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Section I - Kinesiology

Speed of Visual Sensorimotor Processes and Conductivity of Visual Pathway in Volleyball Players

by
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Volleyball is a dynamic game which requires a high level of visual skills. The first aim of this study was to investigate the several aspects of reaction times (RT) to visual stimuli in volleyball players (12) compared to non-athletic subjects (12). By using the tests included in the Vienna Test System (Schuhfried, Austria), simple reaction time (SRT), choice reaction time (CRT) and peripheral reaction time (PRT) were examined. The second aim of this study was to assess the neurophysiological basis of early visual sensory processing in both examined groups. We measured two sets of pattern-reversal visual evoked potentials (VEPs) during monocular central field stimulation (Reti Scan, Roland Consult, Germany). The latencies of waves N75, P100 and N135 were determined. We observed significantly shorter ($p<0.05$) total reaction time to stimuli appearing in the central and peripheral field of vision in the volleyball players compared to non-athletes. With regard to SRT and CRT the main differences between the groups appeared in pre-motor reaction times. Volleyball players had shorter VEPs P100 wave latencies ($p<0.05$) than the non-athlete group. The results indicate faster signal transmission in visual pathways in athletes than in non-athletes. This fact can be attributed to the effect of rapid visual-activity-demanding sports on the central nervous system

Key words: reaction time, visual evoked potentials, volleyball

Introduction

Many studies indicate that athletes have shorter reaction times compared to non-athletes (Harbin et al., 1987, Ando et al., 2001, Venter and Ferreira, 2004, Kokubu et al., 2006, Zwierko, 2008). Moreover, it has been reported that reaction times in athletes depend on the type of sport activity. The athletes training team games and racket-sports have significantly shorter reaction times than athletes in other types of sports (Bhanot and Sindu, 1980, Erickson, 2007, Doğan, 2009). In contrast, some studies have noted no difference in reaction times between athletes of high-speed ball games and non-athletes (McLeod, 1987, Helsen and Starkes, 1999, Thomas et al., 2005). It seems that this controversy may result from differences in the speed of information processing on successive stages of reaction time process.

It is assumed that total reaction time contains premotor and motor components (Botwinick, 1966). Premotor reaction time is the period involving the processing of the stimulus and the interpretation and preparation of the response, while motor reaction time is a physical response and is a peripheral, elec-

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tromechanical time delay in the execution of the program (Smith et al., 1998).

Ando et al. (2001) proved that the central and peripheral visual pre-motor reaction time of soccer players is shorter than in non-athletes. Interestingly, the total reaction time (pre-motor + motor time) was not very different between the groups. Their results suggest that the main differences in reaction times between groups resulted from perceptual and/or central stages of information processing. This suggestion confirms several clinical investigations which show that visual performance, such as facility of accommodation and saccadic eye movement, vergence facility, peripheral awareness and near point of convergence, are significantly better in athletes than others (Christenson and Winkelstein, 1988, Jafarzadehpur et al., 2007). Moreover, Delpont et al. (1991) observed that tennis players and squash players have a faster transmission in visual pathways compared to rowers and non-athlete control subjects. Endo et al. (2006) reported that primary motor cortex activity during a reaction time task in athletes tended to be larger than that of the non-athletes.

In our study we analyzed several aspects of reaction times (RT) to visual stimuli in central and peripheral fields of vision in volleyball players compared to untrained subjects. By using visual evoked potentials (VEPs) recording, we tried to explore the neurophysiological basis of early visual sensory processing of reaction time to a visual stimulus. High-speed ball sports, such as volleyball, have dynamic visual features that need to be rapidly processed by the athlete to determine a successful motor response. During this dynamic game, which requires the player's reaction for many specific stimuli such as the position of the ball or other players, the objects in visual space move very quickly and the player's decision making proceeds in short time (Liviotti et al., 2007). Many visual skills like visual resolution ability, dynamic visual acuity, contrast sensitivity, oculomotor function, visual reaction time and visual coincidence anticipation are significant for volleyball player's performance (Erickson, 2007). On the other hand there are same proofs that the participating in dynamic reactive training can improve visual reaction processing (Ando et al., 2002, 2004) and visual abilities (Land and McLeod, 2000; Kohmura and Yoshigi, 2004). Accordingly, in our study we assumed that volleyball players have shorter reaction times than non-athletic subjects and we tried to test whether the differences between the groups could result from the initial stages of information processing.

Material and Methods

The research involved 12 division I male volleyball players. Their mean age was 22.86±2.09 years with mean sports experience 9.37±3.81 years. The control group included 12 untrained students of Szczecin University (mean age 21.9±1.52 years). Both groups were subjected to routine ophthalmological examinations. All participants had visual acuities of 20/20 or better, were healthy and had no history of systemic or ocular disease. The Bioethical Committee at the Medical Academy in Szczecin with resolution No. BN-001/64/08 on 20th June 2008 approved the research project.

Tests included in the Vienna Test System (Schuhfried, Austria) were used to examine simple reaction time (SRT), choice reaction time (CRT) and peripheral reaction time (PRT) .

1. Simple reaction time (option S1). A reaction cycle consisting of 28 light stimuli, generated at different and randomly selected time intervals. The participants were supposed to perform a key-press response to programmed visual stimuli (yellow light). Below the 'reaction key', the panel had a 'stand-by key'. An examined individual maintained a finger on the 'stand-by key'; in reaction to a visual stimulation, the finger was supposed to be moved as quickly as possible from the 'stand-by key' to the 'reaction key'.

2. Choice reaction time (option S4). In the test phase 48 stimuli were presented of which 16 required a reaction. The critical combination to which the subject was instructed to respond consisted of two visual stimuli (yellow and red lights simultaneously). An examined individual was supposed to react to the programmed visual stimuli (simultaneous yellow and red lights) by pressing the 'reaction key' according to the procedure mentioned above (SRT). The measurements of SRT and CRT were recorded by a computer programme and the following values were calculated: (1) median of total reaction time (duration between the beginning of a given stimulus and pressing the 'reaction key', in ms), (2) median of pre-motor reaction time (duration between the beginning of a given stimulus and the release of the 'stand-by' key, in ms), (3) median of motor reaction time (duration between the release of the 'stand-by' key and pressing the 'reaction key', in ms).

3. Peripheral reaction time. The test consisted of two kinds of tasks conducted simultaneously: one

Table 1

Test results concerning reaction time tests in the groups of volleyball players and non-athletes

	RT tests	median reaction time [ms] mean ± S.D. Volleyball players	Non-athletes	p
SRT	Pre-motor reaction time	240.58±32.33	286.67±48.62	**
	Motor reaction time	106.92±23.38	121.16±33.12	ns
	Total reaction time	347.50±36.37	407.83±52.56	**
CRT	Pre-motor reaction time	364.33±47.95	404.61±49.64	*
	Motor reaction time	118.42±25.64	130.23±26.56	ns
	Total reaction time	482.75±56.66	534.84±60.15	*
PRT	Total reaction time	592.11±39.38	648.61±75.14	*

* $p<0.05$, ** $p<0.01$

concerning peripheral perception and another concerning the centrally-oriented tracking deviation (attention of the examined person was focused in the center of vision). The task of peripheral perception comprised the observation of flashing perpendicular lines which, at different times, appeared in the peripheral vision. The player was to recognize the lines and to react by pressing a foot pedal. The device generated 80 impulses, where 40 appeared on the left and 40 on the right side. Tracking was controlled by steering a "view-finder" with knobs, so that the "view-finder" tied in with a red point on-screen. The proper position of the "view-finder" was confirmed by the flicker of the point. In the test, we used remote measurement of the position of the head (eyes) of the examined players in relation to the field of observation. The device enabled the introduction of an adaptive algorithm guaranteeing the occurrence of impulses in a suitable informational position for every person investigated, i.e. in such a way that they perceived at least 50 % of the impulses. The median of total reaction time for left/right stimuli (ms) was recorded.

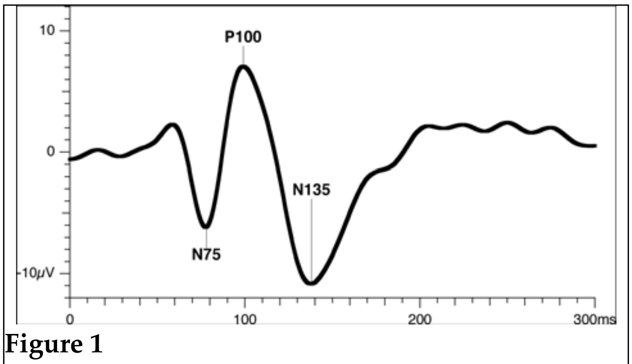

Figure 1

The latency of waves N75, P100 and N135 of the two sets of pattern-reversal visual evoked potentials in volleyball players and non-athletes

All the RT tests were measured randomly for every subject. Before performing the main RT test, each examined subject conducted preliminary tests. Subjects were tested at approximately the same time of day (9-11 a.m.).

4. Visual evoked potentials were recorded with a Reti Scan (Roland, Germany) according to the protocol established by the International Society for Clinical Electrophysiology of Vision (Marmor et al., 2004). VEPs were elicited by a monocularly presented checkerboard pattern-reversal stimuli with an identical checkerboard stimuli with (1) large 1°4′ checks and (2) small 0°16′ checks. VEPs were recorded by surface electrode from 01 and 02 according to the international 10-20 system of electroencephalograph electrode placement (Jasper, 1958). The reference electrode was placed on the vertex (Cz). The subjects were instructed to look at a central fixation point. The application of a white and black checkerboard with an alternating phase change of 1.89 Hz generated a response to the stimulus which is completed before the start of another stimulus. The analysis of such responses was summed and averaged. The result of this procedure was a transient-type PVEP curve (Fig. 1). The latency (ms) of waves N75, P100 and N135 were determined. Two sets of 100 responses were averaged for the right eye.

All data are expressed as mean and standard deviation. The normality of distribution of results was estimated using Shapiro-Wilks tests. Data analysis was performed using ANOVA variance analysis. A p-value less than 0.05 was considered significant.

Table 2

The latency of waves N75, P100 and N135 of the two sets of pattern-reversal visual evoked potentials in volleyball players and non-athletes

VEP waves	VEPs latency [ms] mean ± S.D.		p
	Volleyball players	Non-athletes	
stimuli with large checks (1°4′)			
N75	73.71±4.30	75.41±3.42	ns
P100	103.60±2.60	108.16±4.04	*
N135	148.71±8.73	149.25±9.01	ns
stimuli with small checks (1°16′)			
N75	81.28±3.88	83.41±2.42	ns
P100	106.28±5.12	108.50±3.84	ns
N135	141.00±4.88	145.33±4.49	*

* *p<0.05,*

Results

Table 1 presents the test results concerning reaction times in the examined groups of volleyball players and non-athletes.

We observed a significantly shorter total reaction time to visual stimuli appearing in the central (p_{SRT}<0.01, p_{CRT}<0.05) and peripheral field of vision (p_{PRT}<0.05) in volleyball players compared to non-athletes. Volleyball players have shorter pre-motor SRT (p<0.01) and pre-motor CRT (p<0.05) than the control group. There were no statistically significant differences in motor time with regard to SRT and CRT in the compared groups.

Statistical characteristics of mean latencies of VEPs waves are presented in Table 2. Volleyball players have shorter P100 wave latencies of pattern-reversal VEPs elicited by checkerboard stimuli with large (1°4′) checks than non-athletes (p<0.05). The tendency of shortening latencies of waves N75 and N135 is observed, but the differences are not significant. In pattern-reversal VEPs elicited by checkerboard stimuli with small (1°16′) checks we noted shorter latencies VEPs waves in volleyball players compared to the untrained subjects, but significant difference is ascertained only in N135 wave latency (p<0.05).

Discussion

The findings of our study show that volleyball players have shorter total reaction times to stimuli appearing in the central and peripheral field of vision compared to non-athletes. Our results confirm the findings of previous research (e.g. Venter and Ferreira, 2004, Kokubu et al., 2006, Zwierko, 2008).

With regard to SRT and CRT analysis, the main differences between the groups appeared in premotor reaction times. The results suggest faster signal transmission on perceptual or/and central stages of information processing in volleyball players.

One of the possible explanation of these findings could be the neurophysiological basis of early stage of the information processing. In our analysis of VEPs latencies we observed a tendency of shortening time of signal conductivity in visual pathway in athletes compared to untrained subjects. After the stimulation of the retina, compound action potentials spread via the optic nerve to the lateral geniculate nucleus, and from there to the primary visual cortex (17, 18. and 19. Brodmann’s areas) (Zeki, 1993). Wave N75 occurs due to electrical activity in visual pathways, wave P100 is mainly generated in the primary visual cortex while wave N135 occurs during early processing of the visual stimulus (Allison et al., 1983). However, in the electrophysiological investigation the most repetitive and stable recording was observed with reference to the P100 wave, which is why it is considered to be the most diagnosed VEP parameter (Halliday, 1993). The disorders of the amplitude and latency of VEPs P100 wave often occur by patients with optic nerve diseases (Palacz et al., 2003). Our results show shorter P100 wave latencies (stimuli with large checks) and shorter N135 wave latencies (stimuli with small checks) in volleyball players than non-athletes (p<0.05), which reflects probably a faster transmission in optic nerve and higher activity of the visual cortex. Similarly Delpont et al. (1991) found a shorter P100 latency in tennis and squash players compared to rowers and sedentary subjects. They related the racket sport players' shorter P100 latencies to a greater development of their abilities to rapidly process sensory information. However in cricketers, Thomas et al. (2005) observed a shorter latency for only VEP wave N70, in comparison with the control group. In their study the choice visual reaction time was not different between cricketers and non-athletes.

We suppose that the next central stage of signal transmission in the information processing may also differentiate athletes and non-athletes. Endo et al. (2006) using magnetoencephalography reported that the primary motor cortex (MI) activity during a reaction time task tended to be larger in athletes than in non-athletes. They concluded that long-term physical training promotes MI activity and the effects of reactive task repetition were more clearly apparent in the MI activity of the athletes.

On the other hand, some researchers have suggested that possible explanation for differences between reaction tasks of athletes and non-athletes were psychological factors. For example, Enns and Richards (1997) examined differences between high and low skilled hockey players and a group of non-athletes on two types of cuing tasks. They observed better visual attention performance in high-skilled players. McAuliffe (2004) studied differences in attention set effects between volleyball players and non-athletes. In his results, volleyball players exhibited greater cuing effects in the onset cue-onset target and the color cue-color target condition, which suggests that the athletes had greater attention control that non-athletes. The athlete's higher performance could result from sport practice some processing activities cease to make demands on attention resources (Abernethy 1987). However, athletes do not direct attention to all of the available information, rather they disregard irrelevant information and select sensory cues to concentrate on. Savelsbergh et al. (2002) observed that the expert goalkeepers used a more efficient search strategy involving fewer fixations of longer duration to less disparate areas of the soccer's penalty kick displayed in film, than the novice goalkeepers. The novices spent longer fixating on the trunk, arms and hips, whereas the experts directed the visual attention to more informative cues (kicking leg, non-kicking leg and ball areas). Nougier and Rossi (1999) define the ability to quickly shift attention in the visual space as "attention flexibility". Pesce and Bösel (2001) examined the focusing of visuospatial attention in volleyball players by using a simple reaction time task and recording of event-related brain potentials (ERPs). They argued that skilled volleyball players reduce the attention costs (decrease the efficiency of processing unattended information) by automatizing the use of a span of attention in accordance with their most frequent task demands. Fontani et al. (1999) analyzed a series of attention tests involving reaction times of young volleyball players. During the tests, ERPs were recorded. The authors observed higher amplitude of contingent negative variation (closely related to selective attention) and P300 (an index of the brain activity related to attention and working memory) potentials which were accompanied by a shorter RT. The athlete's ability to focus attention in a spatially selective manner can facilitate the perception of stimuli.

In the present study we found no statistical differences in motor response time to stimuli appearing in the central field of vision ($p_{SRT}>0.05$, $p_{CRT}>0.05$) between the compared groups. Some researchers have shown that trained individuals have faster nerve conduction velocity than those untrained or novices (Hoyle and Holt, 1983, Borysiuk and Waśkiewicz, 2008). Nerve conduction velocity is a measure of the speed of an impulse that can be transmitted along a motoneuron and is strongly related to speed performance in athletes (Ross et al., 2001). However, Colak et al. (2004) observed no statistical differences in the latencies, conduction velocities, or amplitudes of the median motor and sensory nerves in the elbow region between tennis players and non-athletes. The authors concluded that many of the asymptomatic tennis players with abnormal nerve conduction tests have presymptomatic or asymptomatic neuropathy similar to subclinical nerve entrapment or neuropathy. Similarly Ozbek et al. (2006) determined whether asymptomatic physically active volleyball players and non-athletes demonstrated distinct differences in nerve conduction of the ulnar nerve at the elbow. Their study showed no statistical differences in latencies and conduction velocity of the ulnar nerve on the forearm between volleyball players and the control. The results of both studies may suggest a subclinical entrapment neuropathy as a result of strenuous elbow movements in tennis and volleyball players. However, it is difficult to say if this tendency appeared in our analysis with regard to the simple motor and choice reaction times.

In summary, it can be concluded that the differences in reaction time in volleyball players and untrained subjects result from the initial (pre-motor) stages of the information processing. The faster signal transmission in visual pathway in volleyball players in a certain degree explain their shorter reaction time to visual stimuli compared to non-athletes. Our findings suggest that differences in the reaction time and in the speed of signal conductivity in visual pathways between athletes and non-athletes can be attributed to the effect of a dynamic sensory-motor-demanding sport on the central nervous system. Our results confirm that the high level of visual perceptual skills are one of the important factors constructing an athlete's performance in volleyball. With reference to the fact that visual skills can be improved by special visual training (Shibata et al, 1997; Maeda and Tsuruhara, 1999; Kohmura and Yoshigi, 2004), it seems to be significant for the training process to consider using a visual training methods to enhance sport performances. Further investigation will focus on the effects of physical effort on visual sensorimotor processes and neural activity in visual pathways.

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