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Field hockey players have different values of ulnar and tibial motor nerve conduction velocity than soccer and tennis players

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ABSTRACT

The aim of this study was to describe motor nerve conduction velocity in upper and lower extremities in sportsmen. Fifteen high-level field hockey players, seventeen soccer players and ten tennis players were recruited from the Polish National Field Hockey League, Polish Soccer League Clubs, and Polish Tennis Association clubs, respectively. The control group comprised of seventeen healthy, non-active young men. Nerve conduction velocities of ulnar and tibial nerve were assessed with NeuroScreen electromyograph (Toennies, Germany) equipped with standard techniques of supramaximal percutaneus stimulation with constant current and surface electrodes. No significant differences in motor nerve conduction velocities were found between dominant and non-dominant limbs in each studied group. Ulnar nerve conduction velocity measured from above elbow to below elbow was significantly lower only in the field hockey players' dominant limb. Tibial conduction velocity of the field hockey players' non-dominant lower limb was higher in comparison to the tennis players and the control group. There was no significant correlation between body mass and NCV as well as between height of subjects and NCV in both athletes or non-athletes. A slight trend towards a lower TCV values in athletes with longer duration of practicing sport was found. It was most pronounced in the non-dominant lower extremity of field hockey players.

Key words
Nerve conduction • Ulnar and tibial nerve • Field hockey players • Soccer players • Tennis players

Introduction

The determination of nerve conduction velocity is a useful method to describe the status of the peripheral innervation (Kimura, 1984) as well as to diagnose pathophysiological changes including polyneuropathy and neuropathies associated with diabetes, myopathy or carpal tunnel syndrome (Warmolts, 1981; Chang, 2009). Moreover, nerve conduction velocity was often determined to evaluate nerve compression, entrapment syndromes and other injuries in sportsmen (Feinberg, 1997). Nerve conduction studies were also used to assess neuromuscular differences among athletes trained for various athletic endeavors (Kamen, 1984; Sleivert et al., 1995a) indicating diversity of motor nerve conduction velocity among them: faster ulnar and tibial nerve conduction velocity in weight lifters and slower in marathoners compared with jumpers, sprinters and swimmers. Such effects in motor nerve conduction velocity among sports were discussed as a result of both, heredity and environmental factors (Kamen, 1984). The intensive training of sportsmen, including exercises lasting a number of hours daily throughout several years,

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can alone enhance the risk of different, sometimes slowly developing, pathophysiological changes or injuries (Lodhia et al., 2005; Topp and Boyd, 2006). It is known, that vibration, mechanical pressure and other physical factors persistently affecting the surrounding tissue lead to vasoconstriction, development of inflammatory processes or occurrence of diverse microlesions, which can modulate structural or functional changes in afferent and efferent nerves or nerve fibers (Färkkilä and Pyykkö, 1979). Probably, also in sports performance, we cannot rule out that such factors influence the electrophysiological properties of peripheral nervous system (Kleinrensink et al., 1994; Patten, 1995; Dekker et al., 2000; Izzi et al., 2001; Murphy et al., 2003). Several authors even suggested a need for measure conduction velocity of nerves within specific sports to establish a number of additional, specific reference values, which can be helpful during diagnosis of sports injuries (Çolak et al., 2004; Wei et al., 2005; Özbek et al., 2006). Therefore, the aim of this study was to characterize the motor nerve conduction velocity in upper and lower extremities in elite players of certain types of sports.

Methods

Subjects

Sportsmen were recruited in response to information submitted to 1st and 2nd Polish National Field Hockey League, 2nd and 3rd Soccer League Clubs, and Polish Tennis Association clubs in the Wielkopolska region in Poland. The participants admitted to the control group were recruited in response to information announced to the students from the Universities of Poznan, Poland. The study was approved by the local institutional review board and was conducted according to the Helsinki declaration. All participants read and signed an informed consent form before the study. Tested persons involved in the study had to be healthy men aged between 20 and 30 years old. Exclusion criteria were history or symptoms of any neurological or metabolic pathology, especially central neurological deficits, cerebral concussions, vestibular disorders, peripheral neuropathy, diabetes, vascular pathology or other disorders. None of men tested had any injuries of any extremity in the last six months before the study or used any medication.

Experimental procedures

Participants divided into small groups consisted of 4 to 5 persons were investigated one time during 14 days according to their study or training plan. The examination always started at 8 a.m. First of all, each participant filled up a questionnaire concerning all past injuries that have occurred since the beginning of sport activity, duration and frequency of training, and kind of activities. Next, several biometric measurements, including weight, height of participants, length and circumference of upper and lower extremities, were performed. Additionally, in order to determine hand preference the ‘Edinburgh Handedness Inventory’ was used, while lower limb preference was assessed with simple ball kick, a step test, and balance recovery test (Oldfield, 1971; Hoffman et al., 1998). All of above-mentioned measurements were always administrated by one of the investigators.

The neurophysiological measurements were performed in a separate, warm (25°C) and quiet room by the second investigator, who was blinded, to participants’ group assignment. Participants were in a sitting position, with the forearm flexed at 120° (for the ulnar nerve) and in supine position, for the tibial nerve. The skin temperature of each person tested was checked in order to maintain a temperature of 32°C or greater to avoid the influence of temperature on conduction velocity. Nerve conduction velocity measurements were performed using NeuroScreen electromyograph (Toennies, Germany) equipped with standard techniques of supramaximal percutaneus stimulation. The surface brass gold-plated stimulating electrodes (diameter 5 mm) and gold cup recording electrodes (diameter 11 mm) were used in order to evoke and record action potentials. The compound muscle action potentials (CMAPs) were evoked by the electrical stimulation (0.1 ms duration constant current square wave pulses) of ulnar and tibial nerve starting with minimal and progressing to supramaximal intensity of the stimuli.

The ulnar CMAPs were evoked, as shown in Fig. 1A, from the abductor digiti minimi (ADM) muscle after electrical stimulation at the wrist (S_1), below elbow, 5 cm below the medial epicondyle (S_2) and above elbow, 6 cm above the medial epicondyle (S_3). The recording electrodes were placed and taped over ADM muscle on the ulnar side of the hand between the fifth metacarpophalangeal joint and the pisiform

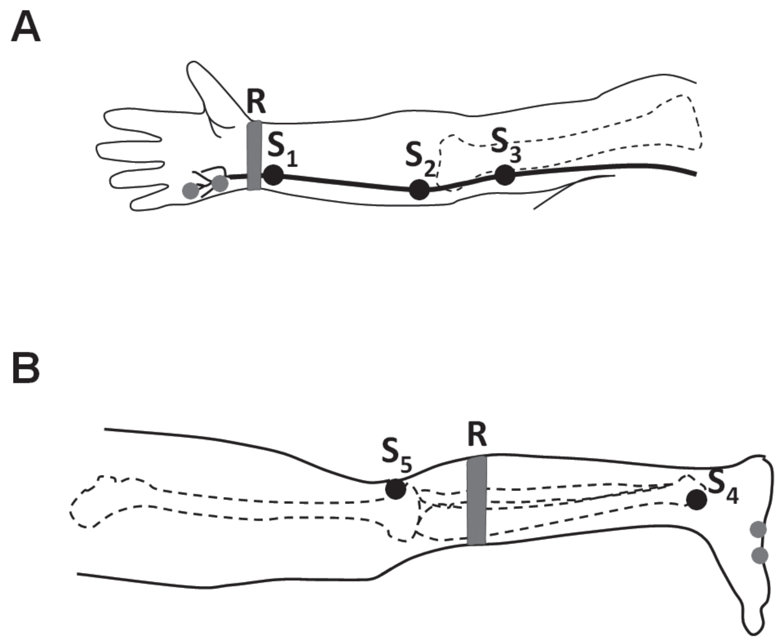

Fig. 1. - Localization of stimulating (black circles) and recording (grey circles) electrodes used during measurements of ulnar (A) and tibial nerve (B) conduction velocities. R = ground.

bone and the distance from center to center was about 3 cm. The placement of electrodes was then double-checked for accuracy by the first examiner.

The tibial motor nerve conduction velocity (TCV) was determined with the same equipment and procedures as previously described. In this case, the active recording electrode (cathode) was placed over the abductor hallucis (AH), approximately 1 cm distal and inferior to the navicular tuberosity and the reference electrode (anode) was positioned 3 cm distal to the recording electrode (Fig. 1B). Stimulation of the tibial nerve was performed distal at the ankle posterior to the medial malleolus (S_4) and proximal in the popliteal fossa (S_5).

Data analysis

The electromyographic (EMG) data achieved from ADM and AH muscles during the ulnar and tibial nerve stimulation were stored on a computer disk and analysed off-line using NeuroScreen software (Toennies, Germany). The motor nerve conduction velocities (MNCV) were determined as a quotient of distance (cm) and latency (ms) of ulnar or tibial nerves in dominant and non-dominant limbs. The latencies of the compound muscle action potential (M wave) at the S_1, S_2, and S_3 stimulation sites were noted from the negative initiation of the evoked response and described as T_1, T_2 and T_3, respectively. Next, appropriate distances were measured from each stimulation point to the active recording electrode to calculate the UCV (S_1-S_3/T_3-T_1), (S_1-S_2/T_2-T_1) or (S_2-S_3/T_3-T_2). For the tibial nerve, the latencies were described as T_4 and T_5 for S_4 and S_5 stimulation points, respectively. TCV was calculated as a quotient: S_4-S_5/T_5-T_4. Additionally, amplitudes were calculated as the height of the evoked responses from baseline to negative peak of CMAPs and expressed in mV.

Results were presented as mean ± standard deviation (SD). Shapiro-Wilk's W test was applied to examine normality in the distribution of data. To describe differences between groups and measurements within upper extremity, the one-way analysis of variance (ANOVA for equal variances and Kruskal-Wallis ANOVA for unequal variances) with Scheffe´ post hoc test (in case of equal variances) were performed. The differences between dominant and non-dominant extremities were assessed with Student's t-test for normally-distributed and Mann-Whitney U test for non normally-distributed values. Additionally, a paired Student's t-test for normal distribution and Wilcoxon signed-rank test for non-normal distribution of values were used in order to describe differences between two measurements within lower extremity.

Correlations were assessed by a Pearson's correlation coefficient or a non-parametric Spearman's rank correlation coefficient. The statistical analysis was performed with Statistica 8.0 software.

Results

Fifteen high-level field hockey players, seventeen soccer players and ten tennis players were investigated. The duration and frequency of their trainings amounted to 2 hours daily, 6 times per week; 2 hours daily, 4 times per week; and 2-3 hours daily, 7-10 trainings per week, respectively. The control group comprised seventeen healthy non-active men at the same age with no history of participating in any kind of regular sport activity (Table I).

Biometric measurements

Both, the sportsmen and non-trained men formed a very homogenous population without significant differences in age, height, weight or body mass index (BMI) between tested groups (Table I). On the other hand, the soccer players were practicing sport 23% and 29% shorter in comparison to the field hockey players and tennis players, respectively. Additionally, dominant and non-dominant lower limb lengths in the soccer players were shorter ($p < 0.05$) when compared to the control group (Table I).

Nerve conduction velocity

In all men tested there were no significant differences in motor nerve conduction velocities between dominant and non dominant extremities. The fastest ulnar nerve conduction velocities were found in the tennis players and were most pronounced at the proximal segment of upper extremities. There were no differences in UCV between the analyzed groups in S_1-S_3 and S_1-S_2 segments (Fig. 2A and C). UCV measured from above elbow (S_3) to below elbow (S_2) (49.0 ± 6.7 m/s) was significantly lower only in the hockey players' dominant extremities, when compared to the soccer players (56.9 ± 6.3 m/s) and the control group (57.7 ± 9.9 m/s) (Fig. 2B).

Table I. - Comparison of the biometric data of athletes and non-athletic subjects.

Variable		Control	F. Hockey	Soccer	Tennis	ANOVA *p*
Age (yrs)		21.3 ± 1.5	21.7 ± 2.1	20.8 ± 0.7	21.5 ± 1.9	0.271
Height (cm)		182.6 ± 6.5	179.9 ± 5.9	178.9 ± 5.5	181.9 ± 7.0	0.322
Weight (kg)		80.8 ± 6.8	75.0 ± 7.8	75.8 ± 6.7	79.4 ± 9.1	0.010
BMI (m^2/kg)		24.2 ± 2.1	23.2 ± 1.9	23.7 ± 1.7	24.0 ± 2.1	0.420
U. limb length (cm)	D	78.2 ± 3.6	76.1 ± 2.6	77.1 ± 3.7	78.6 ± 2.5	0.227
	ND	78.1 ± 3.4	77.2 ± 3.4	76.6 ± 3.4	77.8 ± 2.8	0.746
p		1.000	0.420	0.686	0.175	
Mid-arm perimeter (cm)	D	31.4 ± 2.7	30.3 ± 2.1	30.1 ± 1.9	31.6 ± 2.8	0.239
	ND	30.9 ± 2.8	30.1 ± 2.2	29.7 ± 2.0	31.0 ± 2.9	0.466
p		0.624	0.882	0.605	0.634	
L. limb length (cm)	D	96.1 ± 4.7	92.0 ± 5.0	91.2 ± 4.0*	95.3 ± 5.3	**0.021**
	ND	96.6 ± 4.6	92.2 ± 5.1	91.7 ± 4.4*	95.1 ± 5.1	**0.016**
p		0.924	0.900	0.792	0.921	
Calf perimeter (cm)	D	37.9 ± 2.0	36.7 ± 2.1	38.5 ± 1.9	37.5 ± 2.0	0.088
	ND	38.5 ± 2.2	37.1 ± 2.2	38.5 ± 1.9	37.8 ± 2.4	0.138
p		0.210	0.570	1.000	0.743	
Duration of practicing sport (yrs)			11.3 ± 2.0	8.7 ± 2.1†‡	12.3 ± 3.0	0.001

Values are given as mean ± SD. D = dominant extremity; ND = non-dominant extremity. ANOVA *p* indicates probability of one-way ANOVA for equal variances and Kruskal-Wallis ANOVA for unequal variances. p indicates probability of Student's t-test for normally-distributed and Mann-Whitney U test for non normally-distributed values. Significant p values are shown in bold.
* $p < 0.05$ in comparison to the control group (post hoc tests).
† $p < 0.01$ in comparison to the field hockey players (post hoc tests).
‡ $p < 0.01$ in comparison to the tennis players (post hoc tests).

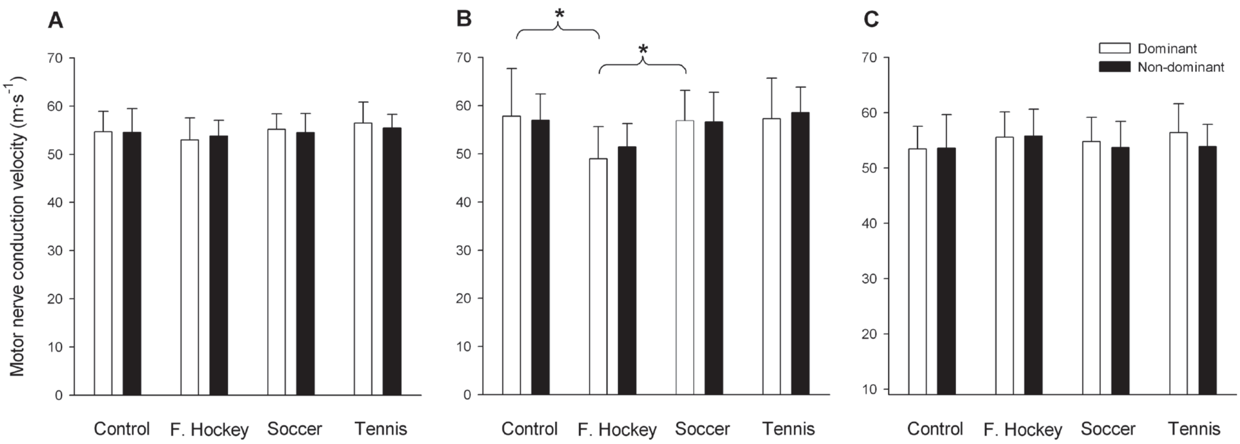

Fig. 2. - The mean values of ulnar motor nerve conduction velocities measured from above elbow to wrist (A), from above elbow to elbow (B), and from elbow to wrist (C). The asterisks above the bars denote significant differences between groups: * $p < 0.05$, ANOVA post hoc test.

Table II summarizes mean values of TCV and indicates significant differences between the groups. It was found that TCV of the field hockey players' non-dominant lower extremity was 12.2% and 9,6% higher in comparison to the tennis players and the control group, respectively. Furthermore, TCV in the dominant extremity was 6.9% higher than that found in the tennis players group.

Amplitudes measured in all 59 persons tested showed significant differences between sportsmen only in relation to the upper limb. The maximal amplitudes of motor fibers of the ulnar nerve in the dominant arm of the tennis players, measured above the elbow (S_3) and at the wrist (S_1), were lower than the amplitudes found in the non-dominant limb (Table III). Moreover, these values were lower in the tennis players at all stimulation points in comparison to the control group, and at S_3 point when compared to the soccer players. Interestingly, amplitudes noted at stimulation point S_3 in the field hockey players' dominant extremities were lower than in the control group. There were no differences between amplitudes recorded at different locations along the nerve in both dominant and non-dominant upper extremities among particular groups studied. On the other hand, we observed lower amplitudes evoked at ankle than those obtained from popliteal fossa among all athletic groups as well as in the control group (Table III).

Correlations

The correlation analysis of data was performed to assess the relationships between motor nerve conduction velocity and biometric variables as well as duration of practicing sport. There was no significant correlation between body mass and MNCV in both athletes and non-athletes (Table IV). Furthermore, no significant correlation between height of persons tested and MNCV apart from TCV and height of soccer players was observed although, in most cases a slight trend towards a lower MNCV values in higher athletes was found (Fig. 3). Additionally, there was no clear relationship between the length or circumference of extremities and nerve conduction velocities among groups studied (Table IV). Only in soccer players there was a significant positive correlation between UCV and dominant upper extremity length and, additionally, a significant negative correlation between TCV and both dominant and non-dominant lower extremity length. Interestingly, UCV was positively correlated with dominant as well as non-dominant arm circumference in the control group (Table IV). Finally, we analyzed the relationships between UCV and TCV velocities and the duration of practicing sport (Fig. 4), in that case only a slight trend towards a lower TCV values in athletes with longer duration of practicing sport. It was found among all athletic groups studied and it was most pronounced in the non-dominant lower extremity of field hockey players. Similar trend was observed in relation to the

Table II. - The mean values of tibial motor nerve conduction velocities.

Value		Control	F. hockey	Soccer	Tennis	ANOVA *p*
TCV [$m \cdot s^{-1}$]						
	D	44.9 ± 3.0	46.7 ± 2.3*	45.6 ± 2.2	43.7 ± 2.7	**0.060**
	ND	44.6 ± 3.4	48.9 ± 5.1†‡	46.1 ± 2.0	43.6 ± 2.5	**0.002**
p		0.589	0.377	0.231	0.796	

Values are given as mean ± SD. D = dominant extremity ; ND = non-dominant extremity. ANOVA p indicates probability of one-way ANOVA for equal variances and Kruskal-Wallis ANOVA for unequal variances. *p* indicates probability of Student's t-test for normally-distributed and Mann-Whitney U test for non normally-distributed values. Significant p values are shown in bold.
* $p < 0.05$ significantly different in comparison to the tennis players (post hoc tests).
† $p < 0.05$ significantly different in comparison to the control group (post hoc tests).
‡ $p < 0.01$ significantly different in comparison to the tennis players (post hoc tests).

UCV but only in field hockey and tennis players, while in soccer players the trend was opposite in both dominant and non-dominant upper extremities.

Discussion

In the present study, we characterized and compared the motor nerve conduction velocity in high-level players of some types of sport, and, for the first time, we recorded data of elite field hockey players. First and the most prominent finding of our study, was the decrease of UCV measured from above elbow to below elbow (S_2-S_3) in dominant upper extremity of field hockey players in comparison to non-trained subjects and soccer players. Moreover, field hockey players' UCV measured at S_2-S_3 segment was lower than the values measured from

Table III. - Amplitudes of the ulnar motor nerve and the tibial motor nerve in dominant and non-dominant extremities among all groups (mV).

		Control	F. Hockey	Soccer	Tennis	ANOVA *p*
Upper extremity						
Above wrist	D	5.8 ± 1.9	3.9 ± 2.1	5.0 ± 1.9	3.0 ± 1.1*	**0.003**
	ND	5.3 ± 2.2	5.2 ± 2.8	5.2 ± 2.0	5.6 ± 3.5†	0.997
Below elbow	D	5.3 ± 2.1	3.8 ± 1.8	4.7 ± 1.5	3.0 ± 1.1*	**0.013**
	ND	4.7 ± 2.2	4.6 ± 2.8	5.0 ± 1.7	5.3 ± 3.4	0.901
Above elbow	D	5.2 ± 2.1	3.4 ± 1.9†	4.8 ± 1.5	2.6 ± 1.0‡§	**0.001**
	ND	4.6 ± 2.0	4.4 ± 2.7	5.0 ± 1.7	5.2 ± 3.2†	0.824
ANOVA *p*	D	0.632	0.736	0.887	0.586	
	ND	0.564	0.735	0.909	0.961	
Lower extremity						
Below knee	D	9.4 ± 4.0	9.1 ± 3.8	8.9 ± 2.9	9.7 ± 3.8	0.951
	ND	9.2 ± 4.5	8.4 ± 3.1	9.3 ± 3.5	9.9 ± 4.6	0.830
Above ankle	D	7.6 ± 2.9	7.0 ± 2.3	6.9 ± 2.7	6.7 ± 2.4	0.819
	ND	6.8 ± 3.9	6.1 ± 3.0	7.3 ± 2.6	6.9 ± 4.3	0.858
p	D	**0.000**	**0.002**	**0.000**	**0.005**	
	ND	**0.000**	**0.000**	**0.000**	**0.000**	

Values are given as mean ± SD. D = dominant extremity; ND = non-dominant extremity. ANOVA *p* indicates probability of one-way ANOVA for equal variances and Kruskal-Wallis ANOVA for unequal variances. *p* indicates probability of Student's t-test or Wilcoxon signed-rank test. Significant p values are shown in bold.
* $p < 0.05$ significantly different in comparison to the control group (post hoc tests).
† $p < 0.05$ significantly different in comparison to the dominant extremity.
‡ $p < 0.01$ significantly different in comparison to the control group (post hoc tests).
§ $p < 0.05$ significantly different in comparison to the soccer group (post hoc tests).

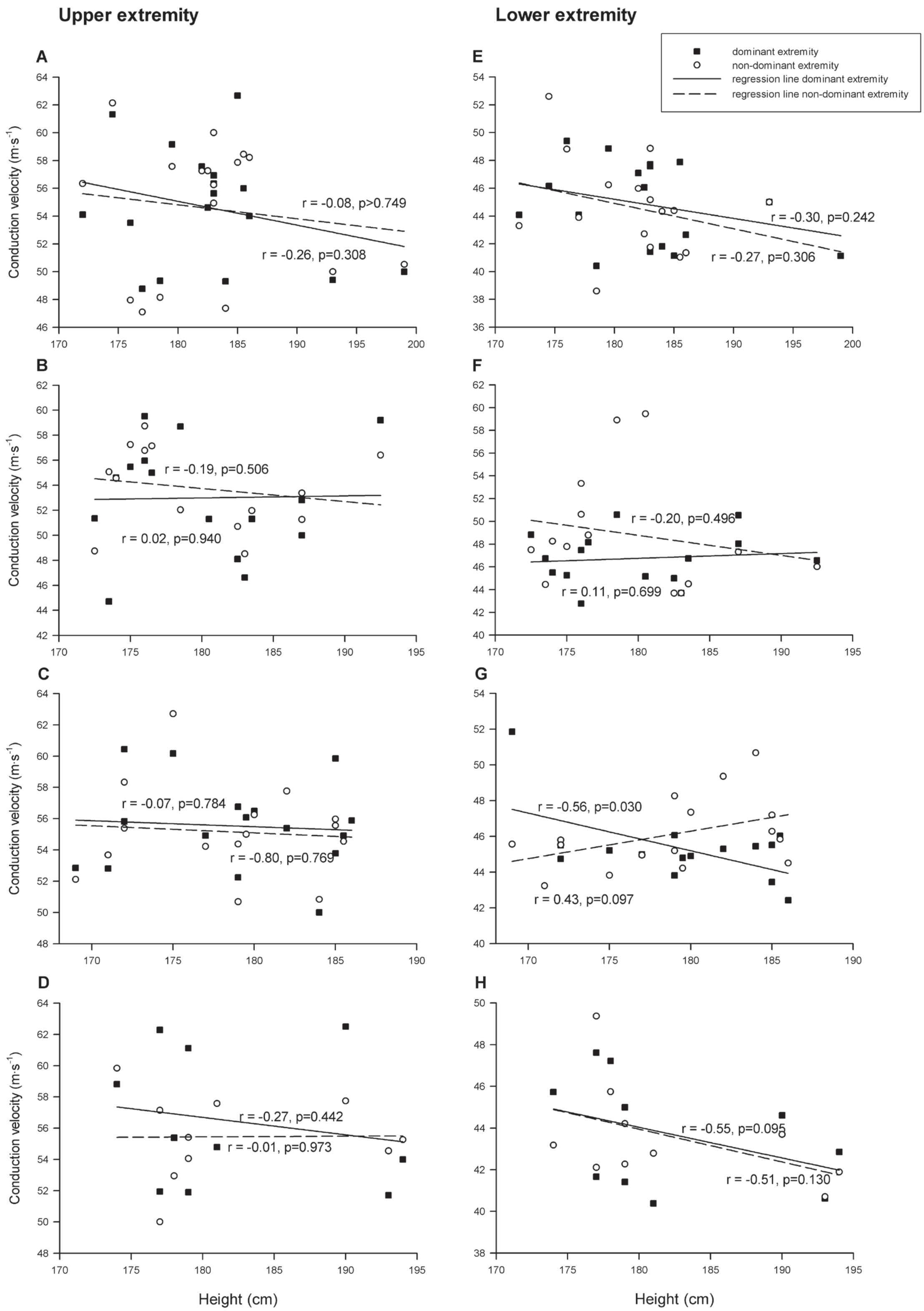

Fig. 3. - Correlations between motor nerve conduction velocity values and height of participants among each group studied. Diagrams A-D present scatter plots of the ulnar nerve motor conduction velocity measured from above elbow to wrist and E-H of the tibial motor nerve conduction velocity as a function of height of participants. A, E = control group; B, F = field hockey players; C, G = soccer players; D, H = tennis players.

Table IV. - Correlations between ulnar and tibial motor nerve conduction velocity and biometric parameters.

	Ulnar nerve						Tibial nerve	
	Dominant limb			Non-dominant limb			Dominant limb	Non-dominant limb
	S_1-S_3	S_1-S_2	S_2-S_3	S_1-S_3	S_1-S_2	S_2-S_3		
Control								
Body mass	0.16	-0.11	0.07	0.27	0.22	0.13	0.01	-0.33
UE length	-0.21	-0.32	-0.45	-0.28	-0.34	-0.20		
Arm perimeter	0.55*	0.24	0.58*	0.60*	0.50*	0.45		
LE length							-0.36	-0.24
Calf perimeter							0.12	-0.17
F. Hockey								
Body mass	0.09	-0.12	0.29	-0.09	-0.10	0.01	-0.16	0.14
UE length	-0.45	-0.35	-0.59	-0.15	-0.15	-0.09		
Arm perimeter	-0.24	-0.17	-0.04	-0.13	-0.17	0.05		
LE length							-0.02	-0.27
Calf perimeter							0.03	0.31
Soccer								
Body mass	0.04	-0.00	0.26	-0.18	-0.12	-0.17	0.09	-0.37
UE length	0.49*	0.45	0.23	0.25	0.13	0.06		
Arm perimeter	-0.04	-0.06	0.06	-0.22	-0.04	-0.30		
LE length							-0.67†	-0.61†
Calf perimeter							0.09	0.01
Tennis								
Body mass	-0.12	0.08	-0.18	-0.04	-0.38	0.27	0.07	-0.32
UE length	-0.36	-0.10	-0.56	0.01	-0.46	0.46		
Arm perimeter	-0.31	-0.04	-0.43	-0.26	-0.41	0.10		
LE length							-0.61	-0.46
Calf perimeter							0.36	-0.16

UE = upper extremity; LE = lower extremity; * $p < 0.05$; † $p < 0.01$.

below elbow to wrist (S_1-S_2), which was opposite to result found in other groups, including the control group. Usually, the values of MNCV measured in the proximal part of an extremity are higher than in the distal part, probably because of larger diameter of fibers in the nerve supplying proximal muscles (Trojaborg and Sindrup, 1969). Presumably, differences in motor nerve conduction velocity observed among various sports result from favorable genetic assets of the athletes but, on the other hand, they can be also a consequence of specific motor tasks for given sport. Sports training can be described as a self-imposed environmental exposure, therefore, in order to understand differences obtained in measurements performed among various sports one should consider gene and environmental factors, as well as gene-environmental interactions and correlations (Brutsaert and Parra, 2006). Several authors noted a relationship between nerve conduction velocity and anthropometric factors, especially the negative correlation between MNCV and the height of studied subjects (Soudmand et al., 1982; Stetson et al., 1992). In our study, apart from negative correlation between the TCV and height and lower extremities length of soccer players', no clear relationships between MNCV and biometric parameters of athletes were observed. On the other hand, we found a trend toward decrease of tibial and ulnar nerve

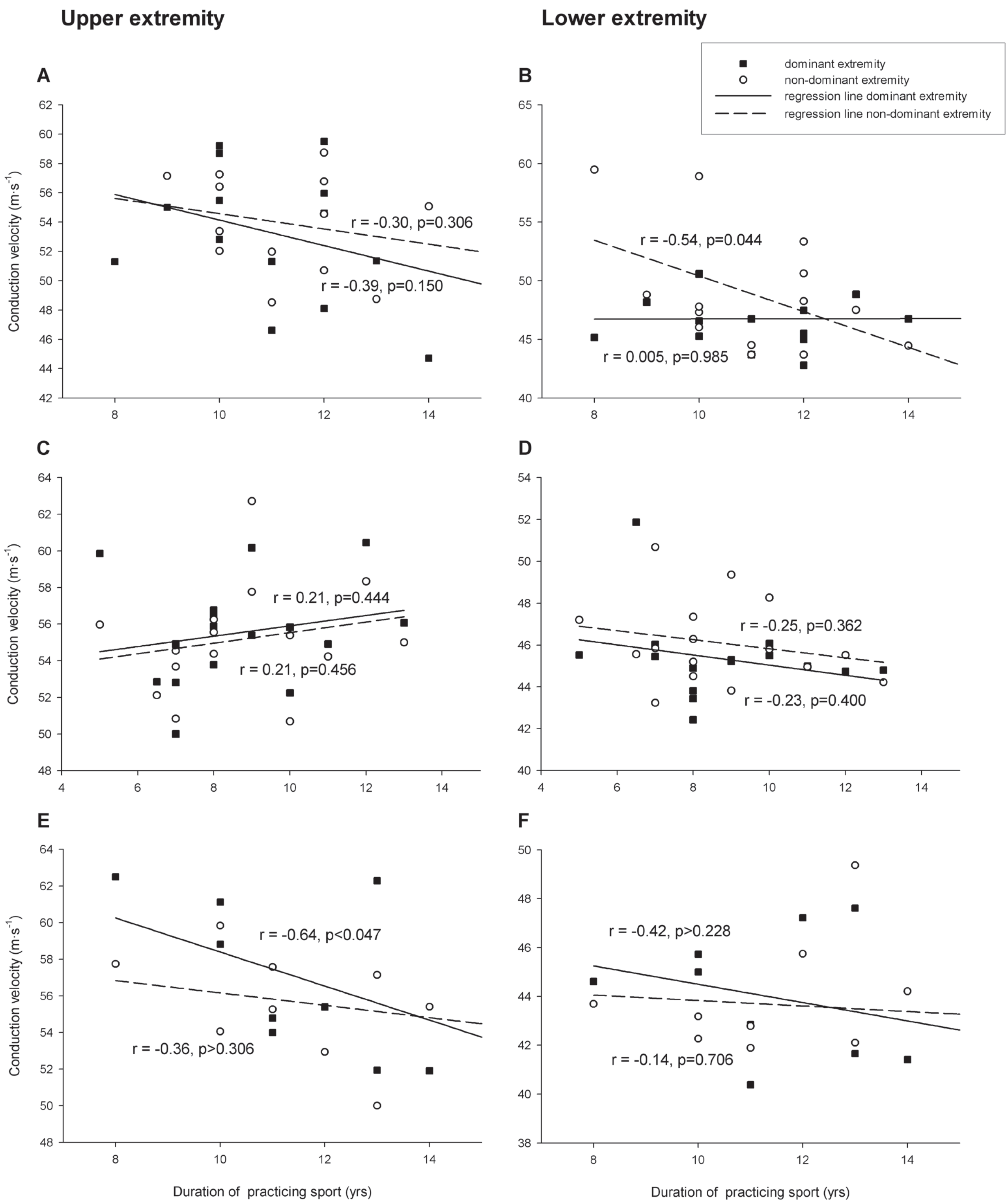

Fig. 4. - The relationships between the duration of practicing sport and ulnar motor nerve conduction velocity measured from above elbow to wrist (A, C, E) and tibial motor nerve conduction velocity (B, D, F). A, B = field hockey players; C, D = soccer players; E, F = tennis players.

conduction velocities with the duration of sport practicing. Interestingly, in soccer players' upper extremities we observed an opposite trend which can suggest possible influence of sport practicing on the motor nerve conduction velocity among those athletes who use additional equipment during a game.

Several possible factors can influence the ulnar motor nerve conduction values among field hockey players. It may be speculated that lowered MNCV at the S_2-S_3 level could be seen not only as a result of genetic peculiarity of MNCV among athletes but also as a result of pathological changes in the proximal part of the ulnar nerve in field hockey players caused by repeated forces and vibrations originating during contact between the stick and the ball, surface or other players. Such forces generated during a swung of a hockey stick can be even greater than forces generated during kicking (Sherker and Cassell, 2002), which can cause overloading or even injury of upper extremities. We hypothesize that vibrations produced during a hit, especially during training or game at the low temperature conditions, can be considered as one of repetitive stress factors modulating the motor nerve conduction velocity. This assumption is supported by an observation that 400 hours of repeated exposure to vibration (2 to 4 hours per day, six day per week) at 60 Hz and 0.4-mm amplitude led to a decrease in motor nerve conduction velocity and degeneration of paranodal myelin (Chang et al., 1994). Moreover, the vasoconstrictor effect of vibration due to the immediate neurogenic reflex mechanism caused a decrease of blood flow in the vibrated and even not-vibrated (contralateral) extremity (Bovenzi et al., 2000), which can lead to increase the pathophysiological effects in the nerves.

Additional possible cause of changes in the ulnar nerve conduction velocity can be the valgus force produced during hard stick contact, which can lead to a strain of the ulnar nerve. Chang et al. (2008) showed that increased carrying angle of the elbow is an independent risk factor of nontrauma-related ulnar neuropathy. Moreover, in hockey players, traction of the nerve can appear during shooting, since abduction, external rotation of the shoulder, together with extension of the wrist, were reported to stretch the ulnar nerve (Topp and Boyd, 2006). That effect can be augmented by compression to the nerve due to contraction of the surrounding muscles and close contact with medial epicondyle, especially during flexion of the elbow (Werner et al., 1985; Byl et al., 2002). The results published so far shows that even lengthening of 6% to 8% for a short period causes transient physiological changes, mainly decreased blood flow, while lengthening of over 11% causes long-term damage (Topp and Boyd, 2006). Özbek et al. (2006) found slowing UCV in the dominant arm of volleyball players and suggested that extreme valgus forces in elbow are capable of causing traction injury of the nerve.

Furthermore, we cannot exclude the possibility that lowered UCV among field hockey players is a consequence of the specific body posture maintained during their sports performance, i.e. upper thoracic kyphosis and dropping shoulders, which may lead to thoracic outlet syndrome (TOS) (Abe et al., 1999). Field hockey demands slouched posture of the player in order to perform several complex motor skills such as dribbling, shooting, ball handling and defensive skills. Abnormal posture (i.e. forward head posture, thoracic kyphosis, scapulae abduction, and shoulder internal rotation) is a relevant predisposing factor to TOS (Mackinnon and Novak, 2002). TOS is associated with compression of one or more of the neurovascular structures traversing the superior aperture of the chest (Urschel and Kourlis, 2007). We hypothesize that UCV in field hockey players can be lowered due to slow mechanisms that produce TOS, since symptoms involving the ulnar nerve appear in 90% of patients with this syndrome (Urschel and Patel, 2003).

In our study, neither soccer players nor tennis players showed any differences of UCV when compared to the control group. Çolak et al. (2004) also have not found any discrepancies in UCV among tennis players, however ulnar sensory nerve conduction velocity (SNCV) as well as MNCV and SNCV of the radial nerve in the dominant arms were delayed. To the authors' best knowledge, there has been no previous research concerning UCV among soccer players.

The amplitude of CMAPs indicates the efficiency of neuromuscular transmission and the number of muscle fibers composing the recorded muscle able to generate action potentials (Wilbourn, 2002). Lower values regarding to the CMAPs amplitude of ADM muscle in the tennis players' dominant upper limb found in our study are not in agreement with data presented by Çolak et al. (2004). However, several authors observed a reduction in CMAP amplitude of motor nerves of the upper limb among non-injured sportsmen and indicated training-induced changes in peripheral nerves (Paladini et al., 1996; Capitani and Beer, 2002). Additionally, we observed slightly decreased values of CMAP amplitude in the dominant upper extremity of field hockey players when compared to the non-dominant arm, while in the soccer and control groups there were no differences.

In our study we found also that the tibial motor nerve conduction velocity in field hockey players was higher than in control group and in tennis players. Interestingly, we observed also the negative relationship between TCV in the non-dominant extremity and duration of practicing sport in those athletes. This result suggests that motor nerve conduction velocity in field hockey players can be even higher at the beginning of their sports career which support the hypothesis of favorable genetic constitution in athletes. Nevertheless, it should be noted that there is a need for longitudinal nerve conduction studies, performed at the beginning and after a long period of training among sportsmen in order to confirm this hypothesis. Differences in nerve conduction velocity among athletes have been studied and discussed by some authors, however it is still difficult to use this knowledge in the sports practice. Kamen et al. (1984) reported that weight lifters had faster tibial CVs than marathoners. On the other hand, jumpers and elite sprinters had slower MNCV than the untrained controls as well as other tested groups of sportsmen (Kamen et al., 1984; Upton and Radford, 1975). Sleivert et al. (1995b) suggested that MNCV is lower in power- than in endurance-type athletes.

In conclusion, in our study motor nerve conduction velocity in proximal part of ulnar nerve of field hockey players was decreased while in the tibial nerve an opposite trend was found. This study shows that the motor nerve conduction velocity of peripheral nerves in upper and lower extremities differ among athletes trained for various athletic endeavors and also suggests that sports training presumably contributes to changes in this parameter. The results obtained from motor nerve conduction velocity studies among different sports can be useful in clinical settings as well as in coaching.

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