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ABSTRACT

Objective To identify anthropometric and behavioral characteristics associated with weight maintenance after an obesity treatment.

Study design Seventy-two adolescents enrolled in a 9-month obesity treatment were followed 1 and 2 years after discharge. Two equally distributed groups, "successful" vs. "limited or no success", were constituted on the basis of the differences in BMI z-score between inclusion and end of follow-up. Anthropometric and behavioral characteristics were compared between groups.

Results Both groups showed a decrease of BMI z-score between inclusion and end of follow-up: 2.09±0.68 SD for the successful group and 0.65±0.43 SD for the group with limited or no success. Groups did not differ during treatment for any of the anthropometric characteristics considered, while differences clearly appeared 1 year after treatment and generally stabilized during the second year. Later adiposity rebound, trend for lower BMI in the mother, and lower total energy intake, more energy at breakfast, less snacking and television during follow-up were recorded in the successful group.

Conclusions

Weight loss maintenance cannot be predicted neither by anthropometry during treatment nor by behavioral characteristics at inclusion, but can already be estimated 1 year after discharge. Early life factors should also be taken into account for the prediction of treatment outcome.

Key words: obesity; adolescent behavior; body composition; feeding behavior; treatment outcome; sedentary behavior; early determinants.

ABBREVIATIONS.

BMI, body mass index; UFE, upper arm fat area estimate; UME, upper arm muscle area estimate.

RUNNING HEAD.

Weight loss maintenance in adolescents

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INTRODUCTION

Obesity is associated with a number of health issues, which can be physical (e.g. hyperlipidemia, hypertension, infertility, cardiovascular and digestive diseases) as well as psychological (e.g. depression, low self-esteem).[1,2] Moreover, obese children have a higher risk than their counterparts to be obese adults[3,4] and, to have an increased morbidity and mortality rate independently of their weight as adults.[5] It is therefore of particular importance to prevent obesity occurrence in children and adolescents.

When prevention is not successful, weight loss treatments are considered. These treatments can have varying durations, but they consistently lead to a weight reduction in children and adolescents.[6-13] Although short term outcomes are encouraging, maintaining weight loss on the long term is often difficult to achieve. Follow-up of children after treatment clearly showed that, while some of them succeeded, a significant number of children could not maintain weight loss within one or two years after the end of treatment.[6,12,14,15] Although it is difficult to give specific figures on treatment outcome, since they strongly depend on evaluation methods and duration of follow-up, it seems that treatment results are generally not satisfactory.[16,17] A significant amount of work is therefore required to improve long-term maintenance of pediatric obesity.

Among adults, successful long-term weight loss maintainers have been shown to share common behavioral strategies, including eating a diet low in fat, frequent self-monitoring of body weight and food intakes, and high levels of regular physical activity.[18] Current data on the characteristics involved in the long-term weight loss maintenance in adolescents are however limited and need to be further investigated. While weight and/or body mass index (BMI) are the main outcome in most studies,

additional anthropometric indicators, which allow a better assessment of body composition and predict associated risk factors, should be included.[19]

We previously reported the influence of 9 month weight-reducing diets containing different amounts of protein and CHO on body composition in obese adolescents and examined dietary and physical activity behavior of the whole group during a 2 y follow-up.[12] In the present study, we compared body characteristics and behavioral patterns in two groups of adolescents according to weight loss maintenance over a 2-year follow-up. In addition, we aimed to evaluate the time when groups differentiated, whether before, during or after treatment.

METHODS

Subjects

This study has been described in details elsewhere.[12] Briefly, 121 obese adolescents, aged 11 to 16 years, were enrolled in a weight-reducing program lasting 9 months beginning in September 1997. The treatment included controlled diet, physical exercise and psychological support. Of the adolescents included, 99 (29 boys, 70 girls, aged 14.3 ±1.2 years) completed the whole treatment. A total of 72 adolescents were included in the follow-up study 1 and 2 years after the end of treatment. Adolescents lost to follow-up did not differ significantly in term of sex, age and BMI at the beginning and end of treatment compared to adolescents remaining in the study. The study was approved by the Ethical Committee for the protection of persons participating in biological experimentation (Hospital Paris Saint-Louis) and adolescents and their parents gave written consent to participate.

Behavioral variables

Diet

The 72 adolescents considered in this study had a mean stay at the center of 9 months and 12 days. Daily energy intake was limited to 1750 kcal until adolescents had reached a body weight goal determined by the physician. Later on, energy intake increased gradually, in 1-week steps, up to 2200 kcal a day on average (depending on age and sex). This diet was then maintained until the end of treatment. The study was first planned to compare the influence of weight-reducing diets containing different amounts of protein and carbohydrates on body composition in obese adolescents and to examine dietary and physical activity behaviors during follow-up.[12] One diet (P^-) included 15% protein and 54% carbohydrate whereas the other diet (P^+) included 19% protein and 50% carbohydrate. The two diets included a similar amount of fat (31%). In both cases, energy distribution over the day was as follow: 20% at breakfast, 31% at lunch, 16% at the afternoon snack and 33% at dinner. Snacking in addition to these four main meals was very occasional in the center. Adolescents were advised to maintain a balanced diet and the same energy level during week-ends and holidays as well as after the end of treatment. Nutrition and in particular, total energy intake, nutrient repartition and daily energy distribution, was evaluated at inclusion in the center and at 1- and 2-year follow-up at adolescent home. Assessment was carried out by dieticians using the dietary history method.[20,21]

Physical activity and sedentary behavior

In the center, adolescents practiced 7h/week of vigorous sports including swimming, tennis, handball, and aerobic, and 7h/week of outdoor activities including walking and playing. They had no possibility to watch television or play video games but were

offered other activities such as reading, acting, and singing. They were advised to maintain physical activity when outside the center, and after the end of treatment. Physical activity (hour/week of regular sport or other activities) and sedentary behavior (hour/week watching television or playing computer) were evaluated at inclusion in the center and at 1- and 2-year follow-up at adolescent home. Assessment was carried out by dieticians using a questionnaire[22] adapted for French children.[23]

Anthropometry

Adolescent weight was obtained in light clothing (dress or shorts, T-shirt) on an electronic scale to the nearest 100 g (Testut, France). Height was measured with a wall-mounted stadiometer (Agencinox, France) and recorded to the nearest 1 cm. During follow-up, weight was measured with an electronic scale to the nearest 100 g (Terraillon, France) and height with a portable stadiometer to the nearest 1 cm (Raven Equipment Limited, UK). Triceps skinfold thickness was recorded at the triceps on the right arm with a Harpenden caliper to the nearest 0.2 mm. All body measurements were performed using standard procedures.[24,25] BMI was computed (weight/height²). Total upper arm area (TUA) was calculated (midupper arm circumference²/4π) using the Jeliffe and Jellife principle.[26] Upper arm fat area estimate (UFE) (arm circumference x (triceps skinfold/2) and upper arm muscle area estimate (UME) (TUA - UFE) were derived from TUA following the Rolland-Cachera et al. formula.[27] This method has been shown to be particularly accurate in the case of obese children and adults[27,28] compared to the Jelliffe and Jeliffe's method[26] that overestimates muscle area. Individual BMI growth curves were drawn based on data (length/height and weight) from adolescent's health booklet. Health booklets are given for all newborns in France by the Ministry of Health, and aim at recording anthropometry and health events

occurring during childhood. Age at adiposity rebound corresponding to the nadir in the BMI growth curves[29] was estimated visually as recommended by Kroke et al.[30]

Statistics

Z-scores were computed for all body characteristics as they allow accounting for the confounding effect of growth. Z-scores of BMI, triceps skinfold thickness, UFE and UME were based on French reference data.[27,31] LMS values using the Cole et al. method[32,33] were used for BMI and triceps skinfold thickness. Z-scores of waist circumference and waist/hip ratio were based on data from the ELANCE French cohort.[34]

Difference in BMI z-score between the beginning of treatment and the end of follow-up was calculated. Adolescents were categorized in two groups, i.e., "success" vs. "limited or no success", based on this difference. Successful adolescents were defined as those having a BMI z-score reduction above the median ($\geq$ 1.24 standard deviation (SD)), whereas those with limited or no success had a z-score difference below the median (< 1.24 SD). Two-tailed Student's t-test was used to determine differences in quantitative physical and behavioral variables between groups. Chi-square test was used for categorical data analysis. Pearson correlations were calculated to evaluate the linear relationship between BMI z-scores values and individual variables. A *P* value of less than .05 was considered statistically significant. The two groups differing in protein content (P^- and P^+) established in the original design were combined in the present analysis since no differences in body measurements were found during treatment and follow-up between the two groups. In addition, an equivalent number of subjects from both diet groups were found in the "success" (18 subjects from each diet group) and in the "limited or no success" (17 subjects from P^- vs. 19 subjects from P^+) groups.

Statistics were performed using SPSS for Windows (Release 12.0.1., SPSS Inc., Chicago USA).

RESULTS

The mean BMI z-score decrease between inclusion and the end of follow-up, was 1.37 ± 0.92 SD in the whole sample. The reduction was 2.09 ± 0.68 SD in the successful group and 0.65 ± 0.43 SD in the group with limited or no success. Changes in z-scores of the different body measurements are shown in Fig. I for both groups.

At inclusion and at the end of treatment, groups did not differ significantly for any of the anthropometric characteristics considered, i.e. BMI, triceps skinfold, waist circumference, waist/hip ratio, UFE and UME. In both groups, all characteristics decreased sharply during treatment ($P < .001$), with the exception of UME, which increased ($P < .05$). After discharge, differences in anthropometric characteristics between the two groups cleared appeared. In the successful group, BMI, triceps skinfold and UFE slightly increased during the 2-year follow-up while waist circumference remained at the same level. In this group, all these indicators remained lower at the end of follow-up than at inclusion ($P < .001$). On the other hand, in the group with limited or no success, main changes in these body characteristics appeared in the first year of follow-up and were less marked afterwards. In this group, BMI remained lower at the end of follow-up than at inclusion ($P < .01$), whereas other indicators did not differ significantly ($P > .05$). Waist/hip ratio decreased during the first year of follow-up in the successful group, while it stabilized in the group with limited or no success. Values were lower at the end of follow-up than at inclusion for both the successful group

($P < .001$) and the group with limited or no success ($P < .05$). In the case of UME, values at 2-year follow-up were not different than at inclusion in both groups ($P > .05$).

Characteristics known to be associated with adolescent obesity are shown in Table I. Adolescents had a mean adiposity rebound occurring early (2.4 years) and even earlier in the case of adolescents with limited or no success. Mothers of successful adolescents tended to have a lower BMI than in the other group. There was no other group difference.

At admission in the center, adolescent energy intake, nutrient and daily energy distribution, as well as the practice of regular sport were comparable ($P > .05$ for all measurements). In addition, both groups included a similar proportion of adolescents who had followed a restrictive diet prior to the treatment ($P = .63$). After treatment, and in particular at 2-year follow-up, successful adolescents had lower energy intake than those with limited or no success (Table II). At 2-year follow-up they consumed less energy from protein (-29.6 kcal), from fat (-151.2 kcal), and particularly from carbohydrates (-234.8 kcal), corresponding to a different energy distribution with a higher proportion of protein. In term of daily energy distribution, the successful group had a greater contribution of lunch and breakfast. Adolescents who did not usually have breakfast were 4 to 5 times fewer in the successful group than in the other group, at 2- and 1-year follow-up, respectively. Successful adolescents snacked significantly less than the others. Adolescents in the two groups did not differ in the practice of regular sport nor of other activities. However, successful adolescents spent less time watching television or using a computer than the other group suggesting a less sedentary behavior.

DISCUSSION

In the present study, factors associated with long-term weight maintenance after a 9-month weight loss treatment were examined.

Adolescents in both groups had a significantly lower BMI at 2-year follow-up than at the beginning of treatment, with about two-thirds of the subjects showing a decrease in BMI greater than 1 SD. This persistence of weight loss is encouraging since after treatment, the adolescents had less support and were exposed to numerous factors likely to compromise their ability to maintain their weight loss. It was previously shown by other authors that children and adolescents are able to maintain some of their weight loss after 1 year[13], 5 years[35] or 10 years[36] of follow-up, and do better than adults[37], although other studies emphasized the considerable relapse after weight reduction programs in children and adolescents.[16,38]

Body measurements were not different in the successful group and in the group with limited or no success, neither at the beginning nor at the end of treatment. In addition, at admission in the center, indicators of behaviors i.e. energy intake, nutrient and daily energy distribution, as well as physical activity, were comparable. This result shows that adolescents have the same likelihood to maintain their weight loss after leaving the center independently of their body measurements and behavioral pattern at inclusion and their weight loss during treatment. In contrast, other authors showed that weight loss maintenance was more likely in less obese than in heavier individuals.[39]

Many authors emphasized the great variation in individual responses to treatment during follow-up.[9,40] In our study, differences between groups appear when adolescents leave the center and come back in their family environment. Anthropometric differences were clearly visible in the first year after the end of treatment. In the second year, a continuous increase was observed for some body characteristics (e.g. waist circumference), while for others the increase was less marked (e.g. BMI) or even nonexistent (e.g. triceps skinfold thickness). These results suggest that the first year is particularly critical for fat mass regain and that anthropometry at 1-year follow-up is a good predictor of long-term weight loss maintenance. In agreement, Snethen et al.[17] recommended that weight loss programs for children should include an appropriate follow-up for at least 1 year, because it is known that individuals who maintain their weight loss for 1 year are likely to show long-term success. In the present study, waist circumference was a particularly good indicator of weight loss maintenance. This measurement is particularly convenient and recommended when studying obesity because of its relationship with diabetes and other diseases.[41]

Adolescents in the group with limited or no success were characterized by a higher energy intake compared to the other group, specifically at 2-year follow-up. They consumed more of all nutrients, but particularly carbohydrates including sucrose. Wing and Hill[18] showed that weight gainers particularly increased their fat intake compared to weight maintainers. In term of daily energy distribution, in the present study, the successful group tended to eat more at breakfast and lunch than the other group, and to snack less. As a rule, the successful group tended to eat more during the first part of the

day (breakfast and lunch) than the other group. This is consistent with other studies reporting altered daily rhythm in the obese.[42-44]

During follow-up, the successful group showed a less sedentary behavior than the other group with significantly less time spent watching television or using computer. However, the practice of sport did not differ significantly between groups. This result shows that it is important to reduce sedentary lifestyle to maintain weight loss. The impact of sedentary behavior on overweight and obesity was shown by numerous authors[45-47] and a reason proposed was the importance of snacking while watching television.[48] In our study, time spent in front of the television or computers at 1-year follow-up was significantly correlated with sucrose ($r = .51$, $P < .001$). Restricting access to television or computers and encouraging alternative activities might therefore be a promising approach to help prevent adolescent obesity or relapse after weight loss. However, the importance of exercise should not be underestimated since physical training is associated with beneficial changes in fat and lean body mass.[22,49] Incidentally, both groups showed a decrease of lean body mass after leaving the center, probably due to a decrease in physical activity.

It is clearly established that age at adiposity rebound is associated with obesity later in life and that it occurs earlier in the obese (around 3 years) than in normal subjects (around 6 years).[50] Mean age at adiposity rebound in the present study was 2.4 years and occurred even earlier in the group with limited or no success. In addition, mothers of adolescents in the successful group tended to have a lower BMI than those in the other group. It is known that children with overweight parents have a greater risk of becoming overweight[4,17,51,52] due to genetic and/or environment. An early adiposity

rebound and high maternal BMI can reflect the influence of early determinants.[50-52] The influence of early life determinants in weight loss maintenance after treatment should therefore not be underestimated. Besides, mother weight can reflect family habits. Thus, family therapy and involvement could be used as improving the support for the child by the family.[53,54]

This type of intervention lasting a few months can present some disadvantages. Adolescents are supervised over a long period and it can be difficult for them to follow an adequate diet without control, after leaving the center. On the other hand, the long period of treatment is likely to favor an imprinting of positive behaviors. The long follow-up in this study presents the advantage to give a good indication of the long term success of treatment, although the drop-out rate may limit the interpretation of the results. Finally, it must be noted that there is no consensus on what method should be used to evaluate success of weight loss maintenance. Success or failure is likely to differ according to the method selected. We defined success of weight loss maintenance using z-score differences between the end of follow-up and the beginning of the study. This method is now increasingly used for this type of evaluation.[10,15]

Conclusion

This study identifies factors related to long-term outcome of weight loss treatment in obese adolescents. Neither behavior at inclusion nor body measurements before and during treatment were associated with weight loss maintenance over a 2-year follow-up. Rather, the difficulty in maintaining weight loss seemed to be related to the difficulty in making permanent changes in dietary and sedentary behaviors after treatment. Some adolescents were able to make life-style changes following advice received during

treatment, while others were not. Weight loss maintenance was also related to the child's age at adiposity rebound and mother's BMI, highlighting the importance of early life determinants as well as the importance of the family environment. The fact that, in the present study, a large proportion of adolescents were able to maintain their weight loss is encouraging. More research is required to identify the factors associated with treatment outcome in order to improve long-term maintenance of weight loss in obese adolescents.

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Fig. I

Changes in body characteristics z-scores in the successful group (—) and in the group with limited or no success (---) at 4 examination points: inclusion (T_0), end of treatment (T_{end}), 1 (F_{1y}) and 2-year (F_{2y}) follow-up after treatment. Differences between groups are shown: *ns* non-significant, * $P < .05$, ** $P < .01$, *** $P < .001$.

BMI: body mass index, UFE: upper arm fat area estimate, UME: upper arm muscle area estimate.