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Original Article

Does attention training induce any changes in the level of the selected cognitive processes in handball players

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Abstract
Problem Statement The goal of the paper is to analyse the changes in the level of attention, peripheral perception and sensorimotor coordination in male and female handball players following neurofeedback-EEG trainings. Handball involves direct fight with the opponent, which requires proper mental preparation. The discipline is becoming more and more dynamic, thus the player needs to make quick decisions based on sudden events and their own psychomotor abilities. Approach The study involved 18 athletes (9 women – 1st league, 9 men – 2nd league) AZS AWF Warsaw in handball. The Vienna Test System was applied: a test to measure attention (COG), peripheral perception (PP-R) and sensorimotor coordination (SMK). Measurements were performed before and after 20 neurofeedback-EEG trainings (training took place twice a week). Each 30-minute training (8 rounds, 3 minutes each with a 30-second break following every round). Results
The differences between the first and second measurement indicate that the male and female handball players subject to the analysis improved their general attention level. The subjects performed a task more precisely in the course of the second measurement ($p<0.05$). Significant differences ($p<0.05$) were also noted in the level of sensorimotor coordination. The subjects improved eye–hand–leg coordination. In the case of peripheral perception, significant differences ($p<0.05$) were observed only in the group of men. Conclusions The neurofeedback-EEG training improved the attention and sensorimotor coordination of male and female handball players as well as peripheral perception in male handball players.
Keywords: neurofeedback, attention, peripheral perception, sensorimotor coordination, team sports

Introduction

Attention strengthens the effectiveness of learning during sport training as well as the effectiveness of the player in the course of athleticcompetition. The process, being a component of a sportsman's motivation, directs their receptive abilities selectively to the stimuli important for the sports goal performance. It simultaneously decreases their sensitivity to insignificant factors from the point of view of the goal (Sternberg, 2005; Gracz, Sankowski, 2000; Nideffer, 1986). The role of attention is varied: it controls interaction with the environment and plays an adaptive role. What is of crucial importance as well is the fact that it combines the past and present, controls and plans future actions (Nideffer, 1986). At present, attention is specified as the process of focusing on one task or source of stimuli despite distraction. Attention makes it possible to precisely register some aspects of the environment, enables learning and quick reaction (Revlin, 2013).

Senses play an important role, perceiving the environmental information and coordinating extremity movements regarding external conditions (Porac, Coren, 1981). These are complex sensorimotor transformations that must continually integrate a large number of sensorimotor inputs and coordinate numerous movements (Ting, 2007). Guy Azemar et al. (2007) consider success in competitive sports to be related to laterality, brain dominance, sensorimotor coordination and visual movement coordination (Bruhn, 2004). It is assumed that the body may control its movements based on feedback from movement it is engaged in.
The discrepancy between the planned and obtained value is determined and properly corrected (Kamiński, 1973). Proprioception and neuromuscular coordination impact sports results and may prevent injuries and their reappearance in the future (Hunziker, 2006).

Peripheral perception is a part of vision which applies only to lateral perception (left and right). Perceiving "distant circumference" refers to the area on the edges of the visual field. The function of peripheral vision useful in sports is providing sensations, being the background of specific visual perception (Hunziker, 2006;, Illodot, 2014; Knudson, Kulka, 1997). The ability of peripheral perception (which may be improved with proper training), impacts sports competition, particularly in the case of handball. Peripheral perception is significant, especially in team sports, since attention is focused not only on horizontal and vertical movements,

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but the players must also focus on the pitch, opponents and the ball (Knudson, Kulka, 1997). Perception is crucial in team sports to take decisions (Planer, 1994).

Team sports are becoming more and more dynamic, thus the player needs to react quickly based on sudden events and their own psychomotor abilities. The player must – during great physical effort, under great emotional strength – quickly perceive, remember, evaluate, infer and act (Panfil, 2006; Roy et all., 2016) Neurofeedback-EEG is a method of improving attention functions. The person subject to the training, owing to biofeedback, may observe changes in the attention concentration and impact their emotional condition. Such an impact gives the possibility of controlling the psychophysiological condition of the body. Repeating the trainings for some time results in improving the abilities of regulating the psychophysiological condition through mechanical learning (Joniak, Joniak, 2010; Thompson, Thompson, 2003; Walkowiak, 2015). Making use of brain plasticity involving the creation of new synaptic connections, brain acquires new information. The person improves brain functioning through the neurofeedback-EEG training, thus weakening the unwanted frequency bands and enhancing the wanted frequency [Joniak,Joniak 2010; Fedotchev, 2010,Hammond, 2007).

Many researchers (Hammond, 2007; Strack, Linden, Wilson, 2011; Vernon, 2005) confirm that the neurofeedback-EEG training improves the concentration of athletes, increases stress resistance and makes it possible to feel better, compose oneself and decrease internal stress. Landers et al. (1991) confirmed the hypothesis that neurofeedback-EEG improves the level of archery performance. Experimental group presented great increase in the accuracy of bowshots. Furthermore,Arns et al. (2008) compared the performance improvement of strokes in the case of golfers participating in neurofeedback-EEG and without such a training. Stroke precision was better in the group training neurofeedback-EEG. Study results by Dupee and Werthner(2011) confirm that the neurofeedback-EEG training helps to reach an optimum level of agitation. In the opinion of 15 Olympians, there was an improvement in stress and emotions management. Mikicin, Szczypińska and Skwarek(2018) confirm that under the influence of the neurofeedback training there was an improvement in the attention of sports shooters. Neurofeedback is also applied in sports gymnastics, where owing to the improvement in cognitive and emotional self-regulation the players also improved efficiency as regards sports tasks (Perry, Shaw, Zaichkowsky, 2011). Other studies by Mikicin et al. (2015) also confirm the positive impact of neurofeedback on swimmers and taekwondo players.

The goal of the study is to analyse changes in peripheral vision, sensorimotor coordination and the attention of male and female handball players following neurofeedback training.

Method

Subjects

The studies were carried out at the Interfaculty Laboratory Neuropsychophysiology of the University of Physical Education in Warsaw. The study covered sports people from AZS AWF Warsaw in handball – women from the 1st league (n=9) and men from the 2nd league (n=9). Participation in the study was anonymous. The players trained a few days a week, took part in sports competition, tournaments and leagues as well as competitive sport (Gabbett, 2003). All the subjects consented in writing to take part in the experiment. All the procedures were approved in accordance with the standards of the Senate Ethics Committee of Scientific Research at the University of Physical Education in Warsaw and the standards specified in the Declaration of Helsinki. Tests from the Vienna Test System were carried out for all the people in the studied group (VST handbook): attention measurement test (COG), peripheral perception test (PP-R) and sensorimotor coordination test (SMK). The measurements were performed before and after 20 neurofeedback-EEG trainings. The results of each person were subject to statistical and qualitative analysis.

- COG (Cognitrone) General attention test

The test analyses attention and concentration and measures the general ability of "being alert". The programme displays four squares constituting one row (display field) and one field below (task field). As regards the subtests not limited by time, the subject is supposed to determine whether an abstract figure presented at the bottom is of the same shape as one of the figures presented in the top row and press the appropriate button (VST handbook). The test presents the following indices:

- sum of correctly accepted answers
- sum of correctly rejected answers
- mean time of correctly accepted (s)
- mean time of correctly rejected (s)

• SMK – sensorimotor coordination

Procedure for sensorimotor coordination measurement (eye–hand–leg). It was designed for diagnostic purposes of controlling abilities. The operations of moving an object may be controlled as far as there is feedback being a sensorimotor information concerning the condition of the object at a given time. The present deviation between the target (required) values and the real ones may thus be first observed, and later corrected. Time necessary for coordination movements depends on the necessary amount of feedback and determines the whole operation. The screen presents a room with the target point (green, inverted "T") and an object that should be controlled (a yellow circle section). The yellow circle section starts performing unpredictable (but identical for all the subjects) movements in three different directions (VST handbook).

Empirical indices in the SMK test
- time in the ideal area in the whole test
- time in the ideal area after the first 5 minutes

- PP- R – Peripheral perception

The PP test covers the area of the ability to receive and process peripheral visual information: recognising the stimuli appearing in the peripheral visual field in the appropriate time is subject to testing. The PP test is composed of two types of tasks performed simultaneously: as regards peripheral perception and central tracking task, owing to which the attention of the subject should be focused in the centre of the visual field. The peripheral perception task covers a secondary observation of blinking vertical lines, which are displayed from time to time in the peripheral visual field. Such a line should be recognised and the subject should react by pressing the pedal. The task involves controlling the "point" using the right knob on the subject's panel so that it aligns with the right dot (point and dot – on the screen). When the point is in a correct position, the dot blinks. Completely new and innovative measurement methods were utilised that enable proper assessment of the angle of sight. Inter alia, a remote measurement of head (eyes) position of the subject in relation to the observation field was used (VST handbook) .

Empirical indices in the PP-R test
- tracking
- peripheral perception

Procedures

The test was performed at the University of Physical Education in Warsaw. The subjects performed twice the COG, PP and SMK tests being part of the Vienna Tests System. The first measurement took place prior to the neurofeedback-EEG tests commencement, while the other following the completion of all the trainings. The neurofeedback-EEG trainings took place with the EEG DigiTrack Biofeedback system. Each player took part in 20 trainings once – twice a week. The subject would seat in an armchair in front of a computer LCD 17'' screen during each session. The frequency of beta band (13–20 Hz), SMR (12–15 Hz) were increased, while the theta band (4–7 Hz) and beta2 (20–35 Hz) were decreased from C3 and C4 electrodes, reference electrodes and grounding were fixed on earlobes. The beta band pictures the readiness and engagement of the cerebral cortex in cognitive activity (Thompson at al., 2008). It is related to better concentration, increased attention and attention condition (Baker, 2007). Each session is composed of 8 rounds (3 minutes each) with 30-second-long breaks between. The training was held by a qualified therapist. Each player was taught correct, relaxing breathing. One neurofeedback-EEG training lasted approx. 40 minutes.

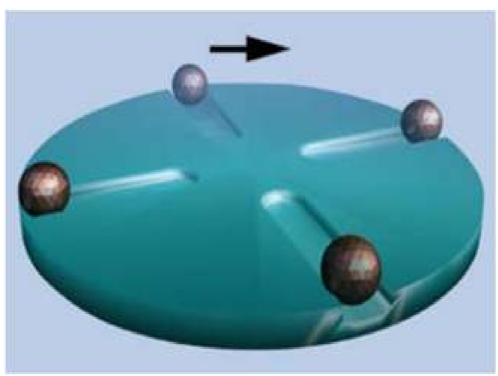

Photo 1 –The subject's desktop in the course of the neurofeedback-EEG training. The goal of the participants was to move four items initially placed on the external edges of the point to the middle. The award was given when the point was filled with all the black points (own source).

Statistical analysis

Variance analysis tests were performed with the use of Statistica software, version 13. Previously, there was a statistical description of variables taking into account the measurement (measurement 1, measurement 2). Having categorised the data depending on the measurement, the following was calculated: mean, standard deviation, minimum and maximum and the Shapiro-Wilk test for small sample was performed, verifying whether the distribution shape is normal (all the variables had a normal distribution $p<0.05$). Research problems were verified using the t test for dependent samples. The goal of the analysis was the change in peripheral vision, sensorimotor coordination and attention in male and female handball players following the neurofeedback-EEG training.

Results

Prior to the variance analysis, there were descriptive statistics performed (mean, standard deviation and maximum and minimum) as well as normal statistics (Kołmogorov-Smirnov test) for variables of the COG, SMK and PP tests. Each variable had normal distribution. Mean results were compared with the standards of the Vienna Tests System. IBM SPSS Statistics, version 22 was used for statistical analysis.

Table 1 – descriptive statistics

Variable	BEFORE		AFTER	
	Mean ± standard deviation	Min – Max	Mean ± standard deviation	Min – Max
COG mean time of correctly accepted answers	1.7 ± 0.27	1,16- 2.32	1.65 ± 0.29	1.02 - 2.24
COG mean time of correctly rejected answers	1.75 ± 0.25	1.2 - 2.10	1.71 ± 0.35	1.03 - 2.53
COG sum of correctly accepted answers	73.66 ± 3.63	68 - 79	75.33 ± 3.05	67 - 80
COG sum of correctly rejected answers	112.5 ± 5.88	99 - 120	114.5 ± 3.91	105 - 120
PP visual field	179.74 ± 5.47	164 - 185.8	179.62 ± 7.79	161.9 - 194
PP tracking deviation with peripheral perception	3.93 ± 0.63	3.2 - 6.1	3.93 ± 0.51	3.0 -5.0
SMK time in ideal area %	4.33 ± 1.85	1.0 -8.0	8.17 ± 3.88	2.0 - 16.0
SMK time in ideal area % after 5 minutes	6.11 ± 2.59	1.0 -12.0	11.06 ± 5.36	2.0 -21.0

While comparing the mean results of the variables subject to the study with the standards of the Vienna Test System, it may be stated that every result of a variable prior to the neurofeedback-EEG training was average. However, mean results of variables subject to the study: COG mean time of correctly accepted answers, COG mean time of correctly rejected answers, SMK time in ideal area % and SMK time in ideal area % after 5 minutes improved – results above the average.

The sum of correctly accepted in the COG test significantly improved ($p<0.05$) after the neurofeedback-EEG training in male and female players. No significant changes in the variables mean time of correctly accepted, mean time of correctly rejected and sum of correctly rejected. The players, after 20 neurofeedback-EEG trainings, solved the tasks in the COG test measuring general attention more precisely – it is indicated by a significant improvement in the index sum of correctly accepted answers ($p<0.05$), which shows the number of cases with identical data and the subject pressed a green button.

Table 2 Variance analysis in the COG test before and after neurofeedback training in male and female players

Variable	T test for dependent samples p<.050*		
	Mean	Standard deviation	p
COG 1 mean time of correctly accepted answers	1.70	0.27	
COG 2 mean time of correctly acceptedanswers	1.65	0.28	0.165
COG 1 mean time of correctly rejectedanswers	1.75	0.25	
COG 2 mean time of correctly rejected answers	1.71	0.34	0.269
COG 1 sum of correctly accepted answers	73.66	3.62	
COG 2 sum of correctly accepted answers	75.33	3.04	0,041*
COG 1 sum of correctly rejected answers	112.50	5.88	
COG 2 sum of correctly rejected answers	114.50	3.91	0.116

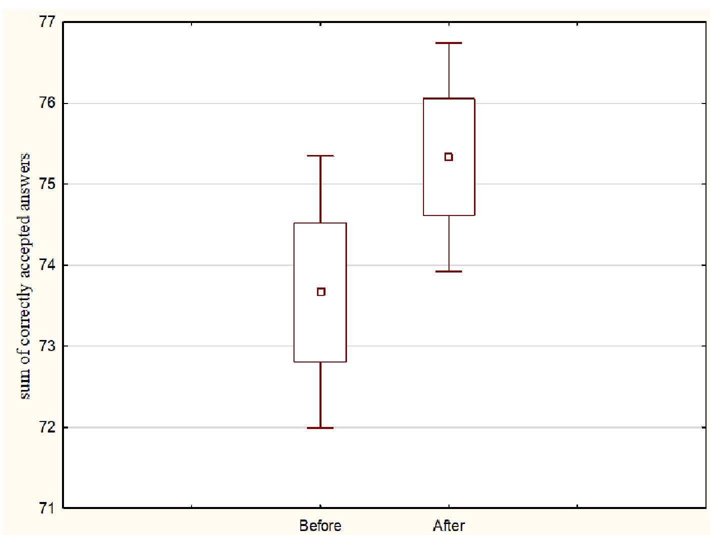

Fig. 1 Differences in the sum of correctly accepted answers before (COG1) and after (COG2) neurofeedback training.

Time in the ideal area improved significantly ($p<0.01$) as well as in the ideal area after 5 minutes ($p<0.01$) in the SMK test after the neurofeedback EEG trainings in male and female players. Sports people improved their sensorimotor coordination in two indices: time in the ideal area in the whole test ($p<0.01$) and time in the ideal area after the first 5 minutes ($p<0.01$), in the SMK test measuring the eye–hand–leg coordination.

Table 3. Variance analysis in the SMK test before and after the neurofeedback-EEG trainings in male and female players.

Variable	T test for dependent samples p<.01**		
	Mean	Standard deviation	p
SMK 1 time in ideal area %	4.33	1.84	
SMK 2 time in ideal area %	8.16	3.88	0,000**
SMK 1 raw time in ideal area % after 5 minutes	6.11	2.58	
SMK 2 time in ideal area % after 5 minutes	11.05	5.36	0,000**

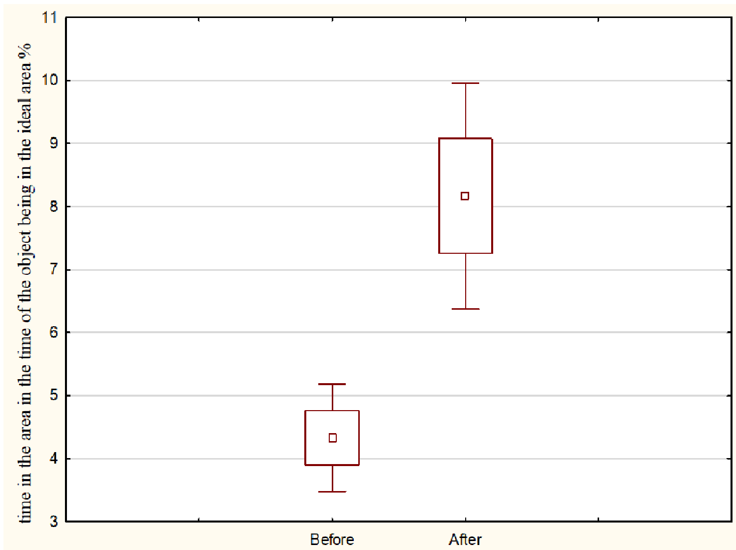

Fig 2. Differences in time in the area in the time of the object being in the ideal area % before (SMK 1) and after (SMK 2) neurofeedback trainings

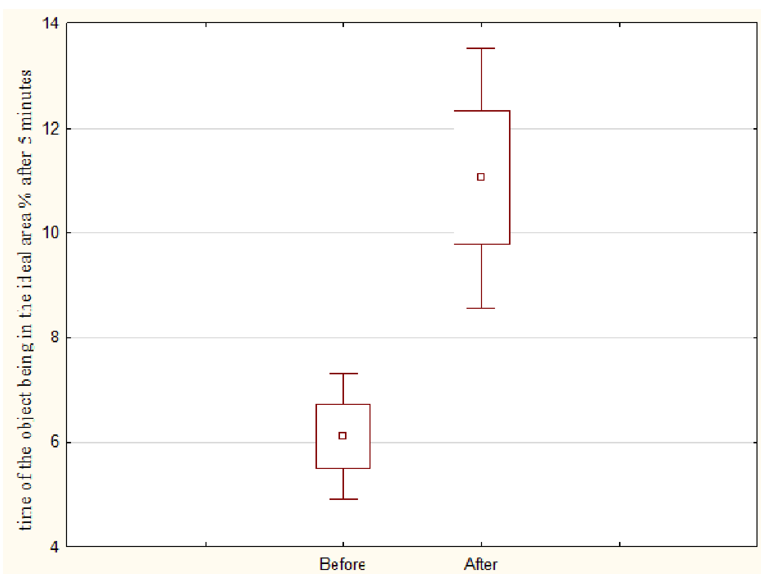

Fig. 3. Differences in the time of the object being in the ideal area % after 5 minutes before (SMK1) and after (SMK2) neurofeedback trainings

Visual field in the PP test ($p<0.02$) significantly improved after the neurofeedback trainings in male players. No improvement was observed in the case of female players. No changes in the variable tracking deviation with peripheral perception in both male and female players.

Table 4. Variance analysis in the PP test before and after neurofeedback trainings in male players

Variable	T test for dependent samples p<.02**		
	Mean	Standard deviation	p
PP1 visual field	178.37	3.73	
PP 2 visual field	184.11	6.35	0,013**
PP 1 tracking deviation with peripheral perception	3.76	0.32	
PP2 tracking deviation with peripheral perception	3.95	0.65	0.290

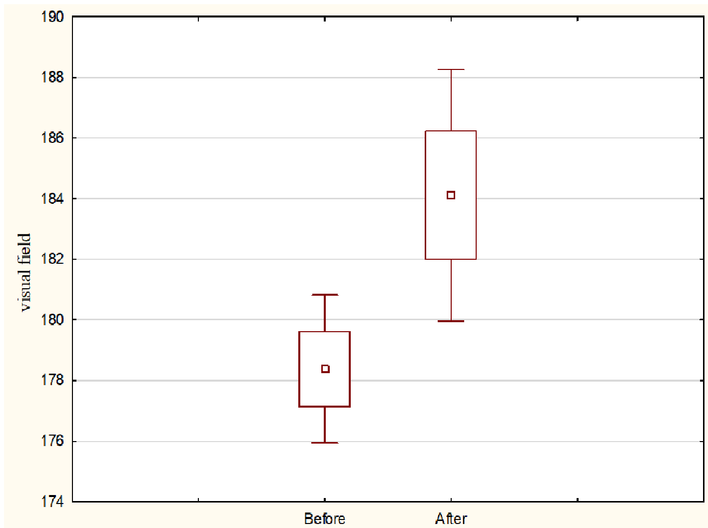

Fig. 4. Differences as regards the visual field before (PP1) and after (PP2) neurofeedback training

Discussion

The goal of the study was to analyse changes in attention, peripheral perception and sensorimotor coordination in male and female handball players after the neurofeedback-EEG trainings. The players performed tasks more precisely after 20 trainings in the COG test measuring general attention – it is indicated by significant improvement in the index sum of correctly accepted answers ($p<0.05$), which covers the number of cases with identical data and the subject pressed a green button (VST handbook) . It may mean that the subjects improved their concentration and attention. This phenomenon may be related to the signal detection theory. Alertness is usually necessary when a given stimulus is present rarely, and following its occurrence immediate reaction is necessary. It is deemed that decreased alertness does not result from decreased sensitivity but rather increase in doubts concerning one's own observations or fatigue. Consistent training may contribute to increase in alertness. The only solution to improve signal detection, in this case, is more frequent rest [Groome, 2014; Green, Swets, 1969]. The results of our study are consistent with the results obtained by Arns et all (2008), Perry, Shaw, Zaichkowsky (2011), Veron (2005), Egner and Gruzelier (2003), which confirm improvement in cognitive functions as regards attention. In the studies by Mikicin et al. (2015) sports shooters, taekwondo players and swimmers also improved their attention following neurofeedback trainings.

Sports people improved their sensorimotor coordination in two indices: time in the ideal area in the whole test ($p<0.01$) and time in the ideal area after the first 5 minutes ($p<0.01$), in the SMK test measuring the eye–hand–leg coordination. It is the percent of the time in which section of the circle was in the ideal scope in partial range (100% = circle segment was always in the ideal range)(VST handbook) . Owing to the training, the players likely will be able to better overcome excessive degrees of freedom of movement, i.e. transform them into a controlled system of movements (simple, complex) as a result of sensor corrections (Bernszetejn, 1991). Researchers (Ting, 2007; Bredin, Azemar, 2007; Bruhn, 2014) claim that the better the players' sensorimotor skills the better their effectiveness in the course of sports competition. It is of particular importance in the case of team sports, where the player needs to take quick decisions based on sudden events and their own psychomotor abilities. Studies by Slope (1992) show that the conditions of work also strongly affect the psychomotor functions. The study covered students of military aviation, where it yielded that the people with low abilities of coping with cognitive stress failed to perform as well in psychomotor activities under stress compared with people with a more developed mechanism of coping with stress. Our study also may prove how important it is to lower emotional stress prior to the competition so that the atheletes may have higher sports results and keep top psychomotor fitness. Male, but not female, players improved their skills as regards peripheral perception in the index: visual field ($p<0.01$), the result of which provides complete visual field in degrees; it is the sum of left and right angle of vision. Calculating the angle of vision is based on the position of the stimulus, the position of the tracking circle and the distance from the head to the measurement unit (VST handbook) .Owing to improvement in the ability to see, it is possible to influence sports competition. Motor skills as well as peripheral perception may be improved through training. Peripheral perception is particularly important in team sports, where attention should be focused on the whole pitch, team members, opponents and – above all – the ball (Planer, 1994; Knudson, Kulka, 1997). On the other hand, female players failed to improve their peripheral skills. This is not conforming to the study by Williams and Thier, who – based on the ANOVA results – confirm the hypothesis that both the vertical and horizontal visual fields are better in the case of sports people as compared with non-athletes. Moreover, there are no differences between genders in sports people and the ones not taking part in competition, except for the vertical level. Women presented a greater high vertical scope of vision (Williams, 2003). Some researchers indicate an important role of other visual training programmes to improve the visual abilities (Williams, Their, 1975). In Adolphe, Vickers and La Plante study (1997), volleyball players took part in a six-week session of perception training to improve their behaviour as regards searching for and increasing accuracy of operation while transmitting information. The programme was based on video techniques and consisted in detecting the ball, tracking and passing on skills. The results have shown improvement in the tracking, tracking time and the ability to keep a stable view of the contact point. Some reports show that the visual functions in sports people are better than in the case of players without the skills. Professional sports people have better visual parameters than sports people of a lower level. Such conclusions may be drawn from the paper (Ishigaki, Miyao, 1993) on dynamic visual acuity of 53 sports people and 46 non-athletes, all university students. Studies show that better players have better visual skills, and every coach's ambition is for their players to be at the top level in every aspect. The drawback of the study is a small sample and no control group. However, the study indicates the most important features/skills (according to the researchers) that a handball player should have to be the most effective. The study may be of use for coaches, players, but it may also be inspirational for new studies to improve a sports training.

Conclusion

The conclusions are as follows:

1) neurofeedback-EEG training improved the attention of male and female handball players
2) neurofeedback-EEG training improved the sensorimotor coordination of male and female handball players, and
3) neurofeedback-EEG training improved peripheral vision in male handball players, but no improvement was observed in female handball players

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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