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

Pilar de Miguel-Etayo1,2, Luis A. Moreno1,2, Iris Iglesia1,2, Silvia Bel-Serrat1,2, Theodora Mouratidou1,2 and Jesús M. Garagorri1,3

1GENUD «Growth, Exercise, NUtrition and Development» Research Group. University of Zaragoza, Zaragoza, (Spain).
2Facultad de Ciencias de la Salud. University of Zaragoza. Zaragoza, (Spain). 3Departamento de Pediatría, Hospital Clínico Universitario Lozano Blesa, University of Zaragoza, Zaragoza, Spain.

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 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 assessed 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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Resumen

Nutrición, actividad física y la modificación del comportamiento alimentario son técnicas muy empleadas en el tratamiento de la obesidad. El objetivo de este estudio 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, uno 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 para 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 del sobrepeso en niños y adolescentes.

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Correspondence: Pilar de Miguel-Etayo.
GENUD «Growth, Exercise, Nutrition and Development». Research Group. Universidad de Zaragoza. Edif. Cervantes. Corona de Aragón, 42. 50009 Zaragoza. E-mail: pilardm@unizar.es
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. 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). Methods to examine changes in children’s body fat composition include simple field methods such as bioelectrical impedance (BIA) and skinfold thickness measurements. 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. 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, 3rd, 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/m² 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 (table I). Seven studies involved a multi-approach intervention focusing on dietary, physical activity and behavioral interventions (D+PA+BT). Five had a dietary and physical...
N = 1,037 references identified from EMBASE database search

N = 524 references identified from MEDLINE database search

N = 7 references identified from hand search

N = 1,540 references identified from databases searches

N = 1,397 references excluded by title and abstract

N = 87 references excluded by inclusion/exclusion criteria

N = 56 relevant references for further analysis

N = 43 references excluded
- 25 descriptive studies or vase reports and cross-sectional studies
- 9 interventions targeting linked to obesity or treatment with drugs
- 2 no body composition changes specifically related to the intervention
- 7 no outcomes of body composition measurements other than weight and height or related-derived indices, during follow-up

N = 1 reference physical activity intervention

N = 5 references dietary and physical activity intervention

N = 7 references dietary, physical activity and behavioral intervention

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

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Sample size (N)</th>
<th>Age (years)</th>
<th>Obesity Criteria</th>
<th>Treatment</th>
<th>Sessions</th>
<th>Intervention</th>
<th>Follow-up</th>
<th>Body composition outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suskind RM et al, 2000</td>
<td>RCT</td>
<td>50 (17 boys and 33 girls)</td>
<td>7-17</td>
<td>Categories of obesity:</td>
<td>36 weeks</td>
<td>Weekly</td>
<td>D + PA + BT</td>
<td>9 months</td>
<td>Weight: (-9.0 kg) Percentage of body fat: Significant decrease Fat Free mass: Significant increase</td>
</tr>
<tr>
<td>Sudi KM et al, 2001</td>
<td>RCT</td>
<td>62 (40 boys and 22 girls)</td>
<td>Mean: BMI &gt;p90% for age and sex</td>
<td>3 weeks</td>
<td>NA</td>
<td>D+ PA</td>
<td>3 weeks</td>
<td>Body mass (kg): boys: (-4±1.4), girls: (-3.7±1.1) Fat Mass (kg): boys: (-4±1.4), girls: (-3.7±1.7) Fat Mass (%): boys: (-4±1.2), girls: (-2.5±1.9) Fat Free Mass (kg): boys: (-0.4±1.7), girls: (-0.4±1.2) Waist Circumference (cm): boys: (-5.5±2.1), girls: (-9±2) Hip Circumference (cm): boys: (-5.5±2.1), girls: (-6.5±2.7)</td>
<td></td>
</tr>
<tr>
<td>Sung RYT et al, 2002</td>
<td>RCT</td>
<td>82 (54 boys and 28 girls)</td>
<td>8-11</td>
<td>Weight &gt;120% of the median weight for height</td>
<td>6 weeks</td>
<td>NA</td>
<td>D+ PA</td>
<td>6 weeks</td>
<td>Training</td>
</tr>
<tr>
<td>Nemet D et al, 2005</td>
<td>RCT</td>
<td>46</td>
<td>6-16</td>
<td>Self-reported weight and height</td>
<td>3 months</td>
<td>Series of 4 evenings</td>
<td>D+PA+BT</td>
<td>12 months</td>
<td>3 months</td>
</tr>
<tr>
<td>Tsiros MD et al, 2008</td>
<td>RCT</td>
<td>47 (16 boys and 31 girls)</td>
<td>12-18</td>
<td>IOTF</td>
<td>20 weeks</td>
<td>Weekly</td>
<td>D+PA+BT</td>
<td>10 weeks</td>
<td>10 weeks</td>
</tr>
</tbody>
</table>

Weight loss: (+0.40 kg) BMI: equal Fat Mass: (-0.30 kg) Percentage body fat: (-0.70 %) Abdominal fat: (-0.10 kg) Lean tissue: (+0.09 kg) Bone mineral content: (+0.80 g) Bone mineral density: (+0.01 g/cm³) 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

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Sample size (N)</th>
<th>Age (years)</th>
<th>Obesity Criteria</th>
<th>Treatment Sessions</th>
<th>Intervention</th>
<th>Follow-up</th>
<th>Body composition outcomes</th>
</tr>
</thead>
</table>
| Davis JN et al, 2009 | RCT | 54 | 14-18 | ≥ 85th CDC percentile | 16 weeks | N: once per week | D+PA (Control [C], Nutrition [N], Nutrition and Strength training [N+ST]) | 16 weeks | N -Weight: (+0.5 kg) -BMI: (-0.4 kg/m²) -BMI z score: equal -BMI percentile: (-0.5) -Total fat: (-1.3 kg) -Total lean: (-1.1 kg) 
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) |
<p>| Tjonna AE et al, 2009 | RCT | 54 | Mean: 14 | Referred for medical treatment at Hospital | 12 months | AIT: twice a week for 3 months | D+PA (intensity-controlled aerobic interval training [AIT] and multidisciplinary approach [MTG]) | 12 months | AIT -Weight: (+0.3 kg) -BMI: (-0.7 kg/m²) -Waist circumference: (+2.8 cm) -Total fat: (-1.3 kg) -Fat weight: (-0.9 kg) -Fat weight trunk: (-1.3 kg) |</p>
<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Sample size (N)</th>
<th>Age (years)</th>
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</tr>
</thead>
</table>
| Kriemler S et al, 2010 | RCT    | 502             | 6-11        | NA                                    | Weekly    | PA       | 9 months     | MTG       | Weight: (+1.1 kg)  
|                        |        |                 |             |                                       |           |          |              |           | BMI: (+0.2 kg/m²)  
|                        |        |                 |             |                                       |           |          |              |           | Waist circumference: (+0.4 cm)  
|                        |        |                 |             |                                       |           |          |              |           | Total fat: (+1.3 kg)  
|                        |        |                 |             |                                       |           |          |              |           | Fat weight: (+0.3 kg)  
|                        |        |                 |             |                                       |           |          |              | 12 months | Fat weight trunk: (+0.2 kg)  
| Johnston CA et al, 2010| RCT    | 60 (33 boys and 27 girls) | 10-14       | BMI for age and gender:  
|                        |        |                 |             | Overweight>85th percentile  
|                        |        |                 |             | Obese >95th percentile     | SH weekly | D+PA+BT | 12 months | SH: (+3.6 kg)  
|                        |        |                 |             |                                       | ILI daily | (self held [SH], instructor-led intervention [ILI]) | 24 months | Weight: (+1.6 kg)  
|                        |        |                 |             |                                       |           |          |              |           | BMI: (+0.4 kg/m²)  
|                        |        |                 |             |                                       |           |          |              |           | BMI z score: (+0.2)  
|                        |        |                 |             |                                       |           |          |              |           | Percentage overweight: (+0.57%)  
|                        |        |                 |             |                                       |           |          |              |           | Triceps skinfolds: (+7.1 mm)  
|                        |        |                 |             |                                       |           |          |              |           | SH: (+3.4 kg)  
|                        |        |                 |             |                                       |           |          |              |           | BMI: (+0.6 kg/m²)  
|                        |        |                 |             |                                       |           |          |              |           | BMI z score: (+0.1)  
|                        |        |                 |             |                                       |           |          |              |           | Percentage overweight: (+0.3%)  
|                        |        |                 |             |                                       |           |          |              |           | Triceps skinfolds: equal  

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Collins CE et al. 2011</td>
<td>RCT</td>
<td>165 (68 boys and 97 girls)</td>
<td>5-10</td>
<td>IOTF</td>
<td>D+PA+BT</td>
<td>Weekly and Monthly</td>
<td>24 months</td>
<td>D (adjusted by age or gender*)</td>
<td>Weight: (-1.71 kg)</td>
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<td>BMI: (1.57 kg/m²)</td>
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<td>BMI z score*: (-0.35 kg/m²)</td>
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<td>Waist circumference: (-1.39 cm)</td>
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<td>Waist to height ratio: (-0.03 cm)</td>
</tr>
<tr>
<td>Magarey AM et al. 2011</td>
<td>RCT</td>
<td>169 (74 boys and 95 girls)</td>
<td>5-10</td>
<td>IOTF</td>
<td>D+PA+BT</td>
<td>Weekly and Monthly</td>
<td>6 months</td>
<td>D (adjusted by age or gender*)</td>
<td>Weight: (0.97 kg)</td>
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<td></td>
<td>BMI: (0.96 kg/m²)</td>
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<td>BMI z score*: (-0.24 kg/m²)</td>
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<td>Waist circumference: (-1.09 cm)</td>
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<td>Waist to height ratio: (+0.02)</td>
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</tbody>
</table>
Table I (cont.)

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Sample size (N)</th>
<th>Age range (years)</th>
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<tbody>
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</tr>
<tr>
<td>12 months</td>
<td>P+HL</td>
<td>BMI z score: (-0.53 ( \text{kg/m}^2 ))</td>
<td>Waist circumference z score: (-0.36 cm)</td>
<td>HL</td>
<td>BMI z score: (-0.24 ( \text{kg/m}^2 ))</td>
<td>Waist circumference z score: (-0.34 cm)</td>
<td></td>
</tr>
<tr>
<td>18 months</td>
<td>P+HL</td>
<td>BMI z score: (-0.31 ( \text{kg/m}^2 ))</td>
<td>Waist circumference z score: (-0.3 cm)</td>
<td>HL</td>
<td>BMI z score: (-0.29 ( \text{kg/m}^2 ))</td>
<td>Waist circumference z score: (-0.28 cm)</td>
<td></td>
</tr>
<tr>
<td>24 months</td>
<td>P+HL</td>
<td>BMI z score: (-0.39 ( \text{kg/m}^2 ))</td>
<td>Waist circumference z score: (-0.47 cm)</td>
<td>HL</td>
<td>BMI z score: (-0.42 ( \text{kg/m}^2 ))</td>
<td>Waist circumference z score: (-0.37 cm)</td>
<td></td>
</tr>
</tbody>
</table>

Savoye M et al, 2011

RCT 174 8-16 BMI >95th percentile 12 months NA D+PA 24 months

Weight: (-2.4 kg) BMI: (-2.1 \( \text{kg/m}^2 \)) BMI z score: (-0.16 \( \text{kg/m}^2 \)) Body fat: (-2.7 %) Body fat mass: (-3.6 kg)

Weight: (+0.3 kg) BMI: (-1.8 \( \text{kg/m}^2 \)) BMI z score: (-0.21 \( \text{kg/m}^2 \)) 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

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<th>Follow-up</th>
<th>Body composition outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shrewsbury VA et al, 2011</td>
<td>RCT</td>
<td>151</td>
<td>13-16</td>
<td>BMI z-scored &gt; 1.0 and &lt; 2.5</td>
<td>D+PA+BT</td>
<td>22 months</td>
<td>NA</td>
<td>2 months</td>
<td>Weight: (-0.2 kg) BMI: (-0.3 kg/m²) BMI z-score: (-0.04 kg/m²) Waist circumference: (-2.4 cm) Waist to height ratio: (-0.01)</td>
</tr>
</tbody>
</table>

activity intervention component (D+PA)\textsuperscript{6,7,10,11,16} and one a physical activity intervention component (PA).\textsuperscript{12}

Two of the studies used skinfolds to measure fat\textsuperscript{5, 8, 18} and two computed the sum of four skinfolds.\textsuperscript{12,13} Three studies calculated some anthropometry-related indices i.e., BMI, BMI z-score and waist to height ratio.\textsuperscript{14,15,17,19} Two studies assessed body fat by BIA \textsuperscript{6,16} and six by DXA\textsuperscript{7, 9-11} (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.\textsuperscript{16} and the highest by Tsiros MD et al.,\textsuperscript{9} 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 techniques did not facilitate drawing of clear-cut conclusions.

Traditional treatment of obesity have resulted in limited success in terms of weight and BMI\textsuperscript{20} 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\textsuperscript{7, 9-11} followed by BIA and skinfolds\textsuperscript{8,16} 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.\textsuperscript{4} The study by Hauroun D et al.\textsuperscript{3} 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