Research Article

The effectiveness of a stress-management intervention program in the management of overweight and obesity in childhood and adolescence

Stavroula Stavrou[1], Nicolas C. Nicolaides[2,3], Ifigenia Papageorgiou[2], Pinelopi Papadopoulou[2], Elena Terzioglou[2], George P Chrousos[1,2,3], Christina Darviri[1*] and Evangelia Charmandari[2,3*]

[1]Postgraduate Course Stress Management and Health Promotion, School of Medicine, University of Athens, Athens, 11527, Greece

[2]Division of Endocrinology, Metabolism and Diabetes, First Department of Pediatrics, University of Athens Medical School, 'Aghia Sophia' Children's Hospital, Athens, Greece

[3]Division of Endocrinology and Metabolism, Clinical Research Center, Biomedical Research Foundation of the Academy of Athens, Athens, 11527, Greece

[*]These authors contributed equally to the study

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Correspondence should be addressed to Stavroula Stavrou; Tel: +30 2107487314, Fax: +30 2106597545, E-mail: stavri_22@hotmail.com

Abstract

Background: Obesity in childhood and adolescence represents a major health problem of our century, and accounts for a significant increase in morbidity and mortality in adulthood. In addition to the increased consumption of calories and lack of exercise, accumulating evidence suggests that childhood obesity is strongly associated with prolonged and excessive activation of the stress system.

Aim: The aim of our study was to assess the effectiveness of a stress-management intervention program, which included progressive muscle relaxation, diaphragmatic breathing, guided imagery and cognitive restructuring, in overweight and obese children and adolescents.

Methods: Forty-nine children and adolescents (mean age ± SEM: 11.15 ± 1.48 years) were prospectively recruited to participate in this randomized controlled study. Of those, 23 participants were assigned into the intervention group, while 26 participants represented the control group. Anthropometric measurements were recorded at the beginning and at the end of the study, and participants were asked to complete the Screen for Child Anxiety Related Disorders (S.C.A.R.E.D.), the Child Depression Inventory (C.D.I.), the Child Behavior Checklist (C.B.C.L.) and the Youth Self Report (Y.S.R.).

Results: The applied stress-management methods resulted in a significant reduction in the body mass index (BMI) in the intervention group compared with the control group [ΔBMI=1.18 vs 0.10 kg/m^2 ($p<0.001$)]. In addition to BMI, these methods ameliorated depression and anxiety, and reduced the internalizing and externalizing problems in the intervention group.

Conclusions: Our study demonstrated that the application of an 8-week stress management program could facilitate weight loss in Greek overweight and obese children and adolescents. Further larger studies are required to evaluate the effectiveness of stress-management methods in overweight and obese subjects.

Introduction

Stress is defined as a state, in which our internal balance, termed homeostasis, is threatened or perceived as threatened by several external or internal stressful stimuli, the stressors (Chrousos & Gold 1992, Chrousos 2009, Nicolaides *et al.* 2015). These unforeseen stimuli activate a highly complex neuroendocrine system, the stress system, which consists of the hypothalamic-pituitary-adrenal (HPA) axis and the locus caeruleus/norepinephrine-autonomic nervous system (Charmandari *et al.* 2003, 2005, Chrousos & Gold 1992, Nicolaides *et al.* 2015). These two components function coordinately through molecular cross-talks at several levels to provide the appropriate adaptive response, termed stress response, to achieve basal ho-

meostasis, or eustasis. If this adaptation is inappropriate in terms of quantity, quality and time, the pathologic stress response may lead to dysfunction of growth, development, metabolism, reproduction, as well as to inadequate, excessive or prolonged immune response, a state termed allostasis or cacostasis (Charmandari *et al.* 2003, 2005, Chrousos & Gold 1992, Nicolaides *et al.* 2015). Accumulating evidence suggests that any improper responsiveness to stressors might participate in the pathogenesis of several pathologic conditions. Indeed, most of the contemporary non-communicable diseases are undoubtedly associated with acute and chronic dysregulation of the stress system. One of these allostatic conditions with many detrimental complications is obesity (Charmandari *et al.* 2003, 2005, Chrousos 2009, Nicolaides *et al.* 2015).

Childhood obesity remains one of the most challenging pathologic conditions of our modern society. Its prevalence is increasing rapidly throughout the word. It is estimated that approximately 42 million of children younger than 5 years are overweight worldwide, with 31 million being in developing countries (WHO, 2016). Moreover, overweight and obesity in childhood and adolescence predisposes subjects to the development of glucose intolerance, insulin resistance, type 2 diabetes and atherosclerotic cardiovascular disease in young adulthood (Charmandari *et al.* 2005, Chrousos 2009, Nicolaides *et al.* 2015, Pervanidou & Chrousos 2011). Therefore, prevention and treatment of obesity in childhood and adolescence is sine qua non for the prevention of the above conditions associated with obesity in adulthood. In addition to the imbalance between energy intake and expenditure, the multifactorial pathogenesis of childhood obesity is strongly associated with prolonged and excessive activation of the stress system (Charmandari *et al.* 2005, Chrousos 2009, Nicolaides *et al.* 2015). The chronic hypersecretion of cortisol, epinephrine, norepinephrine, immune CRH, and interleukin (IL)-6 contribute substantially to the increased secretion of insulin and decreased release of growth hormone, androgens and estrogens, leading to accumulation of visceral fat, loss of bone mass (osteoporosis) and muscle mass (sarcopenia) (Charmandari *et al.* 2005, Chrousos 2009, Nicolaides *et al.* 2015). Consequently, stress management might play an important role in weight loss and increase the sense of well-being and/or performance.

Although many published studies have applied non-diet approaches for obese adults, three of them have included stress management techniques with a dietary intervention (Christaki *et al.* 2013, Katzer & Bradshaw 2008, Manzoni *et al.* 2009). Katzer and Bradshaw (2008) applied relaxation techniques in obese participants for 10 weeks and showed increased stress management but not significant weight loss. Mantzoni and collaborators (2009) demonstrated that new technologies of relaxation can effectively reduce emotional eating, which in turn leads to weight loss. Finally, a recent study by Christaki *et al.* (2013) demonstrated the effectiveness of progressive muscle relaxation and diaphragmatic breathing on weight loss and eating behavior in Greek overweight and obese women. To the best of our knowledge, there is no published study investigating the role of stress-management methods in overweight and obese children.

The aim of the present study was to evaluate the effectiveness of an 8-week stress-management intervention program that includes progressive muscle relaxation, diaphragmatic breathing, guided imagery and cognitive restructuring in Greek overweight and obese children.

Materials and Methods

Trial Design

Our study was a prospective, randomized controlled trial aimed to evaluate an 8-week stress-management program, which included progressive muscle relaxation, diaphragmatic breathing, guided imagery and cognitive restructuring combined with a dietary intervention and physical training in overweight and obese children aged 9-15 years, compared with a control group in which participants only followed dietary instructions and physical training. The study was performed at the Division of Endocrinology, Metabolism and Diabetes, First Department of Pediatrics, University of Athens Medical School, "Aghia Sophia" Children's Hospital, Athens, Greece, between April 2015 and December 2015. The study was approved by the 'Aghia Sophia' Children's Hospital Committee on the Ethics of Human Research, and written informed consent was obtained by the parents of all participants.

Participants

Eighty-five overweight and obese children and adolescents aged 9-15 years with a Body Mass Index (BMI) over the 90th percentile for age and gender were recruited in the study. Patients were randomly assigned to either the intervention or the control group by using random numbers provided by an online generator (www.random.org). Following randomization, 45 children were selected to participate in the intervention group. Of those, 8 participants did not respond to any calls, 9 did not participate after the first session, 4 did not participate in two sessions and did not want to

repeat them, while 1 participant had an accident. On the other hand, 40 children were randomized in the control group. Of those, 5 participants started filling in the questionnaires but refused to continue, while 9 did not fill in the questionnaires until the end of the study. In summary, 23 children participated in the intervention group, while 26 participants represented the control group.

Patients were excluded from the study if there was evidence of i) Chronic illness; ii) Use of any medications for acute or chronic disorders; iii) Genetic syndromes causing obesity; iv) Underlying psychopathology, such as depression or eating disorders, of the participant or the parents; v) Participation in other relaxation techniques (e.g., pilates, yoga, meditation).

Intervention

All children participating in the study followed a low-energy diet, which consisted of 45-50% carbohydrates, 30-35% fat and 15-20% protein. Furthermore, they attended sessions led by a clinical nutritionist and a physical trainer, they were systematically encouraged to follow the Mediterranean diet and were motivated to adopt lifestyle changes. In addition to these sessions, participants in the intervention group attended individually 8 more sessions of the stress-management intervention program. These sessions were conducted by a person specialized in stress-management techniques, and included progressive muscle relaxation, diaphragmatic breathing, guided imagery and cognitive restructuring. The children and the parents of the intervention group were informed about these techniques in detail and were given a CD with recorded instructions. They were encouraged to perform the techniques once a day for 8 weeks and were given a diary to record their effort.

Assessment

Baseline assessments during the first session of the study included medical history, demographic data, anthropometric data and self-reported questionnaires. Participants in both groups were asked to fill in the following questionnaires: the Screen for Child Anxiety Related Disorders (S.C.A.R.E.D.), the Child Depression Inventory (C.D.I.), the Child Behavior Checklist (C.B.C.L.) and the Youth Self Report (Y.S.R.). The anthropometric data were collected and the above-mentioned questionnaires were administered at the final assessments, which took place 8 weeks after the first session.

Anthropometric Data

The body weight and height were measured at the first and the last visit of each child. The body weight was documented to the nearest 0.1 kg, while the height was recorded to the nearest 1 cm. BMI was estimated by dividing weight in kilograms by the square of height in meters. A child was defined as overweight or obese based on Cole's international criteria (Cole *et al.* 2000). The Greek growth charts for age and gender were used to calculate BMI standard deviations (SD) and z-scores.

Screen for Child Anxiety Related Disorders (S.C.A.R.E.D.)

The S.C.A.R.E.D. is a widely used self-report instrument for children and parents designed to screen children for anxiety disorders for the last three months. It consists of 5 questions and respondents were asked to rate each question from 0 (never) to 2 (often or always). Item scores were added to obtain a final score (Birmaher *et al.* 1999). For this dataset, the internal consistency was 0.92 and test-retest reliability was 0.88. The S.C.A.R.E.D. had previously been used in the Greek language successfully (Essau *et al.* 2013).

Child Depression Inventory (C.D.I.)

The C.D.I. is used to detect depressive symptoms in children. It consists of 27 items and the child was asked to choose one of the three provided statements, which is the best for him or her during the last 2 weeks. Each statement was scored from 0 to 2 depending on the severity of the depressive symptom. The provided scores were added for a final score (Kovacs 1985). The C.D.I. was successfully applied to Greek population with internal consistency α=0.80 and test–retest reliability >0.60 (Giannakopoulos *et al.* 2009).

Child Behavior Checklist (C.B.C.L.)

The C.B.C.L. is a well-known questionnaire provided by Achenbach and Edelbrock. It is filled in by parents and is used to evaluate internalizing and externalizing symptoms in children. It consists of 113 questions on specific behavioral problems and parents were asked to score each behavioral item from 0 to 2 depending on the frequency (Aschenbach *et al.* 1991a). The C.B.C.L. had been translated in the Greek language and the internal consistency for internalizing and externalizing problems was 0.90 and 0.94, respectively (Roussos *et al.* 1999).

Youth Self Report (Y.S.R.)

The Y.S.R. is completed by adolescents, who evaluate their own internalizing and externalizing symptoms. It consists of 112 items that are scored from 0 to 2 depending on the frequency of each symptom (Aschenbach 1991b, c). The internal consistency for both internalizing and externalizing symptoms was

Table 1. Characteristics of the study population (n=49). C.D.I.: Child Depression Inventory; S.C.A.R.E.D.: Screen for Child Anxiety Related Disorders. Data presented as mean (SD, range); p values for the comparison between groups by independent samples t-test; · Mann-Whitney U test; Pearson's χ^2 for categorical variables. Statistically significant associations are shown in bold.

Main baseline data	**Total (n=49)**	**Intervention group (n=23)**	**Control group (n=26)**	**p value**
Age (y)	11.15 (1.48, 8.94-14.73)	10.90 (1.33, 8.99-14.68)	11.37 (1.59, 8.94-14.73)	0.275
Sex (n,%) Male Female	 24 (49) 25 (51)	 10 (43.5) 13 (56.5)	 14 (53.8) 12 (46.2)	0.331
Education (n,%) Primary school High school	 42 (85.7) 7 (14.3)	 22 (95.7) 1 (4.3)	 20 (76.9) 6 (23.1)	0.069
BMI (kg/m^2)	27.11 (4.27, 21.30-42.20)	26.74 (3.76, 22.30-37.60)	27.44 (4.73, 21.30-42.20)	0.575
Waist-hip ratio	0.93 (0.09, 0.74-1.17)	0.92 (0.09, 0.74-1.09)	0.93 (0.09, 0.75-1.17)	0.748
Routine	37.59 (5.32, 21-45)	37.70 (5.95, 21-45)	37.50 (4.82, 28-45)	0.899
Daily habits	43.06 (5.88, 26-62)	42.35 (7.30, 26-62)	43.69 (4.33, 36-51)	0.430
Life satisfaction	32.63 (5.22, 18-40)	31.48 (6.16, 18-38)	33.65 (4.08, 25-40)	0.159
C.D.I. score	8.53 (6.67, 1-28)	11.78 (7.94, 2-28)	5.65 (3.43, 1-12)	**0.002**
S.C.A.R.E.D. score, child	2.06 (1.51, 0-6)	2.43 (1.41, 0-5)	1.73 (1.54, 0-6)	0.069•
S.C.A.R.E.D. score, parent	1.88 (1.97, 0-7)	2.39 (2.35, 0-7)	1.42 (1.45, 0-6)	0.229•
Syndrome Scale Scores, child Anxious/Depressed Withdrawn/Depressed Somatic Complaints Social Problems Thought Problems Attention Problems Rule-Breaking Behavior Aggressive Behavior	 54.80 (6.21, 50-72) 54.37 (5.93, 50-69) 54.30 (6.16, 50-73) 56.20 (6.63, 50-73) 54.50 (6.57, 50-78) 54.22 (6.19, 50-73) 51.70 (2.60, 50-60) 53.54 (5.37, 50-76)	 55.68 (7.22, 50-72) 54.18 (6.15, 50-69) 56.55 (6.62, 50-73) 58.09 (7.02, 50-73) 55.50 (6.35, 50-77) 56.27 (6.58, 50-73) 52.50 (3.13, 50-60) 54.68 (4.98, 50-65)	 54 (5.15, 50-66) 54.54 (5.85, 50-68) 52.25 (5, 50-72) 54.46 (5.86, 50-73) 53.58 (6.77, 50-78) 52.33 (5.25, 50-73) 50.96 (1.76, 50-56) 52.50 (5.61, 50-76)	 0.622• 0.829• **0.007•** **0.021•** **0.048•** **0.004•** **0.042•** **0.033•**
Syndrome Scale Scores, parent Anxious/Depressed Withdrawn/Depressed Somatic Complaints Social Problems Thought Problems Attention Problems Rule-Breaking Behavior Aggressive Behavior	 58.85 (9.42, 50-90) 58.63 (9.02, 50-85) 58.72 (8.41, 50-80) 58.41 (7.98, 50-87) 56.50 (7.59, 50-78) 55.33 (6.12, 50-73) 55 (5.80, 50-78) 55.30 (6.25, 50-72)	 60.41 (10.95, 50-90) 59.95 (8.86, 50-78) 61.23 (8.27, 50-76) 61.09 (8.70, 50-87) 57.55 (8.23, 50-73) 57.68 (6.71, 51-73) 55.64 (6.99, 50-78) 56.86 (7.11, 50-72)	 57.42 (7.71, 50-76) 57.42 (9.18, 50-85) 56.42 (8.02, 50-80) 55.96 (6.51, 50-69) 55.54 (7, 50-78) 53.17 (4.69, 50-66) 54.42 (4.52, 50-64) 53.88 (5.09, 50-67)	 0.287 0.346 0.060• **0.028** 0.344• **0.003•** 0.482 0.175•
Internalizing Problems, child	49.69 (11.28, 27-73)	52.18 (10.96, 32-73)	47.30 (11.30, 27-72)	0.149
Internalizing Problems, parent	57.28 (12.03, 34-81)	60 (12.32, 34-81)	54.79 (11.45, 34-76)	0.144
Externalizing Problems, child	48.07 (8.36, 29-67)	50.50 (8.08, 29-62)	45.74 (8.12, 34-67)	0.055
Externalizing Problems, parent	52.15 (9.63, 33-76)	53.73 (10.74, 34-76)	50.71 (8.47, 33-66)	0.293

0.90 in the Greek version (Roussos *et al.* 2001).

Routine, Daily Habits, Life Satisfaction

Daily routine of the participants was assessed with questions concerning: a) daily sleep; b) breakfast; c) lunch; d) dinner. Participants were asked to give possible answers ranging from "never" to "always", as well as to report the regularity of issues of their routine (e.g. "do you have a standard time in eating breakfast every day?"). Total routine was calculated by summing all the answers ranging from 1 "never" to 4 "always". Daily routine was assessed both at the beginning and at

the end of the study.

Daily habits were assessed with a 4-point scale ranging from 1 "never" to 4 "always" for questions concerning eating behavior, physical exercise, participation in sports e.t.c.

Life satisfaction was evaluated with a 5-point scale ranging from 1 "not at all" to 5 "very much". Participants were asked to rate their satisfaction about friendship, school, family, self-image, free time e.t.c.

Statistical Analysis

Continuous variables were summarized with the use of descriptive statistical measures (mean value, standard deviation (SD) and range). Categorical variables were displayed as frequencies and percentages (n, %). The normality of distribution of continuous variables was examined using the Kolmogorov-Smirnov test in order to determine whether or not to use parametric methods for the analysis of the sample data. Association between categorical variables was assessed using χ^2 (chi-square test). Furthermore, in order to examine the differences in mean values of variables, the t-test or the Mann-Whitney U test for independent samples was applied. All the aforementioned statistical tests were two-sided and performed at a 0.05 significance level. Data were analyzed using the SPSS statistical package version 21.0 (SPSS, Chicago, IL).

Results

Demographic, anthropometric and baseline data for the participants

The demographic, anthropometric and baseline data for the participants are presented in Table 1. Twenty-three and twenty-six children and adolescents were assigned in the intervention and control group, respectively. The mean age of the participants was 11.15 ± 1.48 years. Twenty-four of the participants were boys and twenty-five were girls. All of them were students

Table 2. Mean improved difference (pre- vs post-intervention). C.D.I.: Child Depression Inventory; S.C.A.R.E.D.: Screen for Child Anxiety Related Disorders. Data presented as mean (SD, range); p values for the comparison between groups by independent samples t-test; · Mann-Whitney U test; Pearson's χ^2 for categorical variables. Statistically significant associations are shown in bold.

	Total (n=49)	Intervention group (n=23)	Control group (n=26)	p value
ΔBMI (kg/m^2)	0.61 (0.80, -1 to 3)	1.18 (0.62, 0 to 3)	0.10 (0.56, -1 to 2)	**<0.001**
ΔC.D.I. score	1.98 (4.23, -5 to 15)	3.83 (5.47, -5 to 15)	0.35 (1.41, -2 to 5)	**0.004•**
ΔRoutine	0.10 (2.60, -9 to 7)	0.91 (3.58, -9 to 7)	-0.62 (0.75, -2 to 0)	**0.031•**
ΔDaily habits	-1.51 (5.07, -16 to 14)	-1.87 (7.40, -16 to 14)	-1.19 (0.94, -3 to 0)	0.382•
ΔLife satisfaction	-0.65 (2.41, -7 to 7)	-1.13 (3.46, -7 to 7)	-0.23 (0.51, -1 to 1)	0.347•
ΔS.C.A.R.E.D. score, child	0.39 (0.79, -1 to 2)	0.61 (0.94, -1 to 2)	0.19 (0.57, -1 to 1)	**0.040•**
ΔS.C.A.R.E.D. score, parent	0.51 (1.46, -2 to 6)	1 (2.02, -2 to 6)	0.08 (0.27, 0 to 1)	**0.036•**
ΔSyndrome Scale Scores, child				
Anxious/Depressed	-1.37 (5.04, -15 to 10)	1 (5.36, -15 to 10)	-3.54 (3.62, -10 to 3)	**0.001**
Withdrawn/Depressed	-1.87 (6.70, -26 to 10)	0.41 (4.62, -12 to 10)	-3.96 (7.68, -26 to 6)	**0.016•**
Somatic Complaints	1.02 (2.61, -4 to 7)	2.27 (2.80, -1 to 7)	-0.13 (1.83, -4 to 6)	**0.002•**
Social Problems	-0.57 (4.85, -14 to 13)	1.64 (4.86, -12 to 13)	-2.58 (3.96, -14 to 1)	**<0.001•**
Thought Problems	0.01 (4.47, -13 to 15)	1.68 (5.66, -13 to 15)	-1.54 (2.15, -6 to 2)	**0.018**
Attention Problems	-0.54 (5.72, -14 to 13)	2.32 (5.64, -6 to 13)	-3.17 (4.47, -14 to 0)	**0.001•**
Rule-Breaking Behavior	0.04 (2, -5 to 8)	0.77 (2.31, -5 to 8)	-0.63 (1.41, -5 to 2)	**0.003•**
Aggressive Behavior	-1.09 (4.52, -12 to 9)	1.09 (4.11, -9 to 9)	-3.08 (3.98, -12 to 1)	**0.002•**
ΔSyndrome Scale Scores, parent				
Anxious/Depressed	-1.02 (5.71, -11 to 16)	2.64 (5.27, -8 to 16)	-4.38 (3.72, -11 to 7)	**<0.001**
Withdrawn/Depressed	-0.89 (5.81, -12 to 14)	1.68 (6, -12 to 14)	-3.25 (4.58, -12 to 8)	**0.003**
Somatic Complaints	1.35 (5.91, -8 to 22)	3.91 (7.35, -7 to 22)	-1 (2.65, -8 to 4)	**0.019•**
Social Problems	0.91 (4.36, -5 to 13)	3.45 (4.77, -5 to 13)	-1.42 (2.13, -5 to 3)	**<0.001•**
Thought Problems	-0.59 (3.89, -12 to 11)	1.50 (3.71, -4 to 11)	-2.50 (3, -12 to 0)	**<0.001•**
Attention Problems	-0.65 (4.48, -14 to 11)	1.64 (4.17, -11 to 11)	-2.75 (3.72, -14 to 0)	**<0.001**
Rule-Breaking Behavior	0.70 (3.89, -9 to 17)	2.36 (4.46, -4 to 17)	-0.83 (2.51, -9 to 4)	**0.008•**
Aggressive Behavior	-1.43 (4.34, -9 to 9)	0.82 (3.71, -7 to 9)	-3.50 (3.88, -9 to 6)	**<0.001**
ΔInternalizing Problems, child	-0.78 (8.04, -11 to 16)	4.41 (7.49, -11 to 16)	-5.74 (4.79, -11 to 7)	**<0.001**
ΔInternalizing Problems, parent	-0.17 (8.78, -13 to 28)	5.45 (8.85, -13 to 28)	-5.33 (4.59, -11 to 9)	**<0.001**
ΔExternalizing Problems, child	-0.38 (6.03, -11 to 13)	3.32 (5.27, -5 to 13)	-3.91 (4.41, -11 to 7)	**<0.001**
ΔExternalizing Problems, parent	-1.50 (6.05, -12 to 17)	1.86 (6.51, -9 to 17)	-4.58 (3.49, -12 to 2)	**<0.001**

of primary or high school. The mean BMI was 27.11 ± 4.27 kg/m^2 with no significant statistical difference between the two groups (p=0.575). Moreover, the waist-to-hip ratio of the participants in the intervention group was similar to that of the control group (0.92 vs. 0.93; p=0.748). In addition to the demographic and anthropometric data, the two groups showed statistical significant differences with respect to scores of the C.D.I., C.B.C.L. and Y.S.R. questionnaires. These differences could be attributed to the small size of samples. However, no differences were found between the intervention and control group for internalizing and externalizing problems, both in children and parents.

Stress-management methods facilitated weight loss in overweight and obese children and adolescents

The applied stress-management methods resulted in a significant reduction in the BMI in the intervention group compared with the control group (mean difference of BMI (ΔBMI) = 1.18 vs. 0.10 kg/m^2; p<0.001)) (Table 2), indicating that the applied 8-week stress-management program facilitated weight loss.

Stress-management methods ameliorated depression and anxiety, and reduced the internalizing and externalizing problems in the intervention group

Overweight and obese children and adolescents in the intervention group demonstrated a significant reduction in depression and anxiety compared with the control group, as indicated by the ΔC.D.I. score (3.83 vs. 0.35, p=0.004), ΔS.C.A.R.E.D. score for children (0.61 vs. 0.19, p=0.04) and ΔS.C.A.R.E.D. score for parents (1 vs. 0.08, p=0.036). Furthermore, all examined internalizing and externalizing problems had lower scores in the intervention group, compared with the control group, both for children and their parents (Table 2).

Discussion

In the present study, we investigated the effectiveness of an 8-week stress-management intervention program combined with a dietary intervention and physical training in overweight and obese children and adolescents. We demonstrated that the application of progressive muscle relaxation, diaphragmatic breathing, guided imagery and cognitive restructuring in the intervention group resulted in significant weight loss and reduction in the BMI compared with the control group. In addition, the applied stress-management methods resulted in a significant decrease in the depressive and anxiety symptoms, and led to the reduction of the internalizing and externalizing problems in children and adolescents participating in the intervention group.

Several epidemiological studies demonstrated that the prevalence of mental health problems is increased in obese children (Anderson *et al.* 2010, Goldbacher & Matthews 2007, Mustillo *et al.* 2003, Onyike *et al.* 2003). Depressive children have excessive sedentary habits and do not effectively adhere to self-care activities (Pervanidou & Chrousos 2012). Moreover, they have more time to eat and they sleep fewer hours. Sleep deprivation, in turn, results in reduced concentrations of leptin and increased concentrations of ghrelin, which both synergistically increase appetite (Hart *et al.* 2013). In addition to depression, anxiety seems to contribute substantially to overweight and obesity. Indeed, impulsive behaviors are often associated with uncontrolled eating (Graziano *et al.* 2012). Furthermore, children with anxiety disorders are more sensitive for an immediate reward, such as food, and susceptible to eating behaviors without hunger (Cortese *et al.* 2013, Luman *et al.* 2012). Our results show that anxiety and depressive symptoms are significantly reduced in the intervention group, possibly leading to weight loss.

To the best of our knowledge, this is the first study in which a designed stress-management intervention program was applied and evaluated for its effectiveness in overweight and obese children and adolescents. Only three published studies have investigated the role of stress management in obese adults (Christaki *et al.* 2013, Katzer & Bradshaw 2008, Manzoni *et al.* 2009). Of those, the most recent two studies demonstrated that stress-management methods facilitated weight loss in adult participants (Christaki *et al.* 2013, Manzoni *et al.* 2009). Our study demonstrated that stress management could help overweight and obese children lose weight. Therefore this intervention could be used for the prevention and management of overweight and obesity in childhood and adolescence.

Although stress mediators, such as cortisol and ACTH, were not determined in our study, we speculate that the statistically significant weight loss in the intervention group compared with the control group could be attributed to a possible decreased activity of the HPA axis, which is known to display increased activity in obesity. The resultant reduced action of cortisol in tissues involved in metabolism (liver, muscle, adipose tissue) could lead to weight loss in the participants of intervention group. This could be a direct effect of stress management in weight loss. In addition, stress management resulted in lower levels of anxiety, possibly through lower concentrations of corticotropin-releasing hormone (CRH), and depression. Given that the stress system interacts with several homeostatic systems and neurobiochemical mediators, such as serotonin, it is possible that stress management could result

in weight loss indirectly by influencing the expression of these molecules.

In summary, we demonstrated that the application of an 8-week stress-management intervention program results in significant reduction of BMI in overweight and obese children and adolescents. In addition, it ameliorated depression and anxiety, and reduced the internalizing and externalizing problems in the intervention group. Further larger studies are required to evaluate the effectiveness of stress-management methods in overweight and obese subjects.

Competing interests

The authors declare that they have no competing interests.

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