Gaziantep Tıp Derg 2011;17(2): 51-56
Gaziantep Med J 2011;17(2): 51-56

Gaziantep Tıp Dergisi
Gaziantep Medical Journal

Araştırma Makalesi
Research Article

The study of electrophysiological changes in nerve conduction of upper extremities in female volleyball players*

Bayan voleybolcuların üst ekstremite sinirleri iletilerindeki elektrofizyolojik değişiklikler*

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Abstract
This study was conducted to see the influence of the upper extremity movements on the electrophysiological changes on nerve conduction of upper extremities in female volleyball players. Twenty female volleyball players and 20 healthy females, not doing sports, were included in this study. All participants were healthy and right-handed. Bilateral median, ulnar, and radial nerves conduction studies were carried out and statistically evaluated. In volleyball players, right median motor distal latency (MDL) and F wave latency (FWL) were found to be faster ($p<0.05$ and $p<0.001$ respectively); and motor conduction velocity (MCV) was slower ($p<0.01$). In volleyball players, the right median 1st finger sensory conduction velocity (SCV) was found to be slower ($p<0.05$). The right ulnar MDL and FDL were found to be faster ($p<0.001$); and the elbow region MCV was to be slower ($p<0.05$). The right radial SCV of volleyball players were slower ($p<0.05$). In volleyball players, the left median MDL and FWL were faster ($p<0.05$ and $p<0.001$ respectively), and MCV were slower ($p<0.01$). The left ulnar MDL and FDL were found to be faster ($p<0.05$ and $p<0.01$ respectively). The study revealed that the right median and ulnar nerve MCV, SCV, FWL and radial sensory conductions as well as the left median and ulnar MDL and FWL were affected in volleyball players. These results reveal that volleyball can affect nerve conduction velocities especially in the dominant arms.
Keywords: Electrophysiology; nerve conduction; volleyball

Özet
Bu çalışma, üst ekstremite hareketlerinin bayan voleybol oyuncularında sebep olduğu üst ekstremitelerdeki elektrofizyolojik değişiklikleri araştırmak amacıyla yapıldı. Çalışmaya 20 bayan voleybolcu ile spor yapmayan 20 bayan alındı. İki grubun hepsi sağlıklı ve sağ ellerini kullanıyorlardı. Bilateral median, ulnar ve radial sinir ileti incelemeleri yapılarak, istatistiksel olarak karşılaştırıldı. Voleybolcularda, sağ median motor distal latans (MDL) ($p<0.05$) ve F dalgası latansı (FDL) uzun ($p<0.001$) bulundu. Sağ median motor ileti hızı (MİH) ($p<0.01$) ve 1.parmak duysal ileti hızı (DİH) yavaş bulundu ($p<0.05$). Sağ ulnar MDL ($p<0.001$) ve FDL'ları uzun ($p<0.001$) ve dirsek segmenti MİH ise yavaş bulundu ($p<0.05$). Sporcularda sağ radial sinirde sadece DİH yavaştı ($p<0.05$). Voleybolcuların sol median MDL ($p<0.05$) ve FDL uzun ($p<0.001$), MİH ise yavaş bulundu ($p<0.01$). Sol ulnar MDL ($p<0.05$) ve FDL uzun ($p<0.01$) bulundu. Çalışmamızda voleybolcularda sağ median ve ulnar sinir motor ve duysal ve radial sinir duysal iletileri ile sol median ve ulnar motor iletilerinin etkilendiğini gözlendi. Bu sonuçlar dominant kolda belirgin olmak üzere voleybolun sinir iletilerini etkileyebileceğini göstermektedir.
Anahtar Kelimeler: Elektrofizyoloji; sinir iletimi; voleybol

Introduction

Looking at movements specific to volleyball, the only two asymmetrical and powerful movements typical of the game are service and spike. Many studies confirm that these moves require dominant powerful and unidirectional motion. Various factors such as high repetition of motions, high muscular forces and extreme elbow positions affect the peripheral nervous system with or without signs and symptoms. This is one of the reasons to believe that many neurological injuries remain subclinical and are not recognized before neurological damage is permanent. High-velocity arm swinging, nerve stretch and stressful deceleration required during spiking and several different ball-striking activities are considered as the most common causes of the nerve injury (1).

Movements on the court and the skills used in playing are performed repetitively throughout the season. Overuse injuries are more common in competitive athletes who practice for years on sport-specific skills (1).

The purpose of this study was to evaluate the effect of volleyball on electrophysiological changes in nerve conduction velocity of the upper extremities in female volleyball players.

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**This study was presented as an oral presentation at the 24th National Clinical Neurophysiology EEG-EMG Congress between 16th and 20th May in 2007, Antalya/Turkey.*
**Bu çalışma 2007 Yılı 16-20 Mayıs tarihleri arasında Antalya'da gerçekleştirilen 24. Ulusal Klinik Nörofizyoloji EEG-EMG Kongresi nde bildiri olarak sunulmuştur.*

Received 10.12.2010 **Accepted:** 21.02.2011
Geliş Tarihi: 10.12.2010 **Kabul Tarihi:** 21.02.2011

DOI: 10.5455/GMJ-30-2011-25
www.gantep.edu.tr/~tipdergi
ISSN 1300-0888

Materials and methods

The volleyball group consisted of 20 female volleyball players (age 23.90 ± 3.0 years). They had been active in high-level volleyball for 8.5 (5-18) years. The control group consisted of 20 female (age 23.50 ± 2.9 years), not participating in any kind of regular or organized sport activity. Each participant was informed in detail way and directed during the tests. All subjects gave their written, informed consent. The study conforms to the Code of Ethics of the World Medical Association (Declaration of Helsinki).

The participants composing control and experiment groups were each healthy and right-handed. Participants with neuropathy, a trauma which affects the central or peripheral neurological system, Diabetes Mellitus and neck operation were not included in this study. All the recordings ENMG (Electro Neuro Myography) were tested by a neurologist proficient in electrophysiology using a Medtronic Keypoint Electromyography (Medtronic, Denmark) device. Examination room temperature was maintained at 26-28^{o}C. Participants were positioned sitting comfortably (2). The measurements were conducted at the same time of the day to reduce the possible diurnal variation.

Stimulations in nerve conduction studies were done by stable bipolar stimulating electrodes. Surface electrode has anodes and cathodes, 6 mm in diameter and it is placed in 20 mm distance from each other. In every test, ground electrode is placed between stimulating and recording electrodes. Surface disk electrodes were used to record motor and F responses and ring electrodes were used to record sensory recordings. In this study, the frequency filter was 20 Hz for low frequency and 10 KHz for high frequency. Motor stimulation duration was 0.2 msec, sensory and F wave stimulation duration was 0.1 msec. All stimulations were supramaximally 40-70 mA. The responses to supramaximal motor stimulations were taken individually. In sensory responses, average response of 3-10 responses values were used in the analysis.

In this study; upper extremity median, ulnar and radial nerves' motor and sensory conduction velocity, latency and amplitude values as well as median and ulnar F responses were recorded.

The median motor nerve was stimulated distally at the wrist, 7 cm proximally from the recording electrode at the medial wrist between the tendons to the flexor carpi radials and Palmaris longus, and proximally at anticubital fossa, over the brachial artery pulse. The recordings were done with an active recording electrode placed over the lateral thenar eminence of abductor pollicis brevis muscle, and with a reference electrode placed 2-3 cm distally from the recording electrode (3).

The ulnar was stimulated three times in order to find both forearm and elbow segments MCV. The first one was at the wrist, 7 cm from the reference electrode (adjacent to flexor carpi ulnaris tendon); the second one was below-elbow (3-4 cm distal to the medial epicondyle); and the third one was at the upper-elbow (over the medial humerus, between the biceps and triceps muscles, at a distance of 10 cm from the below-elbow site). The recordings were done over the lateral hypothenar eminence of abductor digiti minimi (ADM) muscle (3).

In the F wave study, an average of 7-10 F-responses was recorded. The median F-wave was stimulated at the wrist (in the middle of the wrist between the tendons to the flexor carpi radialis and palmaris longus) and recorded over the abductor pollisis brevis muscle. The ulnar F-wave was stimulated at the wrist (medial wrist, adjacent to the flexor carpi ulnaris tendon) and recorded over the abductor digiti minimi. In the F-wave evaluation the shortest latency responses were used (3). The radial motor nerve was stimulated on the forearm (over the ulna, 5-7 cm proximally to the active recording electrode), and proximal stimulation was given over the spiral groove (at lateral midarm, between biceps and triceps). Recordings were done with an active electrode placed over the extensor indicis proprius muscle, and with a reference electrode placed over 2-3 cm distally from the recording electrode (3). In median, ulnar and radial sensory nerves, the measurements were done antidromicaly. The median SCV was obtained by stimulating the median nerve at wrist. The median SVC of the thumb was measured with active electrode over the metacarpal phalangeal joint and reference electrode on the interphalangeal joint. The median SCV of the 2nd, 3rd and 4th fingers were recorded with an active electrode on the proximal interphalangeal joint and with a reference electrode on the distal interphalangeal joint of 2nd, 3rd and 4th phalanx, respectively (3).

The ulnar sensory responses were obtained by stimulating at the wrist and recording from the 4th and 5th fingers with an active surface ring electrode placed at the proximal interphalangeal joint and a reference surface ring electrode placed at the distal interphalengeal joint (3). Radial sensory responses were obtained stimulating over the distal mid radius and recording with an active surface disk electrode placed over the superficial radial nerve as it runs over the extensor tendons to the thumb and with a reference surface disk electrode placed 3-4 cm distally over the thumb (3).

All distances were measured with a same type of measure. Distances between distal and proximal stimulation points in motor conduction for radial and median nerves were measured. For ulnar motor conduction, the distance between 1st and 2nd stimulation points and the distance between 2nd and 3rd stimulation points were measured. These distance figures were entered into the data base of the device. For sensory conductions, the distance between the stimulation points and the recording electrode was measured and entered into the data base.

The ENMG device automatically calculated motor and sensory conduction velocities through dividing the distance by the difference of latency at both points. In the statistical analyses between volleyball and control groups, the SPSS 13.0 package program for personal computers was used to conduct a (Mann-Whitney U test).

Results

Of the participants in this study, the volleyball players' average age was 23.90 ± 3.00 years, average height was 174 ± 0.7 cm, average weight was 65.30 ± 7.22 kg; control groups' average age was 23.50 ± 2.92 years, average height was 174 ± 0.4 cm, average weight was 62.85 ± 4.32 kg (Table 1). There were not any statistically significant differences between volleyball players and the controls ($p>0.05$). The volleyball players' median MDL (the time that distal stimulation reaches to the recording electrode) ($p<0.05$) and FWL ($p<0.001$) were found to be faster and the MCV ($p<0.001$) was found to be slower.

Table 1. Comparison of physical characteristics of controls and volleyball players

	Controls (n=20)	Volleyball players (n=20)	P
Age (years)	23.50 ± 2.92	23.90 ± 3.00	0.66
Height (cm)	174 ± 0.4	174 ± 0.7	0.61
Weight (kg)	62.85 ± 4.32	65.30 ± 7.22	0.11

Values are given as mean ± SD

The right median 1st finger sensory SCV was found to be slower ($p<0.05$). The right median 2nd, 3rd and 4th; left median 1st-4th finger SCV were not different ($p>0.05$). The volleyball players' median motor amplitudes were higher but the difference was not statistically significant ($p>0.05$) (Table 2).

Table 2. Right and left arm median nerve values

Median nerve	**Right Arm**			**Left Arm**		
	Control (n=20)	Volleyball players (n=20)	P	Control (n=20)	Volleyball players (n=20)	P
MDL (ms)	3.58 ± 0.36	3.81 ± 0.33	**0.05**	3.66 ± 0.35	3.81 ± 0.33	**0.05**
MA (mV)	17.26 ± 4.11	18.88 ± 4.08	0.32	18.42 ± 4.25	18.88 ± 4.08	0.32
MCV (m/s)	62.70 ± 4.64	58.83 ± 4.06	**0.01**	60.31 ± 7.29	58.83 ± 4.06	**0.01**
FWL (ms)	23.14 ± 1.95	24.88 ± 1.61	**0.00**	23.20 ± 1.74	24.88 ± 1.61	**0.00**
Fn 1 SA (µV)	43.40 ± 14.45	40.00 ± 13.76	0.31	43.05 ± 12.08	43.80 ± 17.91	0.78
Fn1 SCV (m/s)	60.73 ± 5.63	57.70 ± 3.86	**0.05**	57.55 ± 6.06	56.81 ± 4.41	0.63
Fn 2 SA (µV)	33.65 ± 12.00	29.75 ± 14.84	0.17	36.25 ± 9.95	33.85 ± 13.09	0.54
Fn 2 SCV (m/s)	62.71 ± 4.08	62.01 ± 4.73	0.73	61.73 ± 4.41	61.20 ± 4.23	0.76
Fn 3 SA (µV)	37.15 ± 8.06	38.65 ± 17.89	0.65	41.65 ± 13.25	48.55 ± 19.35	0.35
Fn 3 SCV (m/s)	62.88 ± 4.48	60.77 ± 5.63	0.08	60.04 ± 3.98	60.31 ± 4.00	0.76
Fn 4 SA (µV)	23.60 ± 5.92	20.08 ± 8.78	0.10	22.45 ± 8.43	20.47 ± 9.71	0.36
Fn 4 SCV (m/s)	62.45 ± 3.87	60.20 ± 4.39	0.08	59.68 ± 4.90	57.77 ± 4.33	0.24

Fn: Finger, FWL: F wave latency, MDL: Motor distal latency, MA: Motor amplitude, MCV: Motor conduction velocity, SA: Sensory amplitude, SCV: Sensory conduction velocity.

The volleyball players' right ulnar MDL (p<0.001) and FWL (p<0.001) was found to be faster and the elbow region MCV (p<0.05) was found to be slower. The left ulnar MDL (p<0.05) and FWL p<0.01) was found to be faster. The bilateral ulnar forearm and left elbow motor conduction values of the two groups did not show a significant difference (p>0.05). The ulnar motor amplitudes of volleyball players' were higher but not significantly different (p>0.05) (Table 3).

Table 3. Right and left arm ulnar nerve values

Ulnar nerve	**Right Arm** Control (n=20)	Volleyball players (n=20)	P	**Left Arm** Control (n=20)	Volleyball players (n=20)	P
MDL (ms)	2.75 ± 0.51	3.08 ± 0.24	**0.00**	2.77 ± 0.46	3.13 ± 0.39	**0.02**
MA (mV)	16.64 ± 3.01	17.27 ± 2.17	0.35	16.37 ± 2.87	17.87 ± 2.51	0.09
MCV 1 (m/s) (forearm)	61.95 ± 7.23	60.35 ± 8.69	0.38	59.75 ± 3.75	59.05 ± 6.39	0.44
MCV 2 (m/s) (elbow segment)	68.95 ± 11.28	61.26 ± 10.10	**0.04**	70.63 ± 9.72	66.27 ± 12.37	0.19
FWL (ms)	23.63 ± 1.86	25.76 ± 1.94	**0.00**	23.46 ± 1.42	25.06 ± 2.04	**0.01**
Fn 4 SA (µV)	32.95 ± 11.97	34.78 ± 17.83	0.91	34.90 ± 10.58	40.60 ± 31.98	0.85
Fn 4 SCV (m/s)	61.05 ± 4.76	58.710 ± 5.21	0.14	59.45 ± 4.70	56.52 ± 4.16	0.10
Fn 5 SA (µV)	25.85 ± 7.48	23.73 ± 11.90	0.14	28.85 ± 8.89	31.00 ± 15.96	0.93
Fn 5 SCV (m/s)	65.13 ± 5.95	61.59 ± 5.64	0.06	61.94 ± 5.21	61.70 ± 5.15	0.85

Fn: Finger, FWL: F wave latency, MDL: Motor distal latency, MA: Motor amplitude, MCV 1: Forearm motor conduction velocity MCV 2: Elbow segment motor conduction velocity, SA: Sensory amplitude, SCV: Sensory conduction velocity.

Table 4. Right and left arm radial nerve values

Radial nerve	**Right Arm** Control (n=20)	Volleyball players (n=20)	P	**Left Arm** Control (n=20)	Volleyball players (n=20)	P
MDL (ms)	2.64 ± 0.40	2.87 ± 0.48	0.06	2.44 ± 0.37	2.65 ± 0.59	0.30
MA (mV)	13.11 ± 2.11	13.81 ± 2.90	0.30	12.20 ± 2.43	13.78 ± 2.89	0.08
MCV (m/s)	63.49 ± 8.02	62.55 ± 9.10	0.39	60.36 ± 8.29	63.14 ± 9.72	0.43
SA (µV)	38.10 ± 14.55	39.00 ± 14.21	0.74	39.55 ± 9.57	38.30 ± 10.47	0.73
SCV (m/s)	67.41 ± 5.08	63.45 ± 6.05	**0.02**	67.73 ± 5.72	65.49 ± 7.28	0.12

MDL: Motor distal latency, MA: Motor amplitude, MCV: Motor conduction velocity, SA: Sensory amplitude, SCV: Sensory conduction velocity.

There was no significant difference between the two groups' bilateral radial motor conduction values ($p>0.05$). The volleyball players' right SCV was slower ($p<0.05$). There was no difference in left radial nerve conduction velocity values. The radial motor amplitudes of the volleyball players' were higher but not significantly different ($p>0.05$) (Table 4).

Discussion

Because of the intensity of the sporting activities and the biomechanics involved, the athlete tends to develop ulnar nerve irritation from mechanical sources; compression, traction, friction (1). Lesions of the ulnar nerve occur most commonly in the region of the elbow joint as the nerve runs in the groove behind the medial epicondyle and descends into the cubital tunnel. In the same way, many studies demonstrate that in volleyball players, after sudden and serious traumas, lesions of nerves in the upper extremities occur (1).

Specific positions of the upper extremity can lead to an increased strain in the ulnar nerve. In previous studies, increased cubital tunnel pressures with elbow fractions have been reported. The excursion of the nerve at the elbow is further increased when the shoulder is placed in abduction, and the wrist and the fingers in extension (1). Kinetic research has shown excessive valgus imparted to the medial elbow during late cocking and acceleration phases of throwing. Volleyball can repetitively stress the elbow and shoulder because of repetitive overhead throwing. Continued valgus and extension forces and subtle laxity may also cause excessive medial soft-tissue stretch, resulting in traction injury to the ulnar nerve and eventually a pathologic condition, ulnar neuropathy (1). Özbek et al studied to determine whether asymptomatic physically active volleyball players and non-actives demonstrate distinct differences in nerve conduction of the ulnar nerve at the elbow. They compared volleyball players to a control group and found that nerve conduction velocity at the elbow segment of the ulnar motor nerve was slower in the volleyball players than in non-active control group participants (1). In our study, we also observed a considerable decrease in volleyball players' elbow segment conduction velocity when compared to the control group.

Meriç found a significant difference between Physical Education students (volleyball-basketball-handball) and a non-active control group. His findings suggested that the upper extremity F response averages of students were slower than that of the control group's (4). His findings were similar to ours in this study. Bromberg et al identified differences between right and left arm median and ulnar nerve conduction velocities when they compared the results of bilateral motor and sensory nerve conduction velocity studies (5).

In our study, when we look at right arm elbow segment ulnar and median nerves measurement values, we found out that ulnar and medial nerve latency were significantly faster in volleyball players than in the controls. When median nerve conduction velocities were compared, it was observed that there was a significant decrease in volleyball players' velocity. However, it was observed that there was no statistical difference in the ulnar motor nerve conduction velocity in the forearm. The reason could be that there is more demyelization at the elbow than in the forearm.

We observed that there was a statistically significant decrease in the volleyball players' right arm radial sensory nerve and their 1st finger median sensory nerve conduction velocities when compared to the non-active controls. The reason for this could be the over- repeated flexion and extension of the wrists while serving and spiking. Previous studies reported that findings in the volleyball players' could have been a result of demyelization rather that axonal degeneration (1). Delayed conduction velocity of motor and sensory nerves and delayed latency and F responses indicate demyelization (6). This process can occur in short-term mechanical force or ischemia. The researches stated that this is due to repetitive overhead arm movement (1).

Conduction velocity in demyelization should be 60-70% lower than normal and amplitude should be 70-80% lower than normal in axonal degeneration. In our study, it was found that velocities and latencies were affected. Although the fact that velocities were affected is not a satisfying result for demyelization, as the amplitudes were not affected we are in the belief that it could be interpreted as mild demyelization.

While the nerve conduction was effected, there were not any clinical symptoms in volleyball players in our study. In this study, volleyball players with no clinical symptoms or minor neuropathy may not show clinical symptoms and they cannot be diagnosed before they become permanent disorders. Understanding degeneration and demyelization mechanisms as well as risk factors is important for training and rehabilitation in volleyball (1).

The findings of the study revealed clearly that nerves particularly in the dominant upper extremities in volleyball players were affected more than those of the control group. This case is interpreted as a sign of asymptomatic neuropathy. The results also were interpreted as volleyball players are likely to have asymptomatic ulnar and median neuropathy.

In order to reveal the relationship between over repeated upper extremity drills and asymptomatic ulnar neuropathies clearly, conduction studies can be done with a larger group of volleyball players, and/or non-active volleyball players after some time, by grouping them according to their active volleyball experience in years or according to the time they stopped playing. Therefore, we believe that the effect of time and whether the differences are transitory will be made known. The results of this study must be interpreted carefully. The small sample size along with the possibility that small differences in where the electrodes are placed, the temperature, and the distance measurements might result in small changes that limit the possibility of drawing definite conclusions.

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