of the median motor and sensory nerves between tennis players and control subjects in either dominant or non-dominant arms, because the median nerve is not in a vulnerable position as it lies through the cubital fossa and is not easily damaged in the elbow region. Entrapment of the median nerve in the proximal forearm is considered a rather rare condition. Median nerve entrapment may occur at the distal humerus when the rarely present ligament of Struthers connects an anomalous bony spur of the humeral shaft to its medial epicondyle.22 Our study showed that the median nerve has no predisposition to nerve entrapment in the elbow region during a game of tennis.

Several authors have performed nerve conduction studies on patients with tennis elbow. We could find no studies in the literature suggesting electrodiagnostic abnormalities in asymptomatic tennis players. This study is the first reported observation of delayed motor and sensory conduction velocity of the radial nerve and sensory conduction velocity of the ulnar nerve in competitive tennis players’ dominant arms compared with control subjects. The structural and functional changes may have a crucial effect on the radial and ulnar nerves in this study. Large numbers of neurological injuries remain subclinical and are not identified before damage is irreversible. However, the clinician can rehabilitate the patient, plan a preventive conditioning program, and modify biomechanics scientifically.

**Take home message**

Many neurological injuries remain subclinical and are not identified before damage is irreversible. However, the clinician can rehabilitate the patient, plan a preventive conditioning program, and modify biomechanics scientifically.

**Authors’ affiliations**

B Bamac¸, T C¸olak, Y S Bamac¸, A Özbek, Department of Anatomy, Kocaeli University, Kocaeli, Turkey

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**REFERENCES**


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