ijer.skums.ac.ir

The effectiveness of neurofeedback on attention deficit disorder in Iran: A meta-analysis study

Mandana Sarokhani[1], Kourosh Sayehmiri[1,2*]

[1]Psychology Dept., Ilam Branch, Islamic Azad University, Ilam, I.R. Iran; [2]Psychosocial Injuries Research Center, Ilam University of Medical Sciences, Ilam, I.R. Iran.

Received: 13/Mar/2016 Accepted: 2/May/2016

ABSTRACT

Background and aims: Neurofeedback is a relatively new therapy focusing on the core symptoms of inattention, impulsivity and hyperactivity. We undertook a meta-analysis to estimate the effectiveness of neurofeedback on attention deficit disorder in Iran.

Methods: International databases as Pubmed, Scopus, ISI, Google Scholar, and national databases as SID, Medlib, Iranmedex, Magiran were searched using the terms of neurofeedback, attention deficit and hyperactivity. The standardized effect size (SMD) of the control group's mean difference was calculated by the standard deviation integration. Data were analyzed using meta-analysis (random effects model). Heterogeneity of studies was assessed using I^2 index and the Der Simonian-Laird method.

Results: Nine studies were reviewed with a sample size of 204 individuals during 1997 to 2005 and Neurofeedback's overall standardized effect size (SMD) on attention deficit disorder was significant in the experimental group before and after the intervention (SMD=1.14; 95% CI, 0.91-1.38, P=0.001). The SMD was not significant in the control group before and after the intervention (SMD=0.09; 95% CI, 0.07-0.24). Meta-regression showed no statistically significant relationship between the year of study, sample size and SMD.

Conclusion: Although international randomized clinical trials have shown that neurofeedback is not effective in ADHD treatment, In Iran, results of the studies showed that neurofeedback was effective in the treatment of some ADHD's indicators and ineffective in some other ADHD's indicators. Overall, neurofeedback was effective in the treatment of ADHD.

Keywords: Neurofeedback, Attention deficit, Hyperactivity, Systematic review, Meta-analysis.

Review article

INTRODUCTION

Attention deficit and hyperactivity disorder are among the most prevalent childhood behavioral disorders. Based on a meta-analysis of evaluating parents and teachers with a sample size of 14731 subjects collected from 16 studies, the prevalence of this disorder was 8% in children aged 7 to 12 years in Iran (95% CI, 5 to 11%).[1] In other studies, the prevalence of the disorder has been reported to be 3 to 7 with higher prevalence in males than females.[2] This is a persistent psychiatric

[*]**Corresponding author:** Kourosh Sayehmiri, Psychosocial Injuries Research Center, Ilam University of Medical Sciences, Ilam, I.R. Iran. Tel: 00989183410782, E-mail: sayehmiri@razi.tums.ac.ir

disorder characterized by sustained symptoms such as inattention or hyperactivity and impulsivity each observed separately or both together.[3] The prevalence of this disorder has been reported to be about 7% in the United States and between 2 and 29% at international level.[4]

In recent years, specialists have proposed various causes associated with attention deficit and hyperactivity disorder.[5] Neurological causes are one sort of attention deficit and hyperactivity disorder causes are also confirmed by numerous studies.[6] The main symptoms of the disease cause emotional, family and social problems such as poor academic performance, family stress and conflicting relationships with peers.[7] Similar symptoms of attention deficit disorder and learning disorder include attention and hyperactivity problems, frustration at the lowest level, low self-esteem, lack of ethics, disorders in social skills, poor academic achievement and increasing school dropouts.[8]

Brain activity can be measured by electroencephalography (EEG). This technique is called EEG-NF. The aim of EEG-NF is obtaining control over certain aspects of the brain's electrical activity through the use of positive reinforcement and self-regulation skills in daily life.[9,10]

Neurofeedback is a special form of biofeedback in which brain waves are used as feedback. In this method, sensors called electrodes are connected to the patient's head and the received information are provided for the patient and therapist through two separate monitors.[11] Neurofeedback treatment was first proposed by Lowell Lobar. The basic idea is that, by observing its abnormal waves, the brain learns to modify itself. This is done in the treatment process based on principles of learning.[12] Neurofeedback is a tool equipped with a computer system used to run neurofeedback training method or Neurofeedback. This tool uses observer equipment connected to the body (electrode) to provide people with information about some of their biological body functions.[13]

Neurofeedback is a neuropsychological training and treatment method so that an individual can learn to alter brain electrical activity in an operant conditioning process.[14] It is also a technique in which people learn to change their pattern of brain waves through operant conditioning.[15] The goal of neurofeedback training is modifying abnormal EEG which results in the promotion of an individual's associated behavioral and cognitive performance.[16]

Neurofeedback significantly decreases cognitive and behavioral symptoms of ADHD and has the effectiveness of medication and even being an alternative to stimulant drugs.[17] In total, in explaining the effectiveness of neurofeedback; it can be asserted that the human brain is capable of healing itself. It refers to the ability to learn or relearn the self-regulating mechanisms of brain waves which have an important role in normal brain functioning.[13] Drug therapy and neurofeedback have improved attention, speed, and accuracy.[18] Neurofeedback effectiveness is based on a learning process and operant conditioning, so the duration of treatment is usually long-term.[19]

The number of clinical trials on the use of neurofeedback in treating hyperactivity disorders is increasing. Although clinical reports and free treatment studies consider using neurofeedback effect in treating ADHD and show that neurofeedback improves attention, behavior control, increases cortical activity and enhances intelligence test scores and academic achievement, double-blind clinical trials and meta-analysis studies with strict criteria, do not consider using neurofeedback effect in ADHD treatment.[10,20,21]

Several studies have been conducted on "Effects of neurofeedback on attention

deficit disorder" in different regions of Iran, each reporting a different result. Some of these studies consider neurofeedback effective in attention-deficit disorder while others do not. However, there is not yet a total estimate of the effectiveness of neurofeedback on attention-deficit disorder in Iranian society. Hence, doing a systematic review and meta-analysis study is necessary to collect all the evidence and data about the effectiveness of neurofeedback on attention-deficit disorder. The present study aimed at evaluating the effectiveness of neurofeedback on attention-deficit disorder in Iran through systematic review and meta-analysis.

METHODS

Nowadays, systematic reviews and meta-analysis studies and reports are done on the basis of guidelines agreed upon by the world's top medical journals' editors, statisticians, epidemiologists and researchers of the world. In a meeting held in 2005 attended by 29 members among journal reviewers, chief-editors, clinicians, statistician, epidemiologists, a checklist of 27 items, known as the PRISMA guidelines, was written for reporting systematic review and meta-analysis studies. This article is written based on the PRISMA guidelines.[22]

Articles which had words like population, intervention, comparators, outcomes, and study designs of interest in their titles were selected for inclusion in the meta-analysis. Articles that were published in English and Farsi were included and no time limitation was considered for an articles' publication time.

This is a meta-analysis study aimed at evaluating the effectiveness of neurofeedback on attention-deficit disorder in Iran. The reviews were done through internet search and manual search of documents in the library of Tehran University of Medical Sciences. The databases of Iranmedex, SID, Magiran, Irandoc, Medlib, IranPsych, Science Direct, ISI, PubMed, Scopus were searched using internet. The search included theses, national and international scientific journals, and papers presented at congresses and organizational reports. In searching national databases, it was conducted only by searching for keywords of neurofeedback to gain high sensitivity, attention deficit and hyperactivity because some sites did not show sensitivity to search operators of (or, and, not). To search international databases, keywords of "Hyperactivity Disorder", "Attention Deficit", and "Neurofeedback" were used. The standard key words in Mesh were used. The strategy of (Attention Deficit and Neurofeedback) was used to search. In addition, the references of the selected articles were screened for finding relevant studies.

First, a list of titles and abstracts of all searched papers in national databases was prepared by two researchers independently (Mandana Kourosh). Then, articles with repetitive titles were excluded. Next, articles' abstracts were reviewed for finding appropriate studies.

Study inclusion criteria were: 1- Studies conducted before and after. 2- Studies evaluating the effectiveness of neurofeedback on attention deficit disorder. Exclusion criteria were: 1- Non-related studies in terms of study method and research topic. 2- Studies, which did not have enough information. 3- Studies which did not mention the mean and standard deviation before and after the intervention. 4- Studies that have low quality due to the STROBE checklist (Strengthening the reporting of observational studies in epidemiology).[23] The quality of the studies was evaluated using the STROBE checklist. The checklist has 22 sections that cover different parts of a report. Each section was given one point and higher points were given

to other sections that we considered more important.

To reduce bias in reporting and error in data collection, two researchers independently extracted data using a standardized data collection form that was already prepared. The form was first designed by the study team and included the following items: The author's name, title of study, year of publication, city of study, journal name, study design, ADHD assessment method, ADHD assessment tool, duration of treatment, duration of each session, the studied age group, sample size, mean and standard deviation before and after the intervention.

The questionnaires used in this study included Wechsler inventories, Connors, Posner, Padua, LDES, Iran cpt, tova, and the index of theta to beta ratio.

Wechsler intelligence scale for children: This scale is to measure intelligence. It is composed of 12 subtests and two of them are used solely as an alternative or supplement. This test has two practical and verbal scales.[24] Conners scale: This scale has been accepted as an appropriate screening instrument to search for (probable sick children) as well as a measure of the severity of symptoms in patients with ADHD.[25] Posner test: This test is the most common experimental model used for the study of visual-spatial attention.[26] Padua inventory: It was developed by Sanavio in Italy in 1980 in the country which has 60 articles used to assess the severity of symptoms in clinical and normal participants.[27] LDES test: This test is used to diagnose learning disabilities and include measures of listening, thinking, speaking, reading, writing, spelling and calculation.

Data were entered from the checklist to the Excel software and transferred from the Excel software to SPSS software and a preliminary analysis of the data was performed with SPSS. Sincemeta-analysis was not possible with SPSS software, data were transferred to the STATA software (version 11.2) and meta-analysis was performed with this software.

As the attention deficit's average score in all studies before and after the intervention was measured in control and experimental groups, the size of the effect (Effect Size) is calculated as follows:

$$\text{SMD} = \frac{ES_E - ES_C}{SD}$$

Where, $ES_{E=}$ the neurofeedback group effect size
ES_C= the control group effect size
SD= common variance
SMD= standardized overall effect size

$$SD^2 = \frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}$$

Where, S_1^2= neurofeedback group variance
S_2^2= control group variance
n_1= the number of samples in the neurofeedback group
n_2= the number of samples in the control group

Given that decreasing the score of some hyperactivity indicators such as inattention, impulsivity, responsiveness volatilities indicates an improvement of ADHD and increasing the score of some indicators such as planning, simultaneous processing and verbal and practical intelligence indicate the effectiveness of neurofeedback, the order of entering some variables was reversed to align the size effect. Heterogeneity of studies was assessed using I^2 index and the Der Simonian-Laird method. Due to the heterogeneity between studies, the overall effect size was assessed using the random effects model. The funnel plot and Egger test were used to evaluate publication bias.

The significance level of P<0.05 was considered as significance level in test of hypnosis.

RESULTS

In the first phase of the search, 20 articles were selected and after reviewing the titles, only 14 relevant articles were identified and included in the second phase which was the evaluation of abstracts. After reading the full text of articles, one article was excluded from the study because its sample size was only two subjects.[28]

Sajadi et al., study was not included in the analysis because the mean and standard deviation were not mentioned in the control and experimental groups.[29]

Finally, 8 appropriate articles were entered into the meta-analysis stage. The flowchart which shows the process of study selection is presented in below (Figure 1).

The description of studies that met our eligibility criteria are presented in Table 1.

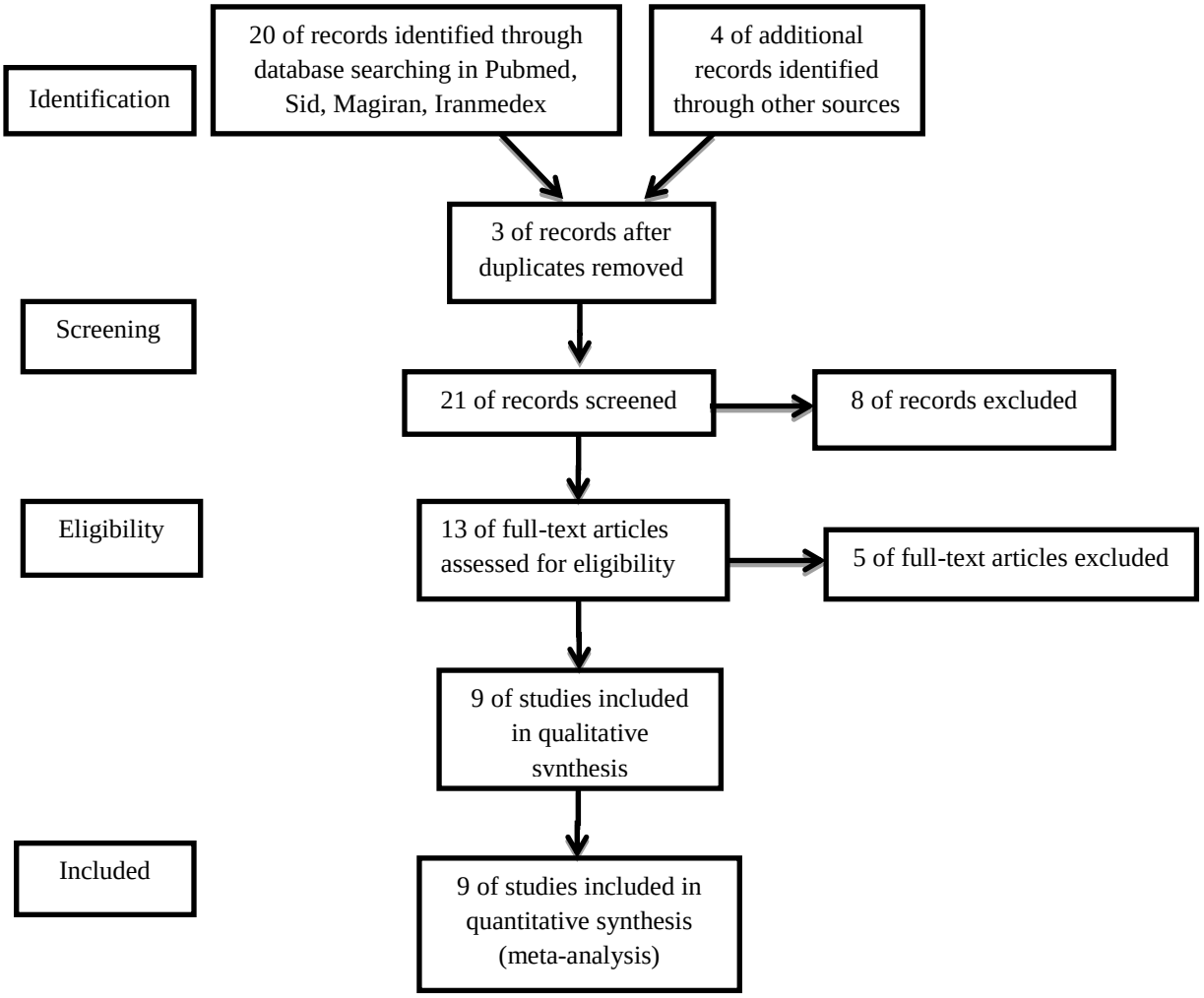

Figure 1: Results of the systematic literature search

Table 1: Included articles' specifications into the meta-analysis on the effectiveness of neurofeedback on attention-deficit disorder in Iran

Reference	Researcher	Questionnaire	Study title	Number of sessions	Session duration	Year
[30]	Hamid Yaghoubi	Wechsler Intelligence	The effectiveness of neurofeedback on cognitive function in children with hyperactivity/attention deficit disorder	30	45 min	2007
[31]	Hamid Yaghoubi	Wechsler Intelligence and Conner's test	Comparing the efficacy of Neurofeedback, Ritalin and combination therapy in reducing symptoms in children with hyperactivity/attention deficit disorder (ADHD)	30		2009
[32]	Fariba Nabavi Alagha	Posner test	The effectiveness of neurofeedback training on cognitive function	20	45 min	2013
[29]	Alireza Sajadi	Posner test	The effect of neurofeedback on the treatment of children's learning disorder in mathematics course in third grade elementary school	20	30 min	2013
[33]	Mohsen Jadidi	Conner's test	Interventions challenge: To what extent each parent management training interventions, neurofeedback and Ritalin improve hyperactivity/attention deficit disorder and Parenting Stress Index	4	120 min	2010
[34]	Narges Nourizadeh	LDES	Effects of neurofeedback on learning deficits associated with attention deficit/hyperactivity disorder	40	60 min	2012
[35]	Mohammad Narimani	Conner's test	Effects of neurofeedback training on reducing ADHD symptoms in female students	20	40 min	2012
[6]	Somayeh Sadati	Sandford and Turner test	Evaluating the effectiveness of neurofeedback treatment on behavioral inhibition and impulsivity among students having attention deficit and hyperactivity disorder	30		2013
[36]	Hossain Vahedi	Tova test	Comparing the effect of neurofeedback treatment and medication on an ongoing performance in hyperactivity attention deficit disorder	20		2012

Table 2: Comparison scores experiment and control group before and after intervention

Firs author	Symptoms code	Sample size in control group	Sample size in experiment group	Control		Experiment	
				Before	After	Before	After
				Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Yaghubi1	1	8	8	108.50±11.40	106.00±12.20	117.75±12.40	111.00±7.30
Yaghubi1	2	8	8	106.50±6.60	105.00±7.50	111.50±5.20	106.50±3.00
Yaghubi1	3	8	8	109.25±7.70	106.75±9.10	116.25±8.80	110.50±3.30
Besharat	4	8	8	3.88±1.4	3.57±1.14	4.1±1.08	3.88±1.14
Besharat	5	8	8	3.43±0.71	3.34±0.71	3.42±0.97	3.43±0.71
Yaghubi2	6	8	8	27.75±10.80	27.75±10.90	11.75±10.80	6.25±10.9
Yaghubi2	7	14	14	33.50±23.50	32.75±14.90	41.50±23.50	17.50±14.9.
Yaghubi2	8	8	8	0.76±0.15	0.75±0.11	0.67±0.15	0.60±0.11
Yaghubi2	9	8	8	0.34±0.13	0.35±0.10	0.29±0.13	0.26±0.10
Yaghubi2	10	8	8	69.75±10.60	78.50±21.40	73.00±10.60	47.50±21.4
Yaghubi2	11	14	14	29.50±4.40	26.75±6.40	29.75±4.40	18.50±6.40
Yaghubi2	12	8	8	11.25±2.00	10.50±3.20	12.75±2.00	6.50±3.20
Yaghubi2	13	8	8	24.00±2.80	21.75±5.30	23.00±2.80	14.25±5.30
Yaghubi2	14	8	8	16.50±2.80	16.50±4.50	15.00±2.80	10.75±4.50
Narimani	16	8	8	108.50±11.40	106.00±12.20	117.75±12.40	111.00±7.30
Narimani	17	8	8	106.50±6.60	105.00±7.50	111.50±5.20	106.50±3.00
Narimani	18	8	8	109.25±7.70	106.75±9.10	116.25±8.80	110.50±3.30
Narimani	19	14	14				
Narimani	20	8	8	108.50±11.40	106.00±12.20	117.75±12.40	111.00±7.30
Narimani	21	8	8	106.50±6.60	105.00±7.50	111.50±5.20	106.50±3.00
Narimani	22	8	8	109.25±7.70	106.75±9.10	116.25±8.80	110.50±3.30
Norizadeh	24	8	8	108.50±11.40	106.00±12.20	117.75±12.40	111.00±7.30
Norizadeh	25	8	8	106.50±6.60	105.00±7.50	111.50±5.20	106.50±3.00
Norizadeh	26	8	8	109.25±7.70	106.75±9.10	116.25±8.80	110.50±3.30
Norizadeh	28	8	8	108.50±11.40	106.00±12.20	117.75±12.40	111.00±7.30
Norizadeh	29	8	8	106.50±6.60	105.00±7.50	111.50±5.20	106.50±3.00
Norizadeh	30	8	8	109.25±7.70	106.75±9.10	116.25±8.80	110.50±3.30
Norizadeh	32	8	8	108.50±11.40	106.00±12.20	117.75±12.40	111.00±7.30
Norizadeh	33	8	8	106.50±6.60	105.00±7.50	111.50±5.20	106.50±3.00
Norizadeh	34	8	8	109.25±7.70	106.75±9.10	116.25±8.80	110.50±3.30
Haghighi	36	8	8	108.50±11.40	106.00±12.20	117.75±12.40	111.00±7.30
Sadati S	37	8	8	106.50±6.60	105.00±7.50	111.50±5.20	106.50±3.00
Sadati S	38	8	8	109.25±7.70	106.75±9.10	116.25±8.80	110.50±3.30
Sadati S	40	8	8	108.50±11.40	106.00±12.20	117.75±12.40	111.00±7.30
Vahedi H	41	8	8	106.50±6.60	105.00±7.50	111.50±5.20	106.50±3.00
Vahedi H	42	8	8	109.25±7.70	106.75±9.10	116.25±8.80	110.50±3.30

9 studies were reviewed with a sample size of 204 individuals during 1997 to 2005 and the effect size was 0.09 in the control group before and after the intervention (95% CI, 0.07-0.24) which was not statistically significant (P>0.263) (Figure 2). As shown in Figure 2, there was no significant difference between any of the criteria for ADHD before and after the intervention in the control group. The heterogeneity of the studies was very high (I^2=99%, P=0.001). High heterogeneity index showed that the results of studies were very different; so, random effects model was used to combine the results of studies (Figure 2).

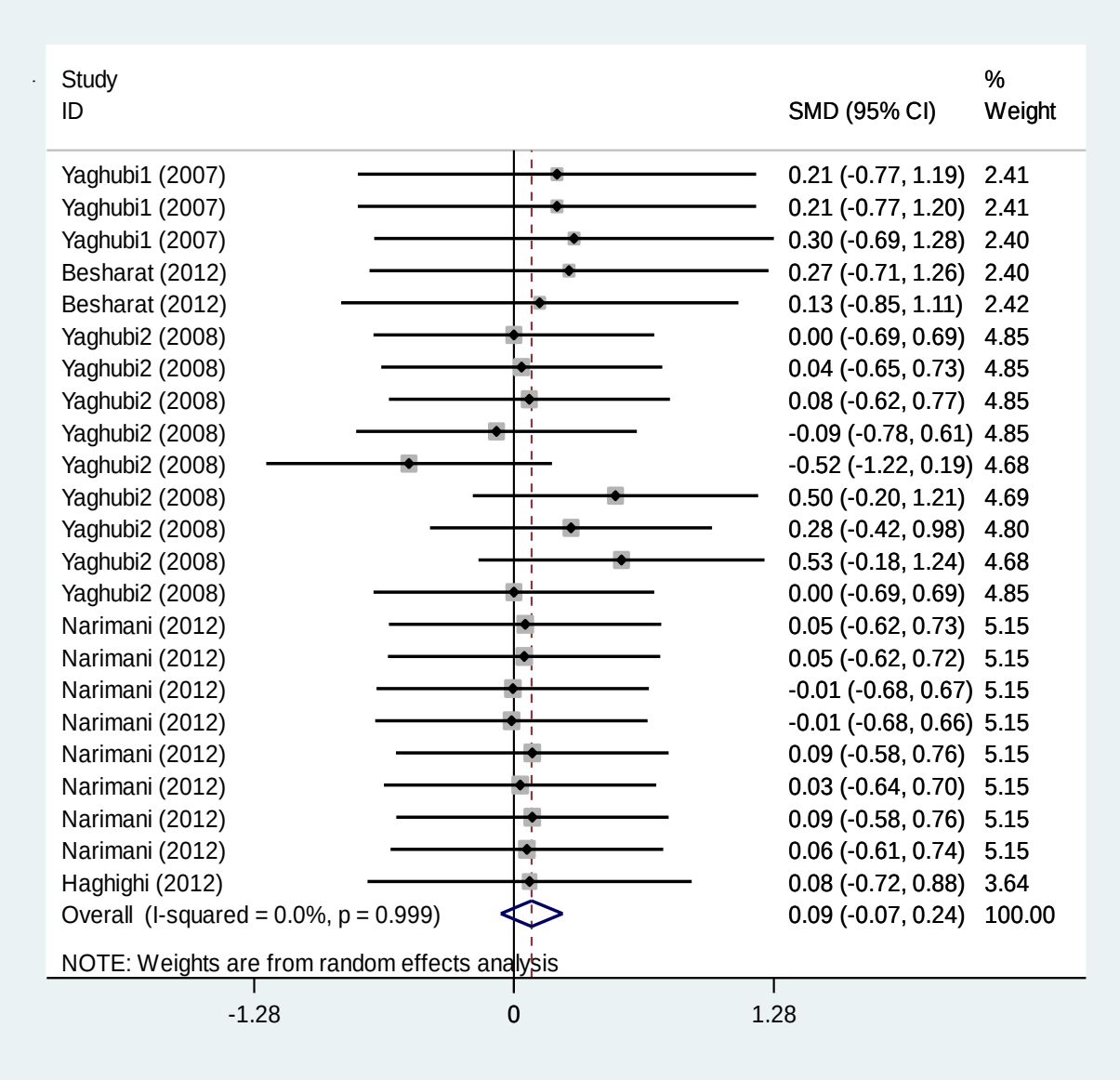

Figure 2: Forestplots of Standardized Mean Difference (SMD), and homogeneity statistics for the ADHD symptoms in the control group before and after intervention

The diamond shows the pooled of SMD in all studies.

Figure 3 showed that the effect size was 0.10 in control and experimental groups before the intervention (95% CI, 0.15-0.34) which was not statistically significant (P=0.42). As shown in Figure 3, there was no significant difference in none of the criteria for ADHD before the intervention in the experimental and control groups except for the Conners Index in the study of Yaghoubi and the number of correct answers index in the study of Narimani (Figure 3). The heterogeneity of the studies was moderate (I^2=59.6%, P=0.001). Moderate heterogeneity index showed that the results of studies were different; hence, random effects model was used to combine the results of studies (Figure 3).

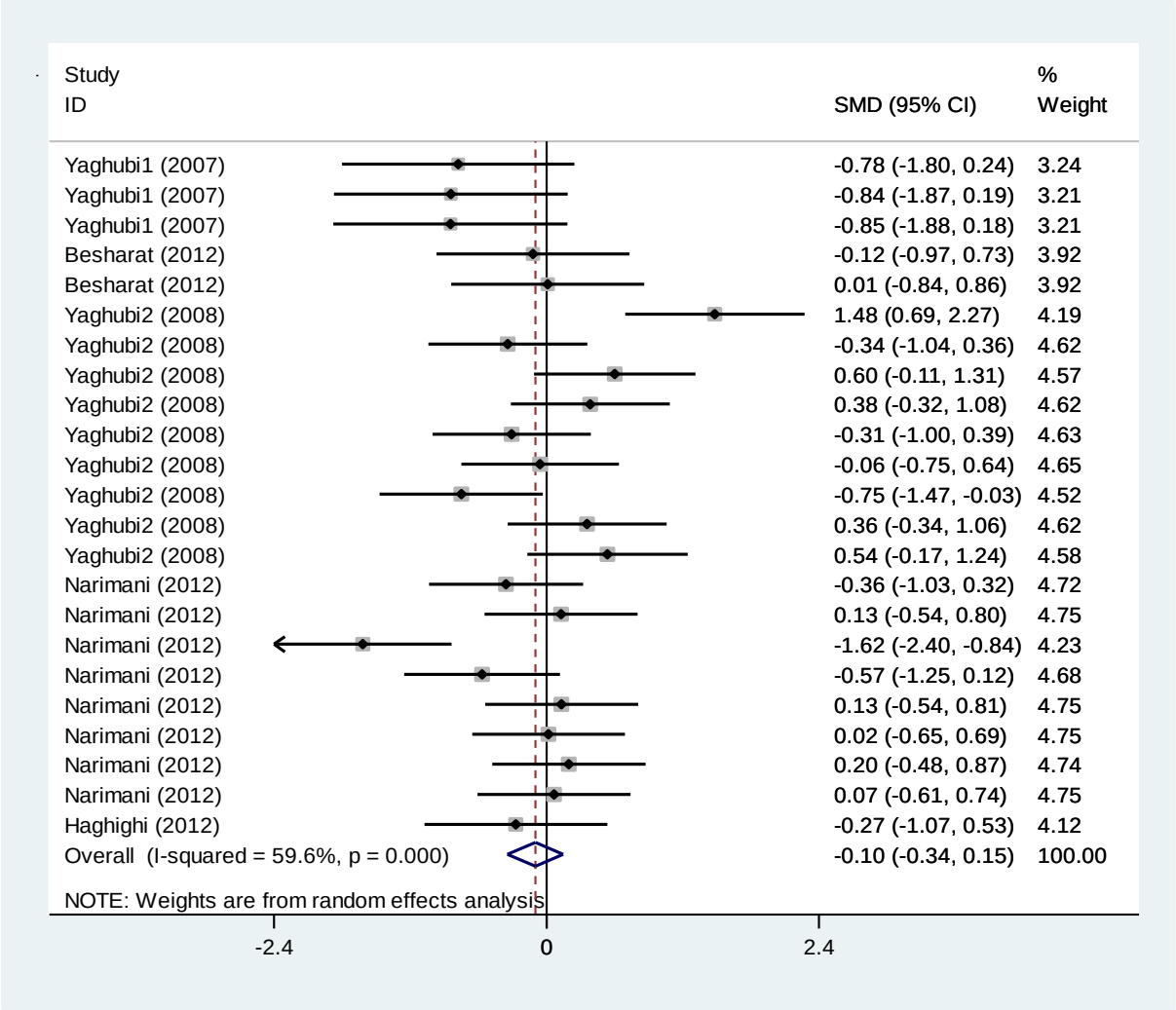

Figure 3: Forestplots of Standardized Mean Difference (SMD), and homogeneity statistics for the ADHD symptoms in the experimental group and the control group before intervention

The diamond shows the pooled of SMD in all studies.

Comparing the indicators of hyperactivity before and after the study in the 8 studies that evaluated the effectiveness of neurofeedback on ADHD with the control group showed that the overall neurofeedback effect was significant. The standardized effect size was estimated to be 1.14 (95% CI, 1.38-0.91) which was statistically significant (P=0.000) (Figure 4). Figure 4 shows that the study of Jacob evaluated the three indicators of practical, verbal and overall intelligence and neurofeedback only increase practical intelligence score significantly (from 106.5 to 111.5), but had no significant impact on the overall and verbal intelligence.[30] Yaghoubi compared the effectiveness of neurofeedback with other treatment methods (Neurofeedback and Ritalin) using Conners and Iran Tova test and results showed that neurofeedback was effective in the impulsivity index of Iran Tova test (17.5-41.5).[31] However, neurofeedback was not significantly effective in indexes of response time, inattention and response fluctuations. In Conner's test (Figure 4),

neurofeedback had a significant effect on all test indexes (hyperactivity, impulsivity, learning disorders, conduct disorder, and all Conners). In Figure 4, when linear segments do not cut a perpendicular to zero, their effect is significant and vice versa. Nurizadeh showed that neurofeedback was significant only in attention index not in other indicators. In the study of Sadatipour et al., neurofeedback had a significant effect on ADHD indexes. By combining all studies using random-effects model, neurofeedback meta-analysis was significant on ADHD indexes (Figure 4).

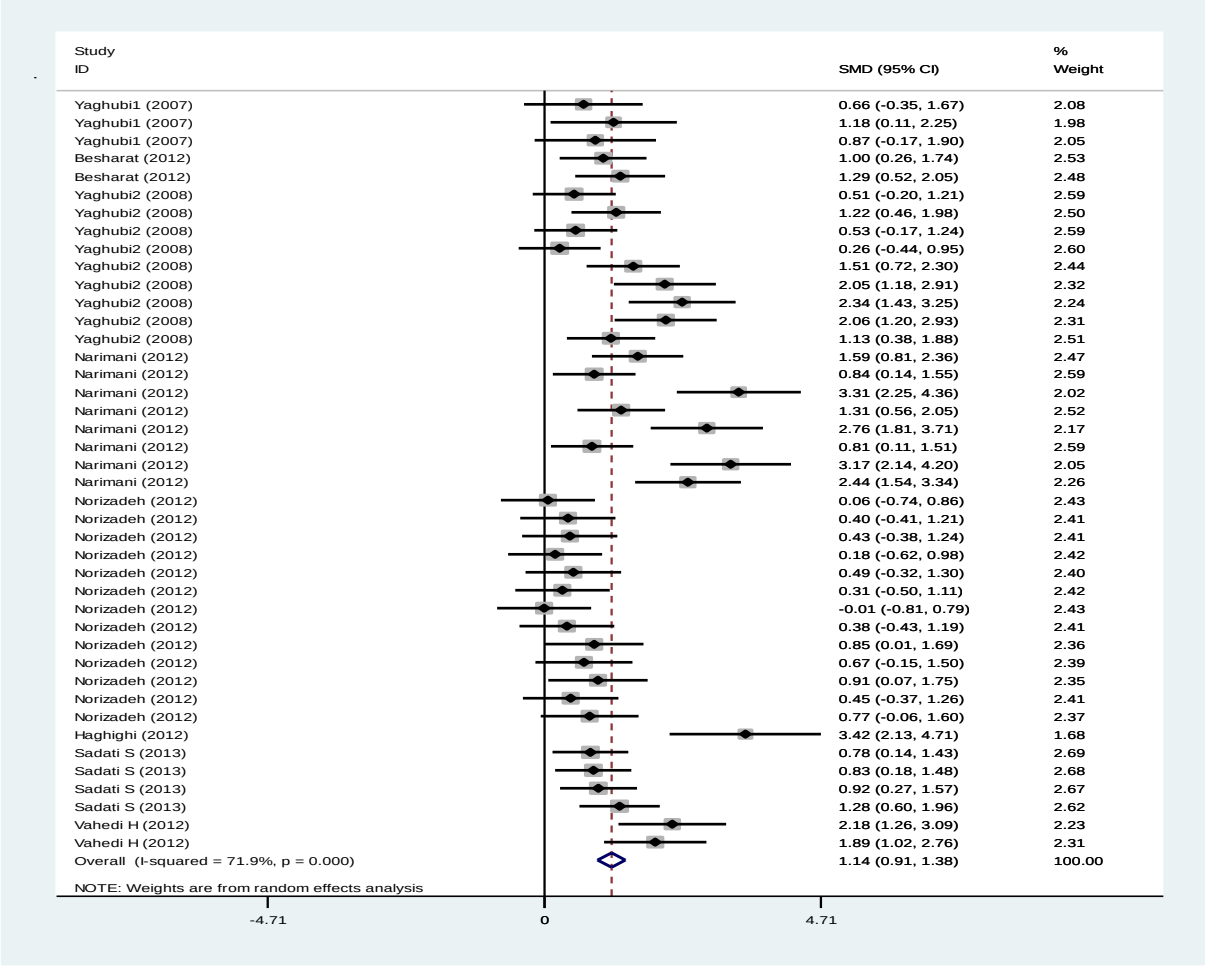

Figure 4: Forestplots of Standardized Mean Difference (SMD), and homogeneity statistics for the ADHD symptoms before and after intervention in the experimental group

The diamond shows the pooled of SMD in all studies.

The heterogeneity of the studies was high (I^2=71.9%, P=0.001). High heterogeneity index showed that the results of studies were different; hence, random effects model was used to combine the results of studies (Figure 4). Standardized effect size of neurofeedback attention deficit disorder indexes was calculated in the experimental group and the control group after the intervention 1.45 (95% CI, 1.6-1.84) which was statistically significant (P=0.001) (Figure 5).

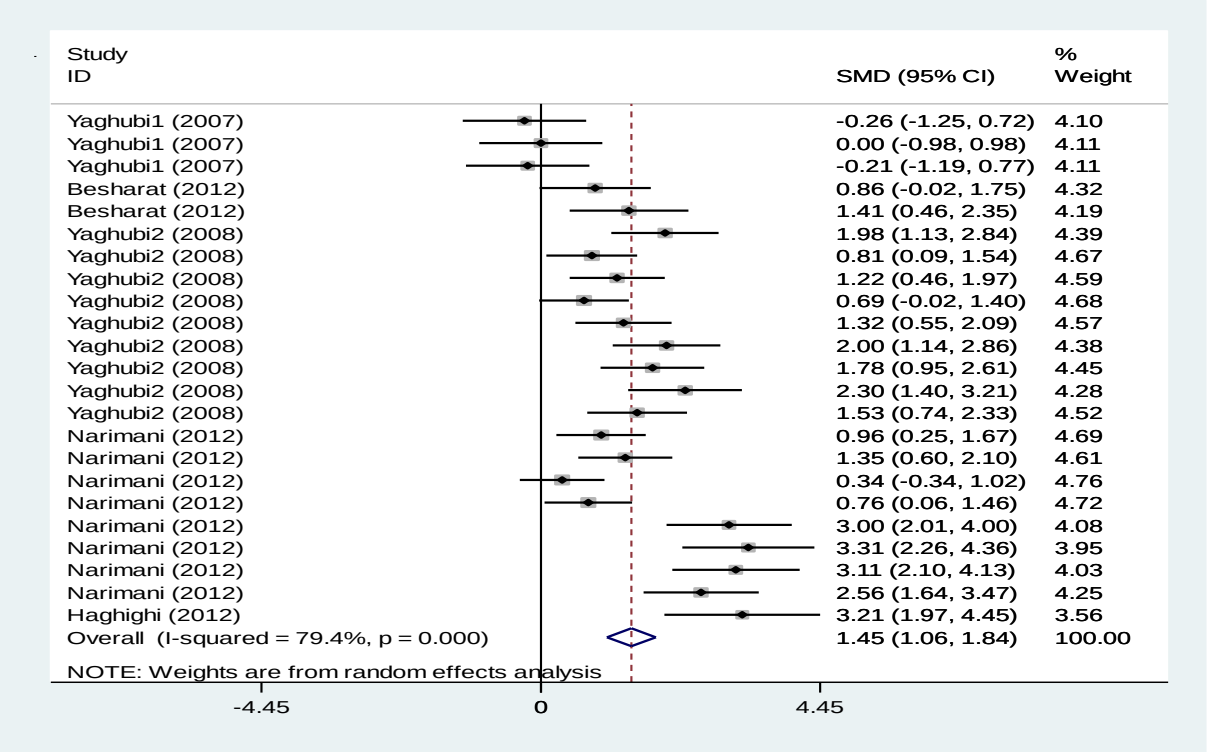

Figure 5: Forestplots of Standardized Mean Difference (SMD), and homogeneity statistics for the ADHD symptoms after intervention in the experimental group and control group

The diamond shows the pooled of SMD in all studies.

Meta-regression model showed no significant relationship between years of study and neurofeedback effect size (P=0.719). There was a direct relationship between sample size and neurofeedback effect size which means that studies with larger sample sizes showed a more significant neurofeedback effect. This relationship is statistically significant with a 10% error, but not significant with error of 5% (P=0.06).

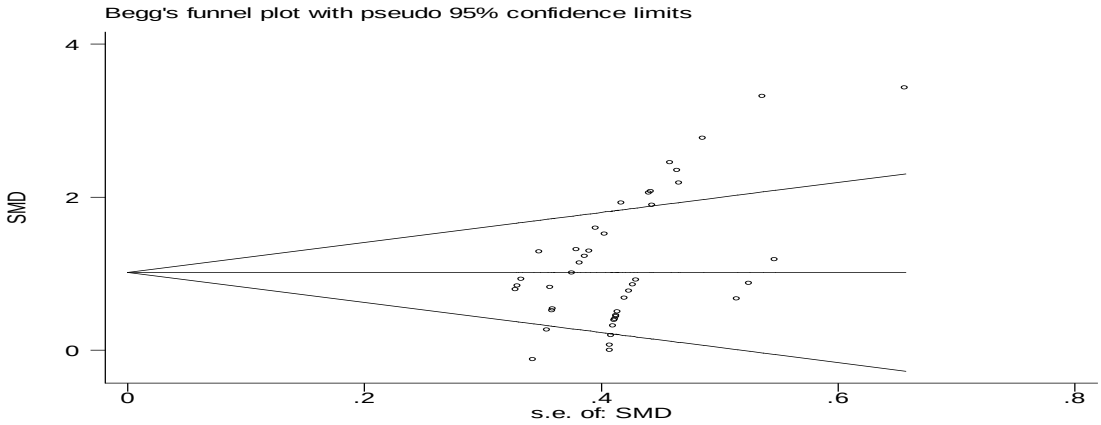

Figure 6: Publication bias plot effect of Neurofeedback on ADHD

Symptoms code	
Verbal IQ	1
Practical IQ	2
Total IQ	3
Theta to beta in CZ	4
Theta to beta in FZ	5
Attention-deficit	6
Impulsiveness	7
Response time	8
Fluctuation response	9
Total score of Kanerz	10
Attention-deficit	11
Impulsiveness	12
Learning disorder	13
Conduct disorder	14
Deletion error	15
Presentation error	16
Correct response	17
Response time	18
Inattention	19
Attention-deficit	20
Impulsiveness	21
Attention-deficit	22
Hear	23
Think	24
Speak	25
Read	26
Write	27
Spell	28
Mathematic	29
Total score	30
Planning	31
Simultaneously process	32
Attention	33
Series process	34
Total score	35
Total score of attention-deficit	36
Behavior	37
Vision behavior	38
Hear behavior	39
Accuracy in response	40

Publication bias figure and Egger test show that the effect of publication bias is statistically significant (P=0.001). It seems that studies which did not show neurofeedback effectiveness to be significantly effective were less likely to be published and included in this study.

DISCUSSION

Nine studies were reviewed with a sample size of 204 individuals in the control and experimental groups during 1997 to 2005 and the neurofeedback overall effect was significant on attention deficit disorder (SMD=1.14, P<0.001). In the control group, there was not a significant difference between measures of hyperactivity before and after the study. So, we can say that Iran's neurofeedback studies had an acceptable design since it is expected that people who have not received any self-treatment do not improve. Also, there was not a significant difference between hyperactivity indexes before the intervention in the neurofeedback and control groups. If hyperactive individuals are included in the experimental and control groups randomly, we expect no significant difference between the indexes in the two groups before the treatment. Among the 43 indexes evaluated in all the studies, only two indexes were significant before the intervention between the control and experimental groups and there was no significant difference in the rest of the indexes. By combining the effect size in all studies, there was not a significant difference between the experimental and control groups before the intervention which showed the suitability of the design.

Yaghoubi investigated the three indexes of practical, verbal and overall intelligence and neurofeedback only increased the practical intelligence score significantly, but the effect on the verbal

and overall intelligence was not significant.[31] In another study, Jacob et al., compared the effectiveness of neurofeedback with other treatment methods (Neurofeedback and Ritalin) using the Conners test and Iran Tova test and results showed that neurofeedback was effective in the impulsivity index of Iran Tova test.[31] However, neurofeedback was not significantly effective in indexes of response time, inattention and response fluctuations. In Conner's test, neurofeedback had a significant effect on all test indexes (hyperactivity, impulsivity, learning disorders, conduct disorder, and all Conners). By combining all studies using random-effects model, neurofeedback meta-analysis was significant on ADHD indexes (Figure 4).

Hilliard analyzed the DNA of brain waves during neurofeedback training in people with attention deficit/ hyperactivity. This study showed that neurofeedback is an effective treatment for ADHD.[32] Gevensleben et al., randomly divided 94 children (6 to 12 years) with ADHD into two groups of drug therapy and neurofeedback and showed that neurofeedback can improve attention and self-management abilities in children with attention deficit hyperactivity disorder.[37] Also, Internal investigations confirm the effectiveness of neurofeedback in treating the symptoms of hyperactivity and attention deficit. For example, Yaghoubi et al., demonstrated that neurofeedback training with Ritalin treatment is effective in reducing the symptoms of attention deficit hyperactivity disorder in children.[31]

Logemann studied neurofeedback effect on attention deficit-hyperactivity disorder in children and results showed that neurofeedback had no impact on the two groups.[38] Although clinical reports and free treatment studies consider using neurofeedback effective in treating ADHD and have shown that neurofeedback improves attention, behavior control, increases cortical activity and enhances intelligence test scores and academic achievement, double-blind clinical trials and meta-analyzes with strict criteria using neurofeedback not effective in ADHD treatment.[10,20,21]

Micoulaud-Franchi carried out a meta-analysis study in France and combined the results of five clinical trials that have assessed the effectiveness of neurofeedback on ADHD and similar SMD index of this study was calculated. The results showed that parents viewed neurofeedback significantly effective on hyperactivity and attention deficit while teachers did not view neurofeedback significantly effective on hyperactivity and attention deficit.[39] Neurofeedback effect size in ADHD total score in parents' view in Micoulaud-Franchi's study was lower than our study (SMD=-0.49).

Given the significance of the effect of publication bias in studies conducted in Iran, those which have shown significant effects of neurofeedback on ADHD have been more likely to be published and this might be one reason that the effect of neurofeedback on ADHD in Iran was more than the meta-analysis study conducted in France. Well-designed studies are needed to be conducted to make the various forms of neurofeedback so that it provides comprehensive scientific evidence about the effectiveness or lack of effectiveness of neurofeedback in treatment of attention deficit hyperactivity disorder.[20]

The limitations of this study include not using the same tool for the assessment of ADHD, the low number of studies, lack of control group in some studies, lack of uniform reporting of studies (mean and standard deviations were not mentioned in some studies and only P-value was listed) and less publishing chance of articles that

did not report significant effects of neurofeedback on ADHD which created publication bias.

CONCLUSION

Despite the inconsistency in the results of studies about the effectiveness of neurofeedback on the treatment of hyperactivity in Iran, the results of this meta-analysis indicated that neurofeedback has a significant effect on ADHD treatment. Therefore, the use of neurofeedback is recommended for ADHD treatment and double-blind trials are suggested to investigate this issue meticulously.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

ACKNOWLEDGEMENT

We would like to thank all individuals who collaborated in this study to collect data and conduct other parts of research.

REFERENCES

1. Arjmandi S, Kikhavandi S, Sayehmiri K. Prevalence of attention deficit hyperactivity disorder among primary school children according to teachers and parents' report: Systematic review and meta-analysis study. J Fundam Ment Health. 2015; 17(5): 213-21.
2. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 4th ed. USA: American Psychiatric Association; 2000.
3. Kessler RC, Adler L, Barkley R, Biederman J, Conners CK, Demler O, et al. The prevalence and correlates of adult ADHD in the United States: Results from the National Comorbidity Survey Replication. Am J Psychiatry. 2006; 163(4): 716-23.
4. Barkley RA. Attention-Deficit/ Hyperactivity Disorder: A Handbook for Diagnosis and Treatment. USA: The Guilford Press; 2006.
5. Kirk S, Gallagher MR, Anastasiow NJ. Educating Exceptional Children Houghton Mifflin Company. USA: Wadsworth Pub; 2000.
6. Sadati S, Afrooz G , Rostami R, Behpajooh A, Shokoohi Yekta M, Ghobari Bonab B. Efficacy of neurofeedback on behavioral inhibition and impulsivity in students with ADHD. Except. Child. 2014; 14(2): 57-66.
7. Goldman LS, Genel M, Bezman RJ, Slanetz PJ. Diagnosis and treatment of attention-deficit/hyperactivity disorder in children and adolescents. Council on Scientific Affairs, American Medical Association. JAMA. 1998; 279(14): 1100-7.
8. Epstein MA, Shaywitz SE, Shaywitz BA, Woolston JL. The boundaries of attention deficit disorder. J Learn Disabil. 1991; 24(2): 78-86.
9. Heinrich H, Gevensleben H, Strehl U. Annotation: neurofeedback - train your brain to train behaviour. J Child Psychol Psychiatry. 2007; 48(1): 3-16.
10. Gevensleben H, Rothenberger A, Moll GH, Heinrich H. Neurofeedback in children with ADHD: validation and challenges. Expert Rev Neurother. 2012; 12(4): 447-60. 11. Gruzelier J, Egner T, Vernon D. Validating the efficacy of neurofeedback for optimising performance. Prog Brain Res. 2006; 159: 421-31.
12. Gunkelman JD, Johnnstone J. Neurofeedback and the brain. J Adult Develop. 2005; 12(2-3): 93-8.
13. Demos JN. Getting started with neurofeedback. New York: WW Norton; 2005.
14. Zoefel B, Huster RJ, Herrmann CS. Neurofeedback training of the upper alpha frequency band in EEG improves cognitive performance. Neuroimage. 2011; 54(2): 1427-31.

15. Frank M, Kathryn NH. Neurofeedback in psychological practice. Prof Psychol Res Pr. 2003; 34(6): 652-6.
16. Becerra J, Fernandez T, Harmony T, Caballero MI, Garcia F, Fernandez-Bouzas A, et al. Follow-up study of learning-disabled children treated with neurofeedback or placebo. Clin EEG Neurosci. 2006; 37(3): 198-203.
17. Thomas R. Rossitera J, Theodore J. Comparison of EEG biofeedback and psychostimulants in treating attention deficit/hyperactivity Disorders. J Neurotherap. 1995; 1(1): 48-59.
18. Fuchs T1, Birbaumer N, Lutzenberger W, Gruzelier JH, Kaiser J. Neurofeedback treatment for attention-deficit/hyperactivity disorder in children: a comparison with methylphenidate. Appl Psychophysiol Biofeedback. 2003 Mar; 28(1): 1-12.
19. Corydon Hammonda D. What is neuro feedback? J Neurother. 2006; 10(4): 25-36.
20. Vollebregt MA, Van Dongen-Boomsma M, Slaats-Willemse D, Buitelaar JK. What future research should bring to help resolving the debate about the efficacy of EEG-neuro feedback in children with ADHD. Front Hum Neurosci. 2014; 15(8): 321. PubMed PMID: 24860487. Pubmed Central PMCID: 4030169.
21. Monastra VJ, Lynn S, Linden M, Lubar JF, Gruzelier J, LaVaque TJ. Electroencephalographic biofeedback in the treatment of attention-deficit/hyperactivity disorder. Appl Psychophysiol Biofeedback. 2005; 30(2): 95-114.
22. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med. 2009; 151(4): 264-9, W64.
23. Von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Ann Intern Med. 2007; 147(8): 573-7.
24. Eric JM, David A, Wolfe M, Eric J. Abnormal child psychology. Pacific Grove, Canada: Cole, Wadsworth; 2005.
25. Conners CK1, Sitarenios G, Parker JD, Epstein JN. The revised Conners' Parent Rating Scale (CPRS-R): factor structure, reliability, and criterion validity. J Abnorm Child Psychol. 1998 Aug; 26(4): 257-68.
26. Niu M, Chen F. 99% Normal adjudication and 1% Super normal adjudication posner paradigm and construction of Chinese scholar- type Jude Mechanism. Asian Soc Sci. 2008; 4(10): 81-84.
27. Goodarzi MA, Firoozabadi A. Reliability and validity of the Padua Inventory in an Iranian population. Behav Res Ther. 2005; 43(1): 43-54.
28. Ghorbani A, Aliabadi F, Nazari M A, Akbarfahimi M. Study of neurofeedback effects on academic achievement of. J Mod Rehab. 2015; 9(3): 1-8.
29. Sadjadi SA, Akhondpour Manteghi A, Hashemian P. Evaluation of neurofeedback therapy in children with mathematic disorder in thirdgrade elementary school. Med J Mashhad. 2014; 57(5): 719-26.
30. Yaghubi H, Jazayeri A, Khushabi K, Dolatshahi B, Niknam Z. Effectiveness of neurofeedbackof performance intelligence in children with ADHD. Rehab J. 2009; 39: 1-7.
31. Yaghubi H, Jazayeri A, Khushabi K,Dolatshahi B, Niknam Z. Comparing the effectiveness of neurofeedback, Ritalin and combination therapy in reducing symptoms in children with ADHD, attention deficit disorder. J Shahed Univ. 2008; 15: 71-84.
32. Luijmes RE. The effectiveness of neurofeedback training on cognitive function. Thought and Behavior in Clinical Psychology[MA theses]. Netherlands: University of Tilburg; 2013.

33. Jadidi M, Shamsaee MM, Mazaheri MM, Khoushabi K, Farrokhi NA. Challenge of Interventions: To what extent parental management training, neurofeedback, and stimulant therapy (Ritalin) improve AD/HD and parental stress index. J Fam Res. 2012; 8(29): 101-18.
34. Baydala L, Wikman E. The efficacy of neurofeedback in the management of children with attention deficit/hyperactivity disorder. Paediatr Child Health. 2001; 6(7): 451-5.
35. Narimani M, Rajabi S, Delavar S. Effects of neurofeedback training on female students with attention deficit and hyperactivity disorder. Arak Univ Med Sci J. 2013; 16 (2): 91-103.
36. Vahedi H, Zaea Y. Compare the effectiveness of neurofeedback treatment and medication on continuous performance improvement hyperactivity disorder. J achieve psychol. 2014; 4(1): 161-74.
37. Gevensleben H, Holl B, Albrecht B, Schlamp D, Kratz O, Studer P, Rothenberger A, Moll GH, Heinrich H. Neurofeedback training in children with ADHD: 6-month follow-up of a randomised controlled trial. Eur Child Adolesc Psychiatry. 2010 Sep; 19(9): 715-24.
38. Logemann HN1, Lansbergen MM, Van Os TW, Böcker KB, Kenemans JL. The effectiveness of EEG-feedback on attention, impulsivity and EEG: A sham feedback controlled study. Neurosci Lett. 2010 Jul 19; 479(1): 49-53.
39. Micoulaud-Franchi1 J-A, Geoffroy PA, Fond6 G, Lopez R, Bioulac S, Philip P. EEG neurofeedback treatments in children with ADHD: An updated meta-analysis of randomized controlled trials. Front Hum Neurosci. 2014; 8(906): 1-7.

How to cite the article: Sarokhani M, Sayehmiri K. The effectiveness of neurofeedback on attention deficit disorder in Iran: A meta-analysis study. Int J Epidemiol Res. 2016; 3(2): 185-200.