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Research report

Influence of weight-loss diets with different macronutrient compositions on health-related quality of life in obese youth

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ABSTRACT

The aims of this study were to compare the effects of weight-loss diets of different macronutrient compositions on weight and health-related quality of life (HRQOL), and to examine the relationship between changes in HRQOL parameters and weight loss during weight-loss programs in obese adolescents.

Seventy one adolescents (12–18 years, BMI > 95th percentile) were randomly allocated to one of three 12-week diet regimens: low-carbohydrate low-fat (LCLF), low-carbohydrate high-fat (LCHF) or high-carbohydrate low-fat (HCLF) diets. Weight, height and fat-mass were measured, and the PedsQL 4.0 questionnaires were administered to the participants at baseline and at the end of the intervention.

Significant similar reductions in BMI, BMI-SDS, and fat percentage occurred in all groups. A significant improvement in HRQOL was found only in the LCLF and HCLF groups. For the entire sample, positive correlations were found between emotional and psychosocial functioning at baseline and the reduction in BMI, BMI-SDS, and fat percentage. By multiple regression analysis, higher baseline emotional functioning and BMI-SDS were significant predictors to higher reduction in BMI-SDS during the intervention. Our results support the importance of evaluating and improving psychosocial functioning before initiation of a weight-loss intervention program in adolescents, and the importance of low-fat diets in weight-loss interventions for adolescents.

Introduction

The prevalence of pediatric obesity has increased dramatically worldwide (Zeller & Modi, 2006) as well as in Israel (Huerta, Gdalevitch, Haviv, Bibi, & Scharf, 2006) in the past decade, accompanied by a growing body of literature on the adverse consequences of obesity on health (Kiess et al., 2001; Sorof, Lai, Turner, Poffenbarger, & Portman, 2004). In youth, obesity also poses a considerable risk of psychosocial impairment and poor developmental adaptation (Gortmaker, Must, Perrin, Sobol, & Dietz, 1993). Recent studies showing an association between impaired health-related quality of life (HRQOL) and obesity in children and adolescents (i.e. De-Beer et al., 2007; Pinhas-Hamiel et al., 2006; Ravens-Sieberer, Redegled, & Bullinger, 2001; Zeller & Modi, 2006) suggest a need for early weight-management interventions. An improvement in HRQOL after weight-loss interventions has been reported in obese adults, even after small to moderate weight loss (Kolotkin, Meter, & Williams, 2001), and in obese children and adolescents who participated in an in-patient rehabilitation program in Germany (Ravens-Sieberer et al., 2001).

However, whether HRQOL variables can serve as pretreatment predictors of weight management remains unclear. In the only studies of this issue to date, Teixeira, Going, and Houtkooper (2002), Teixeira, Going, and Houtkooper (2004), Teixeira, Going, Sardinha, and Lohman, (2005) found that obese women with lower HRQOL at the beginning of a weight-loss program, particularly in the areas of work, health and self-esteem, were more likely to drop out or to finish the study less successfully than the other participants. Data on the influence of the composition of weight-loss diets on psychosocial parameters are also sparse. Most of the studies so far have been short-term and all included only adults. They suggest that the manipulation of carbohydrate and protein intake might be associated with changes in psychological measures, although the results were inconsistent (Benton, 2002; Fischer, Colombani, & Wenk, 2004; Latner & Schwarts, 1999; Markus et al., 1998). The single long-term study,

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conducted by Galletly et al. (2007), in 28 women with polycystic ovary syndrome, revealed that high-protein, low-carbohydrate diets were associated with a significant improvement in psychosocial parameters (depression and self-esteem) compared to low-protein, high-carbohydrate diets, with no difference in the amount of weight loss between the two. Indeed, improved psychological well-being may have been responsible for the better compliance of obese women to a 12-week reduction program based on a high-protein low-fat diet than on a high-carbohydrate low-fat diet (Noakes, Keogh, Foster, & Clifton, 2005).

Data on the effectiveness and safety of low-carbohydrate diets in children are limited (Bailes, Strow, Werthammer, McGinnis, & Elitsur, 2003; Nanoff, Zwiauer, & Widhalm, 1989; Sondike, Copperman, & Jacobson, 2003; Sothern, Despinasse, Brown, Suskind, & Udall, 2000; Willi, Oexmann, Wright, Collop, & Key, 1998). Most studies reported considerable weight loss, with no significant adverse effects, and good compliance in the short term.

The main aims of the present study were as follows: (1) To compare the effects of weight-loss diets of different macronutrient composition on anthropometric parameters and HRQOL in adolescents. (2) To examine the possible relationship between changes in HRQOL parameters during weight-loss programs for adolescents and improvements in anthropometric parameters. We hypothesized that the HRQOL in obese adolescents would be low and would improve after weight loss, and that the change in HRQOL would correlate with the improvement in anthropometric measures. Because of a lack of previous research in adolescents, we were unable to formulate a hypothesis regarding the effect of diet composition on anthropometric and HRQOL parameters in adolescents, or the specific HRQOL parameters that would significantly correlate with changes in anthropometric parameters.

Methods

The study was approved by the local Ethics Committee for Research in Humans of the Israel Ministry of Health. Written informed consent was obtained from all participants and their parents/legal guardian.

Participants

The study sample included 71 adolescents aged 12–18 years, attending the Institute of Endocrinology and Diabetes at Schneider Children's Medical Center of Israel between January and March 2005. Only subjects with a body mass index (BMI) above the 95th percentile for age and sex were considered eligible. Other exclusion criteria were presence of a chronic disease (such as diabetes, renal, heart or liver diseases, thyroid function disorder, or diagnosed psychological disorder), current treatment with a weight-loss-inducing medication, and participation in another weight-loss study or slimming diet within the previous 2 months.

Study design

The intervention program was conducted over the 12-week period from March to June 2005. Participants were randomly allocated to one of three diet groups:

Group a: Low-carbohydrate (60 g, 20%), high-protein (150 g, 50%), low-fat (40 g, 30%); LCLF.
Group b: Low-carbohydrate (60 g, 20%), low-protein (60 g, 20%), high-fat (80 g, 60%); LCHF.
Group c: High-carbohydrate (150–180 g, 50–60%), low-protein (60 g, 20%), low-fat (40 g, 30%); HCLF.

All three diets were limited to 1200 kcal/day. The 60-g limit of carbohydrates in the LCLF and LCHF diets was based on the definition of Bravata et al. systematic review of low-carbohydrate diets (Bravata et al., 2003).

All participant received menus and detailed instruction according to their diet group. In order to increase the compliance to the diet regiment, once a month during the 3 months of intervention all participants received three new different detailed menus according to their diet group. An example of one menu and written instructions for each group is presented in Appendix A. As part of the intervention, they attended weekly sessions with a dietitian and a psychologist. For some sessions, the participants were requested to fill out self-report food diaries. All subjects received a general recommendation to engage in regular physical activity.

Measures

Anthropometric parameters were measured once a week throughout the 12-week intervention. Subjects were weighed without shoes in light clothing using standard calibrated scales. Standing height was measured using a commercial Harpenden–Holtain stadiometer. BMI was calculated as weight in kilograms divided by height in meters squared. To compare BMI values across different ages and by sex, the BMI-standard deviation scores (BMI-SDS) was calculated as measured BMI minus mean BMI for age and gender divided by the adequate standard deviation (SD) according to the growth charts of the Centers for Disease Control and Prevention (Kuczmarski et al., 2002). The new CDC growth charts have been reported to be adequate for assessing Israeli children (Goldstein, Haelyon, Krolik, & Sack, 2001).

Fat-mass percentage was evaluated after overnight fasting by bioimpedance analysis using a single-frequency, 50-kHz leg-to-leg bioimpedance system combined with a digital-scale body composition analyzer (TBF-300, Tanita Corporation of America Inc., Arlington Heights, Illinois).

Questionnaire

The Pediatric Quality of Life Inventory (PedsQL) 4.0 is a generic HRQOL measure developed for children and adolescents (Varni, Seid, & Kurtin, 2001). Scores are calculated for each of the four core subscales (physical functioning, eight items; emotional functioning, five items; social functioning, five items; and school functioning, five items, as well as the two broad domains: physical and psychosocial functioning), and total score. The scales are standardized, ranging from 0 to 100, with higher scores representing better quality of life. The PedsQL has been shown to be reliable and valid, with internal consistency reliability coefficients approaching or exceeding 0.70. For the present study, we used the Hebrew version of the PedsQL 4.0, which has been linguistically validated (The PedsQL Organization) and was previously applied in a study of normal-weight and obese Israeli children and adolescents (Pinhas-Hamiel et al., 2006). The internal consistency (Cronbach α) of the PedsQL in the present study was 0.78.

The PsdsQL 4.0 questionnaires (Hebrew version) were administered to the participants before and after the 12-week intervention.

Statistical analyses

All values are presented as mean $\pm$ SD.

The study was powered using the effect size statistic by Cohen (1998), defined as the difference between two treatment groups divided by the pooled SD. The present study was powered to detect a 4.0% difference in baseline BMI between each pair of the three treatment groups. The pooled SD was estimated to be 5% (Berkowits, Wadden, Tershakovec, & Cronquist, 2003). Assuming a 2-tailed analysis ($\alpha = 0.05$, 80% power) and 30% dropout rate, indicated that 16 adolescents per group would be sufficient to show significant differences.

Baseline differences in continuous variables between the three intervention groups were tested with analysis of variance (ANOVA), followed by post-hoc Tukey B analysis to examine differences between groups. General linear model (GLM) repeated measure analysis of variances was used to asses the trend of change between pre- and post-values of different continuous outcome variables in the entire intervention group (the time effect) as well as to compare it between the three intervention groups (the interaction between the time and the group effect). Further, paired-samples *t*-tests were used to test the significance of changes in the various parameters from baseline to the end of the intervention within each intervention group.

Independent samples *t*-tests were conducted to compare PedsQL scores between the instrument-normative data of a healthy, normal-weight youth sample and our obese subjects at baseline and after 12 weeks of intervention. Pearson correlation coefficients were calculated to examine relationships between anthropometric parameters and HRQOL. Multiple linear regression analysis (stepwise) was used to predict the reduction in BMI-SDS during the intervention. Independent predictors included age, sex, treatment regiment, baseline BMI-SDS and fat mass percentage, and PedsQL scores (four subscales and the total score) at baseline and at the end of the intervention.

Significance tests were two-sided, with type-one error set at 0.05.

All analyses were performed using the Statistical Package for Social Sciences (SPSS) for Windows, version 14.0.

Results

Participants

The study group included 29 boys and 42 girls of a mean age 14.3 ± 1.7 years.

Eighteen participants (7 boys and 11 girls, mean age 14.9 ± 1.8) were allocated to the LCLF group, 17 (4 boys and 13 girls, mean age 14.3 ± 1.6) to the LCHF group, and 36 (18 boys and 18 girls, mean age 14.1 ± 1.8) to the HCLF group. There were no significant differences in the participants' age and gender between the three intervention groups.

Pretreatment anthropometric parameters and HRQOL ratings

The pretreatment anthropometric data and HRQOL (PedsQL) scores are presented in Table 1. Mean BMI-SDS for the whole sample was approximately 4.0, with mean fat-mass percentage accounting for more than 40% of the total body mass in all three groups. There were no statistically significant differences between the groups for any of the anthropometric and HRQOL parameters at baseline.

Comparison of the baseline PedsQL scores of the whole sample with published norms for healthy youth (Varni et al., 2001) (Table 3) yielded significantly lower total PedsQL scores in the study participants for total PedsQL and for the subscales of physical, emotional, and school functioning, and the domain of psychosocial functioning. The score for the social functioning subscale was similar to the norm.

No significant differences were found between genders at baseline in age, BMI-SDS, percent of body fat, and all PedsQL scores (data not shown).

Table 1
Pre- and post-intervention anthropometric parameters values and PedsQL scores – assessment of the time of intervention effect and the interaction between time of intervention and intervention group effect

		LCLF ($n = 15$)	LCHF ($n = 12$)	HCLF ($n = 25$)	Time effect[a] F (d.f.) p	Time* group effect[b] F (d.f.) p
BMI	Baseline	36.0 ± 7.7	33.6 ± 5.5	34.4 ± 6.2	55.1 (1)	1.9 (2)
	End	33.3 ± 8.3	31.6 ± 6.1	32.8 ± 6.2	<0.001	NS
BMI-SDS	Baseline	4.6 ± 1.8	3.9 ± 1.6	4.3 ± 1.7	42.2 (1)	2.3 (2)
	End	3.7 ± 1.8	3.2 ± 1.7	3.9 ± 1.7	<0.001	NS
%Fat-mass	Baseline	42.4 ± 9.7	41.1 ± 5.1	40.3 ± 9.1	32.8 (1)	1.5 (2)
	End	36.9 ± 11.5	38.8 ± 6.2	36.2 ± 9.6	<0.001	NS
Physical functioning	Baseline	67.5 ± 21.5	62.5 ± 20.6	67.8 ± 23.2	15.4 (1)	0.2 (2)
	End	80.3 ± 21.4	77.3 ± 28.0	77.1 ± 21.6	<0.001	NS
Emotional functioning	Baseline	76.1 ± 17.2	70.5 ± 17.8	75.3 ± 21.1	9.0 (1)	0.6 (2)
	End	85.8 ± 17.2	74.6 ± 19.0	86.8 ± 15.3	0.005	NS
Social functioning	Baseline	89.6 ± 8.3	90.0 ± 9.5	88.3 ± 13.0	3.8 (1)	0.1 (2)
	End	93.5 ± 8.0	92.3 ± 9.6	91.5 ± 11.3	NS	NS
School functioning	Baseline	75.0 ± 16.6	72.7 ± 21.4	78.8 ± 16.7	7.4 (1)	0.4 (2)
	End	83.8 ± 11.0	76.8 ± 21.4	83.8 ± 18.1	0.010	NS
Psychosocial functioning	Baseline	80.3 ± 10.7	77.7 ± 14.7	80.8 ± 12.9	15.1 (1)	0.6 (2)
	End	87.7 ± 10.0	81.2 ± 14.7	87.3 ± 11.1	<0.001	NS
Total score	Baseline	75.8 ± 12.4	72.4 ± 12.1	76.2 ± 13.8	21.1 (1)	0.1 (2)
	End	85.1 ± 13.1	79.8 ± 16.1	84.0 ± 13.0	<0.001	NS

LCLF, low-carbohydrate, low-fat; LCHF, low-carbohydrate, high-fat; HCLF, high-carbohydrate, low-fat; BMI, body mass index; SDS, standard deviation score. NS, not significant.

[a] The time effect represents the results of the GLM repeated measure analysis for the difference between the pre-and post-values of each variable in the entire study population.

[b] The time* group effect represents the results of the GLM repeated measure analysis assessing whether the trend of change in each variable differed among the three intervention groups.

Table 2
Changes in anthropometric parameters and PedsQL scores after 12-week intervention in the three intervention groups

	LCLF (n = 15)	LCHF (n = 12)	HCLF (n = 25)
Δ BMI	−2.8 ± 2.3 ($p < 0.001$)	−2.0 ± 1.7 ($p = 0.002$)	−1.5 ± 1.8 ($p < 0.001$)
Δ BMI-SDS	−0.93 ± 0.90 ($p < 0.001$)	−0.62 ± 0.50 ($p < 0.001$)	−0.44 ± 0.65 ($p = 0.002$)
Δ %Fat-mass	−5.5 ± 6.1 ($p = 0.005$)	−2.3 ± 3.1 ($p = 0.024$)	−4.1 ± 4.2 ($p < 0.001$)
Δ Physical functioning	12.7 ± 21.9 (NS)	14.7 ± 24.0 (NS)	10.3 ± 17.7 ($p = 0.018$)
Δ Emotional functioning	9.6 ± 12.8 ($p = 0.019$)	4.1 ± 12.6 (NS)	11.5 ± 22.6 ($p = 0.035$)
Δ Social functioning	3.8 ± 9.2 (NS)	2.3 ± 13.7 (NS)	3.3 ± 8.8 (NS)
Δ School functioning	8.8 ± 10.8 ($p = 0.012$)	4.1 ± 19.5 (NS)	5.0 ± 12.6 (NS)
Δ Psychosocial functioning	7.4 ± 8.3 ($p = 0.007$)	3.5 ± 12.7 (NS)	6.6 ± 8.6 ($p = 0.003$)
Δ Total score	9.3 ± 12.0 ($p = 0.016$)	7.4 ± 14.0 (NS)	7.8 ± 9.4 ($p < 0.001$)

LCLF, low-carbohydrate, low-fat; LCHF, low-carbohydrate, high-fat; HCLF, high-carbohydrate, low-fat; BMI, body mass index; SDS, standard deviation score; NS, not significant. Δ = value at the end of the intervention (12 weeks) minus value at the beginning of the intervention. *p* Value in each cell represents the significance of the change in the relevant parameter (Δ) within the specific intervention group.

Table 3
Scores on generic PedsQL scales at baseline and at the end of the weight-loss program for the entire study sample of obese adolescents compared to healthy non-obese subjects in the same age group

PedsQL scores	Obese youth		Healthy Sample[a]	t^1 (d.f.^{1})	p^1	t^2 (d.f.^{2})	p^2
	At baseline (n = 71)	After intervention (n = 52)					
Physical functioning	65.0 ± 21.6	78.9 ± 22.4	84.4 ± 17.3	8.37 (469)	0.001	2.08 (450)	0.038
Emotional functioning	73.4 ± 17.8	83.6 ± 17.1	80.9 ± 19.6	3.01 (469)	0.003	0.95 (450)	NS
Social functioning	86.7 ± 15.6	91.8 ± 10.5	87.4 ± 17.2	0.32 (468)	NS	1.8 (449)	NS
School functioning	71.7 ± 19.8	82.3 ± 17.0	78.6 ± 20.5	2.62 (455)	0.009	1.25 (426)	NS
Psychosocial functioning	77.3 ± 13.6	85.9 ± 12.0	82.4 ± 15.5	2.60 (468)	0.009	1.57 (449)	NS
Total score	73.1 ± 13.3	83.4 ± 13.7	83.0 ± 14.8	5.27 (470)	<0.001	0.185 (451)	NS

d.f., degrees of freedom. NS, not significant. t^1, d.f.^{1}, p^1: results of *t*-tests comparing PedsQL scores between the instrument-normative data of a healthy sample youth with our obese sample at baseline. t^2, d.f.^{2}, p^2: results of *t*-tests comparing PedsQL scores between the instrument-normative data of a healthy sample youth with our obese sample at the end of the weight-loss program.
[a] Adapted from published data on norms for healthy youth (Varni et al., 2001).

Change in anthropometric parameters and HRQOL after weight-loss intervention

A significant reduction in BMI, BMI-SDS and in fat-mass percentage was noted in the entire study population at the end of the intervention (Table 1: the time effect). No significant differences were found in the trend of change in the anthropometric parameters between the groups (Table 1: the time* group effect).

In each of the three intervention groups the reduction in BMI, BMI-SDS and in the fat-mass percentage was significant (Table 2).

A significant improvement in physical, emotional, school, and psychosocial functioning, as well as in the total PedsQL score was noted in the entire study population at the end of the intervention (Table 1: the time effect). No significant differences were found in the trend of change in the PedsQL scores between the groups (Table 1: the time* group effect). A significant improvement in HRQOL was found in the LCLF group (emotional, school, and psychosocial functioning, and total PedsQL score) and in the HCLF group (physical, emotional, and psychosocial functioning, and total PedsQL score), but not in the LCHF group (Table 2).

By the end of the intervention, the PedsQL scores of the study sample had reached the norms of healthy youth (Varni et al., 2001) for the total PedsQL score as well as all but the physical functioning subscale, which was still significantly lower ($p = 0.038$) in the obese youth as compared to norms (Table 3).

No significant differences were found between genders in reduction in BMI-SDS or in improvement of PedsQL scores (data not shown). The decrease in fat-mass percentage was significantly greater in the boys (−6.8 ± 5.8 vs. −2.4 ± 2.7, $p = 0.007$).

Correlations between anthropometric parameters and HRQOL

For the entire sample, significant positive correlations were found between emotional functioning at baseline and the reduction in BMI ($r = 0.36$; $p = 0.009$), BMI-SDS ($r = 0.34$; $p = 0.014$), and fat-mass percentage ($r = 0.36$; $p = 0.015$); between social functioning at baseline and the reduction in BMI ($r = 0.29$; $p = 0.038$); and between psychosocial functioning at baseline and the reduction in BMI ($r = 0.37$; $p = 0.007$), BMI-SDS ($r = 0.33$; $p = 0.019$), and fat-mass percentage ($r = 0.36$; $p = 0.016$). These correlations suggest that obese youth with better psychosocial functioning especially in the emotional field, show a better improvement in BMI and fat-mass percentage.

For the entire sample, no correlations were found between the changes in HRQOL and the changes in anthropometric parameters (BMI, BMI-SDS and fat-mass percentage) during the 12-week intervention.

A multiple linear regression model for the prediction of the reduction in BMI-SDS

A multiple linear regression analysis equation for factors predicting the reduction in BMI-SDS during the intervention is presented in Table 4. By stepwise regression analysis, we identified two predicting parameters associated with a higher reduction in BMI-SDS during the intervention: higher baseline emotional functioning score ($p = 0.005$) and baseline BMI-SDS ($p = 0.039$). Other potential independent predictors were excluded from the final prediction model (age, sex, treatment regiment, baseline fat-mass percentage, baseline physical, social and school functioning, as well as PedsQL total score, and all PedsQL subscales as well as

Table 4
Multiple linear regression analysis equation for factors predicting the reduction in BMI-SDS during the intervention

Δ BMI-SDS = −1.122 + 0.016 × baseline emotional functioning + 0.142 × baseline BMI-SDS

Emotional functioning score-according to the PedsQL 4.0 (Varni et al., 2001).

the total score at the end of the intervention). The overall R^2 of the model was 0.22 ($p = 0.007$).

The dropout was 16.7% (3/18) in the LCLF group, 29.4% (5/17) in the LCHF group, and 30.6% (11/36) in the HCLF group. The difference was not statistically significant. No significant differences were found between dropout and non-dropout participants in age, all baseline anthropometric parameters (BMI, BMI-SDS and fat-mass percentage) and the PedsQL scores (all subscales and total score) (data not shown). Thirty one percent of the boys (9/29) and 23.8% of the girls (10/42) dropped out of the program, this different was not significant. The rate of boys and girls who dropout from the intervention was not significantly different among the three intervention groups (LCLF: 1/7 boy and 2/11 girls; LCHF: 2/4 boys and 3/13 girls; HCLF: 6/18 boys and 5/18 girls).

Discussion

Our results, in agreement with other studies, indicate that HRQOL is impaired in obese adolescents compared to normal-weight healthy adolescents (De-Beer et al., 2007; Pinhas-Hamiel et al., 2006; Ravens-Sieberer et al., 2001; Zeller & Modi, 2006) and that it improves after participation in a weight-management program (Ravens-Sieberer et al., 2001). The only PedsQL subscale which was similar to published norms (Varni et al., 2001) already at baseline was the social functioning subscale. One possible explanation for this finding is the tremendous need for social ties in this group of adolescents, and their perception of social relationships as being highly important, which makes it difficult for them to admit to a problem in this area.

Our 12-week intervention program resulted in a significant reduction in BMI, BMI-SDS, and fat-mass percentage regardless of the specific diet used (LCLF, LCHF, or HCLF). These results are in line with several reviews of adult studies (Bravata et al., 2003; Crow, 2005), which failed to find any significant benefit of low-carbohydrate diets over other diets in terms of amount of weight loss. However, in one of the few randomized studies of low-carbohydrate diets (20–49 g/day) in youth that included a control group given a high-carbohydrate, low-fat diet, Sondike et al. (2003) reported greater weight loss and a greater decrease in BMI in the low-carbohydrate diet group. The caloric intake in both groups was 1500–2500 kcal/day. Bailes et al. (2003) used a prospective, nonrandomized design to compare youths given a low-carbohydrate diet (30 g/day) with no caloric, fat, or protein limitations or a limited-calorie diet (20% below energy needs by age, sex and ideal weight). They, too, found a significantly greater weight loss and BMI decrease in the subjects on the low-carbohydrate diet; the limited-calories group gained weight, with an increase in BMI. However, allowing participants to choose their diet could impact on compliance. It is difficult to compare these studies with ours because of the diversity in the carbohydrate limitation, the calorie limitation, and the ratio among the macronutrients.

Despite the significant improvement in the anthropometric parameters in all three groups, a significant improvement in HRQOL was found only in the LCLF and HCLF groups, and not in the LCHF group. Studies of the influence of the specific composition of the weight-loss diet on psychosocial parameters have been limited to adults. Although Galletly et al. (2007) also noted no difference in weight loss associated with a high-protein, low-carbohydrate diet and a low-protein, high-carbohydrate diet, however, unlike our findings, HRQOL parameters (especially psychosocial functioning) improved only in the low-carbohydrate, high-protein group. Again, however, comparison of the two studies is difficult because besides the different study populations, Galletly et al. (2007) examined different psychosocial parameters (depression and self-esteem). In other, very short-term studies of macronutrient manipulation, Latner and Schwarts (1999) found that liquid lunches consisting predominantly of protein induced greater feelings of satiety than carbohydrate liquid lunches. Similarly, Fischer et al. (2004) reported higher hunger ratings 1 h after a breakfast of high-fat content than with a breakfast of proteins and carbohydrates; after 3 h, hunger ratings were similar for the fat- and carbohydrate-containing breakfast groups and higher than in the protein group. In all groups, feelings of “energy” were negatively related to hunger sensation. Benton (2002) found that eating high-carbohydrate food was associated with poorer mood and decreased arousal approximately 90 min later, whereas Markus et al. (1998) reported that carbohydrate-rich, protein-poor food prevented an increase in depression when high-stress participants were subjected to uncontrollable stress. In one of the few studies of school-age children, Zhang, Hebert, and Muldoon (2005) analyzed the cross-sectional data of the Third National Health and Nutrition survey. They noted a weak but significant association between total fat intake and shyness, and a significant association of increased intake of polyunsaturated fats/decreased intake of cholesterol with improved performance on cognitive tests. In our study, both the LCLF and the HCLF diets contained less fat (about 40 g per day) and less cholesterol (about 300 mg in the LCLF diet and 150 mg per day in the HCLF diet) than the LCHF diet (about 80 g fat and 480 mg cholesterol). As the fat composition in all the diets was mixed, the LCHF diet, which contained the highest amount of total fat, also had the highest amounts of both saturated and unsaturated fats. Further research is needed to clarify the inconsistent results of these studies and to further examine the effects of different type of dietary fats on weight and HRQOL parameters during weight loss in adolescents.

Our results further suggest that obese youth with better psychosocial functioning especially in the emotional field at baseline, are more likely to have a better improvement in BMI and fat-mass. HRQOL variables have been analyzed as pre-treatment predictors of weight management in very limited number of studies (Teixeira et al., 2005). Similar to our results, two studies of obese adults (Teixeira et al., 2002, 2004) reported an association between HRQOL before obesity treatment and subsequent weight outcomes. Higher BMI-SDS at baseline was also found as a predictor to higher reduction in BMI-SDS during the intervention. This is not surprising because one can expect that participant with a higher level of overweight would lose more weight.

However, contrary to our hypothesis, we failed to find any significant correlation between the changes in HRQOL ratings and the changes in the anthropometric parameters during the 12-week intervention. A possible explanation is attributed to the association which was found between a better HRQOL at baseline and a better improvement in BMI and fat-mass, though participants entering a weight-loss intervention program with a better HRQOL, having less objective capability for improvement their already relatively high HRQOL.

To the best of our knowledge, this is the first intervention study to compare the effects of three diet regimens of different macronutrient ratios on weight and HRQOL parameters in adolescents. However, several limitations should be noted.

Like many other studies of nutritional interventions in humans, the number of participants was small and dropout rate was relatively high. Our dropout rate of 26.8% was close to that of similar studies by Sondike et al. (2003) (20% in the low-carbohydrate diet group and 25% in the low-fat diet groups; 12-week program) and Bailes et al. (2003) (21% in the low-carbohydrate diet group and 38% in the calorie-limited diet group; 2-month program). Although compliance with the regimens in the remaining patients appeared to be good, it is possible that differences in the palatability of the diets or in satiety led to undetected differences in compliance. Our subjects were randomly allocated, but they were not blinded to the diet composition. Finally, as with other patients population (Juniper, 1997), obesity researchers have begun the development and validation of obesity-specific HRQOL measures. Disease-specific instruments target domains and symptoms most relevant to a particular disease. They are typically more sensitive than generic instruments to changes in quality of life that results from treatment (Guyatt, Jaeschke, Feeny, & Patrick, 1996). Further research is needed to examine differences in sensitivity between the PedsQL, a generic measure, and the impact of weight on quality of life-kids, disease-specific measure for adolescents (Kolotkin et al., 2006).

In conclusion, the findings of the present study may have several important implications. First, the significant improvement in HRQOL, which reflects a better psychological adjustment, only in the subjects on the low-fat LCLF and HCLF diets, but not in those treated with the high-fat LCHF diet, may support the importance of low-fat content in weight-loss interventions for adolescents, regardless of the high or low-carbohydrate content. This preliminary finding should be confirmed in further research. Second, for a better outcome, it is important that psychosocial functioning be evaluated and improved before initiation of a weight-loss intervention program. In addition, because weight loss may be difficult to achieve in many youths, directly improving their quality of life by means of a healthy lifestyle intervention program, even in the absence of weight loss, may be desirable goal.

Appendix A

An example of one menu and written instructions for each of the three intervention groups

Example of a high-carbohydrate and low-fat diet	Example of a low-carbohydrate and low-fat diet	Example of a low-carbohydrate high-fat diet
Breakfast		
2 cups of water or diet (low calorie drinks) or 1 cup of tea-no sugar (possible to add artificial sweetener)	2 cups of water or diet (low calories drinks) or 1 cup of tea-no sugar (possible to add artificial sweetener)	2 cups of water or diet (low calories drinks) or 1 cup of tea-no sugar (possible to add artificial sweetener)
2 slices of light bread	2 tablespoons (30 g.) white cheese 5% fat	1 table spoon of white cheese 9%
2 tablespoons (30 g) white cheese 5% fat	Hard boiled egg	Fried egg (1 egg with 1 tea spoon of canola oil)
2 kinds of vegetables sliced	2 kinds of vegetables sliced	2 kinds of vegetables sliced
	1 cup of milk 1% fat	
10 O'clock – mid morning meal		
0.5 l of water	0.5 l of water	0.5 l of water
Medium size full grain-wheat bread roll	2 diet dairy products 0% fat (150 ml. each)	Yogurt bio 3% fat (no sugar. Artificial sweetener is possible)
1 slice of yellow cheese 9% fat		2 cups of different vegetables
2 kinds of vegetables sliced		
1 medium size apple		
Lunch		
2 cups of water or diet drink	2 cups of water or diet drink	2 cups of water or diet drink
Clear soup or light vegetable soup (without soup almonds/noodles or any other kind of addition)	Clear chicken (without soup almonds/noodles or any other kind of addition)	Clear chicken (without soup almonds/noodles or any other kind of addition)
Chicken breast fried in Teflon pan or in the oven (150 g)	Chicken breast fried in Teflon pan or in the oven (300 g)	1 medium size grilled chicken leg (150 g)
3 tablespoons of spiced boiled brown rice	2 cups of vegetables slices with out any oil or sauce, fresh or cooked. Possible to add spices and lemon	Salad from 3 cups of different Vegetables and 1 teaspoon of olive oil
Salad from 3 cups of different vegetables and 1 teaspoon of olive oil		
Mid afternoon meal		
2 cups of water or diet drink	2 cups of water or diet drink	2 cups of water or diet drink
Diet yogurt 0% fat (150 ml)	6 slices of law fat pastrami	Sour cream 15% fat (125 g)
1 medium size Apple	2 cups of sliced vegetables	2 cups of sliced vegetables
Supper	Supper	Supper
2 cups of water or diet drink	2 cups of water or diet drink	2 cups of water or diet drink
2 slices of light bread	Big tuna salad made from the following ingredients:	Big tuna salad made from the following ingredients:
One hard boiled egg	2 cups of different vegetables	3 cups of different vegetables
1 tablespoon of Tehina	1 can of tuna in water	1/4 a can of tuna in oil
Salad from 3 cups of different vegetables and 1 teaspoon of olive oil	2 slices of yellow cheese 9% fat	50 g (1/4 package) Zfatit cheese 16% fat
1 medium size Banana	1 teaspoon of olive oil	1 teaspoon of olive oil
Important remarks:		
To take the maximum advantage of this menu, it is necessary to be strict with the following instructions:	To take the maximum advantage of this menu, it is necessary to be strict with the following instructions:	To take the maximum advantage of this menu, it is necessary to be strict with the following instructions:
1. To prevent dehydrated, it is very important to drink at least 10 cups of water a day. Possible as well-diet drinks without carbohydrate	1. To prevent dehydrated, it is very important to drink at least 10 cups of water a day. Possible as well-diet drinks without carbohydrate	1. To prevent dehydrated, it is very important to drink at least 10 cups of water a day. Possible as well-diet drinks without carbohydrate
2. Avoid drinks or nutrition that contains sugar, like fruit, sweet drinks that have more than 1 calorie in 100 ml	2. Avoid drinks or nutrition that contains sugar, like fruit, sweet drinks that have more than 1 calorie in 100 ml, any kind of candy	2. Avoid drinks or nutrition that contains sugar, like fruit, sweet drinks that have more than 1 calorie in 100 ml, any kind of candy

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Appendix A (*Continued*)

Example of a high-carbohydrate and low-fat diet	Example of a low-carbohydrate and low-fat diet	Example of a low-carbohydrate high-fat diet
3. It is important to make sure that the nutrition based on vegetables, like soup, salads or quick fried vegetables do not contain high-carbohydrate vegetables, like: potato, sweet potato or corn	3. It is important to make sure that the nutrition based on vegetables, like soup, salads or quick fried vegetables do not contain high-carbohydrate vegetables, like: potato, sweet potato, corn or carrot	3. It is important to make sure that the nutrition based on vegetables, like soup, salads or quick fried vegetables do not contain high-carbohydrate vegetables, like: potato, sweet potato, corn or carrot
4. It is important to eat only low-fat food products: white cheese maximum 5% fat, yellow cheese, maximum 9% fat, yogurts 0% fat	4. It is important to eat only low-fat food products: white cheese maximum 3% fat, yellow cheese, maximum 9% fat, yogurts 0% fat	

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