Maternal dietary quality during pregnancy and child appetitive traits at 5-years-old: Findings from the ROLO longitudinal birth cohort study

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ABSTRACT

Maternal diet during pregnancy is an important determinant of birth outcomes and offspring health. The relationship between maternal diet quality during pregnancy and the development of appetitive traits in early childhood has not been extensively researched. We examined associations of maternal diet quality during pregnancy with child appetitive traits at 5 years old. This is a secondary analysis of the ROLO longitudinal birth cohort study. We assessed maternal diet during pregnancy using 3-day food diaries and evaluated diet quality using the Alternative Healthy Eating Index, modified for pregnancy (AHEI-P). Children’s appetitive traits at 5-years-old were assessed using the Child Eating Behaviour Questionnaire (CEBQ) (n = 306). Average AHEI-P score over trimesters was calculated and stratified into tertiles. Maternal and child characteristics were examined across AHEI-P tertiles. Multiple linear regression was conducted to explore associations between maternal AHEI-P scores in each trimester and child appetitive traits at 5-years-old. Women with low AHEI-P scores were younger at childbirth and had higher BMI. In adjusted linear regression maternal AHEI-P was negatively associated with child ‘Desire to Drink’ (Trimester 1: B = −0.014, 95% CI = −0.025, −0.002, p = 0.017; Trimester 2: B = −0.013, 95% CI = −0.025, −0.001, p = 0.035). Trimester 3 AHEI-P was not associated with any child appetitive traits. Maternal diet quality in pregnancy may provide an early opportunity to positively influence the development of offspring’s appetitive traits.

1. Introduction

Maternal dietary intake during pregnancy is an important determinant of birth outcome and offspring health (Barker, 1998). The ‘Development of Origins of Health and Diseases’ theory postulates that transient early life exposures, including inadequate maternal nutrition pre-conception and during pregnancy, may impact offspring development and influence the occurrence of disease in adult life (Barker, 2007). Evidence suggests that fetal growth and development, particularly in early pregnancy, may be influenced by maternal dietary intake (Wu et al., 2004) and that prenatal programming of flavor preference may influence acceptance of foods in early childhood (Mennella et al., 2001). Previous studies have examined the associations between overall maternal diet quality and offspring birth weight (Poon et al., 2013) and growth outcomes (Rodriguez-Bernal et al., 2010; Shapiro et al., 2005); however, the relationship between the quality of maternal diet during pregnancy and the development of child appetitive traits in early childhood has not been extensively researched.

Appetitive traits have been described as persistent dispositions to prefer or eat foods or eating styles that differ between individuals (Carnell &
This includes traits related to appetite and food preference (Dubois et al., 2013). Research suggests that some childhood appetitive traits have a strong genetic basis such as ‘Food Fussiness’ (Cooke et al., 2007; Faith et al., 2013) and ‘Food Responsiveness’ (Llewellyn et al., 2010). Other appetitive traits such as ‘Emotional Over-eating’ and ‘Emotional Under-eating’ are thought to be learned behaviours and are primarily shaped by the shared family environment rather than genetic predisposition (Herle et al., 2018). As per the life course model (Pérez-Escamilla & Kac, 2013), genetics and food exposure in early feeding interact to lay the foundations for life long eating habits (Lillycrop & Burdge, 2011; Pérez-Escamilla & Kac, 2013). Our question relates to the impact of maternal diet quality during pregnancy on child appetitive traits in young children. From birth, infants have an innate preference for sweet foods and tend to reject bitter tastes (Ventura & Mennella, 2011). This may have developed as a survival mechanism to ensure that infants were attracted to energy dense foods and that they avoided toxic foods. However, in addition to this genetic predisposition, research shows that a child’s flavor and taste acceptance are related to what they experience from maternal diet in-utero and through breastfeeding (Mennella et al., 2001). It is postulated that the repeated, early exposure to flavors of foods may help promote their acceptance in later life (Mennella et al., 2001). Whilst taste buds are formed in early pregnancy, it is thought that it is not until the third trimester that they become capable of transmitting gustatory information, when amniotic fluid variations caused by the mother’s diet stimulate fetal taste receptors (Bradley & Mistretta, 1975). However, flavor and odor may be experienced in earlier trimesters (Mennella et al., 2001). Evidence suggests that a child’s food preferences in later stages of life will be shaped by the sensory experience of flavor, odor and taste that they are exposed to through maternal amniotic fluid in pregnancy. Strong food preferences are a distinctive component of appetitive traits such as fussy eating (Carruth et al., 1998).

Research on maternal dietary patterns in pregnancy have been explored using a number of maternal and child outcomes (McGowan & McAuliffe, 2013; Northstone et al., 2008; Torjusen et al., 2012), although to our knowledge none have explored children’s appetitive traits as an outcome. Murrin et al., (2015) investigated whether children’s adiposity at 5 years old could be influenced by maternal dietary patterns during pregnancy (Murrin et al., 2015). Their findings demonstrated that dietary patterns during pregnancy containing higher intakes of processed foods, such as soft drinks, confectionary, pizza, and chips had a significant positive association with childhood overweight and obesity at 5 years old. These findings pose the question as to whether maternal diet quality during pregnancy will influence the development of her offspring’s food preferences and appetitive traits in later childhood, particularly those appetitive traits that are known to be related to child excess adiposity (McCarthy et al., 2015; van Jaarsveld et al., 2014). A child’s behavior towards food will impact the quantity, type and frequency of food eaten, and is considered an important factor in understanding the determinants of childhood obesity (Carneil & Wardle, 2008). Research in both adults (Hays et al., 2002) and children (Herle et al., 2020) have demonstrated that appetitive traits differ between those who are overweight compared to those with a healthy weight. Fetal in-utero exposure to a maternal diet that is of poor quality, i.e., high in fat, sugar and low in fruit and vegetable intake, may be influential in predetermining dysregulation of appetite and or satiety.

It has been established that flavor and odor perception develop and function in-utero (Mennella et al., 2001) and that food and environmental exposures postnatally will continue to contribute to the development of a child’s food preference and eating style. However, maternal food choice during pregnancy may set the stage for how a child’s food preferences and appetitive traits are established through the potential effect of in-utero flavor and odor exposure. This study explores associations between maternal dietary quality in early, mid and late pregnancy and child appetitive traits at 5-years-old.

2. Methods

2.1. Study population

This study is a secondary analysis of the ROLO longitudinal birth cohort study. The primary study was a randomized control trial of a low glycemic diet in pregnancy to prevent the recurrence of fetal macrosomia (birth weight ≥ 4 kg) (Walsh et al., 2012). Secundigravida women (n = 800), aged 18 or above who had previously given birth to a macrosomic infant (>$4 kg) were recruited before their 18th week of pregnancy. Participants were randomized to the intervention group who received low glycemic index dietary advice or the control group who received usual antenatal advice with no specific dietary advice. The primary outcome of this study was birth weight of the infant, with no differences seen between the intervention and control groups. Neonatal adiposity was observed to be slightly lower in the intervention group compared to the control group. Some maternal benefits were demonstrated in the intervention group, with improved glucose homeostasis and less maternal gestational weight gain. Full detailed findings are published elsewhere (Walsh et al., 2012). The mother and child dyads from the original study have been followed up at regular timepoints, including when the children were 5 years old. A total of 401 mother-child dyads attended the 5-year-old follow-up of which 306 provided data on children’s eating behaviours. Ethical approval was provided by ethics committees at Our Lady’s Children’s Hospital, Dublin and the National Maternity Hospital, Dublin Ethics Committees (Ethics reference number: GEN/279/12).

2.2. Measurements

At the first antenatal visit (12–14 weeks) women were weighed in light clothing using a calibrated stand-on digital weighing scales (SECA GmbH & Co. KG, Hamburg, Germany) to the nearest 0.1 kg. Height was measured using a wall-mounted stadiometer. At the 5-year follow-up visit, mother and child weight (kg) were measured using a calibrated stand-on digital weighing scale (SECA 813, GmbH & Co. KG Hamburg, Germany) to the nearest 0.1 kg. Participants were measured in light clothing without shoes. Mother and child standing height were measured, without shoes, with head aligned in the Frankfort plain, using a free-standing stadiometer (SECA 217, GmbH & Co. KG, Hamburg, Germany) and measurements recorded to the nearest 0.1 cm. Body mass index (BMI) was calculated as kg/m². Children’s BMI scores were converted to standardized z-scores according to the 1990 UK age- and sex-specific reference data using Excel LMS Growth macro (Cole et al., 2000; LMS Growth, 2012).

2.3. Exposure: Maternal diet quality during pregnancy

Three-day food diaries were completed in each trimester of pregnancy (trimester 1: 0–14 weeks, trimester 2: 15–28 weeks, and trimester 3: 29–42 weeks’ gestation). The food diaries collected data on typical food and beverage intakes over 3 consecutive days, encouraging inclusion of 1 weekend day during the time period recorded. Participants were instructed to write down everything that they ate and drank for 3 days, including one weekend day e.g., Thurs, Fri, Sat or Sun, Mon, Tues and to quantify their food and beverage intake either by weight or household measures. If a quantity was not clearly recorded, an average food portion was assigned by the research Dietitian using standard portion sizes from the Food Standards Agency (Food Standards Agency Crawley, 2006). Food diaries were analyzed using NetWISP version 3.0 (Tinuiel Software, Llanefchell, UK) based on data from the sixth edition of McCance and Widdowson’s food composition tables (Food Standards Agency, 2002).

Diet quality during pregnancy was assessed using the Alternative Healthy Eating Index modified for Pregnancy (AHEI-P) (Rodriguez-Bernal et al., 2010). The Healthy Eating Index (HEI) is a composite...
quality dietary score which was developed by the US Department of Agriculture (Kennedy et al., 1996). Subsequently, the HEI was modified to create the Alternative Healthy Eating Index (AHEI) and further adapted to be relevant to a pregnant population (AHEI-P) (McCullough et al., 2002; Rodriguez-Bernal et al., 2010). The AHEI-P includes 10 components: vegetables, fruit, ratio of white to red meat, fiber, trans fatty acids, ratio of polyunsaturated to saturated fatty acids, nuts and soy, folate, calcium, and iron. The maximum score achievable is 100 points. For each component 10 points is awarded if the ideal quantity of food is consumed. For every 10% decrease in intake, 1 point is subtracted (Rodriguez-Bernal et al., 2010). The AHEI-P does not specifically include sugar-sweetened beverage (SSB) intake within its scoring, therefore in view of our results and the availability of this data, maternal SSB was identified from 3-day food diaries for further analysis. Maternal sugar sweetened beverage intake included carbonated sweetened drinks, fruit juices, cordials and non-alcoholic beer. Intakes of these drinks were grouped per trimester and mean intake calculated over the 3 days of each trimester.

2.4. Outcome: Child appetitive traits

Child appetitive traits were measured using the Child Eating Behaviour Questionnaire (CEBQ) (n = 306) (Wardle et al., 2001). The CEBQ is a parent reported psychometric measure of eight eating behaviours consisting of 35 items, rated using a five-point Likert scale (1 = Never to 5 = Always). Five items are reverse scored due to opposite phrasing. To determine the score for each subscale, the items within the subscale are summed and its mean calculated by dividing the sum by the number of items within the subscale. A higher score indicates the child is more likely to express this eating behaviour. The CEBQ was developed and validated for use in children aged 4–5 years old, but has been used for children up to 12 years old (Carnell & Wardle, 2007; Sleddens et al., 2008; Wardle et al., 2001). It shows good internal, test-retest reliability and stability over time (Ashcroft et al., 2008). Each of the eight subscales explores a different aspect of a child’s appetitive traits. Four of the eight eating behaviour subscales are considered food approach behaviors, and four subscales are considered food avoidant eating behaviors. The food approach subscales include: ‘Food Responsiveness’ which measures a child’s inclination to eat in response to external food cues (includes 5 items, e.g. ‘Given the choice my child would eat most of the time’); ‘Enjoyment of Food’ measures how much a child enjoys eating (includes 4 items, e.g. ‘My child loves food’); ‘Emotional Overeating’ measures how the child eats in response to emotional stressors (includes 4 items, e.g. ‘My child eats more when worried’) and ‘Desire to Drink’ measures a child’s yearning to consume beverages (includes 3 items, e.g. ‘My child is always asking for a drink’). The food avoidant subscales include: ‘Satiety Responsiveness’ which measures a child’s responsiveness to how quickly they will feel full (includes 5 items, e.g. ‘My child gets full up easily’); ‘Emotional Undereating’ measures a child’s tendency to eat less due to emotional stressors (includes 4 items, e.g. ‘My child eats less when he/she is tired’); ‘Slowness in Eating’ measures the speed at which a child eats their meal (includes 4 items, e.g. ‘My child eats slowly’) and lastly ‘Food Fussiness’ measures a child being choosy about flavor, texture or taste, and reluctance to try new foods (includes 6 items e.g. ‘My child refuses new foods at first’). A total of 306 mothers completed a CEBQ for their child with internal reliability coefficients (Cronbach’s alpha) ranging from 0.695 to 0.928, thus all questions were included in the analysis. The internal consistency for each factor were ‘Food Responsiveness’ (α = 0.822), ‘Emotional Overeating’ (α = 0.758), ‘Enjoyment of Food’ (α = 0.890), ‘Desire to Drink’ (α = 0.864) ‘Satiety Responsive’ (α = 0.779), ‘Slowness Eating’ (α = 0.792), ‘Emotional Undereating’ (α = 0.695), and ‘Food Fussiness’ (α = 0.925).

2.5. Covariates

Mothers completed lifestyle questionnaires after their first antenatal visit for the ROLO study and at the 5-year follow-up. The antenatal questionnaire asked mothers to identify their ethnicity from one of five categories. Maternal education was self-reported and was selected from the following categories ‘no schooling’, ‘primary education only’, ‘some secondary level’, ‘complete secondary level’, ‘some third level (certificate/diploma)’ or ‘complete third level (higher degree)’. The Pobal Haase & Pratschke Deprivation Index (HP Index) was used to allocate a deprivation score as per the participants address or small area (The 2011 Pobal HP Deprivation Index for Small Areas (SA), 2012) using the address of the participant obtained during the primary ROLO study (2007–2011). The HP Index was derived from ‘2011 Census of Population in Ireland’ data, it provides information on a combination of three dimensions of relative affluence and deprivation, specifically demographic profile, social class composition and labor market supply and demand. A negative score (below 0) is classified as socioeconomically disadvantaged and a positive score (above 0) classified as socioeconomically advantaged. Breastfeeding exposure were recorded at 6 months, 2 years and 5 years. At each of these timepoints, mothers reported if they had ever breastfed. At the 2 year and 5-year follow-up mothers reported the age (weeks) their infant commenced solid food. A variable was created to indicate if their child had started solid food as per European (Fewtrell et al., 2017) and national guidelines (Health Service Executive, 2019) that is, that complementary foods are not introduced before four months (17 weeks), but should not be delayed beyond six months (26 weeks).

2.6. Statistical analysis

Continuous data were tested for normality using the Kolmogorov–Smirnov test and visual inspection of histograms. All appetitive trait variables were considered normally distributed; therefore, parametric analysis tests were used. Maternal characteristics were examined for those with AHEI-P data who had returned for the 5-year follow-up, and those who had AHEI-P data but were not part of this analyses. Independent t-tests were completed to test for differences between AHEI-P for each trimester across RCT control and intervention groups. One-way repeated measures ANOVA was performed to examine difference in AHEI-P score over pregnancy. The average AHEI-P score over trimesters was calculated and stratified into tertiles of low, medium and high-quality diet. To provide context of the cohort’s characteristics across AHEI-P score, one-way ANOVA with Tukey tests for post hoc analysis or Kruskal Wallis tests were completed to examine child BMI z-score, maternal age at delivery, maternal BMI at first antenatal appointment, maternal BMI at 5-year follow-up and maternal pabal HP Index across AHEI-P tertiles. Pearson’s correlations examined relationships between maternal AHEI-P score in each trimester and each of the eight children’s eating behaviour scales. Unadjusted and adjusted linear regression analysis was completed to examine associations between AHEI-P score in each trimester and child appetitive traits at 5 years old. Adjusted regression models controlled for maternal BMI at 5-year follow-up, maternal education level, child breastfeeding exposure, timing of introduction of complementary feeding, child age at 5-year follow-up, child sex and original RCT allocation group. In post hoc analysis, to further explore the relationship between maternal SSB intake during pregnancy and child ‘Desire to Drink’ at 5 years old, Spearman’s correlations were completed to examine maternal SSB intake in each trimester and child ‘Desire to Drink’. Statistical analyses were completed using IBM Statistical Package for Social Sciences (SPSS) for Windows, version 24.0 (Armonk, NY: IBM, Corp).

3. Results

The group characteristics are presented in Table 1. Mean (SD) maternal age at delivery was 33.26 (3.88) years. Median (IQR 25th-75th) maternal BMI at the first antenatal visit was 25.18 kg/m² (23.11,27.49) and was similar at the 5-year follow-up. At the 5 year
Table 1

General maternal and child characteristics of included ROLO mothers and 5-year-old children.

|                                | n (%) | Mean (median) | SD (IQR) |
|--------------------------------|-------|---------------|----------|
| Mothers age at delivery (years)| 306   | 33.26         | 3.88     |
| Maternal age at 5-year follow-up (years) | 306 | 38.44         | 3.89     |
| Maternal BMI first antenatal appointment (12-14 wks gestation) (kg/m²) | 306 | (25.18)       | (23.11,27.49) |
| Maternal BMI at 5-year follow-up (kg/m²) | 292 | (24.87)       | (22.77,28.23) |
| Maternal ethnicity - white Irish, n (%) | 306 | -             | -        |
| Child birthweight (g) | 306 | 4019.85       | 452.63   |
| Intervention group - primary ROLO study, n (%) | 163 | -             | -        |
| Pobal HP Index | 306 | (7.45)        | (1.08,12.40) |
| Maternal AHEI-P score | 500 | 54.18         | 9.22     |
| Maternal AHEI-P score average over 3 trimesters (full pregnancy cohort) | 245 | 55.98         | 8.81     |
| Maternal AHEI-P score average over 3 trimesters (5-year follow-up) | 245 | 55.85         | 11.27    |
| Maternal AHEI-P score Trimester 1 (5-year follow-up) | 245 | 56.01         | 10.57    |
| Maternal AHEI-P score Trimester 2 (5-year follow-up) | 245 | 56.12         | 10.32    |
| Maternal AHEI-P score Trimester 3 (5-year follow-up) | 245 | 56.12         | 10.32    |
| Child characteristics at 5-year follow-up | 293 | 16.18         | 1.34     |
| Child sex (male), n (%) | 141 | (46.1)        | -        |
| Child age at 5-year follow-up (years) | 306 | 5.18          | 0.15     |
| Child BMI at 5-year follow-up (kg/m²) | 293 | 16.18         | 1.34     |
| Child BMI category at 5-year follow-up (%) | 46 | -             | -        |
| Overweight, n (%) | 48 | (16.8)        | -        |
| Obese, n (%) | 48 | (16.8)        | -        |
| Maternal education 5-year follow-up | 173 | (61.8)        | -        |
| Complete third level or above, n (%) | 173 | (61.8)        | -        |
| Some third level, n (%) | 54 | (19.3)        | -        |
| Child appetitive traits at 5-year follow-up | 23 (7.8) | - | - |
| Food Responsiveness | 306 | 2.49          | 0.82     |
| Emotional Overeating | 306 | 1.65          | 0.52     |
| Enjoyment of Food | 306 | 3.73          | 0.76     |
| Desire to Drink | 306 | 2.67          | 0.93     |
| Satiety Responsiveness | 306 | 3.06          | 0.66     |
| Sloowness Eating | 306 | 3.04          | 0.78     |
| Emotional Undereating | 306 | 2.70          | 0.86     |
| Food Fussiness | 306 | 3.08          | 0.98     |
| Child early feeding Breastfed, n (%) | 208 | (68.0)        | -        |
| Age of introduction of complimentary solids (weeks)* | 298 | (23.83)       | (19.50,26.00) |

Results presented as mean and standard deviation (SD) for normally distributed variables and. *Median and interquartile range (25th-75th percentile) for non-normally distributed variables; Categorical data presented as n (%). L BMI categories for maternal BMI -World Health Organisation classification |International Obesity Task Force age- and sex specific BMI cut-offs for defining weight status in children 2–18 years. Mean and SD of CEBQ subscales are derived from the sum of each subscale divided by number of items within the subscale; Abbreviations: ROLO; Randomised control trial of low glycaemic diet in pregnancy.

In adjusted analysis, maternal AHEI-P score in trimester 1 (B = −0.014, 95% CI = −0.025, −0.002, p = 0.017) and trimester 2 (B = −0.013, 95% CI = −0.025, −0.001, p = 0.035) were negatively associated with child ‘Desire to Drink’ (Table 2). In adjusted models no associations were observed between maternal AHEI-P score in trimester 3 and child appetitive traits at aged 5-year-old (Table 2). Of the 245 women with AHEI-P data and CEBQ data, under half (45–46%) consumed sugar-sweetened beverages during pregnancy (Supplementary Table 1). Median (IQR) intake per day for trimester 1 was 100 mls (67–237 mls), trimester 2, 118 mls (67–200 mls) and trimester 3, 133 mls (67–230 ml) (Supplementary Table 1). A positive correlation was observed between those who consumed SSB in Trimester 1 (r = 0.196, p = 0.041) and Trimester 2 (r = 0.204, p = 0.031) and child ‘Desire to Drink’ at 5 years old (Table 3). No relationship was observed between maternal intake of SSB in trimester 3 and child ‘Desire to Drink’. Women in the lowest AHEI-P tertile were younger (p = 0.001) and had higher BMI at their first antenatal visit (p < 0.001) and at their 5-year follow-up (p < 0.001) (Table 4). Child BMI z-score at 5 years old, child birth weight or HP index did not differ across maternal AHEI-P tertiles (Table 4). There was no significant difference in mean AHEI-P score across pregnancy trimesters (Wilks Lambada = 1.0, F (2,241) = 0.16, p = 0.853) (Table 5). Examining differences between AHEI-P score across RCT groups, AHEI-P was higher in the intervention group, 57.69 (10.80) compared to the control group 54.47 (10.11), p = 0.017 in the second trimester only (Supplementary Table 2).

4. Discussion

We found that maternal AHEI-P in early and mid-pregnancy were negatively associated with the food approach appetitive trait of ‘Desire to Drink’. We did not find any associations between maternal AHEI-P in late pregnancy and any of the children’s appetitive traits. Maternal intake of SSB in trimester 1 and 2 were positively correlated with child ‘Desire to Drink’. When average AHEI-P across pregnancy was stratified into tertiles, women with the lowest quality diets were younger at age of delivery, and had higher BMI at their first antenatal appointment and at the 5-year follow-up. No differences were observed in child birthweight, child BMI z-score at 5 years old or poba HP index across maternal diet quality.

The CEBQ was originally developed to identify individual eating styles that contribute to the development of childhood underweight or overweight. The ‘Desire to Drink’ construct represents a food approach appetitive trait. High scores denote a more frequent desire to consume drinks, however, responses do not indicate the type of drink the child desires to consume. A twin study (n = 346) investigating the construct of ‘Desire to Drink’ and how it relates to a child’s drink consumption, food preferences and BMI z-score, found that children scoring higher on the ‘Desire to Drink’ CEBQ subscale, had higher preference and consumption of sugar sweetened soft drinks (e.g., Coca cola), fruit squash (cordial) and milk compared to those with lower ‘Desire to Drink’ scores (Sweetman et al., 2008). In another study, examining predictors of appetitive traits, higher consumption of sugar sweetened drinks at 4 years old were associated with higher scores for ‘Desire to Drink’ when the children were aged 7 years old (Costa et al., 2021). There is follow up, over half of women were categorized as having overweight or obesity (World Health Organization, 2000) and 62% of mothers had completed third level education or above. Average AHEI-P over all trimesters for the full pregnancy cohort who had AHEI-P scores available (n = 500) was 54.18, and for the cohort who returned at the 5-year follow up and who also had CEBQ data (n = 245) was 55.98. No significant differences were seen between AHEI-P in the full group and the subset who were included in the current analyses. Mean (SD) child age at the 5-year follow-up was 5.18 (0.15) years, of which 23% were categorized in the overweight or obese range, as defined by the International Obesity Taskforce cutoffs (Cole et al., 2000). Mean scores and SD of each of the eight CEBQ subscales are displayed in Table 1.
Table 2
Association between maternal AHEI-P score in each trimester and children’s appetitive traits at 5 years old.

| AHEI-P score trimester 1 | AHEI-P score trimester 2 | AHEI-P score trimester 3 |
|--------------------------|--------------------------|--------------------------|
|                        | B                        |                         |
|                          |                        | B                        |
| 95% CI                   |                         | 95% CI                   |
| P-value                  |                         | P-value                  |
| Adjusted R²              |                         | Adjusted R²              |
| Food Responsiveness      | 0.005                    | 0.019                    |
|                         | (0.001, 0.015)           | (0.001, 0.015)           |
|                        | 0.074                    | 0.035                    |
|                         | (0.004, 0.114)           | (0.004, 0.114)           |
| Emotion Overeating       | 0.005                    | 0.012                    |
|                         | (0.001, 0.016)           | (0.001, 0.016)           |
|                        | 0.028                    | 0.039                    |
|                         | (0.005, 0.042)           | (0.005, 0.042)           |
| Enjoyment of Food        | 0.014                    | 0.016                    |
|                         | (0.006, 0.024)           | (0.006, 0.024)           |
|                        | 0.087                    | 0.053                    |
|                         | (0.001, 0.174)           | (0.001, 0.174)           |
| Desire to Drink          | 0.015                    | 0.020                    |
|                         | (0.006, 0.024)           | (0.006, 0.024)           |
|                        | 0.072                    | 0.061                    |
|                         | (0.004, 0.147)           | (0.004, 0.147)           |
| Emotional Undereating    | 0.020                    | 0.020                    |
|                         | (0.003, 0.040)           | (0.003, 0.040)           |
|                        | 0.079                    | 0.077                    |
|                         | (0.004, 0.153)           | (0.004, 0.153)           |
| Food Fussiness           | 0.008                    | 0.008                    |
|                         | (0.001, 0.017)           | (0.001, 0.017)           |
|                        | 0.073                    | 0.074                    |
|                         | (0.004, 0.148)           | (0.004, 0.148)           |

Table 3
Correlation between maternal intake of sugar-sweetened beverages and child ‘Desire to Drink’ at 5 years old.

| Desire to Drink | n | r   | p-value |
|-----------------|---|-----|---------|
| SSB Trimester 1 | 109| 0.196| 0.041   |
| SSB Trimester 2 | 112| 0.204| 0.031   |
| SSB Trimester 3 | 108| 0.189| 0.051   |

SSB: Sugar sweetened beverages; includes carbonated sugar sweetened drinks, fruit juices, cordials and non-alcoholic beers; Spearman’s correlations; Statistically significant (p-value < 0.05).

Our results demonstrated that higher quality maternal diet in early and mid-pregnancy, but not in late pregnancy, were associated with lower ‘Desire to Drink’ scores. This conflicts with expected results, as evidence suggests that the third trimester is the period when most flavor learning occurs (Bradley & Mistretta, 1975). Furthermore, in our cohort, mean maternal diet quality did not change significantly from early to late pregnancy. Dietary flavors that have been consumed throughout pregnancy, such as garlic and anise, have been shown to influence a newborn’s facial expression, and mouthing towards that flavor (Hepper, 1995; Schaal et al., 2000). However, in experimental research by Menella et al., (Mennella et al., 2001) it was in the third trimester, that mothers consumed carrot juice, showing that infants exposed to carrot flavor through amniotic fluid had more positive responses to carrot flavored cereal when compared to those who had not been exposed. Apart from the inverse associations observed between maternal diet quality in early and mid-pregnancy and ‘Desire to Drink’, no other associations were observed. Experimental research has examined flavor learning in utero using volatile flavors, such as garlic (Hepper, 1995), carrot juice (Mennella et al., 2001) and anise (Schaal et al., 2000). Diet quality as measured by the AHEI-P, evaluates the diet as a whole, and the strength of flavors and odors within each individual’s diet may vary in their impact on in utero fetal programming of food preference. In addition, the complex interplay of many other factors postnatally, will also influence how a child’s appetitive traits will develop. In a study exploring maternal diet during pregnancy and postpartum, and child diet quality at four years old, the majority of effects observed between maternal diet in pregnancy and the child’s later diet quality was mediated by maternal postnatal diet (Ashman et al., 2016). We further analyzed maternal intake of SSB in view of the associations we observed between maternal diet quality in trimester 1 and 2 and ‘Desire to Drink’, and to our knowledge this has not been previously explored. We observed a weak positive relationship between maternal...
There is increasing interest in the mechanism behind the fetal programming of children born to mothers with overweight, obesity or gestational diabetes (GDM), and how this may impact children’s appetitive traits and body composition later in life. Almost half of our maternal cohort were classified as having overweight or obesity. A lower-quality maternal diet will contain less fruit and vegetables, more refined cereals, and higher fat, sugar and salt containing foods. Therefore, if the child is exposed in-utero to flavors from a lower quality diet lacking in essential phytochemicals, this may influence later food preferences and appetitive traits (Brown & Lee, 2012; Savage et al., 2007). In a prospective study assessing associations between maternal dietary intake in pregnancy and postnatal maternal and paternal dietary intake, with their offspring’s dietary intake at 10 years old, maternal dietary intake in pregnancy was related to offspring dietary intake and adiposity in later life (Brion et al., 2010). Findings indicated that a mother’s intake of fat, protein and carbohydrate during pregnancy was positively associated with the child’s intake of the same nutrients at aged 10. These associations were not observed with the father’s macronutrient intake. Furthermore, the strong associations seen between maternal prenatal diet and the child’s diet at 10 years old were not seen if the child was just exposed to the same foods postnatally. It is hypothesized that this finding may be due to the development of altered eating behaviour and dysfunctional satiety signaling thereby contributing to a predisposition to excess adiposity (Shapiro et al., 2017). A previous wave of the ROLO study, examined associations between maternal intake in pregnancy and child adiposity at 6 months old (Horan et al., 2016). Results showed that maternal dietary intake throughout pregnancy, in particular saturated fat and sodium intake and late pregnancy glycemic index were positively associated with infant adiposity at 6 months of age, however further research on the ROLO cohort at 5-year follow-up showed no evidence that a low glycemic index diet during pregnancy impacted offspring body composition at 5 years old (Callanan et al., 2021). In our cohort, diet quality during pregnancy varied by maternal characteristics, with mothers in the lowest AHEI-P tertile being younger, having higher BMI in early pregnancy and at the 5-year follow-up than those in the highest AHEI-P tertile. Maternal diet quality only significantly differed between intervention and control groups in the second trimester. Limited data is available on the relationship between maternal diet quality in pregnancy of those with obesity or GDM, and child appetitive traits in early childhood.

Table 4

Differences in mother and child characteristics across AHEI-P tertiles.

|                         | Low AHEI-P | Medium AHEI-P | High AHEI-P | P-value |
|-------------------------|------------|---------------|-------------|---------|
|                         | Mean (Median) | SD (IQR) | Mean (Median) | SD (IQR) | Mean (Median) | SD (IQR) |         |
| Child birth weight      | 3995.26 | 475.53 | 4011.88 | 421.34 | 3999.90 | 442.71 | 0.97 |
| Child BMI z-score       | 0.39 | 0.87 | 0.37 | 0.89 | 0.40 | 0.93 | 0.97 |
| Maternal BMI at booking* | (26.24)^a | (24.05,30.60) | 24.82^ab | (22.61,26.56) | (24.13)^a | (22.39,26.57) | -0.001 |
| Maternal BMI at 5-year f/up* | (25.77)^b | (24.09,30.05) | 24.69^ab | (22.45,26.27) | (23.63)^b | (22.53,26.53) | -0.001 |
| Maternal age at delivery | 33.20^c | 4.32 | 34.11^cb | 3.46 | 34.18^c | 3.31 | -0.001 |
| Polkal HP Index*        | (7.25) | (-0.20,12.78) | (7.45) | (0.05,10.90) | (7.45) | (2.58,12.03) | 0.67 |

One way ANOVA with post Tukey tests; *Kruskal Wallis tests with Mann Whitney U to examine differences between groups; Superscript letters denote differences in average AHEI-P across tertiles; Low score =<51.82, Medium score = 51.83–60.10, High score = >60.11. The Polkal HP Index is derived from ‘2011 Census of Population in Ireland’ data, it provides information on a combination of three dimensions of relative affluence and deprivation, specifically demographic profile, social class composition and labor market supply and demand. A negative score (below 0) is classified as socioeconomically disadvantaged and a positive score (above 0) classified as socioeconomically advantage. Statistically significant (p<0.05).

Table 5

Differences in AHEI-P score across trimesters.

|                         | n | AHEI-P trimester 1 | AHEI-P trimester 2 | AHEI-P trimester 3 |
|-------------------------|---|-------------------|-------------------|-------------------|
|                         |   | Mean | SD | df | F | Wilks Lambda | Partial Eta^2 | P-value |
| Low AHEI-P              | 243 | 55.75 | 11.25 | 2 | 0.16 | 1.00 | <0.001 | 0.853 |
| Medium AHEI-P           | 243 | 56.10 | 10.58 |   |   |   |   |   |
| High AHEI-P             | 243 | 56.08 | 10.31 |   |   |   |   |   |

One-way repeated measures ANOVA-within subjects comparison; df; degrees of freedom; Statistically significant (p<0.05).

intake of SSB in trimester 1 and 2 and child ‘Desire to Drink’, but not in the third trimester. Previous research, from a large birth cohort study demonstrated that at seven years old, children of mothers who consumed more SSB mid-pregnancy had higher levels of adiposity (Gillman et al., 2017). Research examining the impact of maternal intake of SSB in pregnancy on diet quality found that maternal diet quality score decreased by 2.3 for every 12 ounces of SSB consumed (Gamba et al., 2019). In addition, experimental research has demonstrated that fetal swallowing frequency increases when sweet solutions are introduced to amniotic fluid, whereas swallowing frequency decreases with the introduction of bitter flavors (Liley, 1972). Gestational diabetes (GDM), and how this may impact children’s appetitive traits and body composition later in life. Almost half of our maternal cohort were classified as having overweight or obesity. A lower-quality maternal diet will contain less fruit and vegetables, more refined cereals, and higher fat, sugar and salt containing foods. Therefore, if the child is exposed in-utero to flavors from a lower quality diet lacking in essential phytochemicals, this may influence later food preferences and appetitive traits (Brown & Lee, 2012; Savage et al., 2007). In a prospective study assessing associations between maternal dietary intake in pregnancy and postnatal maternal and paternal dietary intake, with their offspring’s dietary intake at 10 years old, maternal dietary intake in pregnancy was related to offspring dietary intake and adiposity in later life (Brion et al., 2010). Findings indicated that a mother’s intake of fat, protein and carbohydrate during pregnancy was positively associated with the child’s intake of the same nutrients at aged 10. These associations were not observed with the father’s macronutrient intake. Furthermore, the strong associations seen between maternal prenatal diet and the child’s diet at 10 years old were not seen if the child was just exposed to the same foods postnatally. It is hypothesized that this finding may be due to the development of altered eating behaviour and dysfunctional satiety signaling thereby contributing to a predisposition to excess adiposity (Shapiro et al., 2017). A previous wave of the ROLO study, examined associations between maternal intake in pregnancy and child adiposity at 6 months old (Horan et al., 2016). Results showed that maternal dietary intake throughout pregnancy, in particular saturated fat and sodium intake and late pregnancy glycemic index were positively associated with infant adiposity at 6 months of age, however further research on the ROLO cohort at 5-year follow-up showed no evidence that a low glycemic index diet during pregnancy impacted offspring body composition at 5 years old (Callanan et al., 2021). In our cohort, diet quality during pregnancy varied by maternal characteristics, with mothers in the lowest AHEI-P tertile being younger, having higher BMI in early pregnancy and at the 5-year follow-up than those in the highest AHEI-P tertile. Maternal diet quality only significantly differed between intervention and control groups in the second trimester. Limited data is available on the relationship between maternal diet quality in pregnancy of those with obesity or GDM, and child appetitive traits in early childhood.
Our research has a number of strengths. Dietary data was available for each trimester enabling the calculation of the AHEI-P for each stage of pregnancy, allowing us to examine the importance of nutrient exposure timing to the fetus. The calculation of the AHEI-P provided a method of examining overall quality of the diet that was appropriate to a pregnant population. As this is a longitudinal birth cohort, availability of data for inclusion as potential confounders were available. We also used a validated questionnaire to measure childhood appetitive traits, which further adds to the strength of this study. This study is not without its limitations. It is exploratory in design; thus, power and sample size calculations were not included for this secondary analysis. While every effort was made to control for potential confounders as detailed in the methodology section, it must be acknowledged that apart from the presence or absence of breast feeding and timing of introduction of solids, we were unable to control for other early childhood feeding exposures. Although we had a large sample size for pregnancy data, at 5 years follow-up less data was available on 5-year-old child appetitive traits which reduced our total number for analysis. Selection bias may have been present as selection criteria for the original RCT, meant all children were second born children whose older sibling was macromosaic at birth therefore the sample is not representative of the general population. Furthermore, the mean birth weight for our cohort was over 4 kg, which is indicative of macrosomia, thus, our cohort are potentially obese. In addition, our cohort were well educated and the majority were of white Irish ethnicity.

5. Conclusion

To conclude, in this exploratory analyses, higher scores in AHEI-P in early and mid-pregnancy were associated with lower mean scores for ‘Desire to Drink’ in 5-year-old children. To date, little is known about the development and behavioral significance of child ‘Desire to Drink’, and this area necessitates further investigation, however increased ‘Desire to Drink’ in children may have long term consequences for the development of childhood appetite and dietary intake due to a heightened preference for sweet drinks. While firm conclusions cannot be drawn from the current data, promoting a high-quality diet in pregnancy, particularly in early and mid-pregnancy, may have an important role in laying the foundations for how offspring will respond to the consumption of food and beverages in early childhood. Further longitudinal studies are required, in particular including detailed data on breast-feeding duration, to confirm our findings.

Authorship contributions

FMMA, ECOB and AAG were responsible for the project conception, AD, FMMA, MCC, SLOR, CMMcD designed the research and analysis plan, ECOB and AAG collected the data. JM, MCC and SLC calculated the AHEI-P score, JM collated the database, AD analyzed the data and performed statistical analysis, AD wrote the paper and all authors reviewed and approved the final manuscript.

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Ethical approval

The ROLO longitudinal birth cohort studies were carried out in accordance with the Helsinki Declaration of 1975 as revised in 1983 with institutional ethical approval from the National Maternity Hospital in November 2006 for the primary ROLO study and for the follow-up at 6 months and 2-year in May 2009. The Current Controlled Trials registration number for the ROLO study was ISRCTN54392969. The ROLO Kids 5-year follow-up were approved by the Ethics (Medical Research) Committee in Our Lady’s Children’s Hospital, Dublin, REC reference: GEN/279/12.

Informed consent

Informed written maternal consent was obtained during pregnancy and at each subsequent follow-up.

Availability of data and materials

The datasets used and analyzed during the current study are not publicly available in line with ethical approval but are available from the corresponding author on reasonable request.

Declaration of competing interest

The authors have no conflict of interest to declare.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2022.106291.

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