FOOD COMPOSITION AND ANALYSIS

Newly derived children-based food index. An index that may detect childhood overweight and obesity

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Abstract

A food index (FI) based on a priori knowledge was developed to assess the role of diet on overweight (OW) and obesity (OB) in school-aged children. This included «positive» and «negative» foods based on research evidence and food guidelines, with scores set accordingly. Statistical tests were used to strengthen the sensitivity of the index. The FI was validated using data from the GRECO study. The score ranged from 17 to 53.5 (mean 34.8 ± 5.01) and was inversely associated with body mass index (BMI) (−0.057 ± 0.02; 95% CI −0.098, −0.017) and waist circumference (WC) (−0.08 ± 0.03; 95% CI: −0.137, −0.022). Associations remained significant upon adjusting for age, gender and physical-inactivity (p = 0.02 ad 0.013, respectively). When stratified by gender, the association between FI and WC was not significant for boys (p = 0.08). The association with BMI remained significant for females and males (p = 0.047 and 0.037, respectively). The derived FI seems a valuable tool in detecting OW in children.

Keywords

Children, dietary habits, epidemic, food, obesogenic factors

Introduction

Childhood obesity (OB) rate, nowadays termed an “epidemic”, is rising in the United States and in Europe, regardless of all the population food guidelines and measures that are taken to combat this phenomenon (O’Connor et al., 2006). This is of Global concern (Barton, 2012; Lavie et al., 2009) since in 2013 the number of overweight (OW) children was estimated to be over 42 million globally (WHO) and childhood OB has been associated with an increased susceptibility to chronic diseases later in life (Barton, 2012; Berenson et al., 2012). The latter stresses the need to identify obesogenic factors early on, as underlined by other researchers as well (Barton, 2012).

To date there is much speculation regarding the reasons for the OW epidemic among children worldwide, however the specifics remain inconclusive. Studies on childhood OB have shown that diet and physical inactivity are the most important factors, exceeding the effect of genetic susceptibility (Barton, 2012; Berkey et al., 2000, 2003; Lavie et al., 2009). Many food items have been investigated, such as sweets, sugar-sweetened beverages (ssb’s) and junk food, with inconclusive results but it is now widely accepted that food items interact and no one food alone can be investigated without being confounded by the diet as a whole. This has lead researchers to the search of an index that will accurately measure and assess food intake in relation to specific guidelines with end result overweight/obesity (OW/OB) and chronic disease status.

Most indexes present to date “fit” their populations’ food habits are based on adherence on national dietary guidelines or the Mediterranean pattern (Waijers et al., 2007) and assess dietary intake based on a score created that can possibly explain the relationship of OW and OB with morbidity and mortality. In adults, lower diet quality scores have been found to be consistently associated with higher rates of all-cause mortality, and specific morbidity rates, associations that remain even when confounders are considered (Wirt & Collins, 2009), but to date limited data have been selected on children. Furthermore, data selected on this population are from food indexes that have been adapted for children, not created for them (Feskanich et al., 2004; Golley et al., 2011; Kleiser et al., 2009a; Kranz et al., 2006, 2008; Lazarou et al., 2009).

Few indexes have been designed specifically for children (Feskanich et al., 2004; Golley et al., 2011; Kleiser et al., 2009b; Kranz et al., 2006, 2008; Lazarou et al., 2009, 2011; Manios et al., 2010; Serra-Majem et al., 2004), and according to our literature review, only three (3) indexes have been created for school aged children (Lazarou et al., 2011; Manios et al., 2010; Serra-Majem et al., 2004), only two (2) have been derived (Lazarou et al., 2011; Manios et al., 2015) with the main objective to detect risk for childhood OW and OB. These indexes, however, are either too complex (Lazarou et al., 2011) to be performed (many variables need to be determined, and nutrient calculation is required), or too simplified (Serra-Majem et al., 2004) using a very small scoring system increasing the risk for false results since small dietary variations cannot be detected.
The Revised Healthy Lifestyle Diet Index (R-HLD) has considered many of the above aspects, it includes two non-dietary components, including sedentary life (total time for TV watching and playing computer games) and total Moderate to Vigorous Physical Activity (MVPA) (Manios et al., 2015). Estimates of physical activity, however, can be very difficult to perform, if not actually measured by devices, increasing the risk of bias and confounding. Also, it does not distinguish between certain food items (i.e. red and processed meat) in light of new evidence, showing that red and processed meat may have different mechanisms of action on health and disease (Micha et al., 2010). In our view, although these factors should not be neglected, a pure food index (FI) created for school aged children that will detect OW–OB risk is of primary aim, with the latter factors investigated separately and in combination with the FI in order to obtain clear results.

The goal of this study was to derive a FI with a simple scoring system, able to capture risk of OW and/or OB in school aged children, based on a priori knowledge of potential obesogenic food factors, USDA data and the Mediterranean Food Pyramid guidelines.

Hypothesis

A FI designed for children aged 9–13 years old, based on a priori knowledge and food recommendations-dietary guidelines, will assess dietary habits that potentially increase risk of OW and OB, in order to accurately determine food habits that need change in order to combat increasing rates of childhood OB.

Methods

FI derivation-rational

A total of 14 foods (11 food items and three specified food groups) were selected based on a priori knowledge to be included in the FI (Table 1) for children aged 9–13 years of age, based on a priori knowledge of food items and food patterns. Factors accounted for included research data on specific food and food patterns, age and gender. These foods were categorized as positive- non-obesogenic or negative-obesogenic foods, based on a priori knowledge of food items and food patterns. Foods that belong in the same food group, i.e. vegetables & fruit; meat, legumes and nuts (meat & alternatives) were separated based on their bodily effects, upon findings.

Specifically in this index positive-non-obesogenic foods include: fruit, vegetables, whole grains, fish, nuts, legumes/pulses, milk and yogurt; negative-obesogenic foods include:

| Positive non-obesogenic food | Negative possibly obesogenic food |
|-----------------------------|----------------------------------|
| Fruit                       | Cheese                           |
| Vegetables                  | Red meat                         |
| Whole grains                | Processed food                   |
| Legumes                     | Sugared sweet beverages          |
| Nuts                        | Sweets                           |
| Fish                        | Fast food                        |
| Milk                        |                                  |
| Yogurt                      |                                  |

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|-----------------------------|----------------------------------|
| Fruit                       | Cheese                           |
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| Legumes                     | Sugared sweet beverages          |
| Nuts                        | Sweets                           |
| Fish                        | Fast food                        |
| Milk                        |                                  |
| Yogurt                      |                                  |

\( ^{a}\)Including processed meat, and chips.

\( ^{b}\)Including regular soda, fruit drinks, nectars.

\( ^{c}\)Including puddings and creams, biscuit-cereal bars, cakes/croissant, cookies, jam-marmelade, chocolate and chocolate waffers, chocolate spread and icecream.

\( ^{d}\)Including pizza, souvlaki, hamburger and french fries.

Reasoning for protective and negative foods

Dietary guidelines stress the need to consume whole-wheat grains (USDA), due to their high fiber contents, and latest evidence suggest that these may be associated with lower weight gain (Mozaffarian et al., 2011). All food organizations recommend that grains and cereals should be whole wheat, non-processed and an Acceptable Intake (AI) of 14 g of fiber per 1000 kcal in children and adolescence aged 4–18 years is recommended. A daily vegetables and fruit consumption is also underlined. These were entered separately in the FI as it has been recommended (Waijers et al., 2007), due to their different carbohydrate composition, fiber and nutrient content. Dietary guidelines also stress the need for dairy intake due to the children’s high needs for calcium, phosphorus and magnesium; minerals that support growth. Milk, yogurt and cheese however, were analyzed separately due to their composition differences, with the latter being incorporated in negative foods due to its high saturated fat and sodium content. Furthermore, research has shown a potential beneficial effect of yogurt on health and weight status (Mozaffarian et al., 2011). Evidence has also emphasized the need for vegetable protein intake for health, in adults and children, mainly from legumes and nuts (Matthews et al., 2011; Moreno et al., 2013; Rossi et al., 2013; Turati et al., 2014). Epidemiologic studies and clinical trials suggest that regular nut intake may help in weight loss and is unlikely to contribute to OB despite their high energy density (Rox, 2010). An inverse relationship has also been found between peanut consumers and OW/OB in children compared to non-peanut consumers (Moreno et al., 2013). In 2011, Canada recommended that nuts, legumes and tofu should replace meat as often as possible (Santé et Services sociaux Quebec, 2015). In their 2010 recommendations, USA recommended that fish and seafood should replace meat and poultry whenever possible with an intake of at least two portions of fish per week being supported (AGHE, UK 2011, France 2004).

For the negative foods of the FI, emphasis on recent OW–OB studies, and fat and sodium was given. It has been recommended that children should decrease saturated fat intake to <8% of total daily energy intake (FAO/WHO/UNU, 2004) or to <10% (FAO/WHO/UNU, 2004; Nordic Council of Ministers, 2013) as well as a reduction in sodium. The former recommendation limits red meat, and both suggest a lower processed meat and cheese consumption. Research has shown that children with a high Mediterranean diet score can have a high Na intake, with cheese being a major contributor (Magriplis et al., 2011). Processed food (including processed meat and chips/crisps) were grouped together due to their high sodium and preservative content.

A reduction of total simple sugars intake is also recommended. Institution of Medicine (IoM, 2005) recommended minimizing simple sugars to <25% of a total of 45–65% of total carbohydrates, for children between 4 and 18 years of age. NNR 2012 advises a reduction of simple sugars to <10% of carbohydrates (45–65% in total) for any child over 2 years old and WHO to <10% of total energy intake for all ages. In order to comply with the above recommendations a score on sugar intake from dessert items is warranted, irrespective of the food’s caloric value. The goal of the FI is not to remove all sugar content (addressed by the 4–1 score, compared to 0–1), since this would be unnatural, but to minimize “empty calories” (i.e. jam and marmalade) and energy dense foods, low nutrients content foods (i.e. cookies, cake and chocolate). Sweets encompass sugared solid items, including cake, cookies, sweet pastries like croissant, marmalade, honey, chocolate bar and chocolate spread, and ice-cream. Ready to eat

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(RTE) cereals have been investigated for their potential obesogenic role due to their sugar content, but to date remain controversial. Many studies, however, have found a negative correlation of RTE cereals and body weight in children (de la Hunty et al., 2013; Kostki et al., 2008). Furthermore, whole wheat (ww) RTE cereals were therefore included in positive foods, due on their fiber composition and high nutrient supply through fortification. Potatoes and refined grains were not included since their effects on body weight are either not linked or highly controversial.

This FI separates ssb’s from sweets, due to evidence that these may play a key role in the etiology of OW and OB during childhood, and evidence supporting that liquids have less impact on satiety compared to solid foods (Dennison, 1996; Niissinen et al., 2009; O’Connor et al., 2006). In order to derive measurable and comparable results, a specific definition for ssb’s defined as any liquid containing ≥25% of its calories as simple sugars (Mariner & Annas, 2013) was used in the creation of this FI, including all regular soft drinks, fruit drinks and fruit nectars.

The «Fast-food» category (including souvlaki, hamburger, pizza and fries) included energy dense but nutrient poor foods, high in saturated and trans fatty acids. Fast food intake has been associated with an increase in body weight and waist circumference (WC) OB in children (Nago et al., 2014; Shang et al., 2014). A link was also found with type 2 diabetes in adult women when consuming ≥2 fast-food meals per week (Krishnan et al., 2010).

### Scoring system

A weighting system of 1 or 1.5 was used for positive foods in order to increase the sensitivity of the index in detecting internal variation in dietary habits and to underline the increased requirements of some foods in school-aged children, due to growth, as earlier stressed. To date, in all child-based indices, all individual variables are given the same weight therefore equally contributing to the score. It has been suggested that it is not plausible for all index components to have the same health impact (Wajiers et al., 2007) and furthermore, the same obesogenic or non-obesogenic effect.

More specifically a score of 1–4 was given to protective foods, based on their intake, with 4 given for consuming the maximum recommended intake and 1 if consumption was at the lowest recommended level (Table 2). Intake was specified in total servings per day, with a serving being food dependent (i.e. raw versus boiled vegetables, RTE versus cooked cereal, portion of cheese, meat, milk, etc.) and is depicted in Table 2.

Higher weights (score 1–4 multiplied by 1.5, hence 1.5–6) were then given to whole grains, fruits, vegetables and milk based on data of there increased requirements in school-aged children due to growth, as per the recommendations made by the American Academy of Pediatrics (National Heart, Lung and Blood Institute, 2011) for OB and cardiovascular disease prevention.

For negative-harmful foods the opposite was performed; 4 was given to those consuming the lowest level and 1 to children consuming the highest levels of these food. With regards to fast-food, where no intake is suggested a score of 4 was assigned to no intake and 1 if these foods were consumed more than twice a week. For sweets and ssb’s, the highest score was assigned for a limited intake of less than one portion per week and the lowest score for a frequency of more than three per week.

Table 2 provides a detailed summary of the scoring system for each food separately. The total FI score was obtained by summing the scores assigned to each individual index component. Theoretically based on the total foods in the FI and considering the weights given to four of these, the total FI a child can achieve will range from 16 (minimum value possible) to 64 (maximum value). Higher FI values indicate healthier dietary intake and support the hypothesis of lower probability for OW and OB in school-aged children. Median values were also considered further in the analysis.

### FI validation

The derived FI was validated based on a large cross-sectional study that included Greek children aged 10–12 years old (GRECO study). Complete usual dietary intake was assessed using a 48-item self-administered picture aid FFQ (FFQ can be seen in Supplementary material) through public schools. All participants were asked about their usual frequency of food consumption on average over the last year with response categories ranging from never, 1–2 times per month, once a week, twice a week, 3–6 times per week, to everyday. Visuals were used to help children to understand and address portion sizes. Specifics on the type of food consumed were also asked for, including whole wheat grains and cereals. Total frequency intake was converted to servings per day and these were used to calculate the total FI score per child.

Data from 4832 children leaving in the Greek municipality (semiurban and urban areas), aged 10–12 years were collected. Anthropometrics gathered included measurements by trained personnel, on body weight to the nearest 100 g (Tanita TBF 300), body-standing height without shoes (Leicester height measure) to the nearest 0.1 cm and WC to the nearest 0.1 cm (Seca, non elastic tape, Germany). Percentage of body fat (%BF) and fat mass (kg) were estimated by the foot-to-foot impedance method (Tanita TBF 300). Body mass index (BMI) was calculated by dividing weight (kg) by standing weight squared (m²). Detailed information on sampling and measurements has been already published (Farajian et al., 2011, 2013). After data inspection, a total of 452 children were excluded; 117 children had all data missing; 95 children had left unanswered over 20% of the FFQ (≥10 questions) and 240 individuals had reported implausible energy intake (<600kcal/day or >6000kcal/day). A total of 4439 individuals remained and were included in the FI validation.

Basal Metabolic Rate (BMR) was calculated based on Schofield’s equation (Schofield, 1985).

### Physical inactivity

The FFQ contained questions on television (TV) and computer possession in the bedroom, as well as total time spent (a) watching TV, (b) playing video games, (c) surfing on the Internet and (d) studying. The total sedentary hours were derived and added in order to adjust for physical inactivity as a proxy measure of physical activity.

### BMI category derivation

Children’s BMI cut-offs were defined based on International Obesity Taskforce (IOTF) standards (IV) (Cole & Lobstein, 2012). According to the authors, these new cut-offs are easy to derive and can be expressed as BMI centiles, allowing them to be compared with other BMI references. Children were separated in five categories based on their age and gender specific BMI; underweight, normal weight, OW, obese and morbidly obese, as per IOTF definitions (Table 3). Age and gender were considered since a child’s BMI changes with age, and growth patterns differ between genders (Cole & Lobstein, 2012). They were finally grouped into three categories for the final statistical tests based on the frequency and percentages observed (1: under- and normal-weight; 2: overweight; 3: obese and morbidly obese children) (Table 3).
Table 2. Food index scoring system.

| Score | Food groupa | 4 | 3 | 2 | 1 |
|-------|-------------|---|---|---|---|
| Whole grains *(×1.5)b | ≥4 | ≥3, <4 | ≥2, <3 | <2 |
| Vegetables *(×1.5)b | ≥4 | ≥3, <4 | ≥2, <3 | <2 |
| Fruit *(×1.5)b | ≥3 | ≥2, <3 | ≥1, <2 | <1 |
| Milk *(×1.5)b | ≥2 | ≥1, <2 | >0, <1 | 0 |
| Yogurt | ≥2 | ≥1, <2 | >0, <1 | 0 |
| Fish | ≥2 | ≥1, <2 | >0, <1 | 0 |
| Nuts | ≥3 | ≥2, <3 | ≥1, <2 | <1 |
| Legumes | ≥2 | ≥1, <2 | >0, <1 | 0 |
| Red meat | <1 | ≥1, <2 | ≥2, <3 | ≥3 |
| Processed food | <1 | ≥1, <2 | ≥2, <3 | ≥3 |
| Cheese | ≤1 | >1–2 | ≥2, <3 | ≥3 |
| Fast-food | ≤1 | >0–1 ≥1, <2 | >2 | 2 |
| Sugar sweet beverages (ssb’s) | <1 | ≥1, <2 | ≥2, <3 | ≥3 |
| Sweets | <1 | ≥1, <2 | ≥2, <3 | ≥3 |

aWhole grains, fruit, vegetables, milk, yogurt and cheese are designated in servings per day. Nuts, legumes, fish, fast-food, red meat, processed food, ssb’s and sweets are designated in servings per week.
bWeights of 1.5 were given to whole grains, vegetables, fruits, milk and legumes.
c618 missing values for wgrains (total n = 3817); one missing for fruit (n = 4434); six missing for milk (n = 4429); 114 missing for yogurt (n = 4321); 25 missing in fish group (n = 4410); 40 missing in nuts (n = 4395); 233 missing in legumes (n = 4202); 46 missing in redmeat group (n = 4389); 178 missing in cheese group (n = 4257); zero missings for sweets, ssb’s fastfood and processed food (n = 4435).

Table 3. Children’s weight categorization based on adult’s BMI according to IOTF standards and BMI categories used in FI validation.

| Children’s classification | Respective adult BMI | BMI category | GRECO frequency | Total % | % Boys | % Girls | p Value |
|---------------------------|----------------------|--------------|-----------------|---------|--------|---------|---------|
| Normal weight             | ≥18.5–<25            | 1            | 2327            | 54.87   | 53.97  | 55.72   | 0.572   |
| Underweight               | <18.5                | 2            | 148             | 3.49    | 2.96   | 4.00    |         |
| Overweight                | 25–<30               | 3            | 1260            | 29.71   | 30.18  | 29.26   |         |
| Obese                     | 30–<35               | 4            | 447             | 10.54   | 11.24  | 9.88    |         |
| Morbidly obese            | >35                  | 9            | 59              | 1.39    | 1.65   | 1.15    |         |
| Total                     | n/a                  | 1            | 4241            | 100     | 100    | 100     |         |

Statistical analysis

Data presentation

Descriptive statistics, including frequencies, mean, median, standard deviation (±SD) and range (minimum–maximum values) were calculated for continuous variables and to describe the distribution of the FI. Categorical variables (such as gender, age-group, BMI categories, inactivity level) were summarized as relative frequencies (%).

Probable gender differences were assessed using t-test, whereas differences in age and in BMI categories were assessed using ANOVA, with Bonferroni correction in order to reduce type
1 error (reject the null hypothesis Ho when it is true), a possible error seen with Student’s t-test when analyzing more than two variables.

Scatter plots were constructed for each variable of interest separately to assess linear association with total food score and detect common outliers or any other discrepancies in data.

Food index (FI)

Cronbach-alpha (α) was performed in order to test the interrelation of each variable used in the FI model constructed and in total. Most acceptable values were considered as α = 0.7–0.95 (Tavakol & Dennick, 2011). In order to strengthen the results from Cronbach-α and to confirm the constructive validity of the index, Factor analysis was done. An Eigen value >1 was considered informative.

Via Variance Inflation Factor (VIF), the extent to which pairs of variables provide independent information for purposes of predicting the dependent variable (FI total), given the presence of other variables in the model, was tested. The main aspect was to avoid collinearity. As a rule of thumb, a variable whose VIF values are greater than 10 merit further investigation; tolerance (1/VIF) level less than 0.1 is comparable to VIF+ >10. A high value may mean that the variable could be considered as a linear combination of other independent variables and should be removed. Bootstrap in 100 replications from the data set was also performed to assess results from random sampling.

In order to assess whether the FI can adequately detect children at risk for OW or OB, random sampling without replacement was performed, splitting the GRECO data randomly into two (2) new data sets 75–25%. An OB equation derived from the first data set (75% sample; 3326 random observations) was then applied to the 2nd data set (25% sample):

\[
\text{probability of being obese} = \frac{\exp(b0 + b1 \times \text{score})}{1 + \exp(b0 + b1 \times \text{score})}
\]

The strength of the index was examined by assessing the association of the probability of being OW/OB, as derived from the first sample, with the total FI score achieved by the children from the second sample (25% sample).

Data analysis

Multiple linear regression analysis was performed to test the contribution of each individual food included in the FI on the total score via the coefficient of variation (R²). This is a quantitative measure of the weight each food quartile has on the total FI score alone and when adjusted for the other variables. The coefficient of variation (R²) was determined and was reported as a test of how well the model accounts for the outcome. To overcome the limitation that the coefficient of variation has (increases as the number of variables increase), the adjusted R² were also calculated and reported. A positive adjusted R² indicates that the gain in adding the variable is greater than the charge.

FI scores were depicted in total for each child and then stratified by gender and age, to detect any differences. Total score and median values were compared. Linear regression was used to assess the relationship between total FI score and BMI (continuous) measure, as well as the association between FI and WC. Crude and adjusted measures were investigated, considering age, gender and physical inactivity in the model. The median value of the total FI was assigned as the cut-off point in the analysis to discriminate among the children’s weight status. Specifically, the total food score was dichotomized above and below the median (Q3 & Q4 versus Q1 & Q2), to investigate the upper two quartiles and its association with OW and OB (BMI) compared to the lower two. Logistic regression analysis was used to evaluate potential associations between the median FI score and categorical BMI status assuming linear association. This was firstly seen in unadjusted (crude) format and then probable confounders were assessed by a stepwise approach via multivariable logistic regression. In each step the Likelihood Ratio Test (LRT; Chi square model) was used.

Confounding

Confounders, including age, gender, physical inactivity and potentially energy intake were included in a step-wise approach. Physical inactivity was used as a proxy of sedentary activity and was derived by summing the average time spent watching TV and/or other “screen time” including video games and computer plus the total number of study hours over the week. Statistical analysis was conducted using Stata Version 12.0 (StataCorp., 2011). Differences of p < 0.05 were considered to be significant.

Results

Total FI score in the GRECO population ranged from 17 (min value) to 53.5.(max value). The overall mean was 34.5 (+5.01) and the median score was 34.81, therefore a normal distribution was assumed (Table 4). The mean FI score and the mean inactivity hours, between genders were not statistically different (ANOVA; p = 0.138 and 0.290, respectively), whereas a difference was found in the gender’s mean BMI (p = 0.034), WC (p<0.001) and in total Energy intake (p<0.001). Table 1 summarizes the food that have been used to create the FI, whereas Table 2 depicts the scoring system derived as explained earlier in methods section. In Table 5, the unique variance contribution of each independent food variable to the FI listed and the common variance contributions for all independent variables to the equation were derived. Vegetables and legumes had the highest individual contributions (R²=0.179 and 0.232, respectively). A 0.989 (or 98.9%) total coefficient variation was obtained in the FI model meaning that the variables in the model can explain 98.9% of the total score obtained.

No collinearity was observed among explanatory variables (age, BMI, gender and inactivity). The VIF and tolerance (1/VIF) ranged from 1.02 to 3.31, with the latter being the tolerance level for WC (data not shown). Independency was therefore assumed among the variables.

Children’s weight classification and its relation to adult’s BMI levels as per IOTF standards are given in Table 3. About 58% were depicted as under- and normal-weight (3.49% and 54.87%, respectively), approximately 30% of the children were found OW and 12% were noted as obese, with no evident statistical difference in mean BMI distribution between males and females (p = 0.572). The final BMI categories developed and used for the analysis are also depicted in this table. Children were classified into three groups based on their age: 1 if ≤10, 2 if around 11 years old and 3 if ≥12. Approximately 30% of the total children were in category 1 (28% boys and 32% girls), 49% children in 2 (49.6% boys and 48.9% girls) and 21% in category 3 (22.8% boys and 19.2% girls). A statistically significant difference was observed between age groups and gender (p<0.001). A statistical significant difference was also found when assessing BMI categories between boys and girls (p = 0.03), with approximately 57% of boys versus 60% of girls being under- or normal-weight; 30% boys versus 29% girls being OW; and 13 % boys versus 11% girls being OB. A borderline difference between BMI categories and age groups (p = 0.047) was also found (data not shown).

A statistically significant effect was derived between total food score and child’s BMI (−0.057 ± 0.02, 95% CI: −0.098, −0.017), and their WC (−0.08 ± 0.03, 95% CI: −0.137, −0.022), in a crude
Discussion

The FI score adequately distinguished OW and obese children, from normal and under-weight. With every unit increase in the FI score the children were \(0.057 \times \) less likely to be OW or obese and 0.08 times less likely to have a larger WC, whereas the higher the BMI category the higher the likelihood of children having a FI score below the median. The association remained significant upon adjusting for age, gender and total inactivity.

Composing an index remains a complex matter with a large degree of subjectivity. In order to avoid creating «yet another index» but to expand on the ones already created, data from previous studies derived along with current knowledge on childhood OW/OB and obesogenic factors were used to derive a more sensitive index. Feskanich et al. (2004) suggested and used an index that contained «harmful» foods along with those recommended by organizations. The current FI index expanded upon the researchers work and further distinguished foods based on recent evidence in order to create an index that may detect OW/OB in children. The FI was derived specifically for school aged children, and designed to primarily detect OW and OB in this age group based on a priori knowledge. All known food items that have been shown to add to health, prevent weight increase and those that may increase weight were added. Also potential high-risk foods, not yet proven but speculated to lead to weight increase were added in order to test the interrelatedness of these food items. For example, a large prospective study in the US women found that weight gain was inversely associated with fruit, vegetable, whole grain, nut and yogurt intake (Mozaffarian et al., 2011). This is in accordance with evidence suggesting that an index that includes all components associated with the outcome, separated even if these belong in the same food group, in order to account for interaction between dietary components, as long as they are not interrelated (no collinearity), has a higher diagnostic accuracy compared to indexes that contains only some of the components (Kouruba & Panagiotakos, 2009; Waijers et al., 2007). No collinearity was present in our results and a good Cronbach-alpha (value of 0.7) was derived with this FI.

The role of ssb’s on childhood OW and OB was investigated in a total FI aspect, due to the controversial results (Malik et al., 2006) and potential publication bias (Forshae et al., 2008) when
studied individually. Results obtained support the hypothesis that when ssb’s are consumed in association with a low FI score, the probability for OW/OB in school-aged children increases. This is supported by researchers (Collison et al., 2010) that have reported poor dietary choices in individuals aged 10–19 years with a high intake of sugared sweetened carbonated beverages.

To further decrease subjectivity, a sensitivity analysis, via splitting the data into two new data sets (75–25%) via random sampling was performed upon FI validation by the GRECO study. This strengthened the power of the index to detect OW/OB children since the probability equation derived from the first data set was used to find the probability of OB in the second data set (25% random sample). The FI score was significantly lower among those OW/OB compared to normal or underweight children.

Table 6. Crude and adjusted linear regression between total FI score and BMI, and between total FI score and WC.

| Coefficient (±SE) | p Value | 95% CI |
|-------------------|---------|--------|
| **BMI**           |         |        |
| Total FI           | -0.057 [0.02] | **0.005** | -0.098, -0.017 |
| By Gender         |         |        |
| Males             | -0.058 | 0.05 | -0.12, -0.001 |
| Females           | -0.06 [0.04] | **0.037** | -0.116, -0.004 |
| Waist circumference |       |        |
| Total FI           | -0.08 [0.03] | **0.007** | -0.137, -0.022 |
| By Gender         |         |        |
| Males             | -0.075 [0.04] | **0.077** | -0.158, 0.008 |
| Females           | -0.098 [0.01] | **0.014** | -0.177, -0.019 |
| **Adjusted linear regression** |         |        |
| BMI               |         |        |
| Total FI           | -0.057 [0.02] | **0.005** | -0.098, -0.017 |
| Gender            | -0.058 (0.02) | 0.004 | -0.099, -0.018 |
| Age               | -0.049 (0.02) | **0.017** | -0.090, -0.009 |
| Inactivity        | -0.048 (0.02) | **0.020** | -0.089, -0.008 |
| Waist circumference |       |        |
| Total FI           | -0.08 [0.03] | **0.007** | -0.137, -0.022 |
| Gender            | -0.09 (0.03) | **0.03** | -0.143, -0.029 |
| Age               | -0.075 (0.029) | **0.01** | -0.132, -0.018 |
| Inactivity        | -0.072 (0.013) | **0.013** | -0.130, -0.015 |

Statistical significant results are shown in bold.

Table 7. Acquired results between BMI categories and total FI median score: crude and adjusted data from logistic & multivariable logistic regression.

| BMIa | Coefficient | SE | p Value | 95% CI | Unique chi square | Model chi squareb |
|------|-------------|----|---------|--------|-------------------|------------------|
| Total FIb | -0.069 | 0.03 | 0.007 | -0.121 to -0.0187 | 0.0073 | – |
| Gender | -0.071 | 0.03 | 0.007 | -0.122 to -0.020 | 0.016 | <0.001 |
| Agec | -0.076 | 0.03 | 0.004 | -0.127 to -0.127 | <0.001 | <0.001 |
| Inactivityd | -0.046 | 0.03 | 0.089 | -0.098 to -0.007 | <0.001 | <0.001 |

Table 7. Acquired results between BMI categories and total FI median score: crude and adjusted data from logistic & multivariable logistic regression.

| BMIa | Coefficient | SE | p Value | 95% CI | Unique chi square | Model chi squareb |
|------|-------------|----|---------|--------|-------------------|------------------|
| Total FIb | -0.069 | 0.03 | 0.007 | -0.121 to -0.0187 | 0.0073 | – |
| Gender | -0.071 | 0.03 | 0.007 | -0.122 to -0.020 | 0.016 | <0.001 |
| Agec | -0.076 | 0.03 | 0.004 | -0.127 to -0.127 | <0.001 | <0.001 |
| Inactivityd | -0.046 | 0.03 | 0.089 | -0.098 to -0.007 | <0.001 | <0.001 |

The index was kept simple, by including food items only, in order to be used easily as a tool by trained health care professionals. To date only five other researchers, to our knowledge have addressed school aged children (Feskanich et al., 2004; Lazarou et al., 2011; Manios et al., 2015; Serra-Majem et al., 2004) and only two have derived scores with primary objective to assess OW and OB (Lazarou et al., 2009; Manios et al., 2015).

A scale of 1–4 was used with a weighting system in order to increase its discriminating power. It is reported that indices that have a small scoring scale appear to be less sensitive in their evaluation of dietary intake and fail to capture extremes and intrinsic characteristics of food behaviors and eating patterns (Wirt & Collins, 2009; Waijers et al., 2007), whereas indices with a larger scoring system are more sensitive in detecting small
changes in eating habits, and may allow the score to better discriminate individual intake unfolding internal variability (Waijers et al., 2007).

Results of the present study indicate that as the FI score increases, the probability of a child being OW/OB decreases. In all child-based indices all individual variables are given the same weight, therefore contribute equally to the score. Since this is the first time to our knowledge, that weights are given to food items, and since the exact ‘health’ impact is difficult to ascribe, the weights given may be underestimated, hence further underestimating the probability of a child being OW/OB. Research specifically testing the risk ratio (RR) of the individual index components on OB may be warranted in order to determine more specifically the exact differences in weights of each individual component in the index.

When inactivity, age and gender were controlled for the association increased, and remained statistically significant, in support to other research findings (Feskanich et al., 2004; Lazarou et al., 2011; Manios et al., 2015; Serra-Majem et al., 2004). When energy intake was controlled for, the association between BMI and FI seized to be significant. This is in discordance with Golley et al. (2011), although the FI (DGI-CA) used was not specifically derived to assess OW/OB. Research specifically testing the risk ratio (RR) of the individual index components on OB may be warranted in order to determine more specifically the exact differences in weights of each individual component in the index.

Limitations

Behavioral factors, which have also been greatly studied, have been associated with childhood OW and OB, and have been used in other food indexes (Feskanich et al., 2004; Lazarou et al., 2011; Manios et al., 2015) were not accounted for in this FI, since cheese, a high fat dairy product, was added to the «harmful foods». Furthermore, two cohort studies in young children (Scharf et al., 2013) and adolescents (Berkey et al., 2005) showed that children or adolescents consuming low fat milk had a similar increase in body weight as those consuming full fat. Refined grains were omitted since they are counterbalanced with whole grains. Alcohol was not accounted for due to the age of the population studied. Total fat content and other macronutrients were not separately assessed since the food as a whole, and how these interrelate, and not specific macronutrients, was investigated. This further simplifies the providing an easy tool for use to health care professionals.

Measurements were performed by trained personnel and substantial equipment, decreasing reporting bias, which can decrease the size and reliability of the evidence. Under-reporting of total food intake by children with weight problems or those who were weight concerned, is always a problem. This was accounted for in the analyses where implausible data (>6000 kcal, or <600) were excluded.
The FFQ used to assess children’s dietary habits and intakes in general had a total of 48 questions, with some sub-questions. This may have been overwhelming for a child, therefore leading to reporting bias. However, the FFQ was based on seasonal variability and any discrepancies viewed were either tailored back to the child by a trained professional or were cleaned from the data prior to analysis (i.e. implausible energy intake >6000 kcal). The age group studied affects the results derived since food/nutrient recommendations differ based on their growth and overall needs. Although, food portions and not portion sizes from the data prior to analysis (i.e. implausible energy intake back to the child by a trained professional or were cleaned increase the sensitivity of the index.

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