Blood pressure variation in children with obesity and consumption of ultra-processed foods

Caroline Cortes (krolcortes@hotmail.com)
State University of Rio de Janeiro

Joana Maia Brandão
State University of Rio de Janeiro

Diana Barbosa Cunha
State University of Rio de Janeiro

Vitor Barreto Paravidino
State University of Rio de Janeiro

Rosely Sichieri
State University of Rio de Janeiro

Research Article

Keywords: ultra-processed food, blood pressure, children, obesity

Posted Date: January 13th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2465194/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.

Read Full License
Abstract

Objectives

Investigate the influence in UPF consumption, assessed through dietary and urinary markers, on systolic (SBP) and diastolic (DBP) blood pressure in children with obesity.

Methods

Longitudinal analysis from a randomized clinical trial carried out with children with obesity aged 7 to 12 years. For six months, children and guardians attended monthly individual consultations and educational activities to encourage a reduction in UPF consumption. Body weight, height, blood pressure, and 24-hour dietary recall were measured at all visits. Random urine samples were collected at baseline, at the second and fifth-month follow-up.

Results

A total of 96 children were included in the analysis. Energy, UPF intake and blood pressure showed a quadratic pattern change, with a decrease in the first two months and an increase thereafter. There was an association between the consumption of UPF and DBP. Intake of UPF was correlated to urinary Na/K ratio ($r = 0.29; p = 0.008$) and with dietary Na/K ratio ($r = 0.40; p \leq 0.001$). For every 100g of increase in UPF, DBP increased by $0.28 \text{mmHg}$ ($p$-value = 0.01) and with further adjustment for change in BMI, the increase was $0.22 \text{mmHg}$ ($p$-value = 0.04).

Conclusions

Our findings indicated that UPF intake and not obesity had a greater contribution to the change in DBP, as an additional adjustment for BMI did not influence the results. Therefore, reducing UPF consumption can be a good preventive strategy against hypertension.

What Is Known

- Consumption of ultra-processed foods is associated with an increased risk of cardiovascular disease, however this evidence is still limited in children.

- The aim of this study was to investigate the influence of UPF consumption, assessed using dietary and urinary markers, on systolic and diastolic blood pressure in obese children.

What is new:

- AUP intake had a greater contribution to the increase in BPD.
- Reducing UPA consumption can be a good preventive strategy against hypertension even in the absence of weight loss.

### 1. Introduction

Consumption of ultra-processed foods (UPF) is associated with an increased risk of cardiovascular disease (CVD), as shown in the Framingham Offspring Study, where each daily serving of UPF was associated with a 7% increase in the risk of incident CVD \(^1\). Also, in the French NutriNet-Santé cohort, the consumption of UPF was associated with a 12% increased risk of CVD \(^2\). Hypertension is a major pathway for stroke and other CVD, and sodium, a nutrient abundant in UPF, is directly associated with blood pressure and increases the risk of CVD \(^3\).

An analysis based on data from the 2008–2009 dietary survey indicated that high intake of sodium and low intakes of fruits and whole grains were the largest contributors to Brazilian premature cardiometabolic deaths \(^4\) and data from the Brazilian National Health Survey (PNS) have shown an increase in the proportion of Brazilians over 18 years of age with diagnosed hypertension from 21.4% in 2013 to 23.9% in 2019 \(^5\).

According to the data from the last three Brazilian Household Budget Survey (POF), the percentage of calories from UPF in relation to the total calories available for consumption in households went from 12.6% in 2002–2003 to 16% in 2008–2009 and 18.4% in 2018–2019 \(^6\). Also, a Brazilian longitudinal study showed that the contribution of energy from UPF increased by 10% in the average period of 3-year follow-up of children between 3 and 6 years old \(^7\).

Nonetheless, Brazilians still have a reduced intake of energy from UPF. Rice, beans, coffee, bread, vegetables, and beef remained as the staple items of the Brazilian diet \(^8\). Adolescents in the US have an intake higher than 50% of energy from UPF \(^9\), whereas in Brazil this figure is about 25%.

Although the role of UPF in the development of CVD has been identified among adults \(^1,2,10,11\), this evidence is still limited in children. This study aims to investigate the influence of the changes in the consumption of UPF, evaluated through dietary and urinary markers, on systolic (SBP) and diastolic (DBP) blood pressure in children with obesity.

### 2. Methods

#### 2.1 Study design and population

The data used in this longitudinal analysis are from a randomized clinical trial \(^12\) carried out with children with obesity referred by the National Regulatory System, other medical clinics, and those from the Pediatric nutrition clinic of a University Hospital located in the metropolitan region of the city of Rio de Janeiro, Brazil.
Children with obesity aged between 7 and 12 years were considered eligible. The exclusion criteria were children diagnosed with genetic disorders associated with obesity (congenital leptin deficiency, Down syndrome, Prader-Willi syndrome) or endocrine disorder (hypothyroidism, Cushing's syndrome) and patients already under nutritional monitoring or using drugs to lose weight.

2.2 Data collect

The study was conducted between August 2018 and February 2020 and included 101 participants; however, for the present analysis, we excluded 5 participants due to not having any blood pressure measurements at follow-up.

Children and their guardians participated in individual consultations and standardized monthly educational activities based on the 10 steps of the Food Guide for the Brazilian Population. The guidelines included changes in the family’s behavior in relation to food choices and purchases, with a focus on quality, encouraging a reduction in the consumption of UPF.

Data collection for the present study took place at baseline and the second, fifth, and sixth-month follow-up. The research assistants responsible for the collection were trained in order to standardize data measurement and ensure reliability.

Outcome

Blood pressure was measured at all appointments, with a digital monitor HEM-742 (Omron Healthcare Inc.), previously validated for use in adolescents, on the right arm supported at the level of the heart, using an appropriate cuff size, with the child sitting with feet on the floor and at rest for 5 minutes before measurement. Two measurements were taken, with a minimum interval of 2 minutes, and the average was calculated. If the difference between the 2 measurements was equal to or greater than 5 mmHg, a third measurement was performed.

The SBP and DBP values obtained in mmHg were transformed into a Z score, using the mean and standard deviation of the blood pressure values of the American pediatric population, according to sex, age, and height in Z score.

Blood pressure was classified based on sex, age, and height as normotension, if SBP or DBP values < 90th percentile; prehypertension, if SBP or DBP ≥ 90th and < 95th percentile or SBP ≥ 120mmHg or DBP ≥ 80mmHg; and, hypertension, if the SBP or DBP ≥ 95th percentile.

The models were tested to assess the variation of systolic and diastolic blood pressure over time, using blood pressure measurements in mmHg and Z score.

Exposure

Food consumption was assessed using a 24-hour dietary recall (R24h) performed at each visit, using netbooks equipped with a program based on the multiple-pass method and developed to evaluate the
food consumption of Brazilian adolescents\textsuperscript{16}. Respondents provided detailed information on all foods and beverages consumed in the 24 hours: meal occasion, time, place, and amount of food in household measures. The reported amounts of food were converted into grams or milliliters, and then the nutritional composition was estimated using the Brazilian Table of Food Composition (TACO), of the State University of Campinas\textsuperscript{17}.

The nutritional composition of local preparations was calculated based on the individual components of each preparation, according to information in technical publications from teaching and research institutions. For every 100 grams of edible parts of foods and preparations, total energy (kcal), UPF energy (kcal), sodium (mg), and potassium (mg) values were calculated. Food intake was also classified based on NOVA food classification, defining each food and beverage into 1 of the 4 food groups based on their extent and purpose of industrial food processing: (1) Unprocessed or minimally processed foods; (2) Processed culinary ingredients; (3) Processed foods; (4) Ultra-processed foods\textsuperscript{18}.

Through the sum of energy and grams of food items included in each group, it was possible to calculate the relative contribution of each group to the total daily energy value.

Urinary casual samples were collected at the clinic after 12 hours of fasting, for sodium and potassium measurements at three times: baseline, in the second and fifth-month follow-up. Urinary sample analyzes were performed at the hospital’s clinical laboratory. The Na/K ratio was calculated using sodium and potassium concentrations (mEq/L).

Covariates

The independent variables used in this study were age (years), race/skin color self-reported (black, white, light-skinned black, Asian or indigenous), weight, and height.

Body weight was measured using a portable electronic scale (Tanita BC-558) and height was measured in duplicate using a portable anthropometer (AlturExata). Both measurements were taken at each visit, with the children barefoot, wearing light clothing, with their arms extended along the body, and positioned in the Frankfurt horizontal plane\textsuperscript{19}.

The classification of nutritional status was based on body mass index (BMI) values for age, in z-scores, according to sex, based on the curves proposed by the WHO\textsuperscript{20}. BMI for age was calculated using the WHO AnthroPlus software\textsuperscript{20}, and the values obtained were classified according to the cutoff points recommended for children aged 5 to 19 years: low weight (BMI for age < -2 z-scores), eutrophic (BMI for age \(-2 \leq z\)-scores), overweight (BMI for age \(+1 \leq z\)-scores), obese (BMI for age \(+2 \leq +3 z\)-scores), and severely obese (BMI for age \(+2 < +3 z\)-scores).

2.3 Statistical analysis

Means and standard deviations for continuous variables and frequencies for categorical variables were calculated for variables of interest at baseline.
Linear mixed-effect models were used to evaluate the influence of the change in the consumption of UPF on SBP and DBP, with an unstructured covariance matrix. Interactions between SBP and DBP measurements with grams of UPF, energy of UPF, and sodium urinary samples were tested.

Model 1 was tested adjusted for sex and age and model 2 was adjusted for sex, age, and BMI. All analyses were performed using SAS On demand for Academics.

2.4 Ethical approval

The project was approved by the Research Ethics Committee of the Pedro Ernesto University Hospital (CAAE: 87593118000005259). The Informed Consent Form was signed by the child's parents or legal guardians and the children signed the Informed Assent Form.

3. Results

Of 101 children in the trial, 96 with at least one measure of blood pressure in the follow-up were included in the analysis. Among the 40 girls, 30% were classified with severe obesity, whereas, among boys, 57% received the same classification. Girls had a mean total energy intake of 1611 kcal, and 618 kcal are from UPF. Among boys, these values were 1843 kcal, of which 691 kcal came from UPF. Regarding blood pressure measurements, the mean SBP was 105.3mmHg in girls and 108.3mmHg in boys. The mean DBP was 66.8mmHg in girls and 68.5mmHg in boys (Table 1).

The prevalence of hypertension changed from 14.4 % to 7.3 % for children who remained from baseline to the end of the study, whereas the prehypertension prevalence changed from 12.2% to 7.3% (Table 2).

Observing the values predicted by the models, there was a similar pattern of change of consumption of UPF and means of SBP and DBP; however, only grams of UPF had statistical significance using the quadratic time term (Figure 1). Both food intake and blood pressure decreased at two-month follow-up and increased thereafter. Also, most variables presented this quadratic pattern of change, such as, BMI and measures of food and nutrient intake (energy, percentage energy from UPF, sodium, and potassium, and the ratio of these two nutrients) as well as the urinary measure of sodium and potassium (Table 3). Due to the large variability and small sample size, none of these changes reached statistical significance.

Table 4 shows the correlations between the variables of interest (SBP, DBP, BMI, NA/K ratio) and consumption measures at baseline. We observed that all correlations were positive, with statistical significance between UPF intake in grams and energy, with the Na/K ratio measured by intake and urinary excretion.

In the analysis including all observations during the follow-up, adjusted for age and sex, we observed that any variation in UPF consumption influenced the DBP measurement. For every 100g of increase in the UPF, DBP increased by 0.28mmHg, and with further adjustment for change in BMI, increased by 0.22mmHg (Table 5).
Additional analyzes were performed to evaluate the other 3 food classification groups (unprocessed foods, processed culinary ingredients, processed foods), but no statistical significance was observed (data not shown). All models were also tested with blood pressure in Z-score, with no difference from the results presented in mmHg.

4. Discussion

In this study, we evaluated the influence of changes in UPF consumption on blood pressure in children with obesity. After a 6-month follow-up, we observed a linear association between consumption in grams of UPF and DBP, with no difference for SBP, even after adjusting for BMI. Thus, our findings indicated that food intake and not obesity had a greater contribution for DBP change, as further adjustment for BMI did not influence the results. The role of weight loss on blood pressure is complex and can be explained by change in diet, including a reduction in sodium intake or the Na/K ratio\textsuperscript{21}.

The association between UPF and hypertension involves different aspects. UPF consumption contributes to a negative effect on the nutritional quality of the diets consumed, such as, lower fiber consumption and higher consumption of sugars, unhealthy fats, and salt\textsuperscript{22–24}. Consistent evidence points out the reduction in sodium consumption as a determinant in the prevention of hypertension and reduction of cardiovascular risk\textsuperscript{25–27}. However, the health disorders that UPF causes go beyond unfavorable nutritional composition. These foods have compounds such as acrolein and acrylamide and numerous artificial additives, such as, preservatives, emulsifiers, flavor enhancers, and sweeteners that can act on the intestinal microbiota leading to inflammatory processes and metabolic disorders\textsuperscript{9,28–30}.

Our results are supported by several other studies carried out with adults that showed inadequate food consumption as a predictor of arterial hypertension\textsuperscript{11,31–33}. Mendonça et al.\textsuperscript{11} in a Spanish cohort of adults found that participants included in the highest terciles of UPF consumption had a higher risk of developing hypertension. These participants had a higher intake of salt, saturated fats, and sugar-sweetened beverages, a lower intake of fiber, potassium, vegetables, and fruits, and lower adherence to the Mediterranean dietary pattern. Also, an observational study with young adults, aged between 18 and 45 years, showed a positive association between the consumption of UPF and peripheral blood pressure, and an inverse association between the consumption of unprocessed or minimally processed foods with peripheral and central blood pressure\textsuperscript{33}.

Although a Brazilian cross-sectional study with school children did not find an association between UPF consumption and anthropometric indicators and blood pressure, the increase in the consumption of unprocessed or minimally processed foods was associated with a reduction of DBP of 0.96 mmHg\textsuperscript{34}.

At baseline, univariate analysis showed a positive association between UPF intake and Na/K ratio based on a casual urine sample and dietary, demonstrating that these markers can be good predictors of UPF consumption. The correlation was greater for the dietary ratio compared to the urinary ratio.
Several authors point out the urinary Na/K ratio, in comparison with isolated sodium and potassium values, as a superior option to determine the relationship between blood pressure and the risks of cardiovascular diseases\textsuperscript{35,36}. Pereira et al.\textsuperscript{37}, in a large Brazilian longitudinal study of adult health (ELSA-Brasil), which used a 12-hour night urine sample, showed that the urinary Na/K ratio was a predictor of blood pressure.

Iwahori et al.\textsuperscript{38} presented the Na/K ratio as a measure to assess the reduction of sodium and the increase of potassium in diets. Thus, lower values for the Na/K ratio characterize a diet of better nutritional quality. In addition, the authors showed that the Na/K ratio in casual urine has a greater correlation with the values of 24-hour urine than the measurements of sodium and potassium isolated in casual urine. In our study, we used casual urine samples as an alternative to the 24-hour gold standard to calculate the Na/K ratio, but we found no significance in the associations of these consumption markers with blood pressure.

The major limitation of our research is the loss to follow-up reaching 46\% at the end of the study. High percentages of loss to follow-up are expected in lifestyle interventions to reduce weight. Studies have investigated strategies to increase adherence to diets given that high rates of weight reduction and subsequent regain among individuals attempting to reduce weight are the main problems in these trials\textsuperscript{39}. Therefore, it would be expected losses, although, the statistical analysis used is considered robust when losses are not at the beginning of follow-up. In our cohort, 84\% contributed data after two months.

This study contributes to the recent literature investigating the relationship between the consumption of ultra-processed foods and blood pressure in children. Our findings suggest that consuming less UPF may have an impact on blood pressure in children with obesity, even without a reduction in BMI. Therefore, reducing UPF consumption can be a good preventive strategy against hypertension in middle-income countries like Brazil, which presents UPF consumption much lower than in developed countries. This reinforces the importance of public policies aimed at restricting the availability of ultra-processed foods.

**Abbreviations**

BMI - Body mass index

CVD - Cardiovascular disease

DBP - Diastolic blood pressure

PNS - Brazilian National Health Survey

POF - Brazilian Household Budget Survey

R24h - 24-hour dietary recall
SBP - Systolic blood pressure

UPF - Ultra-processed foods

Declarations

Funding

This study was supported by the National Council for Scientific and Technological Development (CNPq) and from Carlos Chagas Filho Foundation for Research Support in the State of Rio de Janeiro (FAPERJ).

Acknowledgments

The investigators would like to thank all patients and parents for their participation in this study.

Author contributions

Designed the experiments: Diana Barbosa Cunha and Rosely Sichieri. Conceived the experiments: Caroline Cortes and Joana Maia Brandão. Analyzed the data: Caroline Cortes, Vitor Barreto Paravidino and Rosely Sichieri. Wrote and approved the final version of the paper: Caroline Cortes, Joana Maia Brandão, Diana Barbosa Cunha, Vitor Barreto Paravidino and Rosely Sichieri.

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval

The project was approved by the Research Ethics Committee of the Pedro Ernesto University Hospital (CAAE: 87593118000005259).

Consent to participate

The Informed Consent Form was signed by the child's parents or legal guardians and the children signed the Informed Assent Form.

References


**Tables**

**Table 1** Baseline characteristics of participants
<table>
<thead>
<tr>
<th></th>
<th>Male [n=56]</th>
<th>Female [n=40]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutritional status [n (%)]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obesity</td>
<td>24 (42.9)</td>
<td>28 (70.0)</td>
</tr>
<tr>
<td>Severe Obesity</td>
<td>32 (57.1)</td>
<td>12 (30.0)</td>
</tr>
<tr>
<td>Skin color [n (%)]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>19 (33.9)</td>
<td>13 (32.5)</td>
</tr>
<tr>
<td>Black</td>
<td>13 (23.2)</td>
<td>8 (20.0)</td>
</tr>
<tr>
<td>Others</td>
<td>24 (42.9)</td>
<td>19 (47.5)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>9.4 ± 1.6</td>
<td>8.9 ± 1.4</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>27.5 ± 4.6</td>
<td>26.0 ± 2.6</td>
</tr>
<tr>
<td>Food consumption [mean ± SD]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total energy (Kcal)</td>
<td>1843 ± 710</td>
<td>1611 ± 669</td>
</tr>
<tr>
<td>Sodium (g/100g)</td>
<td>2854 ± 1305</td>
<td>2579 ± 1741</td>
</tr>
<tr>
<td>Potassium (g/100g)</td>
<td>2074 ± 781</td>
<td>1914 ± 808</td>
</tr>
<tr>
<td>Na/k total food</td>
<td>1.4 ± 0.6</td>
<td>1.4 ± 0.7</td>
</tr>
<tr>
<td>UPF energy (Kcal)</td>
<td>691 ± 701</td>
<td>618 ± 676</td>
</tr>
<tr>
<td>UPF grams</td>
<td>613 ± 646</td>
<td>583 ± 534</td>
</tr>
<tr>
<td>Sodium (g/100g UPF)</td>
<td>853 ± 1132</td>
<td>1081 ± 1864</td>
</tr>
<tr>
<td>Potassium (g/100g UPF)</td>
<td>461 ± 524</td>
<td>492 ± 631</td>
</tr>
<tr>
<td>Na/k UPF</td>
<td>2.1 ± 1.7</td>
<td>2.4 ± 2.0</td>
</tr>
<tr>
<td>Blood pressure [mean ± SD]</td>
<td>[n=52]</td>
<td>[n=38]</td>
</tr>
<tr>
<td>Systolic (mmHg)</td>
<td>108.3 ± 10.3</td>
<td>105.3 ± 8.4</td>
</tr>
<tr>
<td>Diastolic (mmHg)</td>
<td>68.5 ± 11.2</td>
<td>66.8 ± 6.4</td>
</tr>
<tr>
<td>Urinary measurements [mean ± SD]</td>
<td>[n=48]</td>
<td>[n=33]</td>
</tr>
<tr>
<td>Sodium (mEq/L)*</td>
<td>155 ± 48</td>
<td>153 ± 64</td>
</tr>
<tr>
<td>Potassium (mEq/L)</td>
<td>66 ± 36</td>
<td>45 ± 23</td>
</tr>
<tr>
<td>Na/K urinary</td>
<td>3.6 ± 3.8</td>
<td>4.6 ± 3.3</td>
</tr>
</tbody>
</table>
UPF, ultra-processed foods; SD, standard deviation.
* Urinary sodium additionally lost 1 sample (Female).

**Table 2** Prevalence of Prehypertension and hypertension throughout the study in children with obesity

<table>
<thead>
<tr>
<th>Blood pressure</th>
<th>Baseline [n=90]</th>
<th>Month 2 [n=78]</th>
<th>Month 5 [n=49]</th>
<th>Month 6 [n=41]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Normal</td>
<td>66</td>
<td>73.3</td>
<td>60</td>
<td>76.9</td>
</tr>
<tr>
<td>Prehypertension</td>
<td>11</td>
<td>12.2</td>
<td>11</td>
<td>14.1</td>
</tr>
<tr>
<td>Hypertension</td>
<td>13</td>
<td>14.4</td>
<td>7</td>
<td>9.0</td>
</tr>
</tbody>
</table>

**Table 3** Means and standard deviation (SD) of body mass index (BMI), blood pressure, and dietary markers throughout the study
<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Month 2</th>
<th>Month 5</th>
<th>Month 6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[n=96]</td>
<td>[n=81]</td>
<td>[n=53]</td>
<td>[n=45]</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td>26.9 ± 4.0</td>
<td>26.3 ± 3.8</td>
<td>26.8 ± 4.2</td>
<td>27.2 ± 4.1</td>
</tr>
<tr>
<td><strong>Blood pressure</strong></td>
<td>[n=90]</td>
<td>[n=78]</td>
<td>[n=49]</td>
<td>[n=41]</td>
</tr>
<tr>
<td>Systolic (mmHg)</td>
<td>107.0 ± 9.6</td>
<td>106.4 ± 9.4</td>
<td>105.2 ± 9.9</td>
<td>107.6 ± 8.7</td>
</tr>
<tr>
<td>Diastolic (mmHg)</td>
<td>67.8 ± 9.5</td>
<td>67.3 ± 8.1</td>
<td>67.7 ± 8.9</td>
<td>67.2 ± 9.8</td>
</tr>
<tr>
<td><strong>Food consumption</strong></td>
<td>[n=96]</td>
<td>[n=80]</td>
<td>[n=52]</td>
<td>[n=41]</td>
</tr>
<tr>
<td>Total energy (Kcal)</td>
<td>1746 ± 699</td>
<td>1509 ± 582</td>
<td>1485 ± 547</td>
<td>1852 ± 635</td>
</tr>
<tr>
<td>Sodium (g/100g)</td>
<td>2740 ± 1500</td>
<td>2304 ± 1123</td>
<td>2151 ± 980</td>
<td>2727 ± 1175</td>
</tr>
<tr>
<td>Potassium (g/100g)</td>
<td>2008 ± 792</td>
<td>2037 ± 968</td>
<td>1922 ± 852</td>
<td>2172 ± 906</td>
</tr>
<tr>
<td>Na/k total food</td>
<td>1.4 ± 0.7</td>
<td>1.3 ± 0.7</td>
<td>1.2 ± 0.6</td>
<td>1.4 ± 0.7</td>
</tr>
<tr>
<td>UPF energy (Kcal)</td>
<td>660 ± 688</td>
<td>472 ± 450</td>
<td>486 ± 428</td>
<td>700 ± 679</td>
</tr>
<tr>
<td>UPF grams</td>
<td>601 ± 599</td>
<td>348 ± 341</td>
<td>499 ± 394</td>
<td>576 ± 537</td>
</tr>
<tr>
<td>Sodium (g/100g UPF)</td>
<td>948 ± 1477</td>
<td>716 ± 788</td>
<td>568 ± 743</td>
<td>934 ± 1050</td>
</tr>
<tr>
<td>Potassium (g/100g UPF)</td>
<td>474 ± 568</td>
<td>388 ± 485</td>
<td>377 ± 453</td>
<td>453 ± 449</td>
</tr>
<tr>
<td>Na/k UPF</td>
<td>2.2 ± 1.8</td>
<td>2.4 ± 2.7</td>
<td>1.9 ± 1.8</td>
<td>2.1 ± 1.5</td>
</tr>
<tr>
<td><strong>Urinary measurements</strong></td>
<td>[n=81]</td>
<td>[n=66]</td>
<td>[n=31]</td>
<td>-</td>
</tr>
<tr>
<td>Sodium (mEq/L)</td>
<td>154* ± 54</td>
<td>152* ± 51</td>
<td>163 ± 69</td>
<td>-</td>
</tr>
<tr>
<td>Potassium (mEq/L)</td>
<td>57 ± 33</td>
<td>52 ± 30</td>
<td>67 ± 34</td>
<td>-</td>
</tr>
<tr>
<td>Na/K urinary</td>
<td>4.0 ± 3.6</td>
<td>4.1 ± 3.5</td>
<td>3.1 ± 2.2</td>
<td>-</td>
</tr>
</tbody>
</table>

UPF, ultra-processed foods.
* Urinary sodium additionally lost 1 sample at baseline and month 2.

**Table 4** Correlation between variables of interest to the study with grams and energy of ultra-processed food, in children with obesity at baseline
Table 5 Estimated effects on systolic and diastolic blood pressure per 100 grams of ultra-processed foods

<table>
<thead>
<tr>
<th></th>
<th>Ultra-processed foods grams</th>
<th>p</th>
<th>Ultra-processed foods energy</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure</td>
<td>0.13</td>
<td>0.23</td>
<td>0.07</td>
<td>0.51</td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>0.17</td>
<td>0.11</td>
<td>0.13</td>
<td>0.22</td>
</tr>
<tr>
<td>Body mass index</td>
<td>0.25</td>
<td>0.01</td>
<td>0.13</td>
<td>0.20</td>
</tr>
<tr>
<td>Na/K total food</td>
<td>0.40</td>
<td>≤0.001</td>
<td>0.40</td>
<td>≤0.001</td>
</tr>
<tr>
<td>Na/K urinary</td>
<td>0.29</td>
<td>0.008</td>
<td>0.29</td>
<td>0.009</td>
</tr>
</tbody>
</table>

Model 1: Adjusted for age and sex.

Model 2: Adjusted for age, sex, and BMI.

Figures
Figure 1

Predicted values of systolic and diastolic blood pressure, and grams of ultra-processed foods, adjusted for sex and age

* (time×time)