Original Article

Effectiveness of weight reduction program in adolescents under sanatorium conditions in Poland including the role of diet and energy balance

Julita Regula PhD[1], Jan Jeszka Prof[1] and Anna Gramza PhD[2]

[1]*Department of Human Nutrition and Hygiene, Agriculture University of Poznan , Poland*
[2]*Department of Human Nutrition and Food Technology, Agriculture University of Poznan, Poland*

The aim of this study was to assess the effectiveness of weight reduction program and to develop recommendations for the therapeutic program conducted under sanatorium conditions, taking into consideration the composition of the diet and the share of macrocomponents in the negative energy balance. Investigations were conducted during 12 stays at a sanatorium, lasting for 24 days, with the program of body weight reduction. The study included 174 obese adolescents aged 12 - 16 years. The nutritive value of 288 daily rations was established on the basis of daily menus. Total daily energy expenditure (TDEE) during therapy was assessed by 24-hour heart rate monitoring. The body composition (fat mass FM, fat free mass FFM, body cell mass BCM, total body water TBW) were measured using bioelectrical impedance before and during therapy as well as six month later. Weight reduction program consisted of low energy diet (5.47MJ/24h) and physical exercises. TDEE of individuals staying at the sanatorium considerably (p<0.001) exceeded energy intake from the diet, which was manifested in changes of body weight and body composition of adolescents during the therapy. Six months after therapy at the sanatorium no statistically significant changes were recorded in the mean FFM, BCM and TBW contents. These results made it possible to establish optimum recommendations concerning low-energy diet and the degree of negative energy balance and their interrelations, determining the maximization of fat mass losses at the simultaneous minimization of lean body mass losses.

Key Words: obesity, adolescents, diet, energy balance

Introduction

The problem of excessive body weight pertains to approx. 10% Polish population of children and teenagers aged 6~17 years and in 3%~ 4% of which considerable overweight is found.[1-3] It is important to treat already obese children and teenagers, since children who are obese when reaching puberty have only 25% chance of obtaining an appropriate body weight at maturity, whereas if they are obese when reaching maturity the likelihood of reducing body mass to an appropriate weight is only 3%.[4,5]

During treatment of obesity it is attempted to obtain a negative energy balance through dietary restrictions with a simultaneous intensification of physical activity. The addition of aerobic exercise to a low-energy diet was beneficial in the treatment of moderate obesity because of its favorable effects on body composition, physical activity, and total daily energy expenditure.[6] Too intensive slimming down in case of young people may lead to anorexia nervosa and bulimia, growth retardation, psychoneurological disorders and muscle weight losses. Thus, the course of the slimming therapy needs to be monitored thoroughly and systematically, to follow changes in body components. It is possible at a sanatorium, where a multidisciplinary program of body weight reduction combines a low-calorie diet, exercise and modification of behaviour through consultations with a psychologist and a dietitian.[5-8] Gately suggest that the use of a structured fun-based skill learning programme may provide an alternative method of exercise prescription to help children prolong the effects of the 8 week intervention.[8] Further investigations will help identify the key factors that are necessary for long-term lifestyle modification. Slimming therapy has been assessed in numerous publications, but they focused primarily on the interpretation of changes in body weight and body components.[6-11]

The aim of this study was to evaluate the effectiveness of slimming therapies and to determine on the basis of results recommendations for a program of a slimming therapy offered at a sanatorium, including the composition of a diet and the macrocomponent contents in the negative energy balance.

Methods

Investigations were conducted during 12 stays at a sanatorium in Poland - Rehabilitation and Hospital Center, lasting for 24 days, with the program of body weight reduction. We have been monitoring body weight therapies during 6 years.

Corresponding Author: Dr Julita Regula, Dept of Human Nutrition and Hygiene, Agriculture University of Poznan, Wojska Polskiego 31, 60-624 Poznan, Poland
Tel: +48 61 848 73 39; Fax: +48 61 848 73 32
Email: jumar@au.poznan.pl

Subjects

The study included a population of 174 obese teenagers aged 12-16 lat, staying at a sanatorium for a slimming therapies. Each person stayed in sanatorium only one period. In adolescents no other diseases were found apart from simple obesity and which in the course of the study did not receive any medication. All the examined teenagers and their parents expressed their willingness to participate in the study and the experiment protocol was accepted by the Ethics Commission at the University of Medical Sciences in Poznan.

Diets

All the daily rations in this study were prepared in the kitchen at the sanatorium. Daily menus were developed by the nutritionist from this place. Energy value of 288 daily rations prepared at the sanatorium throughout the whole therapy (12 stays at sanatorium) was established on the basis of daily menus. A computer software package "Dietetic 2001" was used for the calculations, based on the Polish database comprising tables of nutritive value of foodstuffs.[12] To control the correctness of the estimation of nutritive value of the daily rations, chemical analysis of meal samples was conducted in three replications. Energy value was determined using a calorimetric kit KL-10, protein content was determined according to Kjeldahl with a KJELTEC SYSTEM 1026 Distilling Unit, fat content was determined using the Soxhlet method.

Total daily energy expenditure

A non-invasive method of 24h monitoring of pulse rate using a Polar Sport Tester was applied to estimate the total daily energy expenditure (TDEE). For each of the patients included in the study an individual regression dependence was established between oxygen consumption and pulse rate. A respirometer Cardiorespiratory Diagnostic System by Medgraphics USA, coupled with a moving track was used to measure oxygen consumption. Oxygen consumption was measured at rest and when running on the moving track according to the procedure presented by Bradfield and Spady as modified by Jeszka.[13,14,15] From the pulse rate values measured during oxygen consumption testing the threshold pulse, the so-called HR-FLEX (the mean value of the highest pulse at rest and the lowest pulse when exercising), was determined in order to define the borderline between rest and physical activity. The TDEE constituted the sum of partial expenditures – during sleep, low activity <HR-Flex (reading, watching TV, lectures), exercise connected with moderate activity therapy >HR-Flex and pulse rate below 140 beats/min and physical activity with pulse rate above 139 beats/min.

Physical activity

Therapeutic exercise consisted of regularly performed activities: run/walk (covering a specific route of 7 km when marching fast), cycling (with the speed of 14~16 km/h), swimming in the pool, bowling, dancing, walking (at the speed of 4~5 km/h), morning exercises, team sports (basketball, football, volleyball), aerobics, working out in a gym (cycling on a cycloergometer, with the intensity up to 70% VO_2max or running on a moving track with the speed of approx. 10 km/h)

Anthropometric measurements

Subcutaneous fatness was measured using a HARPENDENA caliper, with pressure of 10g/mm^2 contact area, accurate to 0.1 mm, based on three skin-adipose folds: on the arm – over the triceps muscle (TRC); below the scapula (SSC) and over the iliac ala (SIC). Body composition was determined using the bioelectric impendence method with a BIA 101S, AKERN-RJL. Anthropometric measurements, measurements of subcutaneous fatness and body composition were taken once a week at identical time intervals.[16]

Six months after the completion of the therapy at the sanatorium, individuals participating in the study were again examined in terms of the basic parameters of nutritive.

Statistical analyses

Results of testing were subjected to statistical analysis using the analysis of variance for dependent groups, as well as simple and multiple regression. All calculations were performed using a *STATISTICA^{TM}PL 7.0* statistical software package by StatSoft.

Results

Table 1 presents the mean contents of energy, primary nutrients for 288 daily rations and energy balance of teenagers during therapy.

In accordance with the therapeutic recommendations for obesity treatment in teenagers, rations served at the sanatorium had low energy value (by approx. 46% lower than the value of recommended allowance). The reduction of the calorie content of the diet was obtained first of all by lowering the supply of fat. The ratio of polyunsaturated, monounsaturated and saturated fatty acids (P:M:S ratio) of the in-sanatorium diets was ~ 1:1.65:0.65. Diets served at the sanatorium were characterized by a relatively high mean energy supply from protein, and protein

Table 1. The mean contents (mean ± SD) of energy and macronutrients in all daily ration prepared at the sanatorium throughout the whole therapy and energy balance of teenagers

Energy and macronutrients in diets	
Energy (kcal)	1308 ± 87.0
Protein (g)	58.1 ± 4.43
Animal protein (g)	39.9 ± 4.07
Carbohydrates (g)	182 ± 21.8
Fat (g)	37.3 ± 5.62
% energy from protein	18
% energy from carbohydrates	56
% energy from fat	26
Total daily energy expenditure and energy balance	
Total daily energy expenditure (kcal/24h)	2590 ± 150
Energy balance (kcal/24h)	-1282 ± 227

Energy balance = Energy intake (kcal) – Total daily energy expenditure (kcal/24h)

Table 2. Mean body composition of adolescents during and 6 month after weight reduction programs (mean ± SD)

Parametr	Before therapy	After therapy	6 month after therapy
Body mass (kg)	77.6 ± 11.8[a]	73.8 ± 11.1[b]	72.6 ± 9.77[c]
BMI	28.8 ± 3.49[a]	27.4 ± 3.32[b]	27.1 ± 3.29[c]
FM (kg)	31.9 ± 7.50[a]	29.6 ± 7.12[b]	28.4 ± 6.70[c]
FFM (kg)	45.7 ± 6.21[a]	44.2 ± 5.76[b]	44.2 ± 4.72[b]
BCM (kg)	24.6 ± 3.82[a]	23.9 ± 3.38[b]	23.9 ± 2.98[b]
TBW (kg)	34.1 ± 4.48[a]	32.4 ± 4.04[b]	32.2 ± 3.13[b]
Mean skinfold thickness (cm)	2.5 ± 0.64[a]	2.3 ± 0.68[b]	1.98 ± 0.52[c]

Significant difference between within row means of each group is indicated by different superscript letters (ANOVA for dependent groups, $p<0.01$)

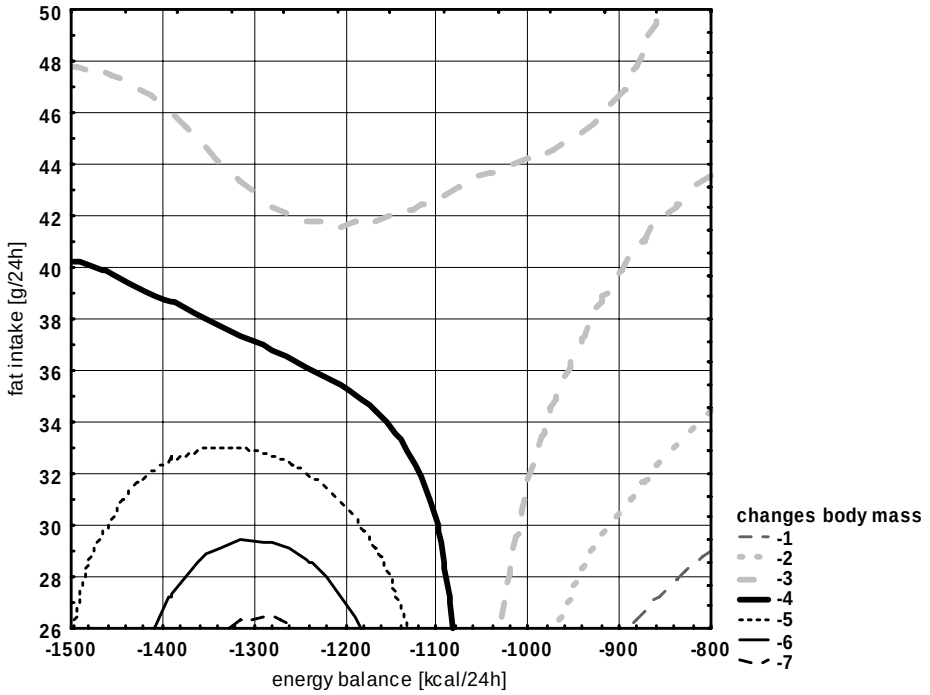

Figure 1. Multiple regression between energy balance (kcal/24h) and fat intake (g/24h) and changes body mass (kg) during therapy r=0.58, $p<0.001$. A high weight loss of adolescents during a therapy was obtained when the negative energy balance was within the range of 1100~1500 kcal/24h, and fat supply in the diet did not exceed ~40 g/day

supply in diets per 1 kg body weight of the patients was 0.75 g.

The TDEE value of obese teenagers staying at the sanatorium considerably exceeded the energy intake from the diet (Table 1). The negative energy balance EB was reflected in changes in body weight and compositions of patients receiving slimming therapy (Table 2). In all the tested individuals a statistically significant reduction of body weight BW, BMI and fat mass FM was reported. During therapy the losses of fat-free mass FFM, body cell mass BCM, and total body water TBW were not prevented.

The assessment of the multiple correlation between weight loss and daily supply of fat and EB showed that a high (approx. 4 kg) weight loss of teenagers during a therapy at the sanatorium was obtained when the negative energy balance was within the range of 1100~1500 kcal/24h, and fat supply in the diet did not exceed 41 g/day (Fig 1). However, if at the same time energy supply from the diet did not exceed 1300 kcal/24h, then a high loss of fat mass amounting to approx. 3 kg was reported (Fig 2).

Slimming therapy in teenagers needs to be conducted in such a way so as to limit the simultaneous losses of body cell mass. Thus, the dependence was assessed between BCM changes and protein supply from the diets and energy balance (Fig 3). It was found that muscle mass of children and teenagers would not change when at a negative energy balance of 1000~1500 kcal/24h when protein supply in the low calorie diet was not lower than 59 g/24h.

The main aim of the slimming therapy was to obtain a reduction of body weight at the expense of adipose tissue and to motivate patents to maintain the positive results of the therapy at a longer time span. In order to answer the question whether the obese individuals after the completion of therapy do not increase their body weight again with the so-called yoyo effect, anthropometric dimensions,

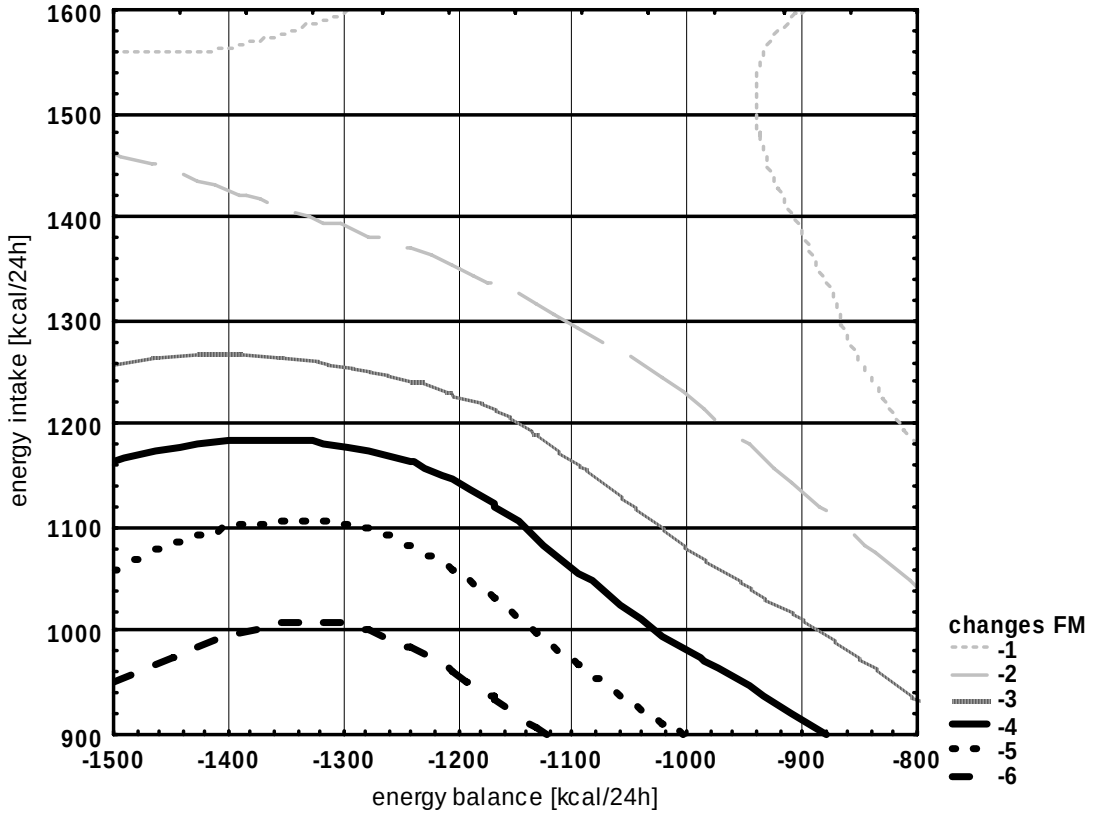

Figure 2. Multiple regression between energy balance (kcal/24h) and energy intake (kcal/24h) and changes fat mass (kg) during therapy r=0.45, $p<0.001$. A high fat mass loss of adolescents during a therapy was obtained when the negative energy balance was within the range of 1100~1500 kcal/24h, and energy intake did not exceed ~1300 kcal/24h

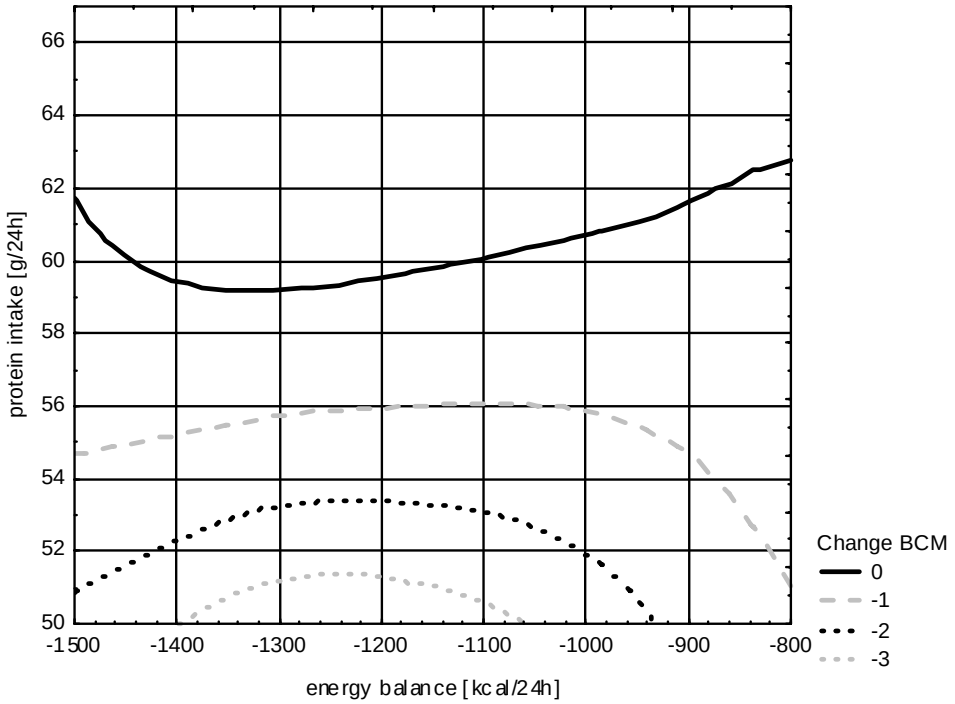

Figure 3. Multiple regression between energy balance (kcal/24h) and protein intake (g/24h) and changes body cell mass (kg) during therapy r=0.42, $p<0.001$. The body cell mass of teenagers would not change when at a negative energy balance of 1000~1500 kcal/24h when protein supply in the diet was not lower than ~59 g/24h

body composition and thickness of skin and fat folds were measured 6 months after the completion of therapy (Table 2). It was found that after that period the mean body mass of all patients decreased significantly ($p<0.01$). However, it needs to be stressed that this significant ($p<0.01$) decrease of body weight was primarily connected with a considerable decrease in the fat mass value. In contrast, no statistically significant differences were recorded in changes of mean FFM content, including BCM and TBW, in the period of 6 months after the completion of therapy.

Discussion

The applied 24-day therapy in obese teenagers affected both their body mass and the fat mass, causing a reduction of these parameters (5% body mass, 7% FM). BW loss was on average 1~2 kg per week, which is consistent with the recommendations of Williams *et. al* [17], who stated that this is the optimal rate of body mass reduction, guaranteeing the long-term effectiveness of therapy.

For the effects of slimming therapy it is essential to reach a markedly negative daily energy balance. The problem of energy deficit in the diet of children and teenagers and the proportions of macrocomponents in the diet is connected with such a selection of components in the low calorie diet so as to obtain a considerable reduction of body mass at the limitation of losses in fat free mass. However, it is not easy to solve this problem due to a lack of precise recommendations which could be simply implemented when planning a sanatorium therapy. Commonly used slimming diets adopted in Polish sanatoria are diets designed for adults, supplying 1000~1500 kcal/day and diets with a very low energy content (VLCD) - below 800 kcal a day.[18-20] There are no studies confirming the effectiveness of such diets in teenagers. Scarce publications report only the principles on which dietary recommendations should be based, concerning the process of body mass reduction for these age groups.[19-22] At the sanatorium low calorie diets were served, with mean energy value of 1308 kcal/day, which was consistent with the proposals of Dietz and Rymkiewicz-Kluczynska**,** so that the energy value of reduction diets used in teenagers could range from 1200~1400 kcal/day.[21,23] A reduction of calorie content was achieved primarily thanks to a lowering of fat and simple carbohydrates. The Polish adolescents are currently consuming, on average ~30% of energy as fats.[1, 15,18] Polish obese adolescents during slimming therapy are recommended to have 20%~28% energy intake from fat and 50%~60% from carbohydrate.[18,20,23] Carbohydrate supply in rations at the sanatorium was established based on remarks by Garrow that a rational reduction diet, apart from low fat content, should contain an appropriate amount of carbohydrates, at least 100 g.[24] This protects from the consumption of systemic protein for energy supply, as well as disturbances in the water balance. Bray emphasized the importance of this macrocomponent in short-term slimming diets of less than 2 weeks. That author stated that carbohydrate intake lower than 50 g/day may lead to ketosis in the organism.[25]

An essential aspect in the composition of a low energy diet for teenagers due to their intensive development is to provide an appropriate supply of quality protein. This makes it possible to reduce the loss of fat free mass and to ensure an appropriate nitrogen balance.[26] In the course of the program of body mass reduction adopted at the sanatorium changes in fat free mass mass were not prevented (mainly changes in total body water, and to a lesser degree changes in body cell mass). Similar results were obtained by Schwingshandl and Borkenstein when applying a 21-day slimming therapy based o increased physical activity and low energy diets of 1000 kcal, in which protein constituted 20% energy, carbohydrates 50% and fat 30%, respectively.[11] They assessed changes in anthropometric parameters and body composition of teenagers aged 9-15 years. Those authors did not prevent losses of fat free mass (max. -2.6 kg), at the simultaneous high changes in BW (from -3.1~8.2 kg).[11] The problem of fat free mass appeared in most publications concerning slimming therapies and it is considered an element practically impossible to be eliminated.[4,5,11,25]

Protein supply in rations applied during therapy was consistent with the assumptions of low energy diet proposed for adults by numerous authors.[18-20, 22-25] Dietz suggested that the amount of energy from protein in diets for children and teenagers should cover 20%~25% daily energy requirement.[21] To obtain such values, supply of products containing quality protein was increased in rations (with no synthetic high protein and low fat substitutes introduced to the diet). Taking into consideration the volume of energy deficit, for each 100 kcal of this deficit, rations used at the sanatorium supplied teenagers with 2.3 g protein. According to Garrow and Bialkowska and Szostak a reduction diet may be considered rational when the supply of protein of high biological value is 1.75 g per each 100 kcal energy deficit.[24, 18]

It needs to be emphasized that the whole low energy diet proposed at the sanatorium was based on commonly available products, which could still be consumed at appropriate proportions by obese teenagers after the completion of the therapy. In diets e.g. low fat dairy products were used, such as no-fat yoghurts and kefirs or low fat cottage cheese. Dishes were cooked or stewed, with no addition of fat or sugar. Children and teenagers consumed 5 meals daily with identical breaks between them, which according to many authors is necessary both in the prevention and treatment of obesity.[3,4,18,22]

Analysis of multiple regressions made it possible to determine how deep an energy deficit needs to be in the diet for teenagers and what proportions of macronutrients need to be in a low energy diet to ensure the effectiveness of the therapy. It turned out that in order to obtain in the course of a slimming therapy a body mass loss of 4 kg, including the loss of adipose tissue of approx. 3 kg, energy intake from the diet should be approx. 1200~1300 kcal/24h, while the supply of fat need to exceed 41 g/24h. Muscle mass did not change when protein supply in the low energy diet was not lower than 59 g/24h.

The key to the success in each slimming therapy is to maintain its positive results over a longer time span. For this reason in the investigations in this study changes in anthropometric parameters were assessed in the patients after 6 months from the completion of therapy. It turned out that after 6 months the mean body mass of all examined teenagers decreased considerably. However, it needs to be stated that this significant body mass decrease was primarily connected with a significant lowering of the fat mass. However, no statistically significant changes were reported in the mean content of fat-free mass in the period of 6 months after the completion of therapy. Schwingshandl and Borkenstein**,** in a study on children and teenagers aged 9~15 years found that the effect of long-term therapy may be significantly affected by the volume of fat free mass loss during therapy. [11] Those authors 4 months after the completion of a 3-week slimming therapeutic stay, when again assessing the body composition of obese children, observed a highly significant correlation

between changes in FFM during therapy and the increase in adipose tissue mass 4 months after its completion.

Bewick claimed that the long-term effect of therapy depends on the development of appropriate habits in children and teenagers during therapy.[27] A multidisciplinary program of body mass reduction applied at the sanatorium, combining a low energy diet, exercise and modification of behaviour, should be introduced to the daily lifestyle after the completion of therapy.[28-30] The best results were obtained when additionally parents were involved in treatment, apart from the child itself. The therapeutic success depends equally on the attitude of the child itself and people around him/her to the problem of obesity. It is necessary to convince parents it is necessary to participate actively in the process of body mass reduction. In conclusion, on the basis of the whole of the presented study it needs to be stated that slimming down of teenagers is a complex problem. Many factors are involved in this process and their interrelations may determine the effectiveness of the whole therapeutic program. The determination of optimal recommendations concerning low energy diet and the volume of a negative energy balance and their interrelations determines the maximization of fat mass losses at the simultaneous minimization of body cell mass losses.

Acknowledgement

The authors wish to thank Maria Gawlinska, director of the Rehabilitation and Hospital Complex in Osieczna, for making possible the study. This study was financed from the funds of the Ministry of Education and Science in Poland as a research project.

References

1. Chrzanowska M, Matusik S. Normal and abnormal height and weight development in children and adolescents in Krakow-changes and trends in the last thirty years. Med Wieku Rozwoj 2004; 8: 53-64.
2. Olejarnik I, Borzecki G, Kowalska M. Frequency of occurrence of obesity and body mass deficits among children of Lublin grammar-schools. Ann Univ Mariae Curie Sklodowska 2004; 5: 325-329.
3. Malecka-Tendera E, Klimek K, Matusik P, Olszanecka-Glinianowicz M, Lehingue Y. Obesity and overweight prevalence in Polish 7- to 9-year-old children. Obes Res 2005;13: 964-968.
4. Dietz W. Critical periods in childhood for the development of obesity. Am J Clin Nutr 1994; 59: 955-959.
5. Schwartz M, Brunzell J. Regulation of body adiposity and the problem of obesity. Arterioscler Tromb Vasc Biol 1997; 17: 584-596.
6. Racette SB, Schoeller DA, Kushner RF, Neil KM, Herling-Iaffaldano K. Effects of aerobic exercise and dietary carbohydrate on energy expenditure and body composition during weight reduction in obese women. Am J Clin Nutr 1995; 61: 486-94.
7. Lazzer S, Meyer M, Derumeaux H, Boirie Y, Vemmorel M. Longitudinal changes in body composition and basal metabolic rate in institutionalized or domiciled obese adolescents. Arch Pediatr 2005; 12: 1349-57.
8. Gately PJ, Cooke CB, Butterly RJ, Mackreth P, Carroll S. The effects of a children's summer camp programme on weight loss, with a 10 month follow-up. Int J Obes Relat Metab Disord 2000; 24: 1445-52.
9. Savoye M, Berry D, Dziura J, Shaw M, Serrecchia JB, Barbetta G, Rose P, Lavietes S, Caprio S. Anthropometric and psychosocial changes in obese adolescents enrolled in a Weight Management Program. J Am Diet Assoc 2005; 105: 364-70.
10. Landers P, Wolfe MM, Glore S, Guild R, Phillips L. Effect of weight loss plans on body composition and diet duration. J Okla State Med Assoc 2002; 95: 329-31.
11. Schwingshandl J, Borkenstein M. Changes in lean body mass in obese children during a weight reduction program: effect on short term and long term outcome. Int J Obes 1995; 19: 752-755.
12. Kunachowicz H, Nadolna I, Przygoda B, Iwanow K. Food composition and nutritive value. IZZ 1998.
13. Bradfield RB. Energy expenditure and heart rates of Cambridge boys at school. Am. J Clin Nutr 1971; 24: 1461-1466.
14. Spady DW. Total daily energy expenditure of healthy free ranging children. Am J Clin Nutr 1980; 33:766-775.
15. Jeszka J, Reguła J, Kostrzewa-Tarnowska A. Evaluation of dietary balance and dietary habits, nutritional status in the obese children. Med Metab 1998; 2:19-24.
16. Lukaski HC. Methods for assessment of human composition: traditional and new. Am J Clin Nutr 1987; 46:537-556.
17. Williams CL, Campanaro LA, Squillace M, Bollella M. Management of childhood obesity in pediatric practice. Ann N Y Acad Sci 1997; 817: 225-40.
18. Bialkowska M, Szostak WB. Choice of treatment method for obesity depending on health status. Pol Tyg Lek 1995; 1: 48–50.
19. Bialkowska M. Comparative studies on low-carbohydrate diet and 1000 kcal diet in the treatment of obesity. Mat Med Pol 1977; 3: 244-251.
20. Hasik J. Treatment of obesity in sanatorium. New Med, 1997; 15: 17-20.
21. Dietz WH. What constitutes successful weight management in adolescents? Ann Intern Med 2006; 18,145: 145-146.
22. Ostrowska L, Karczewski J. Diet in treatment obesity and overweight . Med Metabol 2000, 4: 50.
23. Rymkiewicz-Kluczynska B. Obesity in children and adolescents. Medipress Pediatria 1999; 5: 1.
24. Garrow JS. Obesity. in Garrow JS, James WPT, eds. Human nutrition and dietetics. 9th ed. Edinburgh, Churchill Livingstone 1993: 465-479.
25. Bray GA. The obese patient. In: Major problems in internal medicine 9th ed. Saunders WB, Philadelphia. 1976.
26. Davies HJA, Baird IM, Fowler J, Mills IH, Baillie JE, Rattan S, Howard AN. Metabolic response to low and very low calorie diets. Am J Clin Nutr 1989; 49:745-451.
27. Bewick BM. Behaviour changes in overweight and obese children after a weight loss camp. Intern J Obes 2002; 26: 27.
28. Anderson PM, Butcher KE. Childhood obesity: trends and potential causes. Future Child 2006,16: 19-45.
29. Doak CM, Visscher TL, Renders CM, Seidell JC. The prevention of overweight and obesity in children and adolescents: a review of interventions and programmes. Obes Rev 2006; 7: 111-136.
30. Snethen JA, Broome ME, Cashin SE. Effective weight loss for overweight children: a meta-analysis of intervention studies. J Pediatr Nurs 2006; 21: 45-56.