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Assessment of body composition changes during a combined intervention for the treatment of childhood obesity

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A B S T R A C T

Objective: One of the main objectives in the treatment of childhood obesity is to reduce the percentage of body fat mass without negatively affecting fat-free mass (FFM) and, consequently, longitudinal growth. The aim of this study was to analyze the changes that take place in body compartments in a group of patients with obesity under combined treatment.
Methods: This was a longitudinal study with 109 children with obesity 9.1 to 13.9 y of age included in a combined dietary–behavioral–physical activity intervention. Weight, height, skinfold thickness, and waist circumference were registered, and body mass index (BMI), fat mass index (FMI), FFM and waist-to-height ratio (WHR) were calculated over a period of 12 mo. The BMI z-score allowed us to establish two groups: obesity (n = 50) and severe obesity (n = 59). A nutritional improvement was considered when a decrease of BMI z-score of the initial value occurred after 12 mo of follow-up.
Results: The improvement in nutritional status reached 61.5% (n = 67). In the obesity group with nutritional improvement (n = 32), FMI significantly decreased ($P < 0.005$) and there were no significant differences in weight, height z-score, FFM, and WHR throughout the combined intervention. In the severe obesity group with nutritional improvement (n = 35), there were no significant differences in weight, height z-score, FMI, FFM, and WHR throughout combined intervention.
Conclusions: Maintaining a constant weight in the mid- to long term to improve nutritional status would be adequate in children with infantile–juvenile obesity. However, maintaining a steady weight would not be sufficient for those patients diagnosed with severe obesity.

Introduction

The prevalence of childhood obesity has progressively increased over the past decades, and thus is often considered the most relevant nutritional disorder [1–4]. Its treatment is complex and to date has disappointing results. However, when combined strategies are applied (nutrition education, dietary changes, increased physical activity, and lifestyle changes), results are effective [1–6].

One of the main objectives in the treatment of childhood obesity is to reduce the percentage of body fat mass (FM) without negatively affecting fat-free mass (FFM) and, consequently, longitudinal growth [7–9]. Therefore, it would be necessary to assess changes in body compartments that may take place during interventions designed to reduce excess body fat in patients with obesity.

Dual-energy x-ray absorptiometry (DXA) is considered a reference technique for the assessment of body composition; however, the complexity of installation and management and its high cost make DXA not feasible for daily clinical practice. In fact, current opinions consider that anthropometric techniques should have an eminent role in the assessment of body compartments owing to their simplicity, low cost, reproducibility, and excellent correlation between their values and those obtained using DXA [9–14].

The aim of the present study was to analyze the changes that take place in body compartments (FM and FFM) using anthropometric techniques in a group of children with obesity under combined treatment.

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Material and methods

Participants

This was a longitudinal study conducted with 109 children (53 boys and 56 girls, 9.1–13.9 y of age) diagnosed with nutritional obesity who were evaluated in the external childhood obesity consultation from January 2015 to December 2016. All the participants and their parents or legal guardians were offered adequate information, fulfilled informed consent, and were subsequently included in a combined dietary–behavioral–physical activity intervention program. Clinical evaluation was performed every 3 mo over a period of 12 mo. Pubertal stage was determined in each patient according to Tanner's criteria. Children in Tanner stage I were considered prepubertal, and those in Tanner stages II to V were considered pubertal.

Anthropometric measurements

The following anthropometric measurements were registered in the first consultation and every 3 mo thereafter: weight, height, body mass index (BMI), skinfold thickness (biceps, triceps, subscapular,and suprailiac), and waist circumference (WC).

Weight and height measurements were taken with participants wearing only undergarments and no shoes or socks. Weight was measured using an Año-Sayol scale (reading interval 0–120 kg and a precision of 100 g), and height was measured using a Holtain wall stadiometer (reading interval 60–210 cm, precision 0.1 cm). BMI was calculated according to the following formula: weight (kg)/height^2 (m).

Skinfold thicknesses values were measured to the nearest 0.1 mm on the left side of the body with Holtain skinfold calipers (CMS Weighing Equipment, Crymych, UK). The percentage of total body fat, FM (kg) and FFM (kg) were calculated using the equations reported by Siri et al., adjusted for sex and age [15].

$$\text{Percentage of total body fat (Siri equation)} = [(4.95/\text{body density}) - 4.5]$$
$$\text{FM (kg)} = (\text{percentage of total body fat} \times \text{weight})/100$$
$$\text{FFM(kg)} = \text{weight} - \text{FM}$$

Calculation of body density is as follows:

Boys from 1 to 11 y of age:

$$1.1690 - (0.0788 \times \log \Sigma \text{ skinfold thickness}$$
$$: \text{biceps, triceps, subscapular and suprailiac})$$

From 12 to 16 y of age:

$$1.1533 - (0.0643 \times \log \Sigma \text{ skinfold thickness}$$
$$: \text{biceps, triceps, subscapular and suprailiac})$$

Girls from 1 to 11 y of age:

$$1.2063 - (0.0999 \times \log \Sigma \text{ skinfold thickness}$$
$$: \text{biceps, triceps, subscapular and suprailiac})$$

From 12 to 16 y of age:

$$1.1369 - (0.0598 \times \log \Sigma \text{ skinfold thickness}$$
$$: \text{biceps, triceps, subscapular and suprailiac})$$

In the same way, the fat mass index (FMI) was calculated using the following formula: FM (kg)/height^2 (m).

WC was registered using a tape measure placed on a horizontal line equidistant from the last rib and the iliac crest, and the waist-to-height ratio (WHR) was calculated according to the following formula: waist (m)/height^2 (m). Measurements were performed by the same trained individual.

The z-score values for the BMI and skinfold thickness, and WC were calculated with the program Aplicación Nutricional, from the Spanish Society of Pediatric Gastroenterology, Hepatology and Nutrition (available at http://www.gastroinf.es/nutritional/). The graphics from Ferrández et al. (Centro Andrea Prader, Zaragoza 2002) were used as reference charts [16].

The z-score value for BMI allowed us to establish two groups: obesity (z-score >2 [97th percentile]) and severe obesity (z-score >3 [99th percentile]).

Combined dietary–behavioral–physical activity intervention

The central idea of the program corresponded with the following maxim: "the child becomes skinny keeping a stable weight because he/she is growing" and it included nutritional education, a nutritional intervention, the promotion of physical activity and healthy lifestyles, and self-monitoring of body weight (weekly registration of weight).

The acquisition of basic practical and theoretical skills enough to carry self-monitoring was mandatory to be included in this study. A multidisciplinary team (pediatrician, nurse, and dietitian) educated the patients and their families on nutrition, synchronizing the education, and the first visit. The contents of these structured sessions (nutritional value of the different food groups, food pyramid, physical activity, etc.) were personalized according to the characteristics of each patient and family and continuous guidance was provided for all of them. The program was developed or extended depending on the needs of the patient in subsequent visits.

The approach to maintaining the actual weight was accomplished by means of a diversified and well-balanced diet for the whole family without strict restrictions or immediate or exaggerated weigh loss. The Mediterranean diet, adapted to family customs or the preferences of the patients, was the diet model. It was mandatory to ensure five daily meals, with the requirement that meal schedules were respected. The participants were instructed to avoid eating between meals and to increase the time of intake (eating slowly and chewing the food).

In addition, an individualized scheme to increase physical activity was proposed to each patient and consisted of a daily, regulated (60-min) free-choice activity (swimming, walking, cycling, martial arts, etc.) and an increase in daily activity (such as taking the stairs rather than the elevator, walking, helping with house tasks).

Each family was given a leaflet with general recommendations on usual diet, physical activity (sports and home activity), and a healthy lifestyle.

A good response to treatment (nutritional improvement) was reported when a decrease of BMI z-score of the initial value occurred after 12 mo of follow-up; otherwise, it was considered a failure of treatment.

Statistical analysis

Results are displayed as percentages and means with corresponding standard deviations (SDs). The statistical analysis (descriptive statistics, Student's *t* test, analysis of variance, χ^2 test, and Pearson's correlation) was performed using SPSS version 20 (SPSS, Chicago, IL, USA). Statistical significance was assumed when $P < 0.05$.

This study was approved by the Ethics Committee for Human Investigation at our institution (in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and later amendments).

Results

Of the 109 individuals included in this study, 50 (45.9%) suffered from obesity and the remaining 59 (54.1%) from severe obesity. No significant differences in age (obesity group: 11.07 ± 1.91 y; severe obesity group: 11.14 ± 1.92 y), sex (obesity group: 36% boys and 64% girls; severe obesity group: 40.7% boys and 59.3% girls), or pubertal status (obesity group: 28% prepubertal and 72% pubertal; severe obesity group: 33.9% prepubertal and 66.1% pubertal) were found between obesity and severe obesity groups before the dietary–behavioral–physical activity intervention.

Table 1 shows and compares the mean values of anthropometric characteristics registered between obesity and severe obesity groups before the combined intervention. Mean values of weight, BMI, weight z-score, BMI z-score, skinfold thickness (biceps z-score, triceps z-score, subscapular z-score, and suprailiac z-score), body fat, FM, FMI, WC z-score, and WHR were significantly higher in patients with severe obesity ($P < 0.05$). There were no significant differences in mean values of height, height z-score, and FFM between the two groups.

There was a positive correlation ($P < 0.001$) between BMI z-score and FMI ($r = 0.714$), and between BMI z-score and WHR ($r = 0.650$) among the 109 individuals included in this study. In addition, there was a positive correlation ($P < 0.001$) between BMI and WC z-scores ($r = 0.709$) and between FMI and WHR ($r = 0{,}638$).

The improvement in nutritional status (shown as percentage) in the participants between the beginning and the end of the time of follow-up (12 mo) was 61.5% (n = 67), and revealed no statistically significant differences between obesity (n = 32, 62.7%) and severe obesity (n = 35, 60.3%) groups.

Table 2 shows and compares mean values of anthropometric characteristics registered at the beginning of the study and after 6 and 12 mo of follow-up in the obesity group with nutritional improvement. Mean values of weight z-score, BMI z-score, skinfold

Table 1
Anthropometric characteristics before combined intervention between patients with obesity and severe obesity groups (mean ± SD)

Item	Obesity (n = 51)	Severe obesity (n = 58)	Student's *t* test (*P*-value)
Age (y)	11.07 ± 1.91	11.14 ± 1.92	0.875
Weight (kg)	59.89 ± 15.43	74.39 ± 19.33	0.001
Height (cm)	149.92 ± 13.42	152.11 ± 16.04	0.138
BMI (kg/m^2)	26.16 ± 2.55	31.37 ± 4.25	0.003
Weight z-score	2.47 ± 0.69	4.34 ± 1.42	0.001
Height z-score	0.84 ± 1.03	1.16 ± 1.20	0.469
BMI z-score	2.45 ± 0.23	4.37 ± 1.35	0.001
Skinfold thickness			
Biceps z-score	3.14 ± 1.19	4.26 ± 1.57	0.019
Triceps z-score	2.69 ± 0.81	3.74 ± 1.22	0.008
Subscapular z-score	3.00 ± 1.91	4.46 ± 1.99	0.017
Suprailiac z-score	4.57 ± 1.13	5.34 ± 1.39	0.039
Body fat (%)	38.38 ± 3.03	43.25 ± 1.57	0.019
Fat mass (kg)	23.35 ± 6.02	32.18 ± 8.48	0.008
Fat-free mass (kg)	37.64 ± 9.21	41.73 ± 13.00	0.193
FMI (kg/m^2)	10.21 ± 1.54	13.84 ± 1.84	0.017
WC z-score	1.96 ± 0.68	3.65 ± 1.57	0.001
WHR	0.57 ± 0.35	0.64 ± 0,05	0.016

BMI, body mass index; FMI, fat mass index; WC, waist circumference; WHR, waist-to-height ratio.

Table 2
Anthropometric characteristics throughout combined intervention in obesity group (n = 32) with nutritional improvement (mean ± SD).

Item	Baseline	6 mo	12 mo	ANOVA (*P*-value)
Weight (kg)	56.31 ± 12.84	57.23 ± 12.80	58.71 ± 12.13	0.481
Height (cm)	147.22 ± 13.24	149.31 ± 12.69	152.68 ± 12.36	0.289
BMI (kg/m^2)	25.55 ± 2.53	25.82 ± 2.56	25.04 ± 2.52	0.333
Weight z-score	2.35 ± 0.67	2.13 ± 0.77	1.94 ± 0.76	0.022
Height z-score	0.77 ± 1.05	0.78 ± 1.01	0.70 ± 1.07	0.612
BMI z-score	2.41 ± 0.23	2.11 ± 0.42	1.86 ± 0.43	0.035
Skinfold thickness				
Biceps z-score	3.05 ± 1.10	2.37 ± 1.44	1.62 ± 1.24	0.001
Triceps z-score	2.70 ± 0.91	2.14 ± 0.98	1.69 ± 0.75	0.001
Subscapular z-score	2.84 ± 1.91	2.18 ± 1.93	1.87 ± 1.37	0.001
Suprailiac z-score	4.52 ± 1.06	4.28 ± 1.03	3.87 ± 1.04	0.030
Body fat (%)	38.30 ± 2.66	36.12 ± 3.39	35.02 ± 3.79	0.008
Fat mass (kg)	21.98 ± 6.14	20.92 ± 6.59	20.61 ± 5.70	0.725
Fat free mass (kg)	35.36 ± 9.44	36.23 ± 8.86	38.09 ± 9.07	0.308
FMI (kg/m^2)	9.92 ± 1.49	9.16 ± 1.51	8.79 ± 1.46	0.043
WC z-score	1.86 ± 0,66	1.86 ± 0,66	1.62 ± 0,94	0.291
WHR	0.56 ± 0,03	0.56 ± 0,03	0.55 ± 0,03	0.554

ANOVA, analysis of variance; BMI, body mass index; FMI, fat mass index; WC, waist circumference; WHR, waist-to-height ratio.

thickness (biceps z-score, triceps z-score, subscapular z-score, and suprailiac z-score), body fat, and FMI significantly decreased ($P < 0.05$) during the follow-up period. There were no significant differences in mean values of weight, height, BMI, height z-score, FM, FFM, WC z-score, and WHR throughout the combined intervention.

Table 3 shows and compares mean values of anthropometric characteristics registered at the beginning and after 6 and 12 mo of follow-up in the severe obesity group with nutritional improvement. Mean values of BMI z-score, skinfold thickness (biceps z-score and triceps z-score), and body fat significantly decreased ($P < 0.05$) in the follow-up period. There were no significant differences in mean values of weight, height, BMI, weight z-score, height z-score, skinfold thickness (subscapular z-score and suprailiac z-score), FM, FFM, FMI, WC z-score, and WHR throughout the combined intervention.

Among the 67 participants who experienced improvement in nutritional status, there was a positive correlation ($P < 0.001$) between BMI z-score and FMI ($r = 0.830$) as well as between BMI z-score and WHR ($r = 0.855$). In addition, there was a positive correlation ($P < 0.001$) between BMI and WC z-scores ($r = 0.793$) and between FMI and WHR ($r = 0.761$).

Discussion

The aphorism "a child becomes skinny keeping a stable weight because he/she is growing ..." was the reference of the combined treatment that individuals followed thorughout the 12 mo of treatment. In the beginning, its implementation should guarantee a progressive improvement of nutritional status as a maintenance of weight without negatively interfering on growth would help to progressively reduce BMI.

The objective was not a rushed weight loss within the shortest possible time, but rather to get the child and the family to accept the principles of prevention and the treatment of obesity. Each patient was educated to follow dietary standards and a healthy lifestyle and to incorporate these changes as habits. This not only applied to the child but also to the family. In order to achieve these goals, it is necessary to design programs that combine different elements: nutritional education, dietary changes or restrictions, and increased physical activity or daily activities. This includes self-control because it is important to motivate the patient to get good results [6,17–22].

BMI, even when it does not allow us to define the percentage composition of the different body compartments, is one of the

Table 3
Anthropometric characteristics throughout combined intervention in severe obesity group (n = 35) with nutritional improvement (mean ± SD)

Item	Baseline	6 mo	12 mo	ANOVA (*P*-value)
Weight (kg)	68.64 ± 19.88	69.37 ± 18.29	70.63 ± 18.14	0.662
Height (cm)	148.72 ± 14.35	150.77 ± 14.47	152.70 ± 14.77	0.163
BMI (kg/m^2)	30.36 ± 3.56	30.36 ± 3.56	30.17 ± 3.44	0.427
Weight z-score	4.14 ± 1.42	3.99 ± 1.17	3.68 ± 1.32	0.505
Height z-score	1.06 ± 1.12	1.01 ± 0.96	0.98 ± 1.02	0.828
BMI z-score	4.43 ± 1.49	4.10 ± 1.41	3.70 ± 1.21	0.029
Skinfold thickness				
Biceps z-score	4.27 ± 1.67	3.30 ± 1.60	2.58 ± 1.43	0.001
Triceps z-score	3.64 ± 1.30	3.02 ± 1.04	2.62 ± 1.12	0.001
Subscapular z-score	4.72 ± 2.69	4.27 ± 2.65	3.68 ± 2.69	0.116
Suprailiac z-score	5.61 ± 1.61	5.32 ± 1.64	5.07 ± 1.60	0.166
Body fat (%)	43.09 ± 5.43	40.44 ± 5,46	38.45 ± 6.88	0,008
Fat mass (kg)	28.29 ± 7.60	27.67 ± 7.59	27.66 ± 7.25	0.727
Fat free mass (kg)	41.53 ± 11.73	41.79 ± 11.43	43.02 ± 11.16	0.263
FMI (kg/m^2)	12.67 ± 2.34	12.09 ± 2.52	11.82 ± 2.28	0.181
WC z-score	3.57 ± 1.62	3.29 ± 1.40	3.12 ± 1.17	0.727
WHR	0.64 ± 0.5	0.63 ± 0.04	0.63 ± 0.04	0.568

ANOVA, analysis of variance; BMI, body mass index; FMI, fat mass index; WC, waist circumference; WHR, waist-to-height ratio.

most frequently used anthropometric measurement in the assessment of nutritional status because of its good correlation with the content of body FM measured by DXA [6,9,23,24]. In this study, BMI was applied for the classification of the nutritional status of the children who were included. It is noteworthy that there is a significant correlation between the values of the BMI z-score and the adiposity parameters registered (FMI, WC z-score, and WHR) before and after the combined treatment.

The assessment of subcutaneous fat by skinfold measurements allows the monitoring of changes that will potentially take place in the fat tissue of the different anatomic areas examined, such as arm subcutaneous fat (bicipital and tricipital skinfold) and trunk subcutaneous fat (subscapular and suprailiac skinfold), in patients after interventions designed to reduce excess body fat. The FMI calculated using skinfold measurement shows a good correlation with total body fat evaluated by DXA [9,12–14]. This is one of the main arguments as to why these tools have been used in this study to assess the evolutionary changes in body compartments. In addition, WC has been registered throughout the combined intervention, owing to the clinical relevance as a visceral fat and metabolic risk marker in adulthood [25,26]. It should be emphasized that there are few studies available at present on the application of the different techniques to monitor changes in body composition during the treatment of infant–juvenile obesity (anthropometric indices, bioelectrical impedance, DXA, etc.). To our knowledge, only a few studies have used skinfold measurements to analyze this changes [3,4,22,27,28].

The mean values of weight remained practically stable in the children with obesity who showed nutritional improvement throughout the 12 mo of follow-up, although the mean values of weight z-score—as a consequence of the time elapsed—had significantly decreased. In the same way, mean values of height z-score did not present significant changes and, consequently, the BMI z-score values decreased significantly, therefore getting to mean values of overweight by the end of the period of follow-up. On the other hand, there was a significant progressive reduction in the values of FMI without associated changes in FFM, simultaneous to the decrease in the BMI z-score values. The mean values of WC—as a sign of visceral fat—between the beginning and the end of the follow-up did not show any changes, but it is remarkable that if the weight stabilization were to be maintained in these patients, a progressive reduction in visceral fat probably would be observed.

Within the group of patients with severe obesity who presented with nutritional improvement, mean values for weight z-score—despite the time elapsed—did not significantly decrease, alhough the mean values of weight had remained fairly constant throughout the 12 mo of follow-up. In addition, BMI z-score decreased significantly, but remained within values defined by the condition of severe obesity, although the mean values of height z-score showed no changes. Furthermore, although these patients did not undergo a reduction in FMI, they did show a significant decrease in arm subcutaneous fat (bicipital and tricipital skinfolds) without a simultaneous reduction in trunk subcutaneous fat (subscapular and suprailiac skinfolds) or change in FFM. In the same way, there were no significant changes in mean values of WC in these patients between the beginning and the end of the follow-up.

Conclusions

It could be considered that maintaining a constant weight in the medium to long term to improve nutritional status would be sufficient in individuals with infant–juvenile obesity. This could help reduce body FM significantly without changing FFM and, therefore, altering growth. However, keeping a steady weight would not be enough in patients diagnosed with severe obesity, so it would be necessary to find different strategies to ensure a gradual decrease of weight. Monitoring changes in body composition is mandatory to avoid negative effects in longitudinal growth in these individuals.

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