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The use of neurofeedback method in cognitive function training in the elderly – a systematic literature review

Wykorzystanie metody neurofeedback w treningu funkcji poznawczych u osób starszych – systematyczny przegląd piśmiennictwa

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Kilian J, Wiśniowska-Szurlej A, Kopańska M, Ćwirlej-Sozańska A. The use of neurofeedback method in cognitive function training in the elderly – a systematic literature review. DOI: 10.26444/monz/116642

Abstract

Introduction and objective. Cognitive functioning disorders are a common problem associated with the aging process. One of the non-pharmacological therapeutic methods used in attempts at improvement the cognitive functioning of the elderly is neurofeedback. The aim of the work was to conduct a review of the latest research on the effectiveness of the use of the neurofeedback method in cognitive training of older people.

Brief description of the state of knowledge. Based on a review of literature from 2013–2018 concerning the use of the neurofeedback method in the cognitive training of the elderly, 7 items qualified for the analysis. In the majority of them, the training included persons without diagnosed cognitive impairment. Positive influence on cognitive functions was dependent on the training protocol used; however, the most frequent changes were observed in the range of particular memory functions. In most studies, it was shown that the use of the neurofeedback method in cognitive training is associated with changes in the EEG record of older people.

Conclusions. The results of the conducted analysis indicate a potential of the neurofeedback method in the therapy of cognitive functions of the elderly. It was found that better therapeutic effects were achieved in patients whose cognitive state enabled fully active participation in the training. However, large discrepancies in the training protocols used, and the small number of publications meeting the inclusion criteria, suggest the need for further research, in particular regarding the observation of the long-term effects of the training procedures used.

Key words

neurofeedback, aged, cognitive function, cognitive therapy, systematic review

Streszczenie

Wprowadzenie i cel pracy. Zaburzenia funkcjonowania poznawczego to powszechny problem związany z procesem starzenia się. Jedną z niefarmakologicznych metod terapeutycznych stosowanych podczas prób usprawnienia funkcjonowania poznawczego osób starszych jest neurofeedback. Celem pracy było przeprowadzenie przeglądu najnowszych badań dotyczących efektywności zastosowania metody neurofeedback w treningu funkcji poznawczych osób starszych.

Skrócony opis stanu wiedzy. Na podstawie przeglądu literatury z lat 2013–2018 dotyczącej wykorzystania metody neurofeedback w treningu funkcji poznawczych osób starszych do analizy zakwalifikowano 7 pozycji. W większości z nich treningiem objęte zostały osoby bez zdiagnozowanych zaburzeń poznawczych. Pozytywny wpływ na funkcje poznawcze zależny był od zastosowanego protokołu treningowego, jednakże najczęstsze zmiany obserwowane były w zakresie poszczególnych funkcji pamięci. W większości analizowanych badań wykazano również, iż zastosowanie metody neurofeedback w treningu poznawczym związane jest ze zmianami w zapisie EEG osób starszych.

Podsumowanie. Wyniki przeprowadzonej analizy wskazują, że neurofeedback jest obiecującą formą wspierania funkcjonowania poznawczego osób starszych. Stwierdzono, iż lepsze efekty terapeutyczne osiągane były u pacjentów, których stan poznawczy umożliwiał w pełni aktywny udział w treningu. Duże rozbieżności w stosowanych protokołach treningowych i mała liczba publikacji spełniających kryteria włączenia sugerują jednak konieczność prowadzenia dalszych badań, zwłaszcza w zakresie obserwacji długoterminowych efektów zastosowanych procedur treningowych.

Słowa kluczowe

neurofeedback, osoby starsze, funkcje poznawcze, terapia poznawcza, systematyczny przegląd piśmiennictwa

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Received: 23.10.2019; Accepted: 16.01.2020; Published on line: 07.02.2020

INTRODUCTION

According to statistical data, the percentage of people aged over 65 was 19.4% in Europe in 2017. In Poland, the percentage of people over 65 in 2017 was below the European average. Nevertheless, Poland is among the countries where the aging process is the fastest – in recent years there has been an increase in the percentage of people over 65 with 13.5% in 2009 to 16.5% in 2017 [1]. This phenomenon is related to a large extent to the extension of life as a result of advances in medical sciences and improved access to healthcare services [2]. Extending life is not always related to maintaining health and well-being. According to Węgrzyn, only 7% of people over 75 years of age do not declare any chronic diseases. Therefore, this creates the need to direct State policy on solving the complex medical and social problems of the elderly [3].

One of the common problems of older people concerns cognitive disorders [4]. It is recognized that in highly developed countries the incidence of cognitive impairment in people over 65 is 5–10%, and the risk of their occurrence doubles every 5 years [5]. According to data from the World Health Organization (WHO), cognitive impairment and dementia are among the main causes of disability in older people and affect 35.6 million people worldwide [6]. According to Albert et al., mild cognitive impairment, which is found in 10–20% of the elderly, does not preclude independent functioning; however, regarding one-third of the cases, these disorders are progressive and may lead to the development of dementia [7]. Increasing memory disorders, information processing abilities, problem solving or reaction speed cause deterioration of functional capacity in older people and a significant decrease in their quality of life [8]. This often makes it necessary to provide elderly people with long-term care services, including placement of these people in care institutions. The increase in expenditure on this form of care is a huge burden on the State budget; therefore, currently it is necessary to find effective strategies and forms of therapies preventing the development and intensification of cognitive deficits in the elderly [3,9].

The phenomenon of polypharmacy, commonly occurring in the elderly, and the risk of serious side-effects of anti-dementia drugs, make it necessary to search for non-pharmacological methods of cognitive therapy in the elderly [10]. Klimowa et al. demonstrated that among the non-pharmacological forms of therapy, physical activity, adequate diet and cognitive training have the greatest influence on the maintenance of synaptic transmission [11]. However, Zokaei et al. found that the costs associated with the treatment and care of older people with cognitive impairment far outweighed the costs of simple cognitive training based on modern technologies, which justify continuous development of this form of therapy [12].

The neurofeedback method is based on the use of the brain electrical activity, the purpose of which is to teach people who are trained to influence the electrical activity of their brains [13]. It is believed that synchronic oscillations which underlie the efficiency of fundamental cognitive processes, play a special role in the bioelectric activity of the brain [14]. According to the majority of authors, along with the gradual deterioration of cognitive functions, there are changes in the EEG records which are based on increasing activity of synchronous waves delta (1–4Hz) and theta (4–8 Hz), defined as slow action and decreasing activity of alpha (8–12 Hz) beta (13–21 Hz) and gamma (>30 Hz), referred to as the fast brain waves [13,15]. Therefore, the essence of training based on the neurofeedback method is a modification of the activity of individual brain waves during therapeutic intervention by performing specific tasks [14,15]. According to the training session procedure, 10–20 electrodes are placed on the scalp of the patient which measure electrical activity in specific areas of the brain and provides the patient with feedback information on the monitor screen, usually in a visual or auditory form. This answer indicates whether the brain activity is included in the range defined in the training protocol [16].

To-date, research on the use of neurofeedback-based training has been conducted in many groups, however, the best documented is the positive effect of this form of therapy on the cognitive functioning of people with ADHD [17,18]. As stated by Staufenbiel et al., the majority of previous studies indicating the positive effects of this form of therapy have been carried out in the group of young people; therefore, it is currently uncertain whether the results obtained in this group can also refer to the elderly population [19]. In the opinion of Bamidis et al., the current state of knowledge on the use of neurofeedback in the treatment of cognitive impairment in the elderly does not allow for a clear statement about the effectiveness or lack of effects in the use of this method [20]. However, more and more available literature indicates the growing potential and effectiveness of training using the neurofeedback method to improve cognitive functioning in older people [21,22,23]. On the other hand, Silva stated that the growing number of studies showing the positive effects of this form of therapy in the elderly suggests that age does not exclude brain neuromodulatory ability [24].

According to analysis of the literature, a systematic assessment of the effectiveness of the neurofeedback method in cognitive function training in older people has carried out by only a few researchers [13,25]. The intensive development of research in this area observed in recent years worldwide suggests the necessity to initiate research based on the neurofeedback method in the Polish population. However, this process should be preceded by a thorough analysis of the effectiveness of this form of therapy in the light of the latest literature reports.

OBJECTIVE

The aim of the study was to conduct a systematic review of the latest research on the effectiveness of using the neurofeedback method in cognitive training of older people.

LITERATURE REVIEW

Methods of searching for publications. A systematic review of the literature is considered to be the method of integrating scientific evidence, which uses an explicit protocol for the identification, selection and analysis of data qualified for the review. Its purpose is to minimize bias and strive to obtain credible and reliable scientific evidence [26].

The aim of the analysis was to search the PubMed electronic database, Google Scholar and Science Direct and the ISI Web of Knowledge databases, taking into account publications

from 2013 to the latest to. The results were obtained using the following keywords in the search: neurofeedback, EEG feedback, elderly, and cognitive function. The stages of literature search and the key words applied in the review are presented in Table 1.

Table 1. Stages of literature search

Search stages	Search phrases
1	MeSH: neurofeedback, aged, cognitive therapy Key words: neurofeedback OR EEG feedback AND elderly AND cognitive function
2	Publications in English
3	Publications issued 2013–2018
4	Available abstract

When selecting particular items, the following inclusion criteria were taken into account: publications based on intervention studies, in which the protocol for conducting the therapy session and the duration of interventions were established. In addition, the analysis included publications, in which the study group consisted of elderly people and people of late adulthood (>55 years). Apart from age, the inclusion criterion included also the risk of cognitive impairment, the presence of mild cognitive impairment or early dementia.

On the other hand, the analysis excluded review publications and systematic review of the literature, post-conference papers, as well as interventional studies, in which the study group were people under 55 years of age. Other exclusion criterion were an imprecise definition of the method of conducting the therapy session and the duration of the intervention. Finally, the criterion of exclusion from the analysis was also the coexistence of chronic diseases that may affect the deterioration of cognitive functions (condition after stroke, Parkinson's disease, multiple sclerosis) (Tab. 2).

Table 2. Inclusion and exclusion criteria applicable for the analysis

Inclusion criteria	Exclusion criteria
1. publications based on interventional studies. 2. a specific protocol for conducting the therapy session and duration of the intervention. 3. training based only on the neurofeedback method. 4. research group – older people and people of late adulthood (> 55 years). 5. healthy people at risk of cognitive impairment, in which mild cognitive impairment or early dementia has occurred.	1. review publications, post-conference papers and systematic review of the literature. 2. interventional studies in which the method of conducting the therapy session and duration of the intervention have not been precisely defined. 3. age of the respondents below 55 years. 4. complex therapeutic programmes in which neuro-feedback is not the only form of therapy. 5. co-existence of chronic diseases (e.g. condition after stroke, Parkinson›s disease, multiple sclerosis).

In the course of the search process, 132 records were distinguished, including 62 items via the PubMed database, 49 via the Google Scholar database, 13 via the Science Direct database and 8 via the ISI Web of Knowledge database. After removing the duplicates, 84 publications were qualified for further analysis. Based on the inclusion and exclusion criteria, the available publications were verified and rejected on the basis of title analysis (N=22) and summaries (N=27).

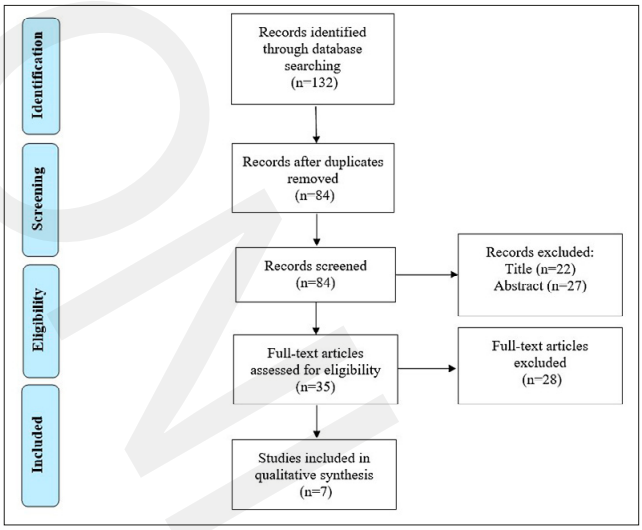

Figure 1. PRISMA 2009 flow diagram

Full-text articles that met the inclusion criteria in the form of a summary (N=35) were then assessed, distinguishing the final number of works included in the analysis (N=7). The verification process of papers was presented at the PRISMA 2009 Flow Diagram (Fig. 1).

DESCRIPTION OF THE STATE OF KNOWLEDGE

Literature analysis. The following aspects of the assessment were distinguished in order to characterize the eligibility criteria: description of the study group, description of the intervention using the neurofeedback method, duration of therapy, description of the obtained results (Tab. 3).

With reference to the research selected for analysis, most were developed by researchers from European countries (N=5), and two by Asian researchers (N=2). The vast majority of works were randomized control studies (N=5), and only two publications were interventional pilot studies (N=2). The study group in the majority of studies were healthy people, without diagnosed cognitive impairment (N=6), and in one research paper, the training with the use of neurofeedback method was extended to people with suspected or an early stage of Alzheimer's disease (N=1). Most of study groups included the people living in society (N=6). Considering one of the studies (N=1), the impact of neurofeedback on the cognitive functioning of older people covered by long-term care was evaluated (N=1).

In the majority of studies, participants were divided into a group receiving training using the neurofeedback method (NF training group) and a group receiving a sham neurofeedback in training (Sham-NF training group), or no intervention (N=5). In other studies, randomization consisted of differentiation of the training protocol in both groups or intervention with a temporary delay. As for the all of the analysed works, the effectiveness of the neurofeedback method was evaluated on the basis of neuropsychological tests carried out before and after the training protocol. Additionally, in six studies (N=5), the analysis of EEG records was used to assess the effectiveness of the training.

The performed analysis indicated a positive effect of training interventions using the neurofeedback method on the cognitive functioning of the elderly; however, the

Table 3. Characteristics of the studies included in the analysis

Author	Study group	Training procedure using the neurofeedback method	Time to conduct trainings	Obtained results
Staufenbiel et al. [19]	10 people without cognitive impairment with an average age 69.2 years, participating in the gamma feedback training, and 10 people with an average age of 66.4 years, participating in beta feedback training.	Sessions lasting 30 minutes, in both groups a tone appears if the upper threshold of gamma (36–44Hz) and beta (12–20Hz) waves is exceeded. Training procedure: – Well-being questionnaire before every training – Intelligence task – Memory task	8 trainings during 21 days, maximum interval between trainings – 2 days	Increased gamma brain activity in the training group subjected to gamma training following the protocol of training session and increased activity of gamma and beta waves in the group subjected to beta training. After the training, these changes did not persist in any of the groups.
Luijmes et al. [27]	10 people over 60 with suspected or early Alzheimer›s disease.	Before and after the training, a single channel EEG record was performed with open eyes lasting a minute. The conducted training lasted 20 minutes with breaks every 5 minutes. During the training session, the participant watched the video and received visual and auditory feedback. The threshold for receiving feedback was set at 70% of the frequency set during the training.	2 training sessions a week for 15 weeks (a total of 30 training sessions). The time of one session – 20 minutes.	Improvements in learning memory and increase in recognition and recall of information were observed. In the area of other cognitive functions, no changes were observed under the influence of NF training.
Wang et al. [28]	16 older people aged 61–72 without cognitive impairment, 16 younger people aged 21–25.	The division of participants into 4 groups – older group receiving NF theta training (4–7Hz) and receiving the sham-neurofeedback training (Sham-NF), younger group receiving the same types of trainings. Before the training, the attentional network test, Modified Sternberg recognition task, and QEEG assessment were used, 2 bands inhibiting augmentation of the signals were used by, e.g. blinking, coughing, teeth clenching and bandpass filters to extract theta frequency for the neurofeedback training group, and random for the sham-neurofeedback training group. The aim of the training was to increase the amplitude of theta waves above the average values achieved in the previous training. Biofeedback was obtained in the audio-visual form (rollercoaster animation)	12 training sessions (3 times a week), each training was composed of 5 3-minute cycles	An increase in the activity of frontal midline theta waves (4–7Hz) in the neurofeedback training group during the training and post-training phase, compared to the pre- training phase. Older people achieved reduced amplitudes of delta and theta waves, and worse results in executive functioning during Sternberg recognition task before neurofeedback training.
Lee et al. [29]	39 people aged 60–70 without cognitive impairment.	Participants division into 2 groups: – intervention group (NF) and control group, which received intervention after an 8-week waiting period. Before starting the training, an individualized EEG profile was established based on the colour Stroop tasks, after which a computational model was built, which was used in training sessions in which data in the EEG were processed to assess an attention score ranged from 0 (low attention) -100 (high attention). This allowed the subjects to control the course of the task displayed on the computer monitor.	24 30-minute training sessions in 8 weeks (3 times a week).	An improvement in parameters relating to immediate memory, visuospatial functions, attention and delayed memory demonstrated; however, statistically significant improvement was observed only in the delayed memory. A statistically significant improvement was also demonstrated in the RBANS total scale index score of neuropsychological test.
Reis et al. [30]	34 people aged over 55 (mean age 65.97) without diagnosed cognitive deficits.	Division of participants into groups receiving: neurofeedback training, neurofeedback training enriched with cognitive training tasks composed of 5 tasks, cognitive training alone, and neurofeedback sham (Sham-NF) group. Neurofeedback training was conducted in 65-minute sessions. Each training was preceded by a 3-minute active baseline (PSD), which was the reference point for the parameters of the next training session and was updated every day of the training. Feedback data contaminated by ocular artifacts, such as the eye blinks, were eliminated. Feedback data was visualized using graphics resembling the human head, neurons and flames.	A research protocol lasting 12 days in which trainings were conducted before 8 days.	An increase in active baseline PSD was demonstrated in the rhythm of alpha AP and RP and frontal theta RP in the group of subjects undergoing neurofeedback training; however, the increase was statistically significant. only in the range of alpha rhythm. Positive effects of theta NF training were also shown in the improvement regarding the results in the neuropsychological Matrix Rotation test, as well as an increase in the alpha rhythm activity in relation to the results obtained before the beginning of training.
Gomes-Pilar et al. [31]	63 people aged over 60 without any cognitive impairment, and a similar level of education.	Division into an NFT group and a control group. Neurofeedback training was based on motor imagery strategies using the BCI system, by means of which individual frequencies of alpha and beta waves in the EEG were implicated. 12,18 and 21 Hz frequencies were used in the training. The training was based on the control of the cursor displayed on the screen. During each session, participants performed 5 different tasks with increasing difficulty levels. At the beginning of the first and at the end of the last session a 2-minute EEG analysis with eyes closed at rest was performed.	5 training sessions, 1 session a week.	There were statistically significant differences between groups in post-scores results in terms of visual perception, immediate memory, and conceptual activity, as well as statistically significant differences in the results of pre and post-scores in terms of visual perception, receptive speech, immediate memory and thematic draws. In the NFT group, there was an improvement in the results of all cognitive functions, except for attentional control. There was no statistically significant improvement in any of the cognitive functions in the control group.

Author	Study group	Training procedure using the neurofeedback method	Time to conduct trainings	Obtained results
Van Eijk et al. [32]	18 people without cognitive impairment, mean age 77.9 in the experimental group, and aged 79.2 in the control group.	Division of the group into an experimental group (NF training) and control group not receiving training. In the NF group, the assumption of the training was to increase of 12–15 Hz low beta activity, in the case of prominent artefacts related to facial muscles, participants were instructed to relax. Participants received feedback every 1 second, each training consisted of 7 different sessions during which participants were motivated to score as many points as possible. The training parameters were determined during the first training session. Visual and auditory feedback was used in the training.	10 training sessions lasting 21 minutes. The trainings were carried out once or twice a week for a period of 9 weeks.	In the group subjected to NF training, a statistically significant improvement in immediate and delayed recall results was observed under the influence of the applied trainings shown in the pre- and post-scores analysis. However, no statistically significant differences were observed between the results in executive functioning and the Groningen Activity Restriction Scale considering the NF training group and the control group in the analysis carried out after the end of the training procedure.

obtained results differed depending on the implemented training protocol. Four authors showed a positive effect of training with the use of neurofeedback on the memory function. Lee et al. observed an improvement in the results related to immediate memory and delayed memory, whereas Gomes-Pilar et al. showed in their work improvement in the results of immediate memory and visual perception, Van Eijk et al. noted the positive influence of the applied intervention on the results of immediate and delayed recall, and Luijmes et al. noticed it in the field of learning memory [27, 29, 31, 32].

Based on the analysis of the results obtained after the end of training in the groups engaged in the training using the neurofeedback method and control groups, it was found that in most cases these groups differed statistically in terms of obtained results. However, the difference, in most of the studies concerned only some of the compared parameters. Taking into account the results of neuropsychological tests, Lee et al. revealed statistically significant differences in the overall Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) result achieved after the end of training, in contrast to the control group which was subjected to neurofeedback training with an eight-week delay. The authors emphasized that the statistical significance obtained in the pilot study indicated the effectiveness of the developed training protocol [29]. The results obtained by Reis et al. indicated the differentiation of results recorded in neuropsychological tests in groups of people subjected to neurofeedback training as an independent form of therapy and training enriched or based only on the standard cognitive training procedure. The authors showed that statistically significant improvement in the Matrix Rotation test results was observed only in the group of people subjected to neurofeedback training which was the only form of therapy. However, the authors emphasized that despite the lack of statistical significance, improvement in neuropsychological tests (Mental Rotation Test and Digit Span Memory Test) was observed in all of the analysed groups [30].

On the grounds of the literature review, it was shown that among the research in which EEG analysis was used as the tool for assessing the effectiveness of therapy, diversity in the brain activity of the subjects undergoing training was observed in most cases. Staufenbiel and et al. indicated that people subjected to gamma neurofeedback training were characterized by increased activity of gamma rhythms during the training session, compared to the group subjected to beta neurofeedback training, in which this increase was not observed.

On the other hand, as for the group subjected to beta training, the authors observed an increase in rhythm activity of both beta and gamma, which may suggest that these rhythms may not be independent of each other. However, the authors pointed out that considering the interval between sessions, no differences were observed between groups, and the increase in the activity of these waves recorded in the group subjected to gamma training was not related to the improvement of the results obtained in the neuropsychological test in terms of intelligence and concentration, and subjective improvement of the well-being of the subjects [19]. Furthermore, Wang et al. observed differences in delta and theta waves activity in the group of younger and older people subjected to neurofeedback training and sham-NF training. The authors showed an increase in theta activity in the post-training phase in the groups subjected to training, as opposed to groups receiving false neurofeedback. On the basis of obtained results, the authors also stated that both in the pre-training and post-training phases, older people (61–67 years) were characterized by a lower level of activity of alpha and theta waves compared to younger people (21–24 years) [28].

With reference to the majority of studies qualified for analysis, the study group consisted of healthy people. The effectiveness of training based on the neurofeedback method in the group of people demonstrating cognitive dysfunctions was assessed in the research only by Luijmes et al. The authors found a beneficial effect of cognitive training by means of neurofeedback on the learning memory function in people with suspected or early Alzheimer's disease, and maintaining the condition of other cognitive functions on the same level. According to the authors, lack of deterioration of cognitive functions during a 15-week period of the training procedure may indicate beneficial effects of this form of therapy in people with Alzheimer's disease. However, the authors emphasized, that as long as an unambiguous beneficial effect of this method has not been recorded, it is not possible to exclude pharmacological treatment during the training sessions [27].

DISCUSSION

Taking into account the analysis of the literature on the effectiveness of the use of the neurofeedback method in the group of older people, it is worth mentioning that so far it has been carried out by only a few authors. Bidzan, on the basis of his own review of research, stated that active cooperation of the patient during training sessions requires the provision of reserves within cognitive functions; therefore, this training can be used only in healthy people or those with a slight

impairment of cognitive functions [13]. This is consistent with the results achieved in the work of the authors of the current review, which indicate that regarding the studies that included healthy people, statistically significant difference in the range of parameters assessed before and after the training sessions were more frequently observed than in people manifesting symptoms of cognitive function impairment. What is more, Rogala et al. conducted a systematic review of interventional studies engaging neurofeedback in training cognitive functions of adult healthy people aged 20–65. The authors found that in most cases the used methodology did not enable its proper influence on the brain regions responsible for the control of individual cognitive functions and behaviour. The authors also emphasized that a small number of studies fulfilling the assumed inclusion criteria in the analysis (N=28) indicates a large discrepancy in the applied methodology and poorly controlled experiments [33]. This statement is consistent with the results achieved in the current review in which the assumed inclusion criteria enabled the inclusion of only seven items in the analysis.

A review of the literature on the effectiveness of the neurofeedback method in the cognitive training of the elderly was also carried out by Jiang et al. Between 2007–2016, the authors reviewed the research carried out in the group of older people. The conducted analysis showed that speaking of all analysed studies an improvement was observed; however, it concerned only selected parameters, which is similar to the results obtained in the current review. With reference to 12 items qualified for the analysis, the vast majority of the improvements concerned the results obtained in concentration tests and working memory [34]. On the other hand, Kueider et al. conducted a systematic review of studies in which the impact of training on cognitive functions of the elderly was evaluated with the use of computer systems based on Neuropsychological Software, Classic Cognitive Training Tasks and Video Games. The authors found a positive effect of the analysed interventions on cognitive functions, which mainly concerned memory, visual capabilities, reaction time and processing speed (processing speed). On the basis of the obtained results, the authors also stated that the lack of computer literacy by the elderly is not a limitation in the use of this type of training, because in many of the analysed studies the subjective perception of the training programmes was positive [35]. In the current review, only one study was included in the analysis in which a slight effectiveness of training using the neurofeedback method was demonstrated in a group of people at the early stage of Alzheimer›s disease. Vigil et al. conducted a review of the literature on the effectiveness of using this form of training in a group of elderly people with diagnosed cognitive impairments, including Alzheimer›s disease and MCI (Mild Cognitive Impairments). Considering six of the analysed studies, all of them presented improvement in some cognitive functions and results achieved in the MMSE (Mini Mental State Examination) test, whereas in two cases, positive changes also related to the process of disappearance of the hippocampus. However, it should be emphasized that in the analysed studies, different diagnostic systems and training protocols were used [36].

CONCLUSIONS

In most of the studies included in the analysis, a positive effect of training based on the neurofeedback method was observed on individual cognitive functions or changes in the EEG record of the elderly. On the basis of the current observations, it appears that better effects of training based on the neurofeedback method were observed in healthy people without diagnosed cognitive impairment, which may be linked with the need for active cooperation of the patient in the course of training. However, the results obtained should be interpreted with caution because according to the analysis of the reviewed literature, the methodology and training protocols used in individual studies were characterized by a large diversity, and the authors pointed to the existing limitations of their research.

It seems, that the small number of publications meeting the inclusion criteria, and too large discrepancies between the applied training protocols, at present do not allow an unambiguous answer to the question of how the effective training based on the neurofeedback method should be constructed. Therefore, there is a need to conduct further research to establish an optimal methodology, especially in the field of observing the long-term effects of the training procedures used. Despite this, it seems that the path of research on the neurofeedback method defined to-date will open new opportunities in the future for further improvement in the current state of knowledge in this field.

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