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Body composition changes during a multidisciplinary treatment programme in overweight adolescents: EVASYON Study

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Abstract

Introduction: **the main objectives of weight-loss interventions are to decrease fat mass while maintaining fat-free mass.**

Objective: **our aim was to address effectiveness body composition changes in overweight adolescents assessed by different body composition methods following an obesity intervention programme.**

Material and methods: **the life-style intervention was multi-disciplinary, with 13 months follow-up. Participants were 13-to-16 year-old overweight, or obese, Spanish adolescents. The adolescents (n = 156; 54.8% females) had body composition measured with anthropometry, dual-energy X-ray absorptiometry and air-displacement plethysmography. All measurements were made at baseline, and after 2- and 13-months. Repeated measures analysis of covariance to compare mean anthropometric changes over time and the Bonferroni correction were applied. Imputation of anthropometric measures was performed.**

Results: **a high significant decrease in fat mass index was achieved in males after 2-and 13-months of intervention as measured by anthropometry (1.16 and 1.56 kg/m^2, respectively), X-ray absorptiometry (1.51 and 1.91 kg/m^2) and plethysmography (2.13 and 2.44 kg/m^2). Moreover, a short and long-term maintenance of fat-and fat-free mass index was observed by X-ray absorptiometry in females (0.94 and 0.68 kg/m^2).**

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CAMBIOS DE COMPOSICIÓN CORPORAL DURANTE EL TRATAMIENTO MULTIDISCIPLINAR EN ADOLESCENTES OBESOS: ESTUDIO EVASYON

Resumen

Introducción: **el principal objetivo de las intervenciones de pérdida de peso es disminuir la masa grasa manteniendo la masa libre de grasa.**

Objetivo: **evaluar la efectividad de una intervención multidisciplinar en la composición corporal de adolescentes con sobrepeso, evaluados mediante diferentes métodos de composición corporal.**

Material y métodos: **la intervención fue multidisciplinar sobre el estilo de vida, aplicada durante 13 meses. Los participantes eran adolescentes entre 13 y 16 años con sobrepeso y obesidad. Los adolescentes (n = 156; 54,8% mujeres) fueron evaluados mediante antropometría, absorciometría dual de rayos X y pletismografía por desplazamiento de aire. Todas las mediciones se realizaron al inicio, a los 2 y a los 13 meses. Se aplicaron análisis de la covarianza de medidas repetidas y la corrección de Bonferroni. Se realizó la imputación de las medidas antropométricas.**

Resultados: **se logró una alta disminución significativa en el índice de masa grasa en los hombres después de 2 y 13 meses de intervención, según antropometría (1,16 y 1,56 kg/m^2, respectivamente), absorciometría de rayos X (1,51 y 1,91 kg/m^2) y pletismografía (2,13 y 2,44 kg/m^2). Por otra parte, el mantenimiento a corto y largo plazo de la grasa y libre de grasa en el índice de masa fue observado por absorciometría de rayos X en las mujeres (0,94 y 0,68 kg/m^2).**

Conclusion: **our multidisciplinary approach to lifestyle intervention has a favourable impact on body fat mass and fat-free mass index as well as waist-to-height ratio, over 13 months intervention in overweight and obese adolescents.**

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Key words: *Adolescents. Body composition. Dual dual-energy X-Ray Absorptiometry. Intention to treat analysis. Weight loss programs.*

Conclusión: **la intervención multidisciplinar sobre estilo de vida tiene un impacto favorable en la masa grasa corporal y el índice de masa libre de grasa, así como en la relación cintura-altura, durante 13 meses de intervención en adolescentes con sobrepeso y obesidad.**

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Palabras clave: *Adolescentes. Composición corporal. Absorciometría dual de rayos X. Análisis de intención de tratar. Programas para la pérdida de peso.*

Abbreviations

FM: Fat mass.
FFM: Fat-free mass, measured by anthropometry and ADP.
BMI: Body mass index.
DXA: Dual-energy X-ray absorptiometry.
ADP: Air-displacement plethysmography.
FMI: Fat mass index.
CSIC: Spanish National Research Council.
MVPA: Moderate or vigorous physical activity.
FMI: Fat mass index, measured by anthropometry and ADP.
FFMI: Fat-free mass index, measured by anthropometry and ADP.
WC: Waist circumference.
HC: Hip circumference.
W-to-H: Waist-to-hip ratio.
WHtR: Waist-to-height ratio.
LM: Lean mass, measured by DXA.
LBMI: Lean-body mass index, measured by DXA.
SD: Standard deviation.
ANCOVA: Analysis of covariance.
ANOVA: Analysis of variance.
CVD: Cardiovascular disease.
MetS: Metabolic syndrome.

Introduction

Obesity during adolescence is associated with several adverse health consequences in adulthood[1]. Recent reviews have shown that multidisciplinary interventions are the most effective in weight management but involves long follow-up periods and diverse health care professionals[2,3]. The main goal of intervention is to reduce fat mass (FM) and to maintain fat-free mass (FFM) while employing periodic monitoring to ensure an appropriate growth pattern[4].

The most widely used measure of obesity is the anthropometric body mass index (BMI) expressed as weight (kg) ÷ height (m^2). However, it does not discriminate between fat-and fat-free tissues[5]. More sophisticated methods include dual-energy X-ray absorptiometry (DXA) and air-displacement plethysmography (ADP)[6] were performed but these methods have not been used widely to differentiate between fat- and fat-free mass changes[3]. Previously, using DXA, we identified BMI and fat mass index (FMI) as the best anthropometric indices in assessing body fat changes in adolescents[7].

The aim of the present study was to assess the body composition changes in overweight and obese adolescents using different body composition methods following two months of intensive intervention plus 11months of extensive intervention.

Materials and methods

Study design

The EVASYON study was a programme applied to Spanish adolescents from five cities: Granada, Madrid, Pamplona, Santander and Zaragoza. The participants were adolescents aged 13–to-16 years, classified as overweight or obese. The intervention was family orientated and multidisciplinary (diet, physical activity and psychological support)[8].

The project followed the ethical standards of the Declaration of Helsinki and Good Clinical Practice recommendations. The study was approved by the Ethics Committee of each participating hospital and by the Bioethics Committee of the Spanish National Research Council (CSIC). The volunteer and/or guardian provided fully-informed written consent to participation.

The participants were recruited among those attending the local obesity clinic. Inclusion criteria were: 1) aged 13-16 years; 2) overweight or obese according to the criteria of Cole *et al.*[9]; 3); of Spanish ancestry, or being educated in Spain; and 4) no concomitant diseases.

All body composition measurements were performed at baseline, at the end of the intensive intervention (2 months), at midpoint of the extensive intervention (6 months), and at the end of the EVASYON treatment programme (13 months)[8]. In the current article we present only the results at the end of the intensive and the extensive intervention periods.

Study population

Based on previous intervention studies in obese adolescents[10,11], we sought to achieve a goal of 2.7%

reduction in total body fat i.e. a "clinically relevant effect" with a statistical power of 90% and an alpha error of 0.05, the estimated sample size was 153 participants[8]. This sample size was increased by 25% to account for potential dropouts and loss-to-follow-up in the participating hospitals. The recruited sample comprised 206 adolescents (84 males and 122 females). As not all children had body composition assessment by the different techniques, analysis groups and sample sizes vary (Fig. 1). Of the adolescents initially recruited, 72.6% (48.0% males) completed the 13months of the intervention programme.

Intervention

The EVASYON treatment programme was conducted in small groups of 9-to-11 subjects over a period of 13 months.

The dietary intervention has been described by Marqués *et al.*[12]. Baseline metabolic rate was assessed according to Schofield *et al.* equations[13], and the physical activity factor was approximated as 1.3. The percentage energy restriction was adapted to excess BMI categories according to reference values obtained in Spanish adolescents[14].

The intensive nutritional therapy had moderate calorie restriction (10-40%) over three weeks applying a fixed full-day meal plan; and six weeks fixed full-day meal plans with food-item and portion exchange. The extensive intervention period had flexible meal plans based on food exchanges[14]. The diets were designed in accordance with macro- and micro-nutrient recommendations[15].

Physical activity intervention was based on the individual's initial physical activity level. This was to programme a progressive increase in the individual's physical activity while reducing sedentary behaviour.

In the intensive intervention, the main goal was to achieve at least 60 minutes of moderate or vigorous physical activity (MVPA) 3 days per week. Later, the goal was to achieve at least 60 minutes of MVPA, 5 days per week. In the extensive intervention the goal was, in addition, that the adolescents should increase physical activity in all daily-life activities.

Individual and family-based psychological support was provided to encourage achievable long-term life-style goals. During the intensive intervention, psy-

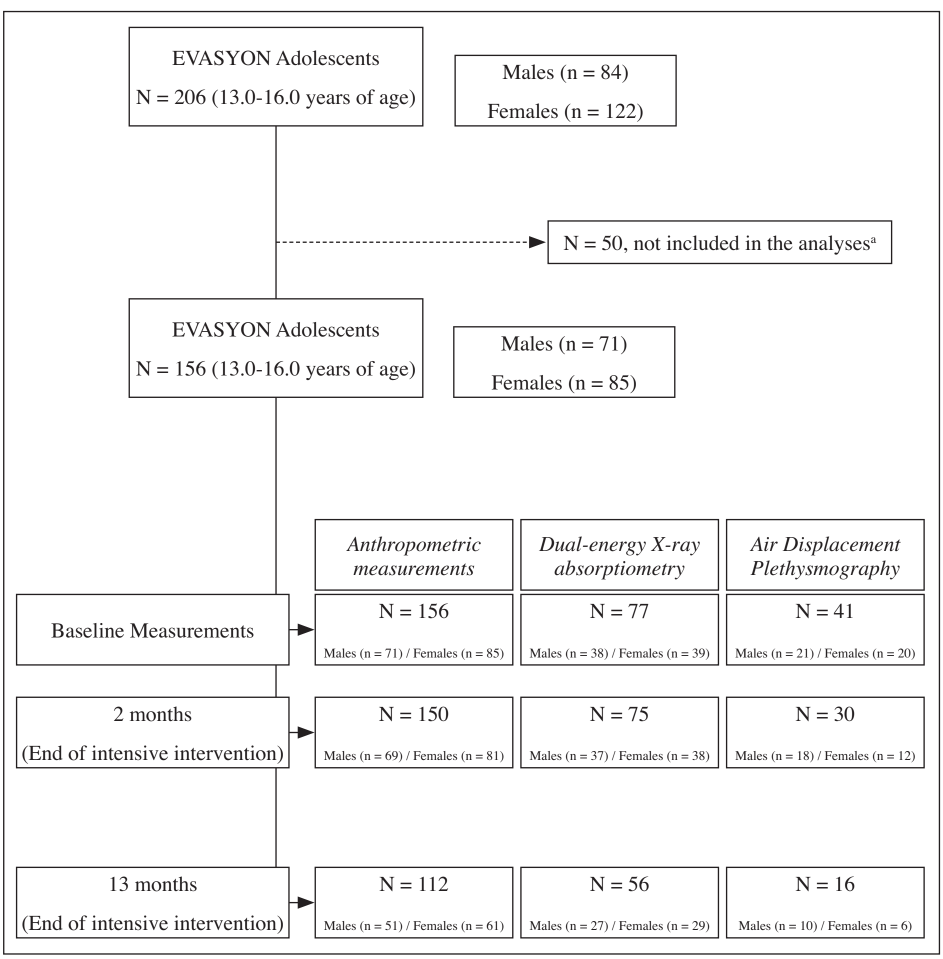

Fig. 1.—Flow chart of the participant population involved in this study from the EVASYON Study.
[a]adolescents were not included in the analyses because, for technical reasons, the participating centre was unable to complete the research protocol.

cho-educational workshops focused on eating and physical activity. During the extensive intervention period, psycho-educational progress was monitored, and positive attitudes reinforced.

Body composition measurements

Body composition was assessed by anthropometry in the overall study sample. In addition we also measured body composition with DXA and ADP in some Centres. The anthropometric measurements were according to the standardised protocols of the AVENA study[16]. Measurements were performed by the same trained investigators in each Centre. Each set of variables was measured 3 times. Weight and height were obtained by standardised procedures. Body mass index (BMI) was calculated as weight/height squared (kg/m^2). Skinfold thicknesses were measured to the nearest 0.1 mm on the left side of the body using a skin-fold calliper (Holtain Calliper; Holtain Ltd., Wales, UK) at the following sites:1) triceps, 2) biceps, 3) subscapular and 4) supra-iliac. Percentage of total body fat was calculated using the Slaughter *et al*. equations[18]. Fat-free mass (FFM) was calculated from total body weight and percentage FM. Body fat and FFM are usually expressed as percentage of total body weight, but an alternative is to express these variables as height squared since more valuable indices are obtained including: FMI [FM (kg)/height (m^2)] and fat-free mass index (FFMI) [FFM (kg)/height (m^2)][19].

Circumferences were measured to the nearest millimetre with an inelastic tape, with the subject standing upright. Waist (WC) and hip circumference (HC) were measured according to the standardised protocols of the AVENA study[16]. Waist-to-hip ratio (W-to-H) and waist-to-height ratio (WHtR) were also calculated as indices of abdominal fat[20].

According to sex-specific BMI, FM (%), W-to-H and WHtR reference curves for Spanish adolescents aged 13-18 years[14,21], we calculated the z-score indices in our obese adolescents in order to normalize the changes. However, cut-off points of FMI and FFMI were calculated to normalize the changes using a sample from AVENA Study which include 2851 Spanish adolescents (52.5% females, 15.29 ± 1.33 years old, 21.63 ± 3.44 kg/m^2) (unpublished results).

Dual-energy X-ray absorptiometry (DXA)

The adolescents from two Centres had their body composition assessed by DXA. In both cities, we used the QDR-Explorer (Hologic Corp. Software version 12.4, Waltham, Mass., USA). Whole body irradiation was slight (calculated as being between 0.05 and 1.5 mrem). The measurements at baseline, at 2 months and at the end of the treatment programme for each subject were performed with the same DXA machine which was regularly calibrated using a lumbar spine phantom. Scanning was with the subject in the supine position, in light underwear without any metallic jewellery. Measurements of bone density are via a thin beam of low-dose X-rays which produce images of the skeleton and fat mass. FM and lean mass (LM) measurements did not include the head.

FM and LM are usually expressed as percentage of total body weight, but an alternative is to express these variables as height squared since more valuable indices are obtained including: FMI [FM (kg)/height (m^2)] and lean-body mass index (LBMI) [LM (kg)/height (m^2)][19].

Air Displacement Plethysmography (ADP-BodPod®)

The adolescents from one Centre had body composition assessed by ADP. The BodPod was calibrated prior to each analysis according to the manufacturer's guidelines. Subjects wore clothing a swimsuit and a swim cap to rule out any air trapped in clothes and hair. Participants were weighed on the BodPod calibrated digital scale and then entered the BodPod chamber. Body volume was measured twice for reliability and, if the readings differed by > 150 mL, a third measurement was taken. Thoracic gas volume was predictive following the manufacturer's recommendations. This value was integrated into the calculation of body volume. Percentage total body fat was calculated using the Siri equations[22].

Statistical analysis

Analyses for males and females were performed separately. Values of the measured variables are presented as mean and standard deviation (± SD) with normality of distribution evaluated with the Kolmogorov-Smirnov test with the Lilliefors correction. Analysis of covariance (ANCOVA), adjusted for age at baseline, and analysis of variance (ANOVA) was used to compare mean anthropometric changes and mean z-score anthropometric changes over time, respectively. *Post-hoc* comparisons were conducted with the Bonferroni correction applied. Imputation of anthropometric measures at 2-and 13-months of follow-up were performed to improve sensitivity analysis; participants lost to follow-up being considered as having baseline values during follow-up.

Differences in outcomes were considered statistically significant at a $p < 0.05$. All analyses were performed with the IBM SPSS package v.19 (IBM Corp., New York, USA).

Results

Initially, 156 participants were recruited. Hence, the study sample included 71 males and 85 females

(14.5 ± 1.1 and 14.7 ± 1.3 years old, respectively). Compared to the females, males at baseline were heavier , taller, greater fat mass percentage, greater FMI, W-to-H and WHtR (all $p < 0.05$) (Table I).

In those with DXA measurements, males had higher LM (kg, %) ($p < 0.05$) and lower FMI (12.01 ± 2.13 *vs.* 13.46 ± 3.84 kg/m^2, p = ns) than females.

In those with ADP measurements, FFM (kg) was higher in males than in females while FM was higher in females than in males, albeit these differences did not reach statistical significance.

Short term body composition changes

The 2-months intensive intervention programme achieved a considerable weight loss (4.27 and 3.35 kg, $p < 0.05$) in males and females, respectively, while height increased by 0.73 and 0.54 cm ($p < 0.05$) in males and females. Consequently BMI decreased by 1.79 and 1.60, kg/m^2 ($p < 0.05$) in males and females, and FMI also decreased by1.16 kg/m^2 ($p < 0.05$) in males (Table I).

Following 2-months of multidisciplinary intervention, in those with DXA measurements, statistically significant decreases in LM (1.41 and 2.3 kg, $p < 0.05$) (Table I) and lean body mass index (LBMI; 0.73 and 0.94, kg/m^2, $p < 0.05$) were observed in males as well as females (Fig. 2). Further, males showed statistically significant reductions in FM (4.03 kg and 2.33%, $p < 0.05$) (Table I) and FMI (1.51 kg/m^2, $p < 0.05$) as well as increases in LM percentage (2.33%, $p < 0.05$) (Fig. 3).

In those with ADP measurements 2-months involve in a multidisciplinary intervention, a significant decrease was observed in FM (percentage, kg) (5.01% and 5.93 kg, $p < 0.05$) and FMI (2.13 kg/m^2, $p < 0.05$) but only in males (Table I).

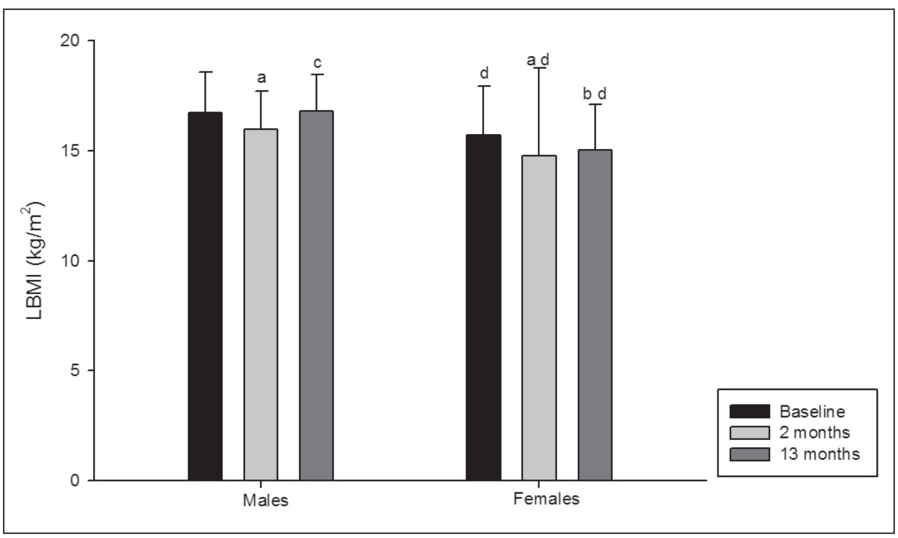

Fig. 2.—LBMI assessed by DXA at baseline, and at 2 and 13 months of follow-up.
[a]Baseline vs. 2 months, $p < 0.05$; [b]Baseline vs. 13 months, $p < 0.05$; [c]2 months vs. 13 months, $p < 0.05$; [d]Boys vs. girls at the same time points, $p < 0.05$.

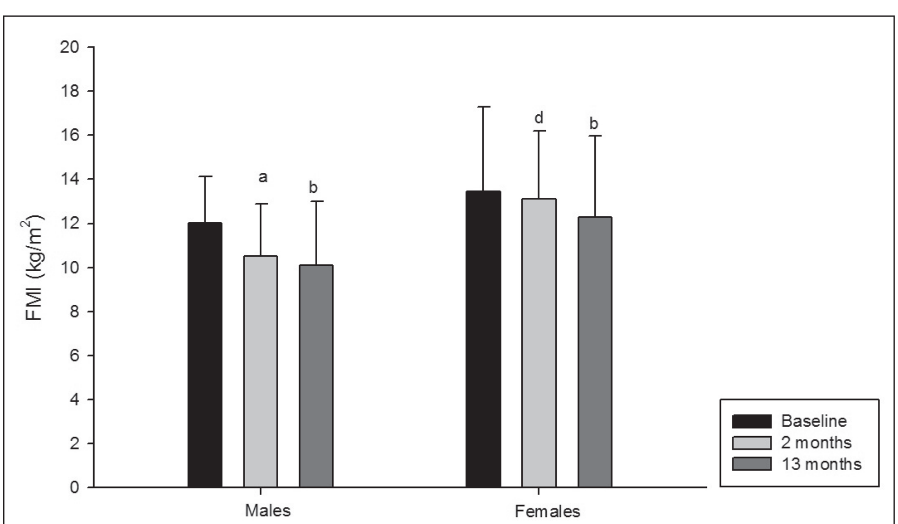

Fig. 3.—FMI assessed by DXA at baseline, and at 2 and 13 months of follow-up.
[a]Baseline vs. 2 months, $p < 0.05$; [b]Baseline vs. 13 months, $p < 0.05$; [c]2 months vs. 13 months, $p < 0.05$; [d]Boys vs. girls at the same time points, $p < 0.05$.

Table I
Characteristics of the participants during the programme (measurements at baseline and 2 and 13 months of follow-up)

	Males					Females				
	N	*Baseline*	*2 months*	*13 months*	*p for trend*	*N*	*Baseline*	*2 months*	*13 months*	*p for trend*
Anthropometric Measures										
Age (years)	71	14.51±1.07	-	-	-	85	14.68±1.32	-	-	-
Weight (kg)	71	90.00±14.94	85.73±14.92^{a}	88.88±16.12^{c}	<0.001	85	83.07±16.53 ^{d}	79.72±15.54^{ad}	79.61±15.65^{bd}	<0.001
Height (cm)	71	167.65±6.45	168.38±6.32^{a}	170.87±7.45^{bc}	<0.001	85	161.65±7.26^{d}	162.11±7.12^{ad}	162.71±7.40^{bcd}	<0.001
Fat Mass (%)[†]	71	36.93±3.66	34.92±4.79^{a}	33.03±6.72^{bc}	<0.001	84	28.88±2.99^{d}	29.54±2.48^{ad}	29.35±2.63^{cd}	0.006
Fat-free Mass (%)[‡]	71	63.06±3.66	65.07±4.79^{a}	67.92±6.26^{bc}	<0.001	84	71.12±2.99^{d}	70.45±2.48^{ad}	70.64±2.94^{d}	0.005
Body Mass Index (BMI) (kg/m^2)	71	31.82±4.48	30.03±4.68^{a}	30.39±5.12^{b}	<0.001	85	31.69±5.39	30.09±5.12^{a}	30.03±5.29^{b}	<0.001
Fat Mass Index (FMI) (kg/m^2)[§]	71	11.85±2.50	10.69±2.79^{a}	10.29±3.41^{b}	<0.001	84	9.08±1.32^{d}	8.93±1.29^{d}	8.79±1.44^{bd}	0.015
Fat-free Mass Index (FFMI) (kg/m^2)[§]	71	19.78±2.27	19.43±2.32^{a}	20.12±2.32^{c}	<0.001	84	22.65±4.57^{d}	21.88±4.35^{ad}	21.32±4.21^{bd}	<0.001
Waist-to-Hip Ratio	70	0.94±0.06	0.93±0.06	0.91±0.08^{bc}	<0.001	84	0.84±0.92^{d}	0.84±0.07^{d}	0.81±0.08^{bcd}	<0.001
Waist-to-Height Ratio	71	0.62±0.06	0.59±0.07^{a}	0.58±0.08^{b}	<0.001	84	0.58±0.07^{d}	0.57±0.07^{ad}	0.55±0.08^{bcd}	<0.001
Dual-energy X-ray absorptiometry (DXA)										
Fat Mass (kg)	38	34.31±7.43	30.28±7.89^{a}	29.62±8.95^{b}	<0.001	39	34.51±10.38	33.78±8.91	31.83±9.72^{b}	0.018
Lean Mass (kg)	38	47.45±6.66	46.04±6.09^{a}	47.75±6.66^{c}	<0.001	39	40.44±7.38^{d}	38.14±6.69^{ad}	40.44±7.38^{cd}	<0.001
Percentage Fat Mass (%)	38	40.77±4.69	38.44±6.03^{a}	36.13±7.26^{bc}	<0.001	39	45.49±4.92^{d}	45.39±5.74^{d}	44.20±6.11^{d}	0.082
Percentage Lean Mass (%)[‡]	38	59.23±4.69	61.56±6.03^{a}	63.87±7.26^{bc}	<0.001	39	54.50±4.92^{d}	54.61±5.74^{d}	55.80±6.11^{d}	0.082
Air Displacement Plethismography (ADP)										
Fat Mass (kg)	21	39.98±9.69	34.05±9.57^{a}	33.68±10.24^{b}	0.004	20	39.38±11.27	37.56±11.58	35.44±12.51^{b}	0.011
Fat-free Mass (kg)	21	49.41±8.85	50.89±7.81	51.75±9.14^{b}	0.031	20	45.43±5.76	45.54±6.39^{d}	45.64±5.95^{d}	0.245
Fat Mass (%)	21	44.75±6.81	39.74±8.18^{a}	39.35±9.95^{b}	0.001	20	46.39±6.01	45.41±6.49^{d}	43.06±7.27^{b}	0.013
Fat-free Mass (%)[‡]	21	55.24±6.81	60.25±8.18^{a}	60.64±9.95^{b}	0.001	20	53.61±6.01	54.59±6.49^{d}	56.94±7.27^{b}	0.013
Fat Mass Index (FMI) (kg/m^2)[¥]	21	14.06±2.77	11.93±3.13^{a}	11.62±3.42^{b}	0.002	20	15.52±3.92	14.87±4.01^{d}	13.94±4.59^{bd}	0.009
Fat-free Mass Index (FFMI) (kg/m^2)[¥]	21	17.36±2.54	17.69±2.42	17.65±2.38	0.270	20	17.98±1.64	17.47±1.84	17.95±1.66	0.198

Values are the differences between baseline and follow-up at 2 and 13 months (mean±SD). The inferential analysis was performed with the common variables using repeated measures ANCOVA test with Bonferroni correction used for mean comparisons of values during the programme, adjusted by age at baseline. [†]Fat Mass (%) calculated according to Slaughter's equation by age and gender. [‡]Fat Free Mass (%) calculated according to 100-FM (%), assessed by Anthropometry, DXA and ADP. [§]Fat Mass Index and Fat-free Mass Index calculated according to Fat Mass (kg) and Fat-free Mass (kg) assessed by Anthropometry. [¥]Fat Mass Index and Fat-free Mass Index calculated according to Fat Mass (kg) and Fat-free Mass (kg) assessed by ADP. [a]Baseline *vs.* 2 months, $p<0.05$; [b]Baseline *vs.* 13 months, $p<0.05$; [c]2 months *vs.* 13 months, $p<0.05$; [d]Boys *vs.* girls at the same time points, $p<0.05$.

Long term body composition changes

The changes were maintained over the 13-months in males and females with respect to BMI (1.43 and 1.66 kg/m^2, $p<0.05$), FMI (1.56 and 0.29 kg/m^2, $p<0.05$), W-to-H (0.03, $p<0.05$) and WHtR (0.03, $p<0.05$). Further, these losses were combined with increases in height (3.22 and 1.06 cm, $p<0.05$) in both sexes; moreover in males significant increases in FFM (4.86%, $p<0.05$) together with a significant decrease in FM (3.9%, $p<0.05$) were observed. Moreover, decreases in FFMI (1.33 kg/m^2, $p<0.05$), were observed only in females.

Following 13-months of the programme, in DXA measurements, there were significant decreases, in males and females, in FM (4.69 and 2.68 kg, $p<0.05$) (Table I) and FMI (1.91 and 1.16 kg/m^2, $p<0.05$) (Fig. 3). Significant decreases were observed in males in percentage FM (4.64 %, $p<0.05$) and increases in LM (4.64 %, $p<0.05$) (Table I). However, in females, there was a significant decrease in FMI (1.16 kg/m^2, $p<0.05$) and in LBMI (0.68 kg/m^2, $p<0.05$ (Fig. 2).

Long-term effects in males and females, with ADP measures, were significant decreases in FM (6.3 and 3.94 kg, $p<0.05$), percentage FM (5.4 and 3.33%, $p<0.05$) and FMI (2.44 and 1.58 kg/m^2, $p<0.05$), with significant increases in FFM (5.4 and 3.33%, $p<0.05$) (Table I).

Normalized characteristics

Regarding the normalized characteristics from our adolescents (Table II), compared to the females, males had higher FM-zscore ($p<0.05$), FMI -zscore ($p<0.05$), and W-to-H ($p<0.05$) at baseline. In contrast, females had higher FFMI-zscore than males ($p<0.05$). These normalized changes were maintained after 2-and 13-months (Table II).

Discussion

The main outcome of the present study was a significant decrease in FMI after 2 and 13-months of a combined therapy of diet, exercise and psychological support applied to overweight and obese adolescents. This was observed in parallel with the long-term maintenance of FFMI. Of note is that our results were obtained using intention-to-treat analysis together with a conservative estimate of body composition data in adolescents who did not complete the protocol.

A multidisciplinary approach involving diverse health care professionals is essential in the success of an intervention programme[2]. Our study findings corroborate those from clinical trials that applied combined behavioural-lifestyle interventions i.e. significant, and clinically relevant, weight and fat mass reductions in overweight children and adolescents[23].

Table II

Normalized anthropometric measures of the participants during the programme (measurements at baseline and 2 and 13 months of follow-up)

	Males					Females				
	N	*Baseline*	*2 months*	*13 months*	*p for trend*	*N*	*Baseline*	*2 months*	*13 months*	*p for trend*
Anthropometric Measures										
Fat Mass z-score (FM z-score) (%)	71	1.94±4.21	1.74±5.13^a	1.63±7.16^{bc}	<0.001	84	1.119±5.86^d	1.15±5.04^d	1.08±5.49^{bcd}	<0.001
Body Mass Index z-score (BMI z-score) (kg/m^2)	71	2.58±1.10	2.14±1.14^a	2.14±1.28^b	<0.001	85	2.70±0.97	2.30±0.94^a	2.32±1.01^b	<0.001
Fat Mass Index z-score (FMI z-score) (kg/m^2)	71	2.95±1.00	2.55±1.08^a	2.41±1.29^b	<0.001	84	2.21±7.69^d	1.99±7.14^d	1.90±7.88^{bd}	0.013
Fat-free Mass Index z-score (FFMI z-score) (kg/m^2)	71	2.83±6.82	2.66±6.90^a	2.87±6.82^c	<0.001	84	4.28±1.44^d	3.92±1.31^{ad}	4.02±1.24^{bd}	<0.001
Waist-to-Hip Ratio z-score	70	1.88±0.89	1.75±0.89	1.50±1.26^b	0.010	84	1.58±8.61^d	1.55±7.42^d	1.23±0.93^{bcd}	0.003
Waist-to-Height Ratio z-score	71	2.99±1.12	2.64±1.23^a	2.48±1.49^b	<0.001	84	2.89±1.03	2.55±1.22^a	2.32±1.20^b	<0.001

Values are the differences between baseline and follow-up at 2 and 13 months (mean±SD). The inferential analysis was performed with the common variables using repeated measures ANOVA test with Bonferroni correction used for mean comparisons of values during the programme. †Fat Mass (%) calculated according to Slaughter's equation by age and gender. ‡Fat Free Mass (%) calculated according to 100-FM (%), assessed by Anthropometry, DXA and ADP. §Fat Mass Index and Fat-free Mass Index calculated according to Fat Mass (kg) and Fat-free Mass (kg) assessed by Anthropometry. ¥Fat Mass Index and Fat-free Mass Index calculated according to Fat Mass (kg) and Fat-free Mass (kg) assessed by ADP. [a]Baseline *vs*. 2 months, $p<0.05$; [b]Baseline *vs*. 13 months, $p<0.05$; [c]2 months *vs*. 13 months, $p<0.05$; [d]Boys *vs*. girls at the same time points, $p<0.05$.

BMI was the best anthropometric index identifying body fat composition changes during the obesity treatment programme together with the more sensitive FMI[7]. FMI and FFMI enabled appropriate comparisons to be made of the changes in fat-or fat-free mass between adolescents of different heights. Our results for FMI and FFMI were obtained from anthropometric, DXA (LBMI) and ADP measurements.

FMI and FFMI have not been widely used to assess obese adolescents. However, cut-off points for FMI and FFMI were recently established by Wells *et al.*[24] applying the 4-component model of body-composition assessment. Further, in a US population, Weber *et al.*[25], using DXA, proposed sex-specific FMI and LBMI reference curves for children and adolescents aged 8-20 years.

WC is a surrogate marker of abdominal fat and is strongly associated with cardiovascular disease (CVD) risk factors[26]. Recently, other indices of abdominal obesity such as W-to-H and WHtR have been reported as being better discriminators of CVD and metabolic syndrome (MetS) risk factors than BMI and/or WC. WHtR is suitable for screening of obesity and MetS in children and adolescents[27]. However, this does not reduce the clinical usefulness of W-to-H as a predictor of CVD risk[26].

A cause of concern in any obesity-reduction intervention is to ensure that normal growth and development are not impeded[4]. Our results showed appropriate height gain in both sexes during the programme. Few intervention studies in obese adolescents report height changes, but those that do have all showed appropriate height gains in child heath units[28,29].

The results of weight-loss interventions on LM in adolescents have been very variable. Early studies using very low calorie diets and MVPA, achieved LM loss in children[30]. In our study, we used a moderate calorie restriction together with MVPA and the LM was conserved in males, and slightly decreased during treatment in females. This was observed when using DXA but not when using anthropometry or ADP.

There were significant BMI decreases (>1 kg/m^2) in males and females after 2 months of the intervention. This is in accord with BMI changes observed after 3-months in intervention groups in other similar studies[28]. During 2-months of a residential treatment programme consisting of moderate calorie restriction in combination with PA and psychological support, Deforche *et al.*[31] achieved higher BMI decreases. This could be due to the controlled environment of their intervention, as opposed to our free-living intervention.

Few intervention studies have addressed FMI changes. Hence, for comparison purposes, we have used the percentage FM value obtained after 2-months on the multidisciplinary treatment to assess fat mass goals. With respect to percentage body fat changes measured by anthropometry, our results were lower than the percentage body fat changes observed in the group studied by Nemet *et al.*[28] after 3-months of intervention. With respect to the laboratory methods used, the males in our study had percentage body fat changes measured by DXA , and the values were higher than the changes obtained by Tsiros *et al.*[32] after 10-weeks of intervention using the same method.

With respect to WHtR changes, our intervention programme achieved higher decreases in males than those achieved by Shrewsbury *et al.*[33] after 2-months intervention applying the social cognitive theory to change dietary intake and activity levels.

The BMI changes observed by Caranti *et al.*[34] were similar to those observed during our intensive intervention period. In our study there were no significant differences between males and females with respect to BMI changes. Similar multidisciplinary treatment programmes have shown greater losses in males than in females (3 *vs.* 1 kg/m^2 respectively) following 6-months intervention promoting changes in sedentary lifestyle and nutritional habits[34], and higher losses in males than females following 9-months of a multidisciplinary weight-reduction programme in severely obese adolescents[29].

The decrease in FMI was higher in males than females when taking into account all the body composition methods used. Caranti *et al.*[34], using anthropometry, obtained results for percentage body fat, but not for FMI. They observed, in males and females, higher decreases in percentage body fat (8.22 and 6.19%, respectively) than we did using anthropometry (3.9 %, in males) following 12-months on a multidisciplinary weight-reduction programme.

Maintaining appropriate levels of LM could help prevent cyclical weight gain. When using DXA, we observed a significant increase in LBMI in males and a significant decrease in females, although the effect sizes observed were lower in both genders. Lazzer *et al.*[29], also using DXA, observed significant decreases in FFM in boys as well as in girls after 9-months in a clinical intervention. However, Ning *et al.*[35], following 6-months in a lifestyle intervention programme, also observed (using DXA) a significant increase in LM in male and female obese adolescents. However, Caranti *et al.*[34], following 12-months in a multidisciplinary treatment, observed significant increases in percentage FFM in males and females (7 and 6%, respectively). These findings are higher than the increases we observed using ADP.

W-to-H and WHtR decreases were significant and were maintained in males and females on conclusion of the study at 13-months, relative to the intensive intervention period. Our results are in agreement with the short-term outcomes in WHtR observed in the Loozit Study[33]. This may indicate that weight loss is associated with a parallel decrease in visceral fat in obese adolescents.

Taking into account the sex-specific FM (%), BMI, W-to-H and WHtR reference curves for Spanish adolescents aged 13-18 years, our obese adolescents were, at least 1.0 score, over the standard population. Moreover, regarding the calculated cut-off points of FMI and FFMI, our sample was over the mean population until 4.5 score.

Our results show short-term decreases of BMI z-score were obtained in both genders. Our BMI z-score losses were greater than in similar weight management programmes after 2-months[33] and 6-months[35].

The main strength of our study is the use of three methods to assess body composition changes in overweight and obese adolescents. ADP is considered the reference standard for assessing body composition changes; DXA is considered a good tool to assess lean body mass, and anthropometry is the most widely used body composition method in clinical settings. Further, the intention-to-treat approach was conducted to increase general applicability. Imputation was performed for this analysis using a conservative approach. i.e. participants lost to follow-up were considered to have baseline values at follow-up.

The main limitation is that the study used data from a multidisciplinary weight- management programme which was designed without a comparison group. Despite the efforts to retain the adolescents within the programme, 28.2% did not complete the protocol. These results are similar those observed in other studies (20.00 to 59.75%). Our findings do not address lean body mass composition. Hydration of fat-free mass (LM) is greater in obese than in normal-weight adolescents.

In conclusion, our multidisciplinary approach to lifestyle intervention has a favourable impact on adolescent BMI, FMI and WHtR over at least the 13-months period of the study, and which supports its effectiveness. In addition, FFMI was also maintained in male and female adolescents.

Appendix

The EVASYON Study Group

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Local clinical research teams in the participating Centres (Principal Investigators are underlined)

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Data management and statistical analyses: Wärnberg J, Calle ME, Barrios L

Statement of authorship

LM, JM-G, JS and PM-E conceived and designed the current study. LM, AM, CC, JM-G and AsM conceived and designed the EVASYON Study. JS and PM-E analysed and interpreted the data. PM-E, MM-M and BZ conducted the laboratory measurements. All authors were involved in writing the initial manuscript and approved the final version submitted for publication. The EVASYON Study Group provided logistics support in the course of the study. Editorial assistance was by Dr Peter R Turner of Tscimed.com the costs of whose services were met by in-house funds.

Conflict of interest statement

The authors not declare conflict of interest.

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