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Characteristics of somatosensory evoked potentials in athletes
Caracteristicile potenţialelor evocate somestezice la sportivii de performanţă

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Abstract
Background. In the literature, the descriptions of the somatosensory system's physiological characteristics in athletes, using somatosensory evoked potentials, are very few.
Aims. The aim of our study was to discover possible characteristics of somatosensory evoked potentials (SEP) in athletes, appertaining to different sport categories: fencing, volleyball, and handball. By measuring some SEP wave parameters (latencies and intervals) and comparing the obtained results, we wanted to emphasize the cortical functional plastic changes induced by specific training and to draw a characteristic neurophysiologic pattern for each studied sport.
Methods. The studied group was formed by 15 professional sportsmen, males, aged between 15 and 23 years, who had practiced professional sport for at least 5 years. By using the Nihon-Kohden MEP 150 device, SEP obtained by stimulating (electric stimuli of an intensity superior by 3-4 mA to the motor threshold, a duration of 0.2 ms and a frequency of 3 Hz) the median nerve at the radiocarpal joint were recorded bilaterally, successively.
Results. SEP waves' (P14, N20, P22-25, N25-30, P35, N40, P45) latencies and the intervals P14-N20 and N20-P25 were measured. Analysis of obtained results did not show statistical significant differences for latencies and interval values of SEP waves. Pearson test revealed a similar neurophysiologic pattern for P35 and N40 waves, when stimulating the right and also, left hand.
Conclusions. Although for the majority of SEP parameters there were no statistically significant differences, some correlations for P14, P35, N40, waves generated by the association cortex, were considerably changed by the functional plastic processes induced by performance sports.
Keywords: somatosensory evoked potentials, fencing, volleyball, handball.

Rezumat
Premize. În literatura de specialitate, descrierile caracteristicilor fiziologice ale sistemului somatosenzitiv la sportivii de performanţă, cu ajutorul PES, sunt foarte puţine.
Obiective. Obiectivul studiului nostru a constat în evidenţierea posibilelor caracteristici ale potenţialelor evocate somestezice la sportivii de performanţă, aparţinând diferitelor ramuri sportive: scrimă, volei, handbal, prin măsurarea unor parametri (latenţe şi intervale) ale acestora şi compararea rezultatelor obţinute, pentru a sublinia modificările plastice funcţionale corticale, induse de antrenamentul specific şi a contura un profil neurofiziologic caracteristic fiecărui sport studiat.
Metode. Grupul de studiu a fost format din 15 sportivi de performanţă, băieţi, cu vârste între 15 şi 23 ani şi experienţă în ramura sportivă practicată, de cel puţin 5 ani. Cu ajutorul dispozitivului Nihon-Kohden MEP 150 s-au înregistrat PES, obţinute prin stimularea (stimuli electrici cu o intensitate superioară cu 3-4 mA pragului motor, o durată de 0,2 ms şi o frecvenţă de 3 Hz) nervului median la nivelul articulaţiei radiocarpiene, bilateral, succesiv.
Rezultate. Au fost măsurate latenţele undelor PES (P14, N20, P22-25, N25-30, P35, N40, P45) şi intervalele P14-N20 şi N20-P25. Analiza rezultatelor obţinute nu a evidenţiat diferenţe semnificativ statistice ale valorilor latenţelor şi intervalelor

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undelor PES. Testul Pearson a relevat, un pattern neurofiziologic similar, pentru undele P35 şi P40, atât în cazul stimulării mâinii drepte, cât şi celei stângi.

Concluzii. Deşi majoritatea parametrilor PES nu au diferit semnificativ statistic, totuşi, câteva corelaţii au fost remarcate pentru undele P14, P35, N40, unde generate de cortexul de asociaţie, semnificativ modificate de procesele plastice funcţionale, induse de sportul de performanţă.

Cuvinte cheie: potenţiale evocate somestezice, scrimă, volei, handbal.

Introduction

Somatosensory evoked potentials (SEP) represent the bio-electrical response generated by the stimulation of a peripheral nerve, thus being a common investigation of the nervous system, with applicability in physical effort physiology, a method for exploring the somatosensory system influx conduction, characterised by a large participation of proprioceptive receptors, which are significantly involved in professional effort.

Paraclinical investigations through evoked potentials have earned a well deserved place in human pathology, both by participating in establishing a diagnosis and by objectively tracking the evolution of the disease and the efficiency of therapy in neurological, ophthalmologic, endocrinological, internal and recovery medicine, otorhino-laryngology and plastic surgery (Christopher et al., 2012; Cruccu et al., 2008; Houlden et al., 2010; Hu et al., 2011; Makarov et al., 2012; Tremblay et al., 2011; Yiming et al., 2013).

In the literature, the descriptions of the somatosensory system's physiological characteristics in athletes, using somatosensory evoked potentials, are very few (Babiloni et al., 2010; Chen et al., 2008; Cruccu et al., 2008; Kido & Stein, 2004; Koya et al., 2013; Matsumoto et al., 2006; Murakami et al., 2008; Sehm et al., 2012).

This is why the aim of our study was to discover possible characteristics of somatosensory evoked potentials (SEP) in athletes, appertaining to different sport categories: fencing, volleyball and handball.

We compared the results obtained by the three groups of sportsmen, without including a group of sedentary subjects, as the somatosensory cortex undergoes specific plastic modifications induced by physical training (Murakami et al., 2008; Zwierko, 2008).

Literature data gathered from this area of interest shows the absence of significant differences between SEP parameters determined in high performance sportsmen (gymnasts, athletes) when compared with tested athletes and with sedentary people (Bulut et al., 2003; Iwadate et al., 2005).

For the present study, the mentioned sports were selected, according to the different use of the upper limbs during training: volleyball players use the most part of their upper limbs, fencers use one upper limb predominantly, and handball players use both upper and lower limbs intensely.

Hypothesis

Long periods of sports activity induce plastic cortical changes, characteristic of each athlete, through the repetitive character of the specific set of movements of each sport, as demonstrated in long-term experimental exercises. So, it is possible to create a characteristic electrophysiological pattern, in concordance with the type of the practiced physical activity, in which case this can be discovered through clinical neurophysiologic tests.

Material and methods

The research was carried out in compliance with the principles of ethics covered by the Declaration of Helsinki and Law No. 206/2004. The research was approved by the Ethics Committee of the University of Craiova – Research Centre for Human Body Motricity (REB-875-15). All subjects included in the study gave their written informed consent to participate in the research.

Research protocol

a) Period and place of the research

The research was performed during 2009-2013, at the Research Centre for Human Body Motricity of the Faculty of Physical Education and Sport Craiova.

b) Subjects and groups

The studied subjects were represented by 15 professional sportsmen, males, aged between 15 and 23 years, who had practiced professional sport for at least 5 years, divided into three groups: 5 fencers, 5 volleyball players and 5 handball players.

c) Tests applied

SEP responses were recorded, obtained by successive and bilateral stimulation of the median nerve (Balzamo et al., 2004; Montain & Tharion, 2010) at the radiocarpal joint (Fig. 1).

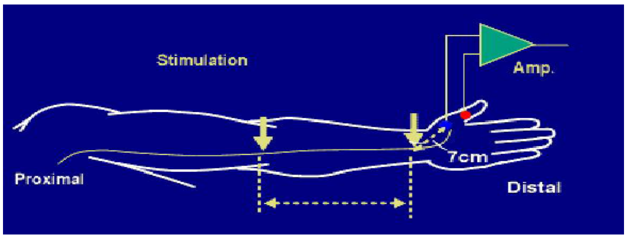

Fig. 1 – Median nerve electric stimulation.

The evoked potentials were obtained by using a Nihon-Kohden MEP 150 device, which can be used both for electromyography and for determining evoked potentials (Van't Ent et al., 2010). Stimulation was made by using electric stimuli, with an intensity superior by 3-4 mA to the motor threshold, a duration of the stimulus of 0.2 ms and a stimulation frequency of 3 Hz (Sehm et al., 2012). The response was recorded with low frequency filters of 10 Hz and a high frequency of 5000 Hz (Gobbele et al., 2007; Lin et al., 2009; Murakami et al., 2008).

The evoked potential was obtained with the help of surface electrodes placed on the head, according to the 10-20 system of electroencephalography (Fig. 2).

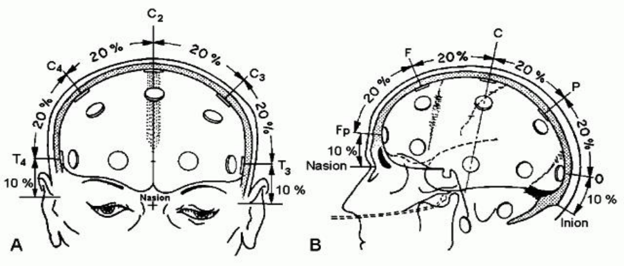

Fig.2 – 10-20 system of EEG electrodes placed on the head.

The reference electrode was the Fz electrode and the recording electrodes were placed contralateral to the stimulation area, at 2 cm posterior of C3 (C3') and C4 (C4'), respectively (Lupescu et al., 2006).

For extracting the evoked potential from the electroencephalographic source line, the averaging method was used, by summing 250-300 evoked responses.

Lines showed wave components from P14 to P45 (P14-15, N20, P22-25, N25-30, P35, N40, and P45), for which latencies, amplitudes and different intervals between maximum points were computed.

Due to the multitude of results obtained, of all these possibilities we retained for subsequent statistical processing only the latencies of the mentioned waves and intervals P14-N20 and N20-P25, which represent intracranial conduction.

d) Statistical processing

The Pearson test and Student test were used for statistical processing.

Results

SEP waves' (P14, N20, P22-25, N25-30, P35, N40, P45) latencies and the intervals P14-N20 and N20-P25 were measured. By processing the values obtained by measuring the characteristic SEP component parameters, we recorded the results presented in Table I.

The analysis of these values shows the fact that the waves' average latency obtained by stimulating the right hand was higher than that obtained for the left hand, although all subjects were right handed. Also, it is noteworthy that the differences between the parameters obtained by stimulating both limbs were statistically insignificant and by analysing statistical correlation, a positive relationship of the latencies from both limbs was shown only for P14 (cervicobulbar conduction), for wave latencies obtained by extralemniscal conduction and in other cortical areas than the specific one, as shown in Table II.

Characterising the parameters recorded for the group of sportsmen belonging to the same sports category was one of the goals of this study, which is why a separate analysis of these subgroups of subjects was made.

When analysing the group of handball players, we obtained the average values of the SEP component waves' latencies presented in Table III.

Like the values of the entire studied group, the waves' latencies obtained by stimulating the right hand were slightly higher compared with those for the left hand, though the differences were statistically insignificant, and the same correlation pattern was obtained for the group of handball players (H); there was one exception, a negative correlation for the P23-25 wave, unidentifiable for the entire studied group (Table IV).

For the group of fencers (F), latencies belonged to the same interval, with the mention that for right-left differences only P14 and P45 had higher values for the stimulation of the right hand. The other SEP components presented lower values for the stimulation of the right hand, compared to those obtained by stimulating the left hand, which was only

Table I

Values of SEP component parameters for the entire group.

SEP - hand		P14-15	N20	P22-25	N25-30	P35	N40	P45
Right hand	Average	17.12	20.13	22.85	25.57	30.78	34.39	38.97
	Std. deviation	1.39	0.74	0.90	1.13	2.42	3.57	3.08
Left hand	Average	16.92	20.05	22.63	25.35	30.40	34.16	38.34
	Std. deviation	0.84	0.92	1.03	1.33	2.69	2.94	2.62

Table II

Differences between SEP parameters and Pearson correlation coefficient values for the entire group.

Right-left differences	P14-15	N20	P22-25	N25-30	P35	N40	P45
P value	**0.65**	0.80	0.55	0.63	**0.69**	**0.86**	**0.56**
Pearson correlation coefficient	**0.79**	**0.07**	**-0.13**	**-0.02**	**0.95**	**0.94**	**0.93**

Table III

Mean and standard deviation values of SEP parameters for the group of handball players

SDV-SEP		P14-15	N20	P22-25	N25-30	P35	N40	P45
Right hand	Average	17.08	19.92	22.43	24.83	31.27	34.98	39.90
	Std. Dev	0.81	0.59	0.85	1.48	3.59	4.12	2.90
Left hand	Average	17.55	20.43	23.20	25.87	31.75	35.00	40.02
	Std. Dev	1.21	0.58	0.90	0.73	3.00	4.79	3.12

Table IV

Differences between SEP parameters and Pearson correlation coefficient values for the group of handball players.

Right-left differences	P14-15	N20	P22-25	N25-30	P35	N40	P45
P value	**0.65**	0.80	**0.55**	0.63	**0.69**	**0.86**	**0.56**
Pearson correlation coefficient	**0.53**	-0.41	**-0.67**	-0.46	**0.93**	**0.97**	**0.96**

found in this sports category (Table V).

During our testing, however, all right-left differences were statistically insignificant, and the same correlation pattern was evidenced for this group, with the exception of the P45 wave (Table VI).

Statistical analysis made for the group of volleyball players (V) revealed values showing no statistical difference for the right-left correlation, and there was a positive correlation of all identified wave latencies, with the mention that this aspect was only found in this tested group (Table VII).

By comparing the values of latencies obtained for SEP components from the subgroups representing the tested sports, a positive correlation was evidenced only in the case of latencies for the N40 wave.

A negative correlation was found for the P35 wave by statistical comparison of H-V and V-F. The same latency of P35 for the H-S correlation showed a positive value, differentiating the two sports.

These aspects were present both for latencies obtained by stimulating the left hand and for those recorded after stimulating the right hand.

Correlations can also be observed for latencies of waves generated by the specific area, without a characteristic pattern, as shown in Table VIII.

As previously mentioned, the values of intracranial conduction intervals P14-N20 and N20-P25 were also processed. These intervals were submitted to the same statistical processing as the latencies of SEP components, with the results displayed in Table VIII.

There was a discordant modification of values for the two intervals for right-left differences: P14-N20 had higher values for right compared to left, the same aspect being revealed for the subgroup of handball players. For the F and the V group, concordant modifications for the right-left differences were recorded. For both intervals, the mathematical sign of the modification differs: for F, the different right-left values were negative, while for V those differences were positive.

So, there were no noticeable correlations of these intervals for the entire studied group. However, subgroup H showed a negative correlation of both intervals, while the F and V correlation was positive, but only for central conduction, interval N20-P25.

By analysing the intersport correlations, we noticed positive correlations between H-V, V-F for the conduction interval, between the brain stem and cortex (P14-N20), following the stimulation of the left hand. Following the stimulation of the right hand, a positive correlation existed only between V and F, while for the same hand when comparing H-F for the same interval, a negative correlation appeared. Also, following the stimulation of the left hand, for the interval P25-N20, a positive correlation was observed when comparing values of the subgroups H-F, and a negative correlation was found when comparing H-V. Following the stimulation of the right hand, the obtained values were positively correlated only for the V-F correlation and at the limit, for the H-V comparison (Table VIII).

Table V

Mean and standard deviation values of SEP parameters for the group of fencers.

SDV-SEP		P14-15	N20	P22-25	N25-30	P35	N40	P45
Right hand	Average	17.10	20.36	23.12	25.72	28.58	32.57	36.55
	Std.Dev	0.93	1.54	1.51	1.58	2.32	2.22	0.58
Left hand	Average	17.35	19.92	22.72	25.04	29.08	33.20	37.48
	Std.Dev	1.26	0.96	1.13	1.61	2.10	2.95	0.50

Table VI

Differences between SEP parameters and Pearson correlation coefficient values for the group of fencers.

Right-left differences	P14-15	N20	P22-25	N25-30	P35	N40	P45
P value	0.76	0.61	0.65	0.52	0.76	0.78	0.056
Pearson correlation coefficient	**0.88**	0.12	0.13	0.20	**0.99**	**0.94**	-0.1

Table VII

Values of SEP component parameters and statistical results for the volleyball group.

SEP		P14-15	N20	P22-25	N25-30	P35	N40	P45
Right hand	Average	16.55	19.90	22.33	25.65	30.82	34.30	38.20
	Std.Dev	0.89	0.45	0.25	0.65	0.74	1.93	2.71
Left hand	Average	16.25	19.96	22.48	25.78	31.03	34.38	38.90
	Std.Dev	1.70	0.68	0.50	0.97	0.49	2.21	4.12
Right-left	P value	0.77	0.87	0.62	0.84	0.63	0.96	0.76
	Pearson correlation coefficient	**0.89**	**0.94**	**0.70**	**0.96**	**0.71**	**0.97**	**0.98**

Table VIII

Statistical results for the intersport analysis.

Correlation	Left hand							Right hand						
	P14-15	N20	P22-25	N25-30	P35	N40	P45	P14-15	N20	P22-25	N25-30	P35	N40	P45
H-F correlation	**-0.71**	0.05	0.30	0.73	0.95	1.00	**-0.76**	**-0.78**	**-0.52**	-0.42	-0.14	0.83	0.87	**-0.53**
H-V correlation	0.75	0.55	**-0.58**	0.35	**-0.91**	0.50	0.49	0.22	0.57	**-0.65**	0.22	**-0.89**	0.73	0.25
V-F correlation	0.72	**-0.75**	0.59	0.98	**-1.00**	1.00	0.66	0.75	**-0.69**	**-0.93**	0.27	**-0.82**	1.00	-0.30
p H-F	0.97	0.57	0.40	0.37	0.19	0.32	0.06	0.81	0.33	0.47	0.33	0.14	0.51	0.10
p H-V	0.39	0.96	0.78	0.27	0.78	0.75	0.37	0.24	0.26	0.14	0.88	0.58	0.79	0.63
p S-V	0.42	0.55	0.31	0.93	0.15	0.33	0.25	0.34	0.94	0.68	0.43	0.16	0.60	0.48

Discussions

The analysis of SEP wave parameters showed that the latencies of these waves obtained by stimulating the right hand were higher than those obtained by stimulating the left hand, for the entire group of sportsmen, while for the three studied sport groups, the same aspect was identified only for handball and volleyball (statistically insignificant differences).

For fencers, waves obtained from the specific cortical area had a lower latency when the right hand was stimulated, compared to those recorded by stimulating the left hand. One explanation for these results may be that handball and volleyball require both arms during the sports effort, without producing a specific differentiated plastic modification of the corresponding cortical area. For fencers, where the dominant arm was almost exclusively used, the process of a specific differentiated plastic modification due to sports training was dominant, leading to a decrease of wave latencies generated by the cortical areas specific to the used limb.

SEP testing proved to be efficient in gauging the sports effort, due to the highlighting of a P14-15 positive correlation (left-right) from records of sportsmen, belonging to each tested sport. Cortical SEP characteristics and aspects recorded for the three mentioned sports revealed lower values, highlighted for the first waves' latencies (P14, N20, P25) in volleyball players, compared to other sportsmen, an aspect which was obtained through successive stimulation of both hands.

The latest waves (P35, N40, P45), originating in the association cortex, had the lowest latencies for fencers, thus mirroring a large extent of plastic modifications, necessary for these localisations to sustain commands from specific areas (Nielsen & Cohen, 2008; Sadowski, 2008; Thomas & Mitchell, 1996). Fencing, being a sport that requires reactions of the lowest latency, stimulates the well defined association areas for specific responses, thus determining the stereotypic movements in this sport. Regarding the P15-N20 interval, which expresses conduction of information between the brain stem and specific cortical areas, its values were more reduced when stimulating the right hand compared to those obtained for the left hand for all three studied sportsmen subgroups, although the differences were statistically insignificant.

The mentioned interval was the expression of path conduction, where the transmission of information was not overly influenced by sports training, an aspect which differs from the N20-P22-25 interval, which reflects the components of the cortical response.

Conclusions

1. Neurophysiologic investigation through somatosensory evoked potentials for professional sportsmen represents a means of highlighting a possible pattern, characteristic of each practiced sport.

2. By analysing the recorded results, differences between the SEP component latencies obtained by successively stimulating both upper limbs could be evidenced. However, these differences were not statistically significant, an aspect which was constant when comparing differences between the groups of sportsmen.

3. By computing the P14-N20 and N20-P25 intervals, an electroneurophysiologic difference of stimuli conduction and a difference in activating somesthetic cortical areas could be evidenced, none of which was sustained from a statistical point of view.

4. The Pearson test showed that, when comparing results obtained by each group of sportsmen, a correlation pattern was present, similar for waves P35 and N40, both for stimulating the right and the left hand.

5. Although for the majority of SEP parameters, no statistically significant differences were found, some correlations for P14, P35, N40, waves generated by the association cortex, were considerably changed by the functional plastic processes induced by performance sports, which is an important reason to continue the study.

Conflict of interest
The authors confirm that this article content has no conflict of interest.

Author contribution
All authors have equally contributed to this article.

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