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Breakfast, plasma glucose and B-hydroxybutyrate, body mass index and academic performance in children from Extremadura, Spain
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**Introduction**

Patterns of breakfast intake among children are a public health concern. Breakfast is one of the principal meals for children since it ends their long nocturnal fast and provides them with the necessary nutrients to face a morning of play and/or studies. Numerous studies have suggested that a deficient breakfast or its omission, even in populations with a good general nutritional status, can interfere with intellectual functions (cognition) and with the normal development of learning in school. Nevertheless, it has yet to be well established which are the metabolic, hormonal, or neurotransmitter factors involved in the relationship between breakfast and cognitive functions. Also, the quality of breakfast meals for children since it ends their long nocturnal fast and provides them with the necessary nutrients to face a morning of play and/or studies. Numerous studies have suggested that a deficient breakfast or its omission, even in populations with a good general nutritional status, can interfere with intellectual functions (cognition) and with the normal development of learning in school. Nevertheless, it has yet to be well established which are the metabolic, hormonal, or neurotransmitter factors involved in the relationship between breakfast and cognitive functions. Also, the quality of breakfast meals for children since it ends their long nocturnal fast and provides them with the necessary nutrients to face a morning of play and/or studies. Numerous studies have suggested that a deficient breakfast or its omission, even in populations with a good general nutritional status, can interfere with intellectual functions (cognition) and with the normal development of learning in school. Nevertheless, it has yet to be well established which are the metabolic, hormonal, or neurotransmitter factors involved in the relationship between breakfast and cognitive functions.

**Abstract**

**Objectives:** Nutritional aspects of breakfast, plasma levels of glucose and \( \beta \)-hydroxybutyrate, body mass index and academic performance have been studied in urban and rural children (Extremadura, Spain).

**Methods:** Representative samples of schoolchildren (3 to 12 years old, random cluster-sampling in schools).

**Results:** Children’s mean caloric intake with breakfast was 331 kcal. Rural population ingested more carbohydrates (46.9 ± 12.3% versus 43.3 ± 13.2% of the total caloric intake) and fewer lipids (40.5 ± 11.8% versus 43.9 ± 12.8% of the total caloric intake) than the urban population. Academic performance was significantly better in the children inhabiting the rural zone than in those of the urban zone. The glycaemia was higher in the urban than in the rural children, and that the contrary was the case for the \( \beta \)-hydroxybutyrate values. Neither glucose nor \( \beta \)-hydroxybutyrate levels were correlated with academic performance values. BMI was significantly increased in the urban versus rural children.

**Conclusion:** The present results emphasize the importance of breakfast and life style in the weight and the academic performance of children.


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**Resumen**

**Objetivos:** En poblaciones rurales y urbanas de niños de Extremadura, España, se han estudiado aspectos nutricionales del desayuno, los niveles plasmáticos de glucosa y de \( \beta \)-hidroxibutirato, el índice de masa corporal y el rendimiento académico.

**Métodos:** Se tomaron muestras representativas de los niños (3 a 12 años de edad) aleatoriamente en las diferentes clases de los colegios seleccionados.

**Resultados:** La ingesta media de calorías en el desayuno fue de 331 kcal. La población rural ingería más carbohidratos (46.9 ± 12.3% versus 43.3 ± 13.2% del total de energía ingerida) y menos lipidos (40.5 ± 11.8% versus 43.9 ± 12.8% del total de energía ingerida) que la población urbana. El rendimiento académico fue significativamente mejor en los niños rurales que en los urbanos. La glucemia era mayor en los niños urbanos que en los rurales, y lo contrario sucedía con los valores de cetonemia. El IMC estaba aumentado significativamente en niños rurales con respecto a los valores en niños urbanos. En conclusión los resultados presentados enfatizan la importancia del desayuno y del estilo de vida en el peso y en el rendimiento académico de los niños.


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depends partly on the life-style of children in a given area and on family traditions.

The present study was designed to further explore the relationship between breakfast, overweight and school learning. It was analyzed the nutritional aspects of breakfast, the plasma levels of glucose and β-hydroxybutyrate, and the academic performance in two populations of children, one from an urban area (the city of Badajoz, 150,000 inhabitants, whose principal economic activity is in the services sector) and the other from a rural area (the town of Olivenza, 10,000 inhabitants, whose principal economical activity is agriculture), separated by 25 km, and both belonging to the Autonomous Community of Extremadura, Spain.

Methods

Representative samples of schoolchildren (3 to 12 years old) were selected in two cities (Badajoz, 150,000 inhabitants, and Olivenza, 10,000 inhabitants, at a distance of 25 km from each other) of the Autonomous Community of Extremadura, Spain, during the 2005-2006 school year. The children were selected by means of random cluster-sampling in schools. At a first stage, one school was selected in each city; at the second stage, the classes and the pupils were selected. Children reported by their parents to be suffering from any chronic disease were excluded from the study.

The study protocol was in accordance with the Helsinki Declaration guidelines and the European and Spanish statutory provisions governing research on human subjects. The research protocol was formally approved by the Research Ethics Committee of the University of Extremadura. The study design was presented to the Board of Governors (Consejo Escolar) of each school, and then a letter containing complete information about the study and securing their written authorization was circulated to the parents of the children invited to participate in the study. The children were given the opportunity to refuse prior to the day of the survey, and their participation in the study was rewarded with a gift.

At the school, anthropometry and nutritional data were collected by a field team trained in anthropometry and in the use of an adapted food-frequency questionnaire (FFQ) previously validated in Spain. This team conducted the survey and obtained the relevant information from the children’s parents. The nutrient database software used for the study was that corresponding to the Spanish database. The diagnosis of obesity was applied when the BMI of a child exceeded the 95th percentile for the same age and sex, the term overweight was applied when the BMI was at or exceeded the 90th percentile for the same age and sex. Academic performance was evaluated by the school’s teachers in accordance with their usual procedures, quantifying it as: 1.0, very poor; 2.0, poor; 3.0, regular; 4.0, good; and 5.0, very good (arbitrary units).

Blood glucose and blood β-hydroxybutyrate levels were determined immediately before the morning break, and before the children ate their mid-morning food (at around 11 a.m.), by taking samples of fresh capillary whole blood from the fingers. The assays were performed using a MediSense Optium Blood Glucose and Ketone Sensor (Abbott Laboratories).

Results

A total of 224 children were studied, aged from 3 to 12 years, and distributed by gender and population as given in table I. With respect to the BMI (kg/m²), the only significant difference (P < 0.05) observed was in the lower value corresponding to the children from the rural area (16.9 ± 3.4) relative to the value corresponding to the children from the urban area (18.4 ± 5.5). The prevalence of obesity and overweight was increased in urban (12.1% and 17.7% respectively) versus rural (8.2% and 12.9% respectively) children. The energy intake with breakfast ranged between 300 and 400 kcal for most children. The only significant difference (P < 0.05) was found between the energy intake of rural (353 ± 149 kcal) versus urban (312 ± 126) children. No significant differences were observed in the percentage of obesity or overweight related to the total energy intake during breakfast. Energy intake with breakfast increased with age until 8-9 years old, and then declined. It was noteworthy that a smaller percentage of the rural area children skipped breakfast (1%) than the urban children (4.04%).

Proteins comprised 12.7 ± 4.1% of caloric intake overall, and the values were similar for boys and girls, and for the urban and the rural groups. Carbohydrates comprised 44.9 ± 12.9% of the total energy intake overall, but now, while the values were similar for boys and girls, the percentage was significantly greater (P < 0.05) in the rural area (46.9 ± 12.3%) than in the urban area (43.3 ± 13.2%) children. This significant difference between the rural and the urban area children is shown in table I.

Table I

| Number of subjects, age, blood levels of glucose and β-hydroxybutyrate (β-OHB), academic performance and BMI measured in the studied children |
|-------------------|-----|-----|-----|-----|-----|
|                   | Total | girls | boys | rural | urban |
| Age (years)       | 7.8 ± 2.6 | 7.7 ± 2.7 | 7.8 ± 2.7 | 7.4 ± 2.5 | 8.0 ± 2.7 |
| Glucose (mg/dl)   | 89.7 ± 12.2 | 88.5 ± 12.8 | 90.3 ± 11.5 | 85.3 ± 11.6 | 93.1 ± 11.6 |
| β-OHB (mmol/l)    | 0.44 ± 0.8 | 0.32 ± 0.8 | 0.38 ± 0.8 | 0.58 ± 0.9* | 0.33 ± 0.7 |
| Academic performance (arbitrary units) | 3.6 ± 0.7 | 3.6 ± 0.7 | 3.6 ± 0.7 | 3.8 ± 0.4** | 3.5 ± 0.9 |
| BMI (kg/m²)       | 17.7 ± 4.7 | 17.8 ± 4.1 | 17.6 ± 5.2 | 16.9 ± 3.4* | 18.4 ± 5.5 |

* P < 0.05; **P < 0.01; ***P < 0.001.
and the urban children was maintained when the absolute value of carbohydrate consumption was considered (table II). Total fat intake was 42.3 ± 12.2% of the energy intake overall, and was significantly lower (P < 0.05) in the rural (40.5 ± 11.8%) than in the urban (43.9 ± 12.8%) children. With respect to the distribution of the different types of fat, the greater consumption of total fats by the boys was maintained in a greater consumption of all the types of fat, including cholesterol (table II).

The intake of vitamins and minerals during breakfast was similar in boys and girls. The significant differences found in the intake of vitamins and minerals between the rural and the urban groups are given in table III. The breakfast of the rural children contained greater quantities of the vitamins thiamine, riboflavin, niacin, cyanocobalamin, folates, and vitamin D, and of the minerals iron, magnesium, and phosphorous.

Milk was part of the breakfast of 91.0% of the rural and 82.9% of the urban children (fig. 1). A typical breakfast of the children in the study consisted of milk with powdered cocoa and sugar, and a choice of biscuits, breakfast cereals, or bread. Some children (between 7 and 13%) consumed margarine or butter. Almost no child included fruit in their breakfast, whether whole or in juices.

The levels of glycaemia measured three hours after breakfast were within the normal fasting limits of glycaemia. It was noteworthy that the levels in the urban children were significantly greater (P < 0.001) than in the rural children (table I). There were also significant differences (P < 0.05) in the values of ketone bodies, but this time the values were higher in the rural than in the urban children. Academic performance (arbitrary units) also presented a higher value (P < 0.01) in the rural (3.8 ± 0.4) than in the urban (3.5 ± 0.9) children.

### Discussion

Numerous studies have suggested that children’s intake of nutrients with breakfast contributes to creating a favourable nutritional environment for the learning process and for physical exercise\(^8\). It is not clear, however, which are the mechanisms that link the nutritional quality of breakfast with cognitive activities in school\(^4\). The learning process is complex, and depends on a multitude of non-nutritional as well as nutritional factors, including social, emotional, psychological, and life-style factors. In order to obtain more data on this interesting problem, it has been studied two populations of children in the Autonomous Community of Extremadura, Spain, with good nutritional and health status. One group of children were pupils of a school in Badajoz (a city of 150,000 inhabitants, service economy, a more modern life-style, and a high proportion of women sharing their work day between housework and a job away from home). The other children were pupils of a school in Olivenza (town of 10,000 inhabitants, agricultural economy, more traditional life-style, and where most women are solely occupied with household tasks).

The BMI distribution of the sample corresponded to that expected for this population group\(^11\). Rural children, carrying a most active life style, presented the lower index of overweight and obesity\(^12\). In the present study was not found any significant correlation between total energy intake with breakfast and overweight. In those children with the lowest energetic breakfast (N = 39; 164.2 ± 31.9 Kcal) was detected a 10.2% of obesity and in that one with the highest energetic breakfast (N = 591.0 ± 101.2) an 8% of obesity.

The children’s mean caloric intake with breakfast was 331 kcal (table II). This value is identical to that reported in the “enKid” study of a sample of more than 3,000 Spanish children\(^4\). The rural children of the present study, however, had a greater caloric intake with breakfast than the urban children, a finding that is contrary to that of the “enKid” study in which the equivalent values were less in rural than in urban areas.

The protein intake was similar in all the groups studied. The carbohydrate intake was greater in the rural than in the urban children. The boys ingested more fats than the girls in absolute terms, although this was simply a consequence of their greater total food intake.

### Table II

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>girls</th>
<th>boys</th>
<th>rural</th>
<th>urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kcal)</td>
<td>331 ± 138</td>
<td>16 ± 110</td>
<td>345 ± 160</td>
<td>353 ± 149*</td>
<td>312 ± 126</td>
</tr>
<tr>
<td>Proteins (g)</td>
<td>9.9 ± 3.5</td>
<td>10.0 ± 2.7</td>
<td>9.7 ± 4.1</td>
<td>10.3 ± 3.5</td>
<td>9.5 ± 3.5</td>
</tr>
<tr>
<td>Carbohydrates (g)</td>
<td>39.6 ± 20.1</td>
<td>38.1 ± 16.0</td>
<td>40.9 ± 23.4</td>
<td>44.5 ± 24.0**</td>
<td>35.4 ± 15.1</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>15.9 ± 8.9</td>
<td>14.8 ± 7.2</td>
<td>16.9 ± 10.3</td>
<td>16.1 ± 9.0</td>
<td>15.7 ± 8.9</td>
</tr>
<tr>
<td>SFA (g)</td>
<td>3.6 ± 4.3</td>
<td>3.0 ± 3.3*</td>
<td>4.3 ± 4.9</td>
<td>3.3 ± 4.3</td>
<td>3.9 ± 4.3</td>
</tr>
<tr>
<td>MUFA (g)</td>
<td>2.5 ± 3.0</td>
<td>2.2 ± 0.2*</td>
<td>3.6 ± 0.34</td>
<td>2.5 ± 3.0</td>
<td>2.6 ± 3.0</td>
</tr>
<tr>
<td>PUFA (g)</td>
<td>0.9 ± 1.5</td>
<td>0.7 ± 0.6**</td>
<td>1.9 ± 0.2</td>
<td>0.9 ± 1.5</td>
<td>0.9 ± 1.4</td>
</tr>
<tr>
<td>Cholesterol (g)</td>
<td>20.2 ± 24.1</td>
<td>16.2 ± 18.5</td>
<td>23.9 ± 28.1</td>
<td>18.8 ± 25.7</td>
<td>21.3 ± 22.8</td>
</tr>
<tr>
<td>Fibre (g)</td>
<td>1.1 ± 0.9</td>
<td>0.9 ± 0.7*</td>
<td>1.2 ± 1.1</td>
<td>1.1 ± 1.1</td>
<td>1.0 ± 0.8</td>
</tr>
</tbody>
</table>

*P < 0.05; **P < 0.01.

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**Fig. 1.—**Percentage of most important foods consumed with breakfast by rural (black bars) and urban (white bars) children.

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Breakfast, plasma glucose and β-hydroxybutyrate, body mass index and academic performance in children...
flect of a generally greater habitual physical activity and more traditional meals and life-style in the rural children. An incorrect diet and a sedentary life-style could lead to a situation of metabolic alteration in which homeostatic mechanisms would tend to maintain the circulating levels of glucose in the blood.

The method that it has been used to establish academic performance possibly does not measure all the potentially confounding factors, but it has the advantage of reflecting the real situation as judged by the children’s own teachers. Academic performance was significantly better in the children inhabiting the rural zone than in those of the urban zone. Neither the glucose nor the β-hydroxybutyrate levels were correlated with the values of academic performance. It is possible that this parameter is also influenced by chronic nutritional factors and by the children’s life-style.

Acknowledgements

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References

7. BOE; Boletín Oficial del Estado. 1993; Real Decreto 561: 14346-14364.