



Revisión

# Body composition changes during interventions to treat overweight and obesity in children and adolescents; a descriptive review

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Abstract

Nutrition, physical activity and behavior-modifying techniques are widely applied components of interventions treating obesity. Our aim was to review available information on the short and long term effects of intervention treatment on body fat composition of overweight and obese children and adolescents and, to obtain a further understanding on how different body composition techniques detect longitudinal changes. In total, thirteen papers were included; seven included a multidisciplinary intervention component, five applied a combined dietary and physical activity intervention and one a physical activity intervention. Body composition techniques used included anthropometric indices, bioelectrical impedance analysis, and dual energy X-ray absorptiometry. Percentage of fat mass change was calculated in when possible. Findings suggested, no changes were observed in fat free mass after 16 weeks of nutritional intervention and the lowest decrease on fat mass percentage was obtained. However, the highest fat mass percentage with parallel increase in fat free mass, both assess by DXA was observed in a multi-component intervention applied for 20 weeks. In conclusion, more studies are needed to determine the best field body composition method to monitor changes during overweight treatment in children and adolescents.

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Key words: *Body Composition. Intervention studies. Cognitive Therapy. Calorie Restriction. Motor Activity.*

## CAMBIOS EN LA COMPOSICIÓN CORPORAL DURANTE EL TRATAMIENTO DE LA OBESIDAD Y SOBREPESO EN NIÑOS Y ADOLESCENTES; REVISIÓN DESCRIPTIVA

Resumen

Nutrición, actividad física y la modificación del comportamiento alimentarios son técnicas muy empleadas en el tratamiento de la obesidad. El objetivo de este trabajo es revisar la información disponible de los efectos a corto y largo plazo del tratamiento del sobrepeso y obesidad en niños y adolescentes en la grasa corporal, y obtener una mejor comprensión de las técnicas empleadas para detectar los cambios longitudinales. Se incluyeron un total de 13 estudios, siete incluyen un tratamiento multidisciplinar, cinco aplicaron un tratamiento combinado de nutrición y actividad física y sólo uno realizaba un tratamiento de actividad física. Las técnicas de composición corporal empleadas incluyeron índices antropométricos, impedancia eléctrica y absorciometría dual de rayos X. El cambio de porcentaje de grasa se calculó cuando fue posible. Los resultados sugieren el mayor cambio en porcentaje de grasa con un aumento paralelo de la masa libre de grasa, ambos determinados con absorciometría dual de rayos X en la intervención multidisciplinar durante 20 semanas. En conclusión, se necesitan más estudios que determinen el mejor método de composición corporal para controlar los cambios durante el tratamiento de del sobrepeso en niños y adolescentes.

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Palabras clave: *Composición corporal. Estudios de intervención. Restricción calórica. Actividad física.*

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## Abbreviations

ADP: Air-displacement plethysmography.  
AIT: Intensity-controlled aerobic interval training.  
BIA: Bioelectrical impedance.  
BMI: Body Mass Index.  
BT: Behavioral Therapy.  
C: Control.  
CDC: Centers for Disease Control and Prevention.  
D+PA: Dietary and physical activity intervention.  
D+PA+BT: Multiapproach intervention.  
DXA: Dual-energy X-ray absorptiometry.  
FFM: Fat free mass.  
HL: Healthy lifestyle.  
IBW: Ideal body weight.  
ILI: Instructor-led intervention.  
IOTF: International obesity task force.  
MTG: Multidisciplinary approach.  
N: Nutrition.  
N+ST: Nutrition and strength training.  
NA: Data not available.  
P+HL: Parenting skills plus healthy lifestyle.  
PA: Physical activity intervention.  
RCT: Randomized Controlled Trial.  
SH: Self held.  
WtH: Waist to hip ratio.

## Introduction

Nutrition, physical activity and behavior-modifying techniques are widely applied components of interventions treating obese children and adolescents.<sup>1</sup> Several methods are available to assess childhood and adolescent obesity but the most widely used, both in clinical and epidemiological settings, are weight, height and body mass index (BMI).<sup>2</sup> Methods to examine changes in children's body fat composition include simple field methods such as bioelectrical impedance (BIA) and skinfold thickness measurements.<sup>3</sup> Other laboratory methods such as hydrodensitometry, isotope dilution, dual-energy X-ray absorptiometry (DXA), and air-displacement plethysmography (ADP) are more accurate and precise but less easy to use in clinical care.<sup>4</sup> Up to date, there is limited evidence indicating appropriateness of methods in capturing body fat changes during obesity management in children and adolescents. Therefore, our aim was to review descriptively available information on the short and long term effects of intervention treatments on body fat composition of overweight and obese children and adolescents and, to obtain a clearer understanding on how different body composition techniques detect longitudinal changes.

## Material and Methods

The searching process covered three relevant electronic databases (Medline, EMBASE and Cochrane Library).

The general strategy included terms related to children and adolescents, weight loss program, physical activity and exercise, intervention, treatment and management. The shared Mesh terms were (((("Child"[Mesh]) OR «Adolescent»[Mesh])) AND (((("Cognitive Therapy"[Mesh]) OR ("Caloric Restriction"[Mesh]) OR ("Motor Activity"[Mesh])) AND ("Body Weight adverse effects"[Mesh] OR "Body Weight/methods"[Mesh] OR "Body Weight/prevention and control"[Mesh] OR "Body Weight/psychology"[Mesh] OR "Body Weight/standards"[Mesh])).

Additional search was carried out on references included in the papers, published reviews and via hand searching. Literature search were limited to articles published between 1990-2011 and the search finished on November, 3<sup>rd</sup>, 2011. The flow chart of the process is illustrated in figure 1.

Studies meeting the following criteria were included in the review: (1) overweight or obese sample, having a BMI equivalent to > 25 kg/m<sup>2</sup> for the corresponding age and sex group (considering the criteria used by the authors), (2) body composition changes specifically related to the intervention, (3) objective of the intervention to reduce energy intake and/or to promote physical activity and/or behavioral therapy, (4) outcomes of body composition measurements other than weight and height or related-derived indices during follow-up (5) randomized controlled trials (RCTs). Applied exclusion criteria included: (1) descriptive studies or case reports and cross-sectional studies, (2) interventions targeting populations with complications linked to obesity or treatment with drugs, (3) not available full text.

The initial search yielded 1540 references after exclusion of duplicates. References were combined in an endnote IX library and screened on the basis of title and abstract; those clearly not meeting the review criteria were excluded. Thereafter, selected references were screened based on full text. Reasons for exclusion were registered. Thirteen studies were finally included. Eight out of thirteen contained enough information to enable the authors to compute percentage changes in body fat percentage following intervention treatment participation; additionally, in six, the authors were able to compute percentage changes in fat free mass (fig. 2).

Appraised studies are summarized in ascending order of publication year (table I). Data extracted included: journal reference, design, number of participants and age at enrolment, intervention and follow-up duration, description of the target of the intervention, number of sessions, and main outcome measurements related with body composition.

## Results

Thirteen RCTs were included<sup>5-17</sup> (table I). Seven studies involved a multi-approach intervention focusing on dietary, physical activity and behavioral interventions (D+PA+BT).<sup>5,8,9,13-15,17</sup> Five had a dietary and physical

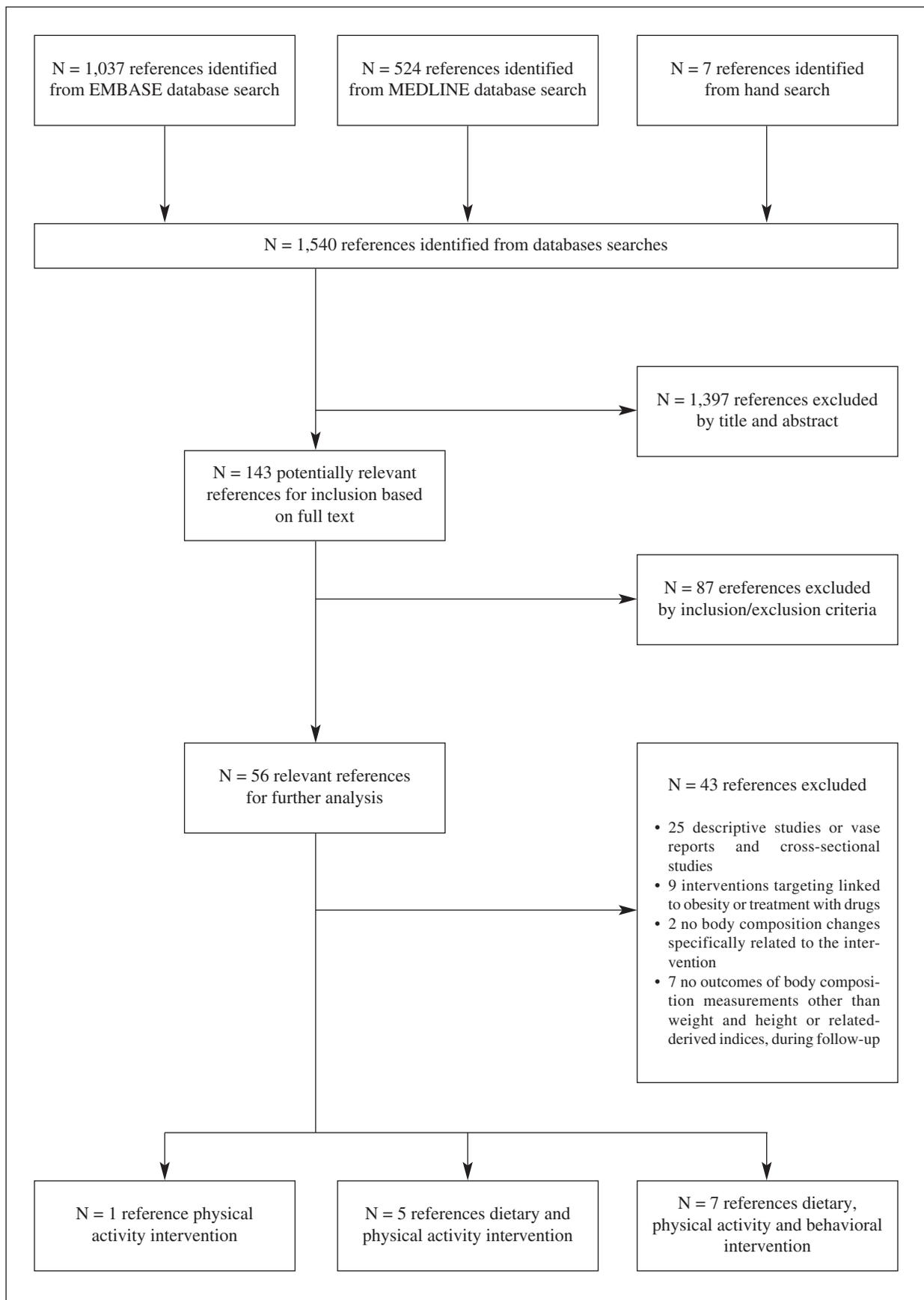


Fig. 1.—Flow chart of the review process.

**Table I**  
Selected RCTs addressing the effect of intervention treatment on body fat composition of overweight and obese children and adolescents

Study	Design	Sample size (N)	Age (years)	Obesity Criteria	Treatment	Sessions	Intervention	Follow-up	Body composition outcomes
Suskind RM et al., 2000 <sup>6</sup>	RCT	50 (17 boys and 33 girls)	7-17	Categories of obesity: Severely: >200% IBW Moderately: >150-199% IBW Mildly: >120-149% IBW	36 weeks	Weekly	D+PA+BT	9 months	Weight: (-9.0 kg) Percentage of body fat: Significant decrease Fat Free mass: Significant increase
Sudi KM et al., 2001 <sup>6</sup>	RCT	62 (40 boys and 22 girls)	Mean: boys: 11.9 and girls: 12	BMI > p90* for age and sex	3 weeks	NA	D+PA	3 weeks	Body mass (kg): boys: (-4±1.4), girls: (-3.6±1.1) Fat Mass (kg): boys: (-4±1.4), girls: (-3.3±1.7) Fat Mass (%): boys: (-4.1±2.7), girls: (-2.5±1.9) Fat Free Mass (kg): boys: (-0.04±1.7), girls: (-0.3±1.2) Waist Circumference (cm): boys: (-5.5±3.2), girls: (-9.2±6) Hip Circumference (cm): boys: (-5.5±3.2), girls: (-6±2.7)
Sung RYT et al., 2002 <sup>7</sup>	RCT	82 (54 boys and 28 girls)	8-11	Weight > 120% of the median weight for height	6 weeks	NA	D+PA	6 weeks	<b>Training</b> -Body weight: (+0.6 kg) -BMI: (-0.2 kg/m <sup>2</sup> ) -Fat Mass (kg): (-0.03 kg) -Fat Free Mass (kg): (+0.08 kg) -Fat Mass (%): (-0.7 %)
Nemet D et al., 2005 <sup>8</sup>	RCT	46	6-16	Self-reported weight and height	3 months	Series of 4 evenings	D+PA+BT	12 months	<b>3 months</b> -BMI: (-1.7 kg/m <sup>2</sup> ) -Body weight: (-2.8 kg) -Body fat percentage (%): (-3.3 %) <b>12 months</b> -BMI: (-1.6 kg/m <sup>2</sup> ) -BMI percentile: (-5.9 kg/m <sup>2</sup> ) -Body weight: (-0.6 kg) -Body fat percentage (%): (-2.3 %)
Tsimos MD et al., 2008 <sup>8</sup>	RCT	47 (16 boys and 31 girls)	12-18	IOTF	20 weeks	Weekly	D+PA+BT	10 weeks	<b>10 weeks</b> Weight loss: (+0.40 kg) BMI <sub>leq</sub> Fat Mass: (-0.30 kg) Percentage body fat: (-0.70 %) Abdominal fat: (-0.10 kg) Lean tissue: (+0.90 kg) Bone mineral content: (+0.80 g) Bone mineral density: (+0.01 g/cm <sup>2</sup> ) Waist circumference: (-0.1 cm) Hip circumference: (-1.5 cm)

**Table I (cont.)**

*Selected RCTs addressing the effect of intervention treatment on body fat composition of overweight and obese children and adolescents*

Study	Design	Sample size (N)	Age (years)	Obesity Criteria	Treatment	Sessions	Intervention	Follow-up	Body composition outcomes
								<b>20 weeks</b>	Weight loss: (-4.30 kg) BMI: (-1.6 kg/m <sup>2</sup> ) Fat Mass: (-4.8 kg) Percentage body fat: (-3.5 %) Abdominal fat: (-0.40 kg) Lean tissue: (+1.10 kg) Bone mineral content: (+0.20 g) Bone mineral density: (-0.01 g/cm <sup>2</sup> ) Waist circumference: (-5.9 cm) Hip circumference: (-5.8 cm)
Davis JN et al, 2009 <sup>10</sup>	RCT	54	14-18	≥85 <sup>th</sup> CDC percentile	16 weeks	N: once per week N+ST: twice per week per week	D+PA (Control [C], Nutrition [N], Nutrition and Strength training [N+ST])	16 weeks	N -Weight: (+0.5 kg) -BMI: (-0.1 kg/m <sup>2</sup> ) -BMI z score: equal -BMI percentile: (-0.5) -Total fat: (-0.1 kg) -Total lean: equal N+ST -Weight: (-0.3 kg) -BMI: equal -BMI z score: equal -BMI percentile: (+0.4) -Total fat: (-1.3 kg) -Total lean: (+1.1 kg)
Tjonna AE et al, 2009 <sup>11</sup>	RCT	54 (26 boys and 28 girls)	Mean: 14	Referred for medical treatment at Hospital	12 months	AT: twice a week for 3 months MTG: two weeks for 12 months	D+PA (intensity- controlled aerobic interval training [AT]) and multidisciplinary approach [MTG])	12 months	3 months AIT -Weight: (+0.3 kg) -BMI: (-0.7 kg/m <sup>2</sup> ) -Waist circumference: (+2.8 cm) -Total fat: (-0.3 kg) -Fat weight: (-0.9 kg) -Fat weight trunk: (-1.3 kg)

**Table I (cont.)**

*Selected RCTs addressing the effect of intervention treatment on body fat composition of overweight and obese children and adolescents*

Study	Design	Sample size (N)	Age (years)	Obesity Criteria	Treatment	Sessions	Intervention	Follow-up	Body composition outcomes
									<b>MTG</b> -Weight: (+1.1 kg) -BMI: (+0.2 kg/m <sup>2</sup> ) -Waist circumference: (-0.4 cm) -Total fat: (-1.3 kg) -Fat weight: (+0.3 kg) -Fat weight trunk: (+0.2 kg) <b>12 months</b> <b>AIT</b> -Weight: (+0.3 kg) -BMI: (-1.8 kg/m <sup>2</sup> ) -Waist circumference: (-7.2 cm) -Total fat: (-2.0 kg) -Fat weight: (-2.4 kg) -Fat weight trunk: (-1.5 kg) <b>MTG</b> -Weight: (+1.8 kg) -BMI: (-0.4 kg/m <sup>2</sup> ) -Waist circumference: (-1.3 cm) -Total fat: (-2.0 kg) -Fat weight: (-0.1 kg) -Fat weight trunk: (-0.6 kg)
Kriemler S et al, 2010 <sup>12</sup>	RCT	502	6-11	NA	9 months	Weekly	PA	9 months	Skinfolds thickness: (+0.39 mm) BMI: (+0.23 kg/m <sup>2</sup> ) Waist circumference: (+1.5 cm)
Johnston CA et al, 2010 <sup>15</sup>	RCT	60 (33 boys and 27 girls)	10-14	BMI for age and gender; Overweight >85 <sup>th</sup> percentile Obese >95 <sup>th</sup> percentile	12 months	SH: weekly ILI: daily	D+PA+BT (self held [SH], instructor-led intervention [ILI])	24 months	<b>12 months</b> <b>ILI</b> Weight: (+3.6 kg) BMI: (-0.2 kg/m <sup>2</sup> ) BMI z score: (-0.2) Percentage overweight: (-0.57 %) Triceps skinfolds: (-7.1 mm) <b>SH</b> Weight: (+7.4 kg) BMI: (+1.6 kg/m <sup>2</sup> ) BMI z score: (+0.1) Percentage overweight: (+3.4 %) Triceps skinfolds: equal

**Table I (cont.)**

*Selected RCTs addressing the effect of intervention treatment on body fat composition of overweight and obese children and adolescents*

Study	Design	Sample size (N)	Age (years)	Obesity Criteria	Treatment	Sessions	Intervention	Follow-up	Body composition outcomes
Collins CE et al. 2011 <sup>14</sup>	RCT	165 (68 boys and 97 girls)	5-10	IOTF	24 months	Weekly and Monthly	D+PA+BT (child-centred physical activity; parent-centred dietary modification and activity and diet program)	24 months	<p><b>24 months</b></p> <p><b>ILI</b></p> <p>Weight: (+9.5 kg)</p> <p>BMI: (+0.8 kg/m<sup>2</sup>)</p> <p>BMI z score: (-0.2)</p> <p>Percentage overweight: (-6.0%)</p> <p>Triceps skinfolds: not measured</p> <p><b>SH</b></p> <p>Weight: (13.1 kg)</p> <p>BMI: (2.2 kg/m<sup>2</sup>)</p> <p>BMI z score: equal</p> <p>Percentage overweight: (+0.7%)</p> <p>Triceps skinfolds: not measured</p>
Magarey AM et al. 2011 <sup>15</sup>	RCT	169 (74 boys and 95 girls)	5-10	IOTF	6 months	Weekly and Monthly	D+PA+BT (Parenting skills plus healthy lifestyle [P+HL], healthy lifestyle [HL])	24 months	<p><b>6 months</b></p> <p><b>P+HL</b></p> <p>BMI z score: (-0.29 kg/m<sup>2</sup>)</p> <p>Waist circumference z score: (-0.34 cm)</p> <p><b>HL</b></p> <p>BMI z score: (-0.22 kg/m<sup>2</sup>)</p> <p>Waist circumference z score: (-0.33 cm)</p>

**Table I (cont.)**

*Selected RCTs addressing the effect of intervention treatment on body fat composition of overweight and obese children and adolescents*

Study	Design	Sample size (N)	Age (years)	Obesity Criteria	Treatment	Sessions	Intervention	Follow-up	Body composition outcomes
								<b>12 months</b>	
								<b>P+HL</b>	
									BMI z score: (-0.53 kg/m <sup>2</sup> )
									Waist circumference z score: (-0.36 cm)
								<b>HL</b>	
									BMI z score: (-0.24 kg/m <sup>2</sup> )
									Waist circumference z score: (-0.34 cm)
								<b>18 months</b>	
								<b>P+HL</b>	
									BMI z score: (-0.31 kg/m <sup>2</sup> )
									Waist circumference z score: (-0.3 cm)
								<b>HL</b>	
									BMI z score: (-0.29 kg/m <sup>2</sup> )
									Waist circumference z score: (-0.28 cm)
								<b>24 months</b>	
								<b>P+HL</b>	
									BMI z score: (-0.39 kg/m <sup>2</sup> )
									Waist circumference z score: (-0.47 cm)
								<b>HL</b>	
									BMI z score: (-0.42 kg/m <sup>2</sup> )
									Waist circumference z score: (-0.37 cm)
Savoie M et al, 2011 <sup>16</sup>	RCT	174	8-16	BMI >95 <sup>th</sup> percentile	12 months	NA	D+PA	24 months	<b>6 months</b>
									Weight: (-2.4 kg)
									BMI: (-2.1 kg/m <sup>2</sup> )
									BMI z score: (-0.16 kg/m <sup>2</sup> )
									Body fat: (-2.7 %)
									Body fat mass: (-3.6 kg)
									<b>12 months</b>
									Weight: (+0.3 kg)
									BMI: (-1.8 kg/m <sup>2</sup> )
									BMI z score: (-0.21 kg/m <sup>2</sup> )
									Body fat: (-3.9%)
									Body fat mass: (-3.7 kg)

**Table I (cont.)**

*Selected RCTs addressing the effect of intervention treatment on body fat composition of overweight and obese children and adolescents*

Study	Design	Sample size (N)	Age (years)	Obesity Criteria	Treatment	Sessions	Intervention	Follow-up	Body composition outcomes
Shrewsbury VA et al, 2011 <sup>17</sup>	RCT	151 (72 boys and 79 girls)	13-16	BMI z-scored > 1.0 and <2.5 Equivalent ≥85 <sup>th</sup> CDC percentile	24 months	NA	D+PA+BT	22 months	<b>24 months</b> Weight: (5.9 kg) BMI: (-0.9 kg/m <sup>2</sup> ) BMI z score: (-0.20)(kg/m <sup>2</sup> ) Body fat: (-3.6 %) Body fat mass: (-0.6 kg)
									<b>2 months</b> Weight: (-0.2 kg) BMI: (-0.3 kg/m <sup>2</sup> ) BMI z score: (-0.04)(kg/m <sup>2</sup> ) Waist circumference: (-2.4 cm) Waist to height ratio: (-0.01)

RCT: Randomized Control Trial. IBW: Ideal body weight. D + PA + BT: dietary, physical activity and behavioral interventions. D+PA: dietary and physical activity intervention. PA: physical activity intervention. BT: behavioral therapy. BMI: Body mass index. NA: data not available. IOTF: International Obesity Task Force. CDC: Centres for Disease Control. C: Control. N: Nutrition. N+ST: Nutrition and Strength training. MTG: Multidisciplinary approach. SH: Self Held. ILI: Instructor-led intervention. P+HL: Parenting skills plus healthy lifestyle. HL: Healthy lifestyle.

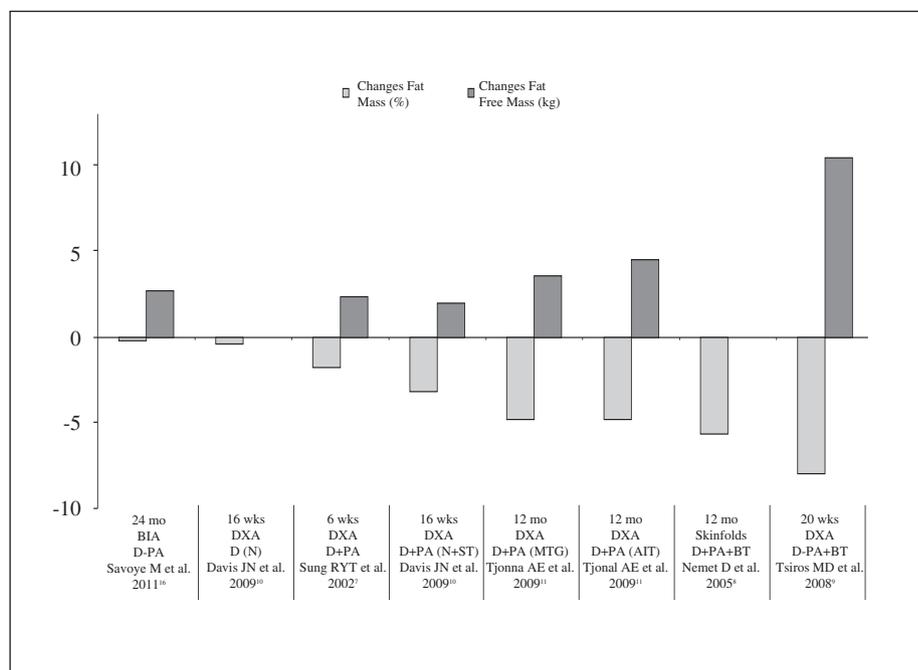


Fig. 2.—Changes in fat mass (%) and fat free mass percentage (kg) following intervention treatment participation calculated in 8 studies. mo: months. wks: weeks. BIA: bioelectrical impedance analysis, DXA: dual energy X-ray absorptiometry. D + PA + BT: dietary, physical activity and behavioral interventions. D+PA: dietary and physical activity intervention. PA: physical activity intervention. C: Control. N: Nutrition. N+ST: Nutrition and Strength training. AIT: Intensity controlled aerobic interval training. MTG: Multi-disciplinary approach.

activity intervention component (D+PA)<sup>6,7,10,11,16</sup> and one a physical activity intervention component (PA).<sup>12</sup>

Two of the studies used skinfolds to measure fat<sup>5,8,18</sup> and two computed the sum of four skinfolds.<sup>12,13</sup> Three studies calculated some anthropometry-related indices i.e., BMI, BMI z-score and waist to height ratio.<sup>14,15,17,19</sup> Two studies assessed body fat by BIA<sup>6,16</sup> and six by DXA<sup>7,9-11</sup> (table I).

The percentage of change of fat mass and fat free mass was calculated by the authors according to published outcomes (fig. 2). The lowest percentage change was observed by Savoye M et al.<sup>16</sup> and the highest by Tsiros MD et al.,<sup>9</sup> indicating that body fat percentage decreases were in parallel to increases in fat free mass (FFM) percentage. No trends in body fat percentage changes according to length of follow up, body composition method or year were observed. It seems to be a direct relationship between body fat percentage and complexity of the intervention, as it is shown Nemet D et al. and Tsiros MD et al.<sup>8,9</sup>

## Discussion

This descriptive review appraised available information examining short and long term effects of single and multidisciplinary interventions on body fat composition of overweight and obese children and adolescents. A total of thirteen studies were selected and appraised; a structured and targeted search was performed in order to identify all relevant studies. Findings suggested that the highest fat mass percentage with the parallel increase in fat free mass both assess by DXA was observed in a multi-component intervention applied for 20 weeks.<sup>9</sup> However, differences in follow-up duration, sessions applied dur-

ing intervention and body composition techniques did not facilitate drawing of clear-cut conclusions.

Traditional treatment of obesity have resulted in limited success in terms of weight and BMI<sup>20</sup> when applied separately. Our results indicated that induced body fat composition changes were higher when multidisciplinary interventions were used. The majority of the studies used DXA,<sup>7,9-11</sup> followed by BIA and skinfolds<sup>8,16</sup> to detect changes. However, evidence of validation studies addressing accuracy of body composition techniques in assessing changes are lacking with an exception of that for DXA estimates.<sup>4</sup> The study by Hauroun D et al.<sup>3</sup> validating BIA in obese children and adolescents suggested that BIA provided reliable measures and could be used in routine clinical monitoring.

In conclusion, available literature assessing changes in body composition during treatment in overweight and obese children and adolescents is scarce. Further studies, comparing field methods with reference standards are necessary in order to identify body composition indices able to capture fat mass changes in obese children in multidisciplinary and multi-approach interventions.

## Conflict of interest

None declared

## Author Contributions

Conception and design of the study: (PM-E), (LM) and (JMG).

Searching process, collection, assembly, analysis and/or interpretation of data: (PM-E), (II), (SB-S) (LM) and (JMG)

Drafting and revision of the manuscript: (PM-E), (LM), (II), (SB-S), (TM) and (JMG).

Approval of the final version of the manuscript: (PM-E), (LM), (II), (SB-S), (TM) and (JMG).

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## References

1. Martínez-Gomez DS, Gomez-Martínez MA, Puertollano E, Nova J, Warnberg OL, Veiga, et al. Design and evaluation of a treatment programme for Spanish adolescents with overweight and obesity. The EVASYON Study. *BMC Public Health* 2009; 9: 414.
2. Moreno LA, Mur L, Fleta J. Re: "Does body mass index adequately capture the relation of body composition and body size to health outcomes?". *Am J Epidemiol* 1999; 149 (7): 681-2.
3. Vicente-Rodríguez G, Rey-Lopez JP, Mesana MI, Poortvliet E, Ortega FB, Polito A et al. Reliability and intermethod agreement for body fat assessment among two field and two laboratory methods in adolescents. *Obesity (Silver Spring)* 2012; 20 (1): 221-8.
4. Haroun D, Croker H, Viner RM, Williams JE, Darch TS, Fewtrell MS et al. Validation of BIA in obese children and adolescents and re-evaluation in a longitudinal study. *Obesity (Silver Spring)* 2009; 17 (12): 2245-50.
5. Elberg J, McDuffie JR, Sebring NG, Salaita C, Keil M, Robotham D et al. Comparison of methods to assess change in children's body composition. *Am J Clin Nutr* 2004; 80 (1): 64-9.
6. Suskind RM, Blecker U, Udall JN Jr, von Almen TK, Schumacher HD, Carlisle L et al. Recent advances in the treatment of childhood obesity. *Pediatr Diabetes* 2000; 1 (1): 23-33.
7. Sudi KM, Gallistl S, Borkenstein MH, Payerl D, Aigner R, Moller R et al. Effects of weight loss on leptin, sex hormones, and measures of adiposity in obese children. *Endocrine* 2001; 14 (3): 429-35.
8. Sung RYT, Yu CW, Chang SKY, Mo SW, Woo KS, Lam CWK. Effects of dietary intervention and strength training on blood lipid level in obese children. *Arch Dis Child* 2002; 86 (6): 407-10.
9. Nemet D, Barkan S, Epstein Y, Friedland O, Kowen G, Eliakim A. Short- and long-term beneficial effects of a combined dietary-behavioral-physical activity intervention for the treatment of childhood obesity. *Pediatrics* 2005; 115 (4): e443-9.
10. Tsiros MD, Sinn N, Coates AM, Howe PR, Buckley JD. Treatment of adolescent overweight and obesity. *Eur J Pediatr* 2008; 167 (1): 9-16.
11. Davis JN, Kelly LA, Lane CJ, Ventura EE, Byrd-Williams CE, Alexandar KA et al. Randomized control trial to improve adiposity and insulin resistance in overweight Latino adolescents. *Obesity* 2009; 17 (8): 1542-8.
12. Tjonna AE, Stolen TO, Bye A, Volden M, Slordahl SA, Odegard R et al. Aerobic interval training reduces cardiovascular risk factors more than a multitreatment approach in overweight adolescents. *Clinical Science* 2009; 116 (4): 317-26.
13. Kriemler S, Zahner L, Schindler C, Meyer U, Hartmann T, Hebestreit H et al. Effect of school based physical activity programme (KISS) on fitness and adiposity in primary school-children: cluster randomised controlled trial. *BMJ* 2010; 340: c785.
14. Johnston CA, Tyler C, McFarlin BK, Poston WSC, Haddock CK, Reeves RS et al. Effects of a school-based weight maintenance program for mexican-american children: Results at 2 years. *Obesity (Silver Spring)* 2010; 18 (3): 542-7.
15. Collins CE, Okely AD, Morgan PJ, Jones RA, Burrows TL, Cliff DP et al. Parent diet modification, child activity, or both in obese children: an RCT. *Pediatrics* 2011; 127 (4): 619-27.
16. Magarey AM, Perry RA, Baur LA, Steinbeck KS, Sawyer M, Hills AP et al. A parent-led family-focused treatment program for overweight children aged 5 to 9 years: the PEACH RCT. *Pediatrics* 2011; 127 (2): 214-22.
17. Savoye M, Nowicka P, Shaw M, Yu S, Dziura J, Chavent G et al. Long-term results of an obesity program in an ethnically diverse pediatric population. *Pediatrics* 2011; 127 (3): 402-10.
18. Shrewsbury VA, Nguyen B, O'Connor J, Steinbeck KS, Lee A, Hill AJ et al. Short-term outcomes of community-based adolescent weight management: The Loozit (registered trademark) Study. *BMC Pediatrics* 2011; 11.
19. Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RJ, Van Loan MD et al. Skinfold equations for estimation of body fatness in children and youth. *Hum Biol* 1988; 60 (5): 709-23.
20. Dyer RG. Traditional treatment of obesity: does it work? *Baillieres Clin Endocrinol Metab* 1994; 8 (3): 661-88.