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Outcomes of Neurofeedback Training in Childhood Obesity Management: A Pilot Study

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Abstract

This pilot study sought to evaluate the neurofeedback training outcomes in childhood obesity management. The study involved 34 overweight and obese children, age 6–18 years (12 patients in the intervention group, 22 in the control group). Complete assessment of children was done before the intervention and 3 and 6 months after the intervention; eating behavior and quality-of-life questionnaires were assessed at study start and 6 months after. All children received classic lifestyle recommendations for weight management, while the intervention group also had 20 neurofeedback sessions (infra–low-frequency training). The neurofeedback intervention was associated with less weight loss compared with classic weight management. The mean change in body–mass index standard deviation score at 3 months was -0.29 for the intervention group and -0.36 for the control group ($p=0.337$); after 6 months, the changes were -0.30 and -0.56, respectively ($p=0.035$). Quality of life improved similarly for both groups. Subjective outcomes reported by patients in the intervention were less snacking, improved satiety, enhanced attention capacity, ameliorated hyperactivity, and better sleep patterns. Larger studies, with training methods involving both the left and right cortices, should further clarify the role of neurofeedback training in obesity management.

Introduction

Childhood obesity has reached ''epidemic'' proportions worldwide.[1] Current treatment has had limited results.[2] Alternative therapies are needed in addition to the classic lifestyle recommendations. For many obese children, body dissatisfaction, the physical discomfort of obesity, and social stigma may trigger or exacerbate depression, guilt, anxiety, and feelings of low self-esteem.[3] Consequences of these psychological stresses may increase energy intake and/or reduce physical activity. Appropriate management of these conditions could break this vicious cycle.

Neurofeedback is a biofeedback technique with proven results in attention-deficit/hyperactivity disorder and autism spectrum disorders.[4–6] In addition, recently, studies using neurofeedback training showed improvements in the treatment of other disorders, such as depression and addiction.[7–10] Neurofeedback uses electroencephalography to give patients real-time information about their brainwaves, thus teaching them how to alter their brainwave activity. Electrodes are attached to the scalp and selected frequency components are displayed for the patient through a user interface, such as a video game. The purpose is to provide real-time information to the central nervous system in order to train it to produce patterns of brain activity, to voluntarily adjust the brain waves, and achieve psychological comfort.

The prefrontal cortex is known to be critically involved in broad aspects of executive behavioral control.[11] Several studies have implicated the prefrontal cortex in eating behavior by showing increased prefrontal activation during observation of food stimuli,[12,13] and another showed left prefrontal activation during meal taste perception using functional magnetic resonance imaging.[14] Volkow and colleagues showed different patterns of prefrontal metabolic activity in obese patients by using positron emission tomography.[15,16] They found associations between striatal dopamine D2 receptors and prefrontal cortex metabolism in obese patients, suggesting that decreases in striatal D2 receptors may contribute to overeating via striatal prefrontal pathways, which participate in inhibitory control and salience attribution. The authors suggest that this association between striatal D2 receptors and metabolism in somatosensory cortices (regions processing palatability) could underlie one of the mechanisms through which dopamine regulates the reinforcing properties of food.[16]

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In addition, some studies have suggested that childhood obesity is associated with a decreased ability to modulate cognitive control by the prefrontal cortex and anterior cingulate cortex, which supports action monitoring.[17,18]

The hypothesis for the current study was that targeting neurofeedback to train the prefrontal cortex could improve eating behavior.

Neurofeedback training can influence appetite regulation, anxiety, and depression, which results in comfort eating and a compulsion surrounding food.[7–9] If attention to these factors is combined with improved lifestyle behaviors, recovery may be substantially improved. At the time of this writing, no studies have confirmed that neurofeedback training is useful in the treatment of obesity. Therefore, this pilot study aimed to evaluate outcomes of neurofeedback training in management of childhood obesity.

Materials and Methods

Patients

Between January 2011 and July 2012, 34 overweight and obese children and adolescents, aged 6 to 18 years (12 children in the intervention group, 22 controls), were referred to our hospital for obesity management and integrated in the study. Inclusion criteria were (1) residency in the city of the study institution (to enable easy access to sessions); (2) body–mass index (BMI) >85th percentile for age and sex according to the 2000 Centers for Disease Control and Prevention U.S. growth references,[19] and (3) a prior medical assessment to screen for obesity-related complications (such as insulin resistance with the Homeostasis Model Assessment index, impaired glucose tolerance, and hepatic steatosis). Exclusion criteria were monogenic obesity, long-term treatment with medication known to influence weight, and diagnosed eating disorders.

Assessment

Anthropometric measurements (weight, height) were recorded with correctly calibrated measuring tools at the beginning of the program and at 3 and 6 months. The child was considered to be overweight if the BMI was above the 85th percentile for age and sex; the child was considered to be obese if the BMI was above the 95th percentile for age and sex (Centers for Disease Control and Prevention growth references).[19] Pubertal stage was evaluated by Tanner criteria. Complete history and demographic data of the participants were documented. At the beginning of the study and after 6 months, children and parents completed validated questionnaires inquiring about eating behavior and quality of life: the Three Factor Eating Questionnaire[20,21] and the KINDL quality-of-life questionnaire, disease-specific obesity module.[22] The Three Factor Eating Questionnaire is an 18-item questionnaire scored on a 4-point Likert-type scale. It assesses eating patterns in children across three separate factors: cognitive restraint, uncontrolled eating, and emotional eating. The revised German KINDL^{R} quality-of-life questionnaire in overweight and obese youths includes 12 items in six domains: physical well-being, emotional well-being, self-esteem, family, friends, and functional aspects. Items are scored on a 5-point Likert-type scale.

Twenty-two patients were included to the control group. They received lifestyle behavior recommendations and were reassessed at follow-up after 3 and 6 moths.

Behavioral recommendations

All children in the intervention and control groups received lifestyle behavior recommendations from a single counselor, in accordance with the Expert Committee Recommendations Regarding the Prevention, Assessment, and Treatment of Child and Adolescent Overweight and Obesity.[23]

Neurofeedback training

The 12 patients in the intervention group had 20 individual neurofeedback sessions held during a maximum period of 14 weeks (10-week period in most cases). The sessions consisted of approximately 30 minutes of infra–low-frequency neurofeedback training.[24] NeuroAmp 1101 equipment was used (AD Instruments, Oxford, United Kingdom). The computer system used for clinical neurofeedback was Cygnet1® neurofeedback software (EEG Info, Singen, Germany) integrated with Somatic Vision (Encinitas, CA) videogames and run by means of a Windows (XP or Vista; Microsoft Corp., Redmond, WA) operating system using standard personal computer desktops and high-resolution monitors. Feedback was provided through videogames (Dual Drive Extreme, Inner Tube, and Advanced Media Player; Somatic Vision). Electrodes were applied after scalp preparation (NuPrep; Weaver and Co., Aurora, CO) using standard electrode paste (Ten20 Conductive; Weaver and Co.) to secure three sintered silver/silver chloride scalp electrodes at the eft prefrontal (frontopolar Fp1), left temporal (temporal T3), and Fpz (a vertex prefrontal scalp electrode placement) locations as ''ground'' electrode. The Fp1-T3 bipolar recording was used under the theory that enhanced cognitive control would be promoted. The present protocol differs from the Othmer method in its exclusive focus on prefrontal placement. This choice was made to limit variables and have a standardized protocol.

The baseline performance test consisted of symptom profiles, which were reviewed further at each session. The optimal reinforcement frequency[25] was determined for the individual during neurofeedback session based on subjective reporting by the patient and/ or observer ratings of behavioral alertness. When high-arousal symptoms (eye discomfort, fatigue) were shown, the operator decreased the frequency; if low-arousal symptoms (sleepiness, lethargy) emerged, the frequencies were increased slowly. If the patients was more calm and alert, the frequency was decreased. Infra-low rewards frequencies that started from 0.5 Hz were further optimized during several sessions, and most cases stabilized at 0.0005 Hz.

Statistical analysis

BMI standard deviation score (BMI-SDS) was calculated by the following formula: (measured BMI value − average value in the reference population SD in the reference population). For calculating SDS for each child LMS growth, a Microsoft Excel add-in, was used.[26] Questionnaire results were interpreted in percentages from maximum score. Behavior questionnaires results were interpreted as percentages

Table 1. Descriptive Statistics for Intervention and Control Group

Parameter	Intervention group (n = 12) Range	Intervention group (n = 12) Median (mean)	Control group (n = 22) Range	Control group (n = 22) Median (mean)	p-Value
Age	6.2–17.6	11.1 (11.2)	6.1–18.6	10.3 (10.9)	0.800
BMI (kg/m^2)	22.5–38	26.3 (27.5)	19.4–41	27.7 (28.1)	0.737
BMI-SDS at beginning	2.1–3.6	2.68 (2.79)	1.6–6.1	2.85 (2.76)	0.893
BMI-SDS at 3 months	1.8–3.4	2.36 (2.5)	1.3–5.7	2.41 (2.39)	0.611
BMI-SDS at 6 months	1.6–3.6	2.33 (2.48)	0.8–5.5	2.39 (2.2)	0.268
Quality of life impairment at baseline (%)	30.7–78.7	41.3 (47.3)	33.2–78.7	50.7 (52.4)%	0.412
Improved quality of life after 6 mo (%)	4–17.3	9.3 (9.3)	0–17.3	9.3 (8.5)%	0.620
Men/women (%)		42/58		50/50	
Prepubertal/pubertal (%)		36/64		36/64	
Obese/overweight (%)		81.8/18.2		85.8/14.2	

BMI, body–mass index; BMI-SDS, BMI standard deviation score.

from 0% to 100% representing best to worst behavior; for the quality-of life questionnaire, 0% to 100% represented good to poor quality of life.

Statistical data were analyzed with SPSS softs for Window, version 17, for Windows (SPSS, Inc., Chicago, IL). Descriptive statistics were run on all the variables and presented as percentages, means, and SDs. To test homogeneity of variances, the Levene test of homogeneity of variance was used. Statistical significance between continuous variables was assessed using the paired *T*-test, with $p < 0.05$ considered to represent statistically significant differences. Binary logistic regression was used to obtain odds ratio; for correlations, the Pearson coefficient (rho) was used.

Ethical considerations

The hospital's Ethics Committee approved the study. Upon admission to the program, each parent signed an inform consent form in accordance with the Declaration of Helsinki. Patients were informed about the neurofeedback technique and that this technique is hypothesized to help them better cope with the lifestyle changes they have to make in order to lose weight. Patients were also informed that they could redraw from the study any time they wanted, without this ever affecting future medical services.

Results

Four adolescents and one preadolescent patient were excluded from the intervention group who did not complete the 20 neurofeedback sessions because of various reasons (they did not observe the results they had expected, the patient or parent lost interest, and the parent did not fully understood the neurofeedback technique and feared that the child would be harmed). One child in the control group could not be contacted for reassessment and thus was excluded. Two other children in the control group were excluded because they were younger than 6 years of age and severely obese (BMI SDS > 5). Dropout rates at 6 months were 29.4% for the intervention group 4% for the control group. The final groups consisted of 12 children in the intervention group and 22 in the control group.

The intervention and the control group are descriptively presented in Tables 1 and 2. Range and means for age, BMI, and BMI SDS and percentages in quality-of-life improvement for both groups are shown in Table 1, along with ratios of sex proportions, obesity prevalence, and prepubertal versus pubertal percentages.

Table 2 presents the most common motivations for addressing the medical practitioner. Those seen most frequently were obesity-related complications (from patient history) and associated disorders; the most common pattern of familial history was parental obesity.

Mean change in BMI-SDS at 3 months was −0.29 for the intervention group and −0.36 for the control group ($p = 0.337$). However, mean BMI-SDS change at 6 months was −0.30 for the intervention group and −0.56 for the control group ($p = 0.035$). Figure 1A (box-and-whisker plot) presents

Table 2. Frequency of Motifs for Presentation, Family History, and Obesity-Related Complications in the Intervention and Control Groups

Variable	Intervention group (%)	Control group (%)
Motivation for presentation		
Parent concern	66.6	54.5
Aesthetic concern	33.3	36.3
Referred	0	9
Family history		
Both parents obese/overweight	33.3	18.2
Father obese/overweight	25	9
Mother obese/overweight	16.6	40.9
Both parents normal weight	25	31.8
Complication/associated disorders		
Orthopedic problems	50	59
Elevated blood pressure	16.6	13.6
Impaired glucose tolerance	8.3	27.2
Insulin resistance	8.3	9
Rebound obesity (yo-yo effect)	0	4.5
Polycystic ovaries	8.3	9
Attention deficit	8.3	4.5
None	25	18.2

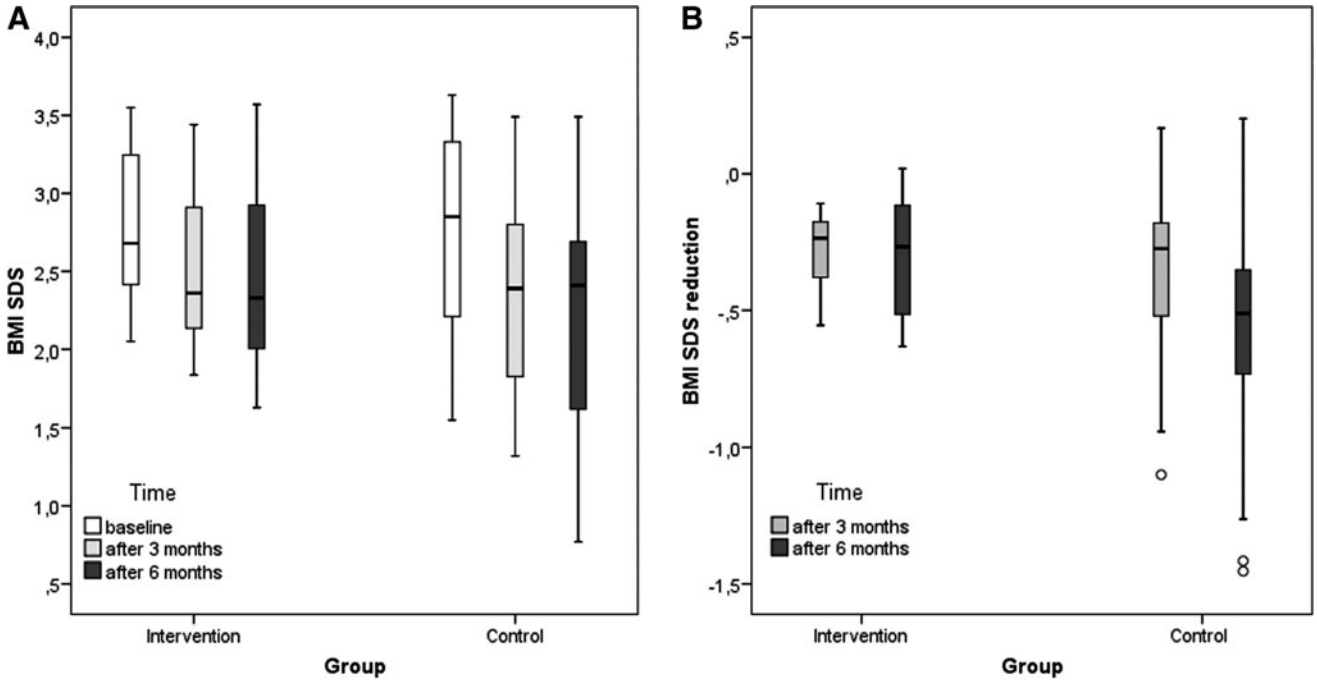

FIG. 1. Body–mass index standard deviation score (BMI-SDS) **(A)** and BMI-SDS reduction **(B)** in intervention and control groups, at baseline (before intervention), at 3 and after 6 months follow-up. In these box-and-whisker plots, the bottom and top of the box are the first and third quartiles, and the band inside the box is the median. The ends of the whiskers are the minimum and maximum of all of the data. The *white circles* are the outliers.

BMI-SDS for both groups at baseline and 3 and 6 months; Figure 1B. shows the BMI SDS reduction at 3 months and 6 months. Three children in the control group had achieved a reduction in BMI SDS above 1 SD at 6 months compared with none in the intervention group.

Questionnaire results are presented in Table 3 as differences in scores, initially and after 6 months, with mean score in percentages (SD), and *p*-value to test statistically significant differences between intervention and control participants. Results from the KINDL quality-of-life questionnaire showed similar improvements (decrease) in score after 6 months for both groups. Improvements in quality of life were, as reported by patients and parents, associated with higher physical effort tolerance, less fatigue, less occurrence of heart palpitations, and ameliorated body self-perception. The Three Factor Eating Questionnaire revealed differences between groups as follows: The uncontrolled eating factor was statistically significantly improved after 6 months in intervention group. Cognitive restraint was significantly more increased in the control group. Emotional eating improved in both groups.

Table 3. Questionnaire Results: Differences in Scores Between Baseline and 6 Months

Questionnaire	*Intervention (%)*	*Control (%)*	p-*Value*
KINDL^R quality of life	9.33 (4.33)	8.41 (4.42)	0.573
TFEQ uncontrolled eating factor	9.07 (1.79)	6.96 (4.48)	0.057
TFEQ cognitive restraint factor	−3.03 (3.77)	−7.13 (5.91)	0.020
TFEQ emotional eating factor	6.05 (14.94)	4.88 (15.52)	0.834

Values are presented as mean score (standard deviation).
KINDL^R, German generic quality of life instrument for children; TFEQ, Three Factor Eating Questionnaire.

BMI-SDS reduction at 6 months, in both groups, was strongly and significantly correlated with BMI-SDS reduction at 3 months ($r = 0.77$; $p = 0.000$) and with quality-of-life improvement ($r = 0.56$; $p = 0.001$). In the intervention group, BMI-SDS reduction at 6 months was significantly correlated with cognitive restraint increase ($r = -0.36$; $p = 0.036$).

Subjective outcomes reported by patients (or parents) in the intervention group were less snacking (75%), improved satiety (41.6%), enhanced attention capacity in school, homework, and sport activities (33.3%), ameliorated hyperactivity (33.3%), and better sleep patterns (16.6%). However, at 6 months patients (or parents) reported a slowly fading effect of the benefits obtained through training.

Regarding adverse effects or disturbances that could be attributed to neurofeedback training, one adolescent girl presented cephalgia during two consecutive sessions, which disappeared by the end of the session. No other concerns during or after the sessions, such as sleep alterations, agitation, or drowsiness, were noted by patients or parents. Preadolescent patients were very attracted to and interested in sessions and were keen on returning to the training, whereas adolescents did not show the same interest. At

6-month follow-up, 16% of participants asked for the possibility of continuing the neurofeedback sessions.

Discussion

The descriptive statistics show similar distributions with regard to age, sex, and pubertal distribution; BMI at baseline; and BMI-SDS at baseline in the intervention and control groups.

The main outcome of the study, BMI-SDS reduction after 6 months, was significantly higher in the control group than the intervention group. These findings contradicted the hypothesis of the study: that neurofeedback training alongside classic lifestyle recommendations would produce greater sustainable weight loss over time. Regarding the clinical significance of BMI-SDS, several studies found that a reduction of >0.5 improved cardiovascular risk factors and intima-media thickness as an early marker of atherosclerosis.[27–29] In the current study, 47.8% of controls reached BMI-SDS reduction >0.5, while 18.1% of participants in the intervention group achieved BMI-SDS reduction >0.5 at 6 months. Because this is a small study, the fact that 3 of 22 children in the control group, compared with none in the intervention group, had achieved a BMI SDS reduction above 1 SD at 6 months, had strongly influenced the results for the group as a whole. No commonalities were identified in these 3 children.

Longer periods of follow-up may be needed to perceive a better pattern for weight loss sustainability.[27] Studies inquiring about treatment outcomes in childhood obesity have shown substantial short-term benefits as well as some evidence for long-term maintenance of the treatment effects. The most successful programs adopt a multidimensional approach, but most pediatric obesity interventions are marked by small changes in relative weight and substantial relapse.[30,31] Despite encouraging results in the short term, treatment for obesity in adults and children is typically followed by weight regain.[2,32]

The intervention group had higher dropout rates compared with controls. This was probably a result of different follow-up frequencies, considering that the intervention group had to come to the hospital 23 times during the study period compared with 3 times in the control group. Nonetheless, adherence was an important issue for the intervention group. Depending on the intervention, other studies on weight management have reported high attrition rates in both children and adults, ranging from 27% to 73%.[32–35]

Questionnaire results in our study showed similar improvements in quality-of-life score in the intervention and control groups, although the controls had greater weight losses and there was a strong correlation between weight loss and quality of life. Improved quality of life could be attributed to neurofeedback training. The study considered the possibility that the patients in the intervention relied too much on the neurofeedback training to ''magically'' make them lose weight and thus they made less effort to alter their lifestyle, but this supposition could not be verified.

Regarding neurofeedback training method, an alternative protocol that involves both left and right cortices could bring superior benefits that need to be further assessed.[11] Another method to optimize the procedure is to start the neurofeedback training at the bottom of the frequency range (where most of them optimized) in order to facilitate the ability of trainees to be better aware of their state shifts there, which further might ease the optimization procedure.[24]

The Expert Committee coordinated by Barlow[23] concluded that treatment outcomes should include the establishment of permanent healthy lifestyle habits as a good outcome, regardless of weight change, because of the long-term health benefits of these behaviors. Equally important are the improvements in the associated medical conditions. In general, decreasing BMI to a value below the 85th percentile is a desirable outcome. A possible issue for concern is that rapid weight loss (as in the control group) usually implies extraordinary efforts in diet and exercise, efforts that could be unhealthy and that probably cannot be maintained as permanent behaviors. In addition, rapid weight loss may prompt liver fibrosis as an entity in nonalcoholic fatty liver disease, which is associated with obesity, diabetes, insulin resistance, and hypertriglyceridemia. Currently, the best therapy for nonalcoholic fatty liver disease is slow, progressive weight loss through dietary modification and exercise.[36] Roles of degree of weight loss, method of weight loss, distribution of fat reduction, and other variables[37] can influence long-term health outcome, and prolonged follow-up is needed for assessing these aspects, underlining the need for further studies.

Metabolic markers such as insulin resistance, glucose tolerance, degree of nonalcoholic fatty liver disease, and lipid profiles could provide important information on the effect of weight loss, but the current study did not assessed these markers after the intervention.

One limitation of the study is the small number of patients, which led to diminished statistical significance; however, this is a pilot study, the first to document the neurofeedback outcomes in childhood obesity management.

Multiple factors influence both weight gain and weight loss. Several were considered (see inclusion and exclusion criteria, Tables 1 and 2); however, other factors not accounted for could be socioeconomic status, education status of parents, parent commitment, degree of motivation to alter behavior, school and familial environment, genetics, birth weight, and psychological factors.[38–40] In addition, method and operator expertise could affect neurofeedback training outcome.

A direction for future studies could also be targeted neurofeedback training intervention for patients diagnosed with eating disorders, for which behavior training with neurofeedback will likely have a bigger effect.

Conclusions

Considering the childhood obesity epidemic and the limited results in conventional management, alternative treatment options are urgently needed. For this pilot study neurofeedback training was hypothesized to improve weight loss outcome, but results showed greater weight loss in the control group. The children who trained with neurofeedback had similar improvement in quality of life as the controls, although the weight loss was smaller. Subjective outcomes reported by patients with neurofeedback training were less snacking, improved satiety, enhanced attention capacity, ameliorated hyperactivity, and better sleep pattern.

Larger studies, with training methods involving both the left and right cortices, should further clarify the role of neurofeedback in obesity management.

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Author Disclosure Statement

No competing financial interests exist.

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