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# Associations between energy and fat intakes with adiposity in schoolchildren – the Cuenca Study

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**Abstract**

***Introduction:*** **the relationship between changes in energy intake (EI) over the last few decades and the trends towards of excess weight in children is still debated.**

***Objective:*** **to examine the relationship between energy and macronutrient intakes with adipostity in children, controlling for cardiorespiratory fitness (CRF) as a surrogate measure of physical activity.**

***Method:*** **we conducted a cross-sectional study of 320 schoolchildren aged 9-11 years (54.5% girls). We collected data on socio-demographic variables, and measured weight, height, waist circumference (WC), and fat mass percentage by bioimpedance analysis. Fat mass index (FMI) was calculated as fat mass (kg) divided by height (m) squared, to adjust for body size. Energy (kcal) and macronutrient intake (percentages) were measured by two non-consecutive 24-h recalls (weekday and weekend day), using the Young Adolescents' Nutrition Assessment on Computer (YANA-C) software program; CRF was measured by the 20-m shuttle run test.**

***Results:*** **boys in the 4th quartile of the WC distribution had lower fat intake (34.9%) than boys in the 1st (42.4%; p = 0.019) and 2nd quartiles (41.6%; p = 0.022). Children in the 1st quartile of the FMI distribution had higher daily EIs than children in the 4th quartile (1762.3 kcal *vs.* 1496.8 kcal; p = 0.023). All macronutrient intakes relative to weight were lower in children in the more adipose categories for weight status, WC and FMI (p < 0.001).**

***Conclusion:*** **adiposity was inversely related to energy and fat intakes. Excessive EI and high EI from fats not appears to be directly associated with the current obesity epidemic among schoolchildren living in Cuenca (Spain).**

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Key words: *Children. Energy intake. Obesity. Cardiorespiratory fitness.*

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**ASOCIACIÓN ENTRE LA INGESTA ENERGÉTICA Y DE GRASAS Y LA ADIPOSIDAD EN ESCOLARES - ESTUDIO CUENCA**

**Resumen**

***Introducción:*** **la relación entre los cambios en la ingesta energética en las últimas décadas y el incremento en las cifras de obesidad en niños está aún en debate.**

***Objetivo:*** **examinar la asociación entre la ingesta energética y de macronutrientes con diferentes medidas de adiposidad en niños, controlando por resistencia cardiorrespiratoria como una medida sustituta de la actividad física.**

***Método:*** **se realizó un estudio observacional sobre 320 escolares de entre 9 y 11 años (54,5% niñas). Se tomó información sobre variables sociodemográficas y se midió peso, altura, perímetro de cintura y porcentaje de masa grasa a través de bioimpedancia. El índice de masa grasa fue calculado dividiendo la masa grasa (en kg) entre la altura al cuadrado (en m), para ajustar por el tamaño corporal. La ingesta energética y el porcentaje de macronutrientes fueron medidos con dos recordatorios de 24-h en días no consecutivos (entre semana y fin de semana), empleando el software Young Adolescents' Nutrition Assessment on Computer (YANA-C); el *fitness* cardiorrespiratorio fue medido a través del test de 20 metros de ida y vuelta.**

***Resultados:*** **los niños en el cuarto cuartil de perímetro de cintura tienen una ingesta de grasas menor (34,9%) que los chicos en el primer (42,4%; p = 0,019) y segundo cuartil (41,6%; p = 0,022). Los escolares en el primer cuartil de índice de masa grasa tienen mayor ingesta energética total que los escolares del cuarto cuartil (1762,3 kcal *vs.* 1496,8 kcal; p = 0,023). Las ingestas de macronutrientes relativas al peso son menores en los sujetos de las categorías más altas de estatus ponderal, perímetro de cintura e índice de masa corporal (p < 0,001).**

***Conclusión:*** **la adiposidad está inversamente asociada con las ingestas energética y de grasas. Una excesiva ingesta energética y de grasas no parece estar directamente asociada con la actual epidemia de obesidad de los escolares de Cuenca (España).**

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Palabras clave: *Niños. Ingesta energética. Obesidad. Resistencia cardiorrespiratoria.*

**Abbreviations:**

%EIC: Percentages of energy intake from carbohydrate.
%EIF: Percentages of energy intake from fat.
%EIP: Percentages of energy intake from protein.
BMI: Body mass index.
CRF: Cardiorespiratory fitness.
EI: Energy intake.
FM: Fat mass.
FMI: Fat mass index.
PA: Physical activity.
WC: Waist circumference.
YANA-C: Young Adolescents' Nutrition Assessment on Computer.

## Introduction

Paediatric obesity has become a global public health problem[1,2]. The prevalence of childhood overweight/obesity was over 35% in 2010 in the province of Cuenca, Spain[3]; similar rates of overweight/obesity have been reported for other Spanish study[4], some Mediterranean countries[5] and the USA[1].

Childhood overweight and obesity have been associated with decreased quality of life and psychosocial problems and are strongly associated with long-term effects on mortality and morbidity[2].

Obesity is influenced by both genetic and lifestyle factors[5,6], such as dietary habits and physical activity patterns. In the industrialised countries higher consumption of energy-dense foods and the increase in the prevalence of sedentary behaviours have been repeatedly established as the main factors underlying the global obesity epidemic[5,7]. Among them, the increase of total intake and the decreased in the practise of physical activity had created a positive energy balance with the result of weight gain[8,9]. However, this theory has not always been demonstrated.

Some cross-sectional studies have reported a positive association between energy intake and adiposity[8,10], but others have found no association[11] or a negative association[12-14]. Similarly studies that addressed the relationship between fat intake and weight in children have reported either positive, negative or no association between these variables[6,8,13,15]. The lack of assessing the influence of physical activity on EI is an important weakness of most studies reporting an association between EI or the macronutrient composition of the diet and adiposity[8,15]. Cardiorespiratory fitness (CRF) is greatly influenced by regular physical activity[16], and a negative association between adiposity and CRF in children has previously been reported[16,17].

In the unclear relationship between energy intake and obesity, are need explanations for the increase of BMI over the last decades. One of the most consolidated in the last years is the theory about the amount of fat cells is based on the physical activity play early in life, instead the amount of energy intakes[18].

The aim of this study was to analyse EI and the macronutrient composition of EI in term of body composition categories, controlling for CRF, in children aged 9-11 years from Cuenca, Spain.

## Materials and Methods

### *Design*

We conducted a cross-sectional analysis of baseline measurements (September-November 2010) from a cluster-randomised trial whose study methods have been reported elsewhere[19] (trial registered at Clinicaltrials.gov, number NCT01277224). The aim of this trial was to assess the effectiveness of the MOVI-2 program in preventing overweight and reducing cardiovascular risk in 4th and 5th grade primary schoolchildren in Cuenca, Spain. All the 783 primary schoolchildren aged 9-11 years old who belonged to one of the 20 public schools in the province of Cuenca, Spain, were invited to participate. Participants completed two testing sessions in a time-span of one week. Body composition and fitness were assessed in the first session and a 24-h diet recall was conducted; a further 24-h recall was completed in the second session.

### *Ethical and legal considerations*

The study was approved by the Clinical Research Ethics Committee of the 'Virgen de la Luz' Hospital in Cuenca. After the study had been approved by the Director and Board of Governors (*Consejo Escolar*) of participating schools, parents were asked to provide written consent for the participation of their children.

Data were collected at the schools by trained members of the research group as outline bellow.

### *Measures*

a) Body composition

Participants were weighed twice whilst wearing light clothing, using a digital scale with an accuracy of 100 g. Height without shoes was measured twice using a wall-mounted stadiometer, to the nearest 0.1 cm. The mean of these measurements was used to calculate BMI (kg/m$^2$). Children were assigned to weight status categories using the gender- and age-specific cut-offs defined by Cole et al., overweight: > mean + 1 SD; obesity: > 2SD + mean; thinness: < mean – 2SD[20]. Waist circumference (WC) was defined as the average of two measurements taken with flexible tape at the waist. The percentage fat mass (FM) was estimated using a bioimpedance analysis system (BC-418, Tanita Corp, Tokyo, Japan). Finally, fat mass index (FMI = fat mass/height$^2$ – kg/m$^2$) was calculated. This index has been widely used in studies in children; it is considered a more appropriate index of fatness than body fat percentage as height is more appropriate as measure of children's body size than weight[21]. Sexual maturation was assessed by parents using figures depicting the Tanner stages of sexual maturity.

b) Food consumption

Energy and macronutrient intake were estimated using a self-administered computerised 24-h dietary recall, the Young Adolescents' Nutrition Assessment on Computer (YANA-C). 24-h recalls are the best method of collecting information about intake and have been recommended for comparing data on food intake in different groups of European adolescents[22]. YANA-C makes it possible to assess the dietary intake of adolescents in a broad international context and show moderate to good levels of reliability and validity[23]. The Spanish version of the YANA-C questionnaire was administered twice in a time-span of one week –once with respect to a weekday and once with respect to a weekend day. Pupils completed the program independently, with two or three staff members on hand to provide assistance if required. When children had completed the questionnaire the researchers checked the overview screen for extreme values or missing data. Staff members had been previously trained with specific instructions about including information about intake of fluids, bread, sauce and other foods that children often forget when they complete these questionnaires. The mean of the two 24-h recalls was used as a measured of total daily EI (in kJ) and total daily nutrient intake. Percentages of EI from carbohydrate (%EIC), protein (%EIP) and fat (%EIF) and macronutrients (g) relative to weight (kg) were calculated. The compositions of all of food and beverages were estimated using the food composition tables produced by the Centre for Superior Studies in Nutrition and Dietetics (CESNID)[24].

c) Cardiorespiratory fitness

CRF was assessed by the 20-m shuttle run test; and VO2 max was calculated using the Léger protocol[25]. The 20m shuttle run test or adaptations is the test most commonly used for assessing CRF in the epidemiological studies involving young people[17].

*Statistical analysis*

The normality and homoscedasticity distributions of the investigated variables were examined by using graphical (normal probability plot) and statistical procedures (Kolmogorov-Smirnov test). Basic descriptive statistics (mean and standard deviation) were calculated.

Pearson's correlation coefficient was used to assess correlations between variables. One-way analysis of covariance (ANCOVA) was used to assess group differences in energy and macronutrient intake with weight status, WC and FMI, as group factors, controlling for age, sex and CRF. The Bonferroni test was used for pairwise comparisons.

The level of significance for all statistical tests was set at $p \leq 0.05$. All calculations were performed using IBM SPSS Statistics 22.

## Results

Three hundred and twenty (54.5% girls) of the 783 schoolchildren who were invited to participate completed all the measurements. Anthropometric data, food consumption, CRF and weight status are presented in table I. Girls were taller than boys (142.9 cm vs. 140.6cm; p=0.003) and had a higher FM (27.0 vs. 24.1; p<0.001). Boys had better CRF, expressed as VO2 max, than girls (44.3ml/kg/min vs. 41.5ml/kg/min; p<0.001) and a higher mean protein intake: weight ratio (2.0g/kg vs. 1.8g/kg; p<0.05). There were no differences in sociodemographic characteristics between children who participated in our study and eligible children who did not.

Table II shows the bivariate correlations between anthropometric variables, energy and macronutrient intake and CRF. EI was negatively associated with FM (r=-0.186; p<0.001) and FMI (r=-0.134; p<0.05); %EIP was positively associated with BMI, WC, FM, and FMI (r ranged from 0.115 to 0.130; p<0.05) and weight-adjusted intakes of carbohydrate, protein and fat were negatively associated with all anthropometric variables and positively associated with CRF (p<0.01).

Tables III to V show means for EI, percentage of energy from macronutrients and weight-adjusted intake of macronutrients by BMI, WC and FMI, respectively, controlling for age and CRF, by sex.

Table III presents data showing that fat intake was higher in normal weight boys than their overweight peers (41.3% vs. 36.6%; p=0.045). When macronutrient intake was expressed relative to weight the highest intakes were found in underweight children; their intakes were higher than those of obese children (p<0.001).

Table IV presents data showing that %EIF was lower in boys in the 4th quartile of the WC distribution (34.9%) than in boys in the 1st quartile (42.4%; p=0.019) or 2nd quartile (41.6%; p=0.022).

Finally, table V presents data showing that EI was higher for children in the 1st quartile of the FMI distribution (1762.3kcal) than in the 4th quartile (1496.8 kcal; p=0.023). %EIP was lower for children in the 2nd quartile (16.9%) than children in the 4th quartile (19.2%; p=0.05). The %EIF was higher for boys in the 1st quartile of the FMI distribution (43.6%) than boys in the 4th quartile (35.4%; p=0.015); %EIF was also higher in the 1st quartile of the FMI distribution for the sample as a whole (41.3%) than in the 4th quartile (36.5%; p=0.018).

**Table I**
*Descriptive characteristics of subjects*

| | Overall (n=320) | | Boys (n=146) | | Girls (n=174) | | |
|---|---|---|---|---|---|---|---|
| | Mean ± SD | | Mean ± SD | | Mean ± SD | | $P^a$ |
| Age (years) | 10.0 ± 0.5 | | 10.0 ± 0.5 | | 10.0 ± 0.4 | | 0.335 |
| Height (cm) | 141.9 ± 6.9 | | 140.6 ± 6.6 | | 142.9 ± 7.0 | | **0.003** |
| Weight (kg) | 39.3 ± 9.2 | | 38.7 ± 8.7 | | 39.9 ± 9.5 | | 0.236 |
| BMI (kg/m²) | 19.4 ± 3.4 | | 19.2 ± 3.6 | | 19.4 ± 3.7 | | 0.908 |
| WC (cm) | 68.9 ± 9.2 | | 68.9 ± 9.2 | | 68.8 ± 9.3 | | 0.978 |
| FM (%) | 25.7 ± 6.5 | | 24.1 ± 7.0 | | 27.0 ± 5.7 | | **<0.001** |
| FMI (kg/m²) | 5.2 ± 2.3 | | 4.9 ± 2.4 | | 5.4 ± 2.2 | | **<0.001** |
| Tanner stage | 1.6 ± 0.7 | | 1.6 ± 0.7 | | 1.6 ± 0.6 | | 0.345 |
| (I–II/III–V) (%) | 86.8 (13.2) | | 85.6 (14.4) | | 87.7 (12.3) | | 0.721 |
| EI (kcal) | 1612.1 ± 506.8 | | 1648.0 ± 516.9 | | 1582.0 ± 497.7 | | 0.245 |
| Carbohydrate (%) | 42.6 ± 9.5 | | 42.0 ± 9.4 | | 43.2 ± 9.6 | | 0.251 |
| Protein (%) | 18.0 ± 4.6 | | 18.4 ± 4.9 | | 17.6 ± 4.5 | | 0.131 |
| Fat (%) | 39.4 ± 8.6 | | 39.7 ± 8.5 | | 39.2 ± 8.7 | | 0.611 |
| Carbohydrate/weight (g/kg) | 4.6 ± 2.0 | | 4.7 ± 2.0 | | 4.5 ± 2.0 | | 0.426 |
| Protein/weight (g/kg) | 1.9 ± 0.8 | | 2.0 ± 0.8 | | 1.8 ± 0.8 | | **0.041** |
| Fat/weight (g/kg) | 2.0 ± 1.0 | | 2.0 ± 1.1 | | 1.9 ± 0.9 | | 0.140 |
| CRF (ml/kg/min) | 42.8 ± 4.3 | | 44.3 ± 4.7 | | 41.5 ± 3.3 | | **<0.001** |
| | % | n | % | n | % | n | |
| Underweight (%) | 8.4 | 27 | 8.2 | 12 | 8.6 | 15 | 0.941 |
| Normal weight (%) | 55.0 | 176 | 54.1 | 79 | 55.7 | 97 | 0.856 |
| Overweight (%) | 28.4 | 91 | 30.8 | 45 | 26.4 | 46 | 0.458 |
| Obese (%) | 8.1 | 26 | 6.8 | 10 | 9.2 | 16 | 0.575 |

BMI, body mass index; WC, waist circumference; FM, fat mass; FMI: fat mass/height²; EI, energy intake; CRF, cardiorespiratory fitness. aGender group comparisons were conducted by T-test for continuous variable and Pearson´s x2 for categorical variables prevalence of ponderal status and Tanner stage. Statistically significant values are presented in bold ($p \leq 0.05$).

**Table II**
*Bivariate correlations among anthropometric characteristics and energy intake*

| | EI | %EIC | %EIP | %EIF | C/Wt | P/Wt | F/Wt |
|---|---|---|---|---|---|---|---|
| Weight | -0.092 | 0.000 | 0.085 | -0.049 | -0.573** | -0.524** | -0.493** |
| BMI | -0.097 | -0.033 | 0.119* | -0.030 | -0.549** | -0.468** | -0.458** |
| WC | -0.089 | -0.013 | 0.130* | -0.058 | -0.547** | -0.453** | -0.468** |
| FM | -0.186** | 0.009 | 0.128* | -0.081 | -0.559** | -0.500** | -0.495** |
| FMI | -0.134* | -0.016 | 0.115* | -0.046 | -0.537** | -0.463** | -0.470** |
| CRF | 0.064 | 0.035 | -0.011 | -0.031 | 0.332** | 0.293** | 0.224** |

EI, energy intake; %EIC, percentage of energy ascribed to carbohydrates; %EIP, percentage of energy ascribed to protein; %EIF, percentage of energy ascribed to fat, C/Wt, carbohydrates (g)/ weight (kg); P/Wt, protein (g)/ weight (kg); F/Wt, fat (g)/ weight (kg); BMI, body mass index; WC, waist circumference; FM, fat mass; FMI, fat mass/height²; CRF, cardiorespiratory fitness; *$p<0.05$; **$p<0.01$.

**Table III**

*Mean differences in energy intake, percentage of energy from macronutrients and total macronutrients intake relative to weight, by weight status, controlling for cardiorespiratory fitness and age, by sex*

| | Weight status[1] | EI (kcal) | %EIC | %EIP | %EIF | C/Wt(g/kg) | P/Wt(g/kg) | F/Wt(g/kg) |
|---|---|---|---|---|---|---|---|---|
| | | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD |
| Boys | Underweight(n=12) | 1801.5 ± 363.1 | 39.4 ± 9.4 | 18.1 ± 4.3 | 42.4 ± 9.0 | 6.4 ± 1.3[b,c] | 3.0 ± 0.8[a,b,c] | 3.1 ± 1.0[b,c] |
| | Normal weight (n=79) | 1673.0 ± 518.6 | 40.7 ± 9.1 | 18.0 ± 4.9 | 41.3 ± 8.4 [d] | 4.9 ± 1.9 | 2.1± 0.8[e] | 2.3± 1.2[d,e] |
| | Overweight (n=45) | 1603.1 ± 554.5 | 44.2 ± 9.9 | 19.2 ± 5.3 | 36.6 ± 8.4 | 4.2 ± 1.9 | 1.7 ± 0.8 | 1.5 ± 0.7 |
| | Obese (n=10) | 1469.8 ± 543.2 | 44.5 ± 10.0 | 18.2 ± 2.8 | 37.3 ± 8.4 | 3.4 ± 1.3 | 1.2 ± 0.4 | 1.0 ± 0.6 |
| | p* | 0.604 | 0.297 | 0.682 | 0.051 | **0.005** | **<0.001** | **<0.001** |
| Girls | Underweight (n= 15) | 1699.2 ± 315.3 | 46.0 ± 10.1 | 16.5 ± 4.3 | 37.5 ± 7.3 | 7.3 ± 2.1[a,b,c] | 2.6 ± 0.6 [a,b,c] | 2.7 ± 0.8 [a,b,c] |
| | Normal weight (n=97) | 1590.2 ± 491.8 | 43.3 ± 8.8 | 17.4 ± 4.7 | 39.3 ± 8.0 | 4.8 ± 1.7[d,e] | 1.9 ± 0.8[d] | 2.0 ± 0.9[d] |
| | Overweight (n=46) | 1489.0 ± 525.8 | 42.9 ± 11.6 | 18.0 ± 4.3 | 39.0 ± 10.5 | 3.3 ± 1.1 | 1.5 ± 0.6 | 1.5 ± 0.9 |
| | Obese (n=16) | 1689.1± 553.0 | 40.4 ± 7.6 | 18.8 ± 3.6 | 40.8 ± 8.6 | 3.1 ± 1.0 | 1.5 ± 0.4 | 1.4 ± 0.5 |
| | p* | 0.358 | 0.497 | 0.509 | 0.797 | **<0.001** | **<0.001** | **<0.001** |
| Overall | Underweight (n= 27) | 1733.7 ± 330.8 | 43.8 ± 9.7 | 17.0 ± 4.3 | 39.2 ± 8.0 | 6.9 ± 1.8[a,b,c] | 2.7 ± 0.7 [a,b,c] | 2.8 ± 0.9 [a,b,c] |
| | Normal weight (n=176) | 1624.6 ± 503.1 | 42.4 ± 8.9 | 17.6 ± 4.8 | 40.0 ± 8.2 | 4.9 ± 1.8[d,e] | 2.0 ± 0.8[d,e] | 2.1 ± 1.0[d,e] |
| | Overweight (n=91) | 1548.8 ± 543.2 | 43.0 ± 10.7 | 18.8 ± 4.9 | 38.2 ± 9.5 | 3.7 ± 1.5 | 1.6 ± 0.7 | 1.5 ± 0.8 |
| | Obese (n=26) | 1623.0 ± 538.3 | 41.6 ± 8.4 | 18.7 ± 3.3 | 39.8 ± 8.4 | 3.2 ± 1.1 | 1.4 ± 0.4 | 1.3 ± 0.5 |
| | p* | 0.432 | 0.817 | 0.210 | 0.458 | **<0.001** | **<0.001** | **<0.001** |

%EIC: percentage of energy ascribed to carbohydrates; %EIP: percentage of energy ascribed to protein; %EIF: percentage of energy ascribed to fat; C/Wt: carbohydrates (g)/ weight (kg); P/Wt: protein (g)/ weight (kg); F/Wt: fat (g)/ weight (kg). Statistically significant values are presented in bold ($p \leq 0{\cdot}05$). [1]Body mass index cut off according to International Obesity Task Force (IOTF) criteria.
[a]Significant difference between underweight and normal weight.
[b]Significant difference between underweight and overweight.
[c]Significant difference between underweight and obese.
[d]Significant difference between normal weight and overweight.
[e]Significant difference between normal weight and obese.
[f]Significant difference between overweight and obese.
[*]Bonferroni-adjusted pairwise comparisons.

**Table IV**
*Mean differences in energy intake, percentage of energy from macronutrients and macronutrients intake relative to weight, by quartiles of waist circumference, controlling for cardiorespiratory fitness and age, by sex*

| | WC | EI (kcal) | %EIC | %EIP | %EIF | C/Wt (g/kg) | P/Wt(g/kg) | F/Wt(g/kg) |
|---|---|---|---|---|---|---|---|---|
| | | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD |
| Boys | Q1 (n=36) | 1742.3 ± 497.3 | 39.7 ± 9.8 | 18.0 ± 4.8 | 42.4[c] ± 9.3 | 5.9 ± 2.2[b,c] | 2.6 ± 0.8[a,b,c] | 2.9 ± 1.2[b,c] |
| | Q2 (n=35) | 1671.1 ± 468.9 | 41.6 ± 9.0 | 16.9 ± 3.7 | 41.6 ± 8.9[e] | 4.9 ± 1.6 | 2.0 ± 0.7 | 2.3 ± 1.1[e] |
| | Q3 (n=38) | 1537.1 ± 472.5 | 40.5 ± 8.5 | 19.9 ± 5.2 | 39.6 ± 6.7 | 3.9 ± 1.7 | 1.9 ± 0.7 | 1.7 ± 0.7 |
| | Q4 (n=35) | 1625.3 ± 625.1 | 46.1 ± 10.3 | 19.0 ± 5.1 | 34.9 ± 9.0 | 4.0 ± 1.7 | 1.6 ± 0.8 | 1.3 ± 0.9 |
| | p* | 0.469 | 0.065 | 0.074 | **0.015** | **<0.001** | **<0.001** | **<0.001** |
| Girls | Q1 (n=43) | 1674.5 ± 414.1 | 43.4 ± 8.9 | 16.3 ± 4.6 | 40.3 ± 7.6 | 6.3 ± 2.1[a,b,c] | 2.3 ± 0.9[b,c] | 2.6 ± 0.8[a,b,c] |
| | Q2 (n=45) | 1601.6 ± 471.6 | 44.4 ± 8.7 | 17.6 ± 4.8 | 38.0 ± 7.7 | 4.8 ± 1.6[d,e] | 1.9 ± 0.7[e] | 1.9 ± 0.7[e] |
| | Q3 (n=43) | 1525.2 ± 576.3 | 42.2 ± 10.0 | 17.8 ± 4.4 | 40.0 ± 9.5 | 3.7 ± 1.3 | 1.6 ± 0.7 | 1.7 ± 0.9 |
| | Q4 (n=43) | 1525.7 ± 499.8 | 42.7 ± 10.8 | 18.7 ± 4.1 | 38.5 ± 9.7 | 3.1 ± 1.0 | 1.4 ± 0.6 | 1.3 ± 0.7 |
| | p* | 0.564 | 0.759 | 0.190 | 0.570 | **<0.001** | **<0.001** | **<0.001** |
| Overall | Q1 (n=79) | 1699.9 ± 451.3 | 42.1 ± 9.3 | 17.0 ± 4.6 | 40.9 ± 8.4 | 6.1 ± 2.1[a,b,c] | 2.4 ± 0.8[a,b,c] | 2.7 ± 1.0[a,b,c] |
| | Q2 (n=80) | 1635.3 ± 469.3 | 43.5 ± 8.8 | 17.2 ± 4.4 | 39.3 ± 8.3 | 4.9 ± 1.6[d,e] | 1.9 ± 0.7[e] | 2.1 ± 0.9[e] |
| | Q3 (n=81) | 1530.9 ± 527.3 | 41.4 ± 9.4 | 18.7 ± 4.9 | 39.8 ± 8.3 | 3.8 ± 1.5 | 1.7 ± 0.7 | 1.7 ± 0.8 |
| | Q4 (n=78) | 1572.4 ± 561.9 | 43.5 ± 10.5 | 19.1 ± 4.5 | 37.5 ± 9.4 | 3.4 ± 1.4 | 1.5 ± 0.7 | 1.4 ± 0.8 |
| | p* | 0.256 | 0.434 | **0.025** | 0.156 | **<0.001** | **<0.001** | **<0.001** |

WC, Waist circumference; EI, energy intake; %EIC, percentage of energy ascribed to carbohydrates; %EIP, percentage of energy ascribed to protein; %EIF, percentage of energy ascribed to fat; C/Wt, carbohydrates (g)/ weight (kg); P/Wt, protein (g)/ weight (kg); F/Wt, fat (g)/ weight (kg). Statistically significant values are presented in bold ($p \leq 0.05$).
[a]Significant difference between Q1 and Q2.
[b]Significant difference between Q1 and Q3.
[c]Significant difference between Q1 and Q4.
[d]Significant difference between Q2 and Q3.
[e]Significant difference between Q2 and Q4.
[f]Significant difference between Q3 and Q4.
*Bonferroni-adjusted pairwise comparisons.

**Table V**
*Mean differences in energy intake, percentage of energy from macronutrients and macronutrients intake relative to weight by quartiles of fat mass index, controlling for cardiorespiratory fitness and age, by sex*

| | FMI | EI(kcal) | %EIC | %EIP | %EIF | C/Wt(g/kg) | P/Wt(g/kg) | F/Wt(g/kg) |
|---|---|---|---|---|---|---|---|---|
| | | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD |
| Boys | Q1 (n=36) | 1809.1 ± 504.8 | 39.2 ± 9.7 | 17.2 ± 4.2 | 43.6 ± 9.1[c] | 6.1 ± 2.3[b,c] | 2.6 ± 0.8[a,b,c] | 3.1 ± 1.2[a,b,c] |
| | Q2 (n=37) | 1715.1 ± 449.9 | 42.3 ± 8.9 | 17.4 ± 5.2 | 40.4 ± 8.6 | 5.0 ± 1.4[e] | 2.1 ± 0.7[e] | 2.3 ± 1.1[e] |
| | Q3 (n=37) | 1593.7 ± 621.3 | 41.5 ± 8.9 | 19.2 ± 3.8 | 39.3 ± 7.9 | 4.0 ± 1.8 | 1.9 ± 0.8 | 1.7 ± 0.9[f] |
| | Q4 (n=36) | 1474.2 ± 483.0 | 44.8 ± 10.2 | 19.8 ± 5.7 | 35.4 ± 8.4 | 3.5 ± 1.4 | 1.4 ± 0.6 | 1.1 ± 0.6 |
| | p* | 0.170 | 0.233 | 0.177 | **0.015** | **<0.001** | **<0.001** | **<0.001** |
| Girls | Q1 (n=43) | 1744.4 ± 384.0 | 43.7 ± 8.4 | 16.7 ± 4.7 | 39.7 ± 6.6 | 6.5 ± 1.9[a,b,c] | 2.4 ± 0.8[a,b,c] | 2.6 ± 0.8[a,b,c] |
| | Q2 (n=44) | 1616.4 ± 573.0 | 43.6 ± 9.5 | 16.6 ± 4.2 | 39.7 ± 9.8 | 4.7 ± 1.7[d,e] | 1.8 ± 0.6 | 2.0 ± 0.9[e] |
| | Q3 (n=44) | 1477.4 ± 465.9 | 40.7 ± 10.2 | 18.6 ± 4.7 | 40.6 ± 9.1 | 3.6 ± 1.4 | 1.7 ± 0.8 | 1.7 ± 0.8 |
| | Q4 (n=43) | 1491.7 ± 499.9 | 44.8 ± 10.0 | 18.5 ± 4.1 | 36.7 ± 8.6 | 3.2 ± 1.0 | 1.4 ± 0.6 | 1.2 ± 0.6 |
| | p* | 0.109 | 0.224 | 0.090 | 0.202 | **<0.001** | **<0.001** | **<0.001** |
| Overall | Q1 (n=79) | 1762.3 ± 441.8[c] | 41.8 ± 8.9 | 16.9 ± 4.5 | 41.3 ± 7.8[c] | 6.3 ± 2.1[a,b,c] | 2.5 ± 0.8[a,b,c] | 2.8 ± 1.0[a,b,c] |
| | Q2 (n=81) | 1654.0 ± 519.3 | 43.3 ± 9.2 | 16.9 ± 4.7[e] | 39.8 ± 9.2 | 4.8 ± 1.5[d,e] | 1.9 ± 0.7[e] | 2.1 ± 1.0[d,e] |
| | Q3 (n=81) | 1536.2 ± 544.0 | 41.1 ± 9.6 | 18.8 ± 4.3 | 40.0 ± 8.5 | 3.9 ± 1.6 | 1.8[f] ± 0.8 | 1.7[f] ± 0.8 |
| | Q4 (n=79) | 1496.8 ± 491.6 | 44.3 ±10.1 | 19.2 ± 5.0 | 36.5 ± 8.5 | 3.3 ± 1.2 | 1.5 ± 0.6 | 1.2 ± 0.6 |
| | p* | **0.023** | 0.180 | **0.005** | **0.018** | **<0.001** | **<0.001** | **<0.001** |

FMI, fat mass index (kg/m$^2$); EI, energy intake; %EIC, percentage of energy ascribed to carbohydrates; %EIP, percentage of energy ascribed to protein; %EIF, percentage of energy ascribed to fat; C/Wt, carbohydrates (g)/ weight (kg); P/Wt, protein (g)/ weight (kg); F/Wt, fat (g)/ weight (kg). Statistically significant values are presented in bold (p≤0.05).
[a]Significant difference between Q1 and Q2.
[b]Significant difference between Q1 and Q3.
[c]Significant difference between Q1 and Q4.
[d]Significant difference between Q2 and Q3.
[e]Significant difference between Q2 and Q4.
[f]Significant difference between Q3 and Q4.
*Bonferroni-adjusted pairwise comparisons

In both sexes weight-adjusted intakes of carbohydrate, protein and fat were higher in children in the lower WC and FMI categories than those in the higher categories ($p<0.01$).

## Discussion

This study estimated total EI and macronutrient intake for various body composition categories, adjusting for a surrogate measure of physical activity, CRF. Our data indicated that both energy and fat intake were lower in children who had higher weight or adiposity categories (WC and FMI).

### *Energy intake and adiposity*

It is frequently assumed that overweight children have higher EIs than their non-overweight counterparts but this has not always been confirmed by data from cross-sectional studies; there have been reports of negative associations, positive associations or lack of association between EI and adiposity from both cross-sectional and prospective studies[26].

In our study, children in either lower weight or adiposity categories had higher EIs than their peers with greater FM. Negative association between total EI and FM[27] or BMI[6,14,28] have been observed repeatedly. Several possible explanations for this counterintuitive negative relationship between EI and adiposity have been suggested as consciously or unconsciously obesity-related under-reporting[27], or under-reporting due to errors in estimating portion size, although in this respect, results are controversial[6]. This bias may partly account for the inconsistencies in the data and lack of consensus on relationship among critical variables[27]. The second explanation proposes that there are differences in energy expenditure related to weight status categories such that the reduction in EI in fatter children is insufficient fully to offset their lower energy output[9]. This argument is consistent with an international observation, which found that the increase in childhood adiposity over recent decades has coincided with a reduction in EI and %EIF[29].

In recent years it has been proposed that vigorous physical activity and mechanical stimulation of the body at an early age stimulate stem cells to differentiate into bone and muscle rather than fat, with the result that ingested nutrients tend to be partitioned into lean tissue rather than fat. In consequence, active youths tend to ingest more energy than their sedentary peers without an increase in the percentage of their body mass that is fatty tissue[18].

The current body of evidence does not provide a clear picture of the main drivers of present trends in weight gain[30]; we note however that our data are consistent with results from two other cross-sectional studies the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) and the European Youth Heart Study (EYHS), which showed that EI was negatively associated with FM[12].

### *Macronutrients and adiposity*

The amount of carbohydrates reportedly consumed by the participants was lower than international recommendations (≥55%), even in the lean subjects[15]. %EIC in overweight and obese children was no higher than in their lean counterparts, before and after adjusting for CRF. Several studies have reported a negative association between adiposity and %EIC[11,31]. When carbohydrate intake is expressed in grams per kilogram of body weight, children with a higher percentage of body fat or excess weight have a significantly lower carbohydrate intake than leaner peers. This negative association between carbohydrate intake: weight ratio and adiposity indicators has also been reported in a previous study reported that it may be due to the lower energy density of carbohydrates, or because carbohydrates are more satiating and convert to body fat less efficiently than others macronutrients[13].

Conversely a high protein intake may indicate unhealthy dietary choices which result in higher adiposity[32]. A longitudinal study that followed children from an early age have reported a positive relationship involving protein intake, body size and adiposity[33]. Similarly in cross-sectional studies, %EIP has been reported to be higher in overweight children[34], a finding replicated in this study: we found that %EIP was higher in the most adipose children than in less adipose peers (with lower WC or FMI). When protein intake was expressed in grams per kilogram body weight these differences were reversed; although %EIP increased with the adiposity, EI decreased and protein intakes in grams was lower across all adiposity categories. More robust longitudinal studies are needed to clarify the relationship between obesity and dietary intake.

Finally, researches investigating fat intake and body composition in children have reported inconsistent evidence. Some studies have reported positive between fat intake and adiposity[11,15], whilst others have found no associations[8,27,32] or a negative association[6]. In our sample %EIF was negatively associated with adiposity in children before and after adjusting for CRF.

Previous researches on associations involving macronutrients, EI, and adiposity have produced mixed results and lack of control variables is a common problem in this research. Data on physical activity levels should always be considered in analyses of the relationship between EI and adiposity indicators. Some previous studies which have reported positive association between EI and adiposity did not consider PA, EI and adiposity jointly[6,9,28], and others studies relied on self-reported PA data[13,27].

The advantages of this study include: the use of youth self-report data on diet, which is less likely to be influenced by social desirability bias than when parents are the responders, since parents are still primarily responsible for the dietary intake of school-age children; and the statistical control of the potential confounding role of physical activity by including measured data on aerobic capacity, which is a proxy for daily physical activity levels[17].

*Limitations*

A number of limitations of this study should be considered. The main limitation is the use of a cross-sectional design, which renders it impossible to make causal inferences. Secondly, the high non-response rate (46%) may have affected the representativeness of the sample; estimations of mean macronutrient intakes should be treated with caution, although reported differences between body composition categories should be reliable. Thirdly, there are some methodological problems relating to assessment of diet in children, whether directly or by adult proxy[28]. Although new technologies to measured energy intake may be more accurate, 24-h recalls offer the possibility of underreporting in obese children. This bias has been reported when comparing obese with non-obese individuals, but our study also presents patterns of intake in thinner children. In addition, to minimize underestimation a member of the research team conducted a review of the six meal occasions before children had finished the 24-h recall. Finally, we did not control for variance in sexual maturation; in our opinion the homogeneity of the sample with respect to this variable (see table I) made this unnecessary. Moreover, not all parents answered the question related on the Tanner stages, thus, the control for this variable would diminish, in an important way, the statistical power of our study.

## Conclusions

Overall, our study demonstrated that in a population-based sample of schoolchildren from Cuenca, Spain, adiposity was negatively associated with EI, after controlling for aerobic capacity. Furthermore, our data also showed that %EIF was lower in more adipose children. Our data are important from the public health point of view, because they suggest that promoting physical activity rather than simply reducing the amount of EI should be effective to prevent excess weight in children. Future research should include three or more 24-h dietary recalls in order to increase the statistical power of the analysis by reducing variability in estimates of the dietary components; sugars and starches should be discriminated. Objective measurement of physical activity using accelerometers should be a part of future longitudinal studies to elucidate the independent influences of diet and physical activity on the current obesity epidemic.


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