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# Dietary pattern trajectories in early childhood and their associations with patterns of maternal feeding practices in a multi-ethnic Asian cohort

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## Abstract

**Background** Maternal feeding practices play a major role in children's dietary intakes. However, there is limited data on the associations between trajectories of dietary patterns (DPs) and patterns of maternal feeding practices during early childhood.

**Methods** Using data from a multi-ethnic Asian cohort study, namely the Growing Up in Singapore Towards healthy Outcomes (GUSTO), dietary intakes were measured using Food Frequency Questionnaires in children at 18 months, 5 and 7 years of age. Maternal feeding practices were assessed using validated questionnaires at 15 months, 3 and 5 years of age. Principal component analysis was used to derive 2 major DPs at all time-points as well as patterns of maternal feeding practices. Group-based trajectory modelling was used to identify trajectory groups for the derived DPs. Multivariable logistic regression examined associations between patterns of maternal feeding practices and DP trajectory groups.

**Results** Two DPs, namely the 'healthy' and 'less healthy' were consistently derived at 18 months, 5 and 7 years of age. From each DP, 2 stable DP trajectory groups were further identified between 18 months and 7 years of age. For the 'healthy' DP trajectory, majority of the children (Group 1) formed a consistent average adherence trajectory group (91.8%) while the remaining children (Group 2) showed a higher but decreasing adherence (8.2%) to this DP. For the 'less healthy' DP trajectory, most children (Group 1) formed a consistent average adherence trajectory (95.5%), while the remainder (Group 2) showed consistent higher adherence to this 'less healthy' DP (4.5%). Two patterns of maternal feeding practices were derived and labelled as 'structured with autonomy support' and 'coercive control', respectively, at ages 15 months, 3 and 5 years. Children whose mothers showed high adherence to the structured with autonomy

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support feeding practices at age 5 years were significantly more likely to be associated with the higher but decreasing 'healthy' DP trajectory group [OR = 3.62 (95% CI: 1.64, 7.99)].

**Conclusions** A small number of children in this multi-ethnic study showed high adherence to the 'healthy' or 'less healthy' DP trajectory groups, respectively, while the majority showed average adherence to either of these trajectories. The positive association between structured with autonomy support maternal feeding practices and higher z-scores for the healthy DP trajectory highlights the importance of guiding parents on appropriate feeding practices.

**Keywords** Dietary pattern trajectories, Early childhood, Maternal feeding practices, GUSTO study, Group-based trajectory modelling

## Background

Alongside rapid growth and increased nutritional needs, early life exposure to foods from infancy to childhood contributes to the development of specific food and taste inclinations which may be associated with life-long dietary habits [1]. Although growing evidence suggest that nutrition early in life has a profound effect as risk factors for chronic diseases in later life, information on the maintenance or changes of specific dietary patterns between infancy and childhood are scarce, particularly in Asian children [2]. Several studies in Western countries have reported the tracking or maintenance of empirically derived dietary patterns identified during infancy and early childhood [3–8]; however, only a few studies have examined dietary pattern trajectories (e.g. never healthy trajectory; always healthy trajectory) across these age groups [9–12]. Trajectory groups or trajectories for major dietary patterns identify homogenous subgroups with similar characteristics i.e. akin developmental changes in the mean food intakes over a period of time [13]. Determination of dietary pattern trajectory groups early in life may provide information on population subgroup at risk as well as the timing for when effective intervention and promotion of healthful dietary intakes should be emphasised.

Parental feeding practices play a notable role in the development of eating habits during the malleable stage of infancy and childhood [14, 15] as they shape how much, what and when children consume foods [16]. While a number of longitudinal studies have evaluated parental feeding practices, these were mainly linked to child's weight status or specific food groups such as fruits, vegetables and snacks, but did not examine children's overall dietary patterns [17]. The analysis of dietary patterns usually provides a comprehensive understanding of the whole diet and therefore may provide a better indication of disease risks than single food groups or nutrients. Furthermore, findings from the abovementioned studies were rather equivocal and tended to focus on specific feeding practices or domains such as restrictive and controlling practices [17]. For instance, a few observational studies in Australia and the US have reported prospective

associations between 'restriction' and 'food reward' feeding practices and increase in weight and BMI in children aged 1.5 to 7 years [18–20].

The lack of consistent findings in the abovementioned longitudinal studies could partly be due to parenting feeding practices co-occurring or that assessment of single domains in the feeding practice instruments may not be holistic. As it is possible for parents to employ several feeding practices day to day, evaluating the synergistic relationships of these practices may allude to better understanding of diet-linked parenting practices [21–23]. Furthermore, early life feeding practices that accompany either healthy or unhealthy dietary intakes have often been reported to cluster. A few observational studies have reported that combination of parenting practices including positive modelling, structured rules, high involvement and supportive, and non-directive were associated with favourable dietary intakes as well as obesity-reducing behaviours in children [21–24].

To the best of our knowledge, no studies have assessed associations between trajectories of dietary patterns and patterns of maternal feeding practices between infancy and childhood. Understanding the combination of feeding practices that support healthier dietary intakes and identification of the 'critical' timing and types of food intakes that are amenable to change between infancy and childhood will be valuable to inform public health programs and interventions for parents. Using a multi-ethnic Asian pregnancy cohort study, namely the Growing Up in Singapore Toward healthy Outcomes (GUSTO) in Singapore, this study aimed to examine the tracking of dietary patterns using trajectory modelling between infancy and childhood and their associations with patterns of maternal feeding practices.

## Methods

### Study design and participants

The present study used data from the Growing Up in Singapore Towards healthy Outcomes (GUSTO) cohort – an ongoing mother-offspring study in Singapore [25]. The GUSTO study recruited pregnant women (aged ≥18 years) in their first trimester from 2 major public

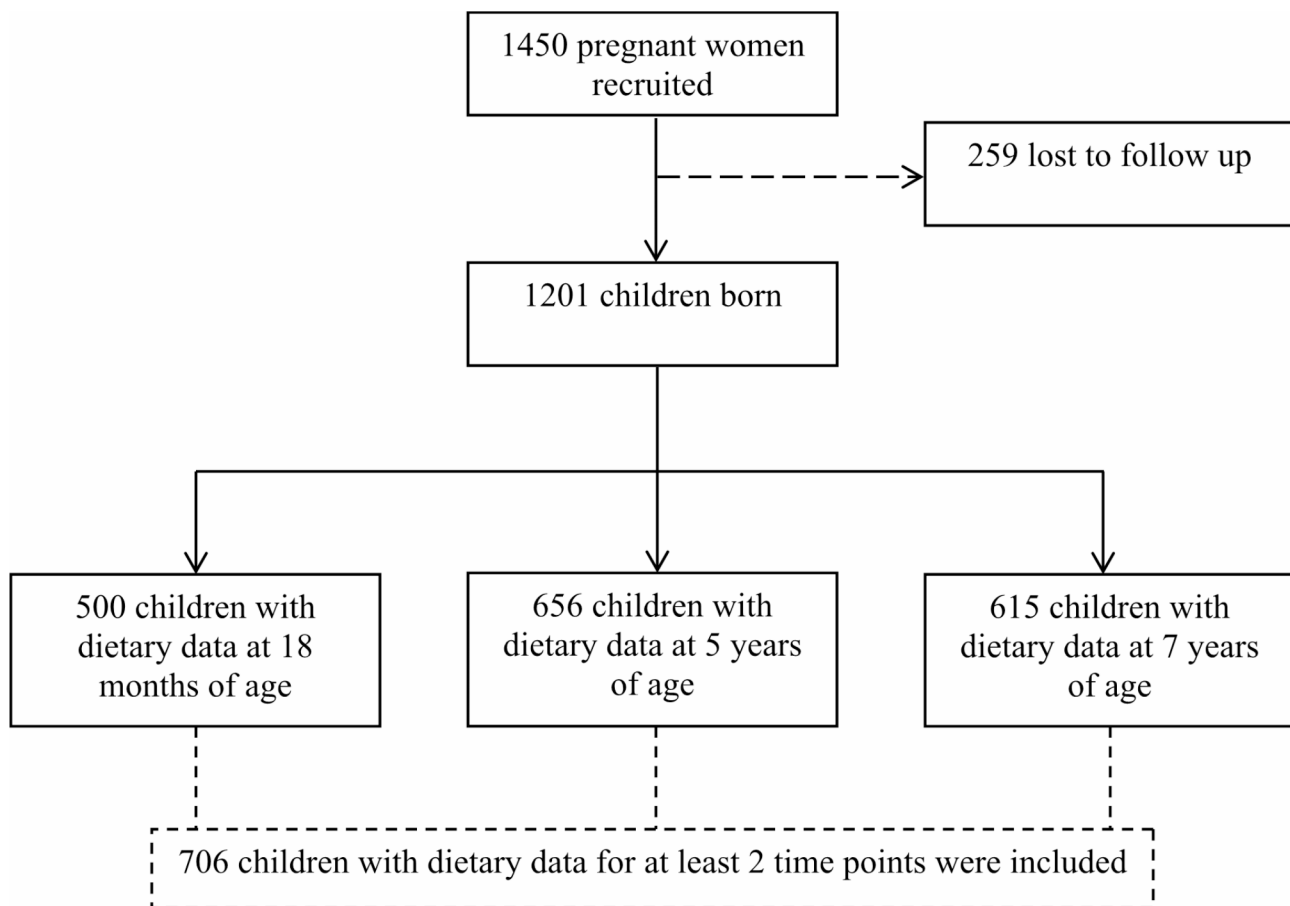
maternity units in Singapore (National University Hospital and KK Women's and Children's Hospital) between June 2009 and September 2010. These women are Singapore citizens or permanent residents of Chinese, Malay or Indian ethnicity with homogenous parental ethnic background. Detailed description of the study design and recruitment criteria have been published previously [25].

Children of these mothers were followed up from birth. The present study included children with dietary data from at least two follow-up time-points at 18 months, 5 and 7 years of age for the analysis of dietary pattern trajectories (Fig. 1). Additionally, maternal feeding practices assessed at 15 months, 3, and 5 years of age were incorporated into the study. All procedures in GUSTO have received ethical approval from the Institutional Review Boards at the 2 public maternity units (CIRB 2018/2767; DSRB D/2009/00021, B/2014/00406) where the women were recruited. Written informed consent was acquired from the participants at study recruitment. The Strengthening the Reporting of Observational Studies in Epidemiology-Nutritional Epidemiology (STROBE-nut) checklist was used for the reporting of this study (Additional File 1) [26].

#### Assessment of dietary intakes

Validated food frequency questionnaires (FFQ) were used to assess dietary intakes of children at 18 months, 5 and 7 years of age. The FFQ was first developed to assess dietary intake of 18-month-old children in GUSTO. The list of food items in the FFQ was created based on data from 24-hour recalls or 3-day diet records collected from the GUSTO children at 12 months and with reference to the validated Southampton Women's Survey 12 Month Infancy Questionnaire [27]. Inputs from paediatric dietitians were also sought to include foods commonly consumed at 18 months of age. This FFQ was subsequently modified to closely reflect dietary habits of 5 and 7-year-old children. Details on the development and validation of the FFQ used at each time-point have been previously published [28–30].

The FFQs at 18 months, 5 and 7 years of age comprised of 94, 112 and 120 items, respectively, covering food groups such as breads, spreads, cereals, rice and rice dishes, noodles and pasta, vegetables and legumes, fruits, poultry and meat, fish and seafood, eggs, savoury and sweet snacks, desserts, fast food, dairy products, and beverages. Mothers (or caregivers familiar with the



**Fig. 1** Flowchart of participants included in dietary pattern trajectories in the Growing Up in Singapore Towards healthy Outcomes (GUSTO) study

child's diet) were asked to indicate their child's frequency of consuming each food item in the previous month, and the average amount consumed using household measurements. To assist in portion size estimation, images of standard household utensils (e.g. bowls, spoons, and a standard plate), and portion sizes of several food items (e.g. dessertspoons of meat or vegetables, pieces of fruits, a bowl of cereals, a slice of cake) were provided.

### Derivation of dietary patterns

At each time-point (18 months, 5 and 7 years of age), the FFQ items were collapsed into 42 food groups based on similar nutritional composition and culinary use (Additional File 2). Principal component analysis (PCA) with varimax rotation was conducted separately at each time-points to derive dietary patterns. The number of factors chosen to retain was based on eigenvalues > 1, the break point of the scree plot, and the interpretability of the factors [31]. Two dietary patterns were derived at each time-point and their combined percentage of total variance ranged from 8 to 22% (Additional File 3). The Kaiser-Meyer-Olkin values were 0.72, 0.68, and 0.73 for 18 months, 5 and 7 years of age, respectively. Detailed information on the factor loadings for each food groups included in the PCA are summarised in Additional File 3. Apart from some slight differences, the identified dietary patterns were largely similar and consistent in the factor loadings for most of the food groups as well as their directions, at all ages. Overall, one pattern was characterised by fish and seafood, vegetables, poultry meat, nuts, seeds and legumes, thus labelled as the 'healthy' dietary pattern; the other pattern was characterised by low-fibre bread, processed meat, fast foods, potatoes, fishes and poultry meat that were deep-fried and curried and chocolate and sugary confectioneries, thus labelled as the 'less healthy' dietary pattern.

Each child received a z-score (z-score mean=0 and SD=1) for the 'healthy' and 'less healthy' dietary patterns, which indicated the extent the child's dietary intake adhered to these identified dietary patterns, correspondingly, relative to the rest of children in this study. A dietary pattern z-score of less than zero, equivalent to zero, and more than zero indicate lower adherence, average adherence and higher adherence to the identified dietary patterns, respectively.

### Modelling of dietary patterns trajectories

The z-scores for both 'healthy' and 'less healthy' dietary patterns were employed in group-based trajectory analysis to identify trajectory groups for each dietary pattern from 18 months to 7 years of age in all children. Group-based trajectory analysis is a statistical method that assigns individuals into groups with similar patterns of a longitudinal measure and therefore the variability in

trajectory shapes for each DP in this study i.e., 'healthy' or 'less healthy' can be assessed. An underlying data distribution of censored normal model was used to identify the trajectory groups for the 2 derived dietary patterns [32]. The number of trajectory groups were determined based on the average of Bayesian Information Criteria (BIC), Akaike Information Criteria (AIC) proportion of estimated trajectory groups (the smallest group includes at least 5% of participants) and statistics of model fit [33]. Children were classified into each of the dietary pattern trajectory groups based on the maximum estimated probability of belonging to each group [34]. Two trajectory groups were found to be the best model fit based on their interpretability, proportion of estimated belongings and showed sufficiently high average posterior probability of belonging to each group (0.75–0.90), and therefore included in this study (Additional File 4). Correspondingly, two trajectory groups for each of the two dietary patterns ('healthy' and 'less healthy') from 18 months to 7 years of age, respectively, were included in this study.

### Assessment of maternal feeding practices

Maternal feeding practices were assessed using the Infant Feeding Questionnaire (IFQ), Preschooler Feeding Questionnaire (PFQ) and Comprehensive Feeding Practices Questionnaire (CFPQ) when the children were 15 months, 3 years and 5 years of age, respectively [35, 36]. The assessment of feeding practices at these ages were deemed suitable as this is when table foods, food preferences and exposures are much established during childhood. The questionnaires were self-administered by mothers in English (the official working language used in Singapore). Mothers who required the questionnaires to be translated to other languages such as Mandarin, Malay or Tamil were excluded.

The IFQ was used to assess maternal feeding beliefs and practices for the first time when their children were 15-months of age [37]. This 28-item self-report measure employed a 5-point Likert scale ranging from 'never' to 'always' or from 'disagree a lot' to 'agree a lot'. Factor analysis of the original IFQ revealed 7 subscales: concern about infant undereating or becoming underweight, concern about infant's hunger, awareness of infant's hunger and satiety cues, concern about infant overeating or becoming overweight, feeding infant on a schedule, using food to calm infant's fussiness and social interaction with the infant during feeding. The use of IFQ in this cohort was previously published elsewhere [35].

The PFQ was designed for parents of children aged between 2 and 5 years of age, and assesses parents' feeding practices as well as beliefs and concerns about their child's weight [37]. The PFQ comprises of 35 items measuring 8 subscales: difficulty in child feeding, concern about child being overweight, using food to calm the

child, child's control of feeding interactions (refers to understanding the extent to which a child is involved in or influences their feeding experiences), age-inappropriate feeding, pushing the child to eat more, concerns about child overeating and being under or overweight, structure during feeding interactions. Mothers rated their response on a 5-point Likert scale ranging from "never" to "always" or "disagree" to "agree". Further details on the PFQ and its validation have been previously published [36, 37].

The CFPQ was designed for parents of children aged 18 months to 8 years [38]. The CFPQ comprises 49 items measuring 12 subscales: child control, emotion regulation, encourage balance and variety, environment, food as reward, involvement, modelling, monitoring, pressure to eat, restriction for health, restriction for weight control, and teaching about nutrition. Similar to the PFQ, mothers rated their response on a 5-point Likert scale ranging from "never" to "always" or "disagree" to "agree". The CFPQ is a well-known measure that has been extensively used and validated to assess parental feeding practices with preschool aged children. It has also been validated for use in a Malaysian population [39], which has very similar ethnic profile, cultural and dietary practices to Singapore. Further details on the CFPQ and its validation have been previously published [36, 38].

#### Derivation of maternal feeding practices patterns

To identify patterns of maternal feeding practices, PCA with varimax rotation was performed separately at 15 months, 3 years, and 5 years of age. The analysis incorporated the 7 subscales from the IFQ, 8 subscales from the PFQ, and 12 subscales from the CFPQ. Similar to derivation of dietary patterns, the number of factors chosen to retain was based on eigenvalues > 1, the break point of the scree plot, and the interpretability of the factors [31].

PCA conducted on maternal feeding practices at 15 months of age did not capture similar feeding practices patterns as observed at 3 and 5 years of age (Additional File 5). This is likely because at 15 months, infants are still largely dependent on caregivers for selecting and preparing foods / meals. They only become more independent and require more autonomy as they grow older. This is aligned with Vaughn et al., who recommends that child age and development stage are important factors to consider when examining relationships between feeding practices and child diet [15]. Instead, the scores of the individual subscales from the maternal feeding practices at 15 months of age were presented under Table 1 to illustrate their relationships with the children adhering to different DPs.

At both 3 and 5 years of age, two patterns of maternal feeding practices were derived, which we labelled as 'structured with autonomy support' and 'coercive control',

respectively (Additional File 5). The Kaiser-Meyer-Olkin values were 0.61 and 0.72 for ages 3 and 5, respectively. The percentage of variations for all maternal feeding practices items ranged from 18 to 24% and 15–25% for 'structured with autonomy support' and 'coercive control' patterns, respectively from 3 to 5 years of age (Additional File 5).

At 3 years of age, the 'structured with autonomy support' pattern was characterised by greater structure during feeding interactions (0.772), pushing the child to eat more (0.439) and less concern about child overeating or being overweight (-0.558); while the 'coercive control' pattern was characterised by concern about child being underweight (0.651), as well as practices of age-inappropriate feeding (0.645), child's control of feeding interactions (0.611), using food to calm the child (0.604) and difficulty in child feeding (0.588).

At 5 years of age, the 'structured with autonomy support' pattern was characterised by practices of modelling (0.732), balance and variety (0.723), teaching about nutrition (0.690), healthy environment (0.644), monitoring (0.485) and involvement (0.337); while the 'coercive control' pattern was mainly characterised by practices of giving food as reward (0.762), emotion regulation (0.666), restriction for health (0.502), pressure to eat (0.383) and restriction for weight control (0.375).

Each mother received a z-score for each pattern of maternal feeding practices and was subsequently categorized into high (z-score ≥ 0) and low adherence (z-score < 0) to each pattern for the ease of interpretation in the subsequent analyses.

#### Maternal characteristics

Data on maternal age, ethnicity, highest educational attainment and household income were collected at the recruitment visit. At 26–28 weeks' gestation, mothers' self-reported cigarette smoking and environmental tobacco smoke (ETS) exposure during pregnancy were obtained via interviewer-administered questionnaires. Maternal dietary intake during pregnancy was also assessed at 26–28 weeks' gestation using a 24-hour recall administered by trained clinical staffs. Overall diet quality was assessed using the Healthy Eating Index for pregnant women in Singapore (HEI-SGP) in which a higher score indicated a better diet quality [40].

#### Postnatal or child characteristics

Information on infant sex was retrieved from hospital delivery records. Mothers' breastfeeding practices (duration of any breastfeeding) were obtained via interviewer-administered questionnaires during postnatal visits at week 3, week 6 and at every 3-month interval from 3 to 12 months of age. Infant birth weight was measured to the nearest gram using a calibrated scale (SECA 334

**Table 1** Maternal, child and early life characteristics according to the trajectories of dietary patterns (DP) in the GUSTO cohort

	Less healthy DP			Healthy DP		
	Group 1 (n = 674, 95.5%)	Group 2 (n = 32, 4.5%)	p-value	Group 1 (n = 648, 91.8%)	Group 2 (n = 58, 8.2%)	p-value
	Mean ± SD / n (%)	Mean ± SD / n (%)		Mean ± SD / n (%)	Mean ± SD / n (%)	
<b>Maternal characteristics<sup>a</sup></b>						
Age at recruitment, years	31.5 ± 5.1	29.2 ± 5.9	0.02	31.4 ± 5.2	31.4 ± 4.6	0.97
Ethnicity						
Chinese	426 (63.2)	1 (3.1)	< 0.001 <sup>b</sup>	386 (59.6)	41 (70.7)	0.13
Malay	150 (22.3)	26 (81.3)		169 (26.0)	7 (12.1)	
Indian and others	98 (14.5)	5 (15.6)		93 (14.4)	10 (17.2)	
Highest education						
None, primary, or secondary	186 (27.7)	15 (46.9)	0.01	189 (29.3)	12 (21.1)	0.06
Post-secondary	231 (34.4)	14 (43.8)		229 (35.4)	16 (28.1)	
University	254 (37.9)	3 (9.4)		228 (35.3)	29 (50.8)	
Household income, SGD						
< 2000	40 (8.0)	3 (11.5)	0.04	41 (8.6)	2 (3.9)	0.18
2000–5999	244 (48.9)	18 (69.2)		240 (50.7)	22 (43.2)	
≥ 6000	215 (43.1)	5 (19.3)		193 (40.7)	27 (52.9)	
Total HEI score at 26wk of pregnancy	53.5 ± 13.5	45.3 ± 14.6	< 0.001	52.9 ± 13.7	55.5 ± 12.7	0.15
<b>Child's characteristics<sup>a</sup></b>						
Sex						
Female	327 (48.5)	12 (37.5)	0.22	317 (48.9)	22 (37.9)	0.11
Male	347 (51.5)	20 (62.5)		331 (51.1)	36 (62.1)	
Duration of any breast feeding, months						
Less than a month	134 (20.6)	10 (32.3)	0.14	138 (22.1)	6 (10.5)	0.01
1 to less than 3 months	127 (19.5)	9 (29.0)		126 (20.2)	10 (17.5)	
3 to less than 6 months	122 (18.8)	4 (12.9)		120 (19.2)	6 (10.5)	
More than 6 months	267 (41.1)	8 (25.8)		240 (38.5)	35 (61.5)	
<b>Child's anthropometry<sup>a</sup></b>						
At birth						
Weight, kg	3.13 ± 0.44	3.13 ± 0.40	0.95	3.13 ± 0.44	3.10 ± 0.42	0.58
Recumbent length, cm	48.72 ± 2.34	48.66 ± 2.18	0.88	48.71 ± 2.33	48.82 ± 2.31	0.73
Year 5						
Weight, kg	18.43 ± 3.24	18.75 ± 4.00	0.59	18.42 ± 3.29	18.68 ± 3.21	0.59
Height, cm	108.99 ± 4.65	108.72 ± 5.20	0.76	108.86 ± 4.64	110.25 ± 4.85	0.03
BMI z-score	0.03 ± 1.27	0.23 ± 1.27	0.38	0.06 ± 1.31	-0.09 ± 1.28	0.42
Year 7						
Weight, kg	23.62 ± 5.04	23.64 ± 7.45	0.98	23.62 ± 5.21	23.63 ± 4.73	0.98
Height, cm	121.26 ± 5.19	120.05 ± 6.37	0.21	121.12 ± 5.23	122.20 ± 5.50	0.15
BMI z-score	0.10 ± 1.41	0.13 ± 1.49	0.91	0.11 ± 1.42	-0.05 ± 1.37	0.41
<b>Early-life exposures<sup>a</sup></b>						
Maternal smoking status during pregnancy						
Non-smoker	592 (89.0)	20 (64.5)	< 0.001 <sup>b</sup>	558 (87.5)	54 (93.1)	0.32
Ex-smoker	63 (9.5)	9 (29.0)		68 (10.7)	4 (6.9)	
Current smoker	10 (1.5)	2 (6.5)		12 (1.8)	0 (0.0)	
Environment tobacco smoke exposure at home during pregnancy (26 weeks)						
No	454 (69.4)	10 (33.3)	< 0.001	421 (66.9)	43 (78.2)	0.08
Yes	200 (30.6)	20 (66.7)		208 (33.1)	12 (21.8)	
Environment tobacco smoke exposure at workplace during pregnancy (26 weeks)						
No	584 (90.7)	24 (82.8)	0.19 <sup>b</sup>	554 (89.6)	54 (98.2)	0.04
Yes	60 (9.3)	5 (17.2)		64 (10.4)	1 (1.8)	



**Table 1** (continued)

	Less healthy DP			Healthy DP		
	Group 1 (n = 674, 95.5%)	Group 2 (n = 32, 4.5%)	p-value	Group 1 (n = 648, 91.8%)	Group 2 (n = 58, 8.2%)	p-value
	Mean ± SD / n (%)	Mean ± SD / n (%)		Mean ± SD / n (%)	Mean ± SD / n (%)	
Infant Feeding Questionnaire (15 months) <sup>c</sup>						
Concern about infant undereating or becoming underweight	1.8 (1.3)	1.5 (1.1)	0.24	1.8 (1.3)	1.8 (1.2)	0.63
Concern about infant's hunger	0.0 (1.5)	1.0 (2.6)	0.01	0.0 (1.5)	0.0 (0.9)	0.11
Awareness of infant's hunger and satiety cues	3.5 (0.8)	3.8 (1.0)	0.09	3.5 (0.8)	3.5 (1.0)	0.56
Concern about infant overeating or becoming overweight	0.7 (1.0)	1.3 (1.1)	0.27	0.7 (1.0)	0.7 (1.0)	0.42
Feeding infant on a schedule	1.5 (1.5)	1.5 (1.5)	0.10	1.5 (1.5)	2.0 (1.0)	0.05
Using food to calm infant's fussiness	1.5 (1.1)	2.0 (1.6)	0.02	1.5 (1.5)	1.5 (2.0)	0.71
Social interaction with the infant during feeding	2.0 (1.0)	1.8 (2.0)	0.52	2.0 (1.4)	2.0 (0.9)	0.14

*P* < 0.05 is considered significant

<sup>a</sup>Missing data: Maternal age (*n* = 9); Maternal highest education (*n* = 3); Household income (*n* = 181); Maternal HEI score at 26th weeks of pregnancy (*n* = 65); Duration of any breast feeding in months (*n* = 25); Year 5 weight and height (*n* = 17); Year 5 BMI z-scores (*n* = 18); Year 7 weight and BMI z-scores (*n* = 30); Year 7 height (*n* = 29); Maternal smoking status during pregnancy (*n* = 10); Environment tobacco smoke exposure at home during pregnancy (26w) (*n* = 22); Environment tobacco smoke exposure at workplace during pregnancy (26w) (*n* = 33); Infant Feeding Questionnaire (*n* = 182)

<sup>b</sup>Fisher's Exact Test

<sup>c</sup>Scores are reported in median (inter-quartile range); results were analysed using Mann-Whitney U test

weighing scale; SECA Corp). Recumbent birth length was measured from the top of the head to the soles of the feet using an infant mat (SECA 210 mobile measuring mat; SECA Corp) to the nearest 0.1 cm. At ages 5, 7 and 8 years, children's weight (kg) was measured in light clothing using a SECA 803 weighing scale, and height (cm) with a stadiometer (SECA 213, Hamburg, Germany). Age- and sex-specific BMI z scores were calculated based on the WHO standards and references [41].

### Statistical analysis

Descriptive statistics included mean and standard deviation for continuous variables, and number and percentage for categorical variables. Separate multivariable logistic regression analyses were performed to determine the associations between the 'healthy' and 'less healthy' dietary pattern trajectory groups and patterns of maternal feeding practices at ages 3 and 5 years. Crude and adjusted odds ratios (OR) and their 95% confidence intervals (CIs) were reported, accordingly. Potential covariates in these multivariable analyses included mother's age, ethnicity, highest education and their diet quality score during pregnancy. Modelling of dietary patterns trajectories were performed using STATA/SE version 15.0 (Stata-Corp, 2017) and all other analyses were performed using SPSS version 26 (IBM Corp., 2019). The significant level for all statistical analyses was set at *P* < 0.05.

## Results

### 'Less healthy' dietary pattern trajectories

Figure 2 shows the two trajectory groups for the 'less healthy' (left panel) dietary pattern. Majority of the children formed a trajectory group with consistent average

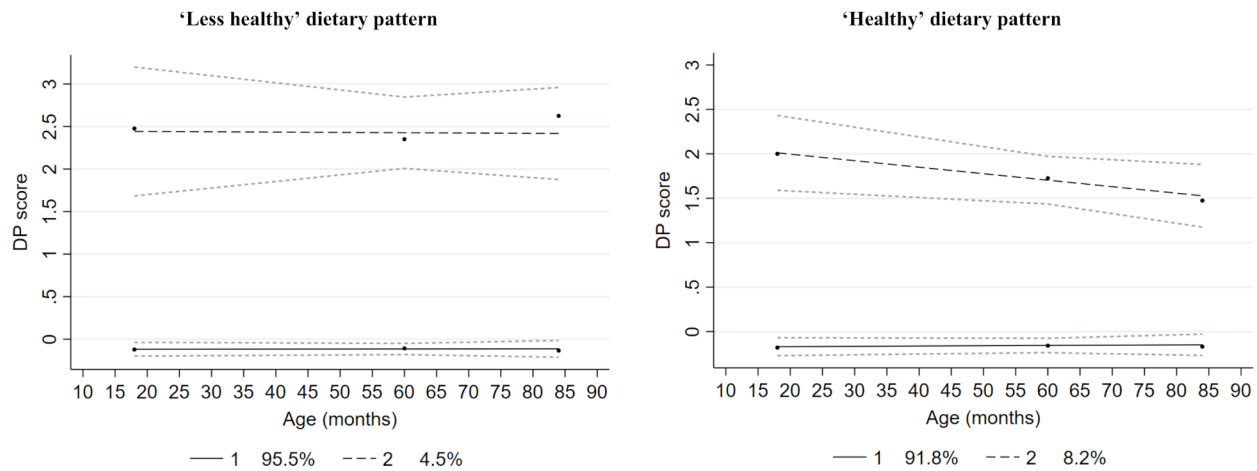
adherence (dietary pattern z-scores close to zero) to the 'less healthy' (95.5%) dietary pattern from 18 months to 7 years of age (Group 1). The remaining 4.5% of children formed a trajectory group with higher adherence (dietary pattern z-scores more than zero) to the 'less healthy' dietary pattern throughout, from 18 months to 7 years of age (Group 2).

### 'Healthy' dietary pattern trajectories

Figure 2 presents the two trajectory groups for the 'healthy' (right panel) dietary pattern. It was observed that the majority of children (91.8%) had consistent close to average adherence for this pattern from 18 months to 7 years of age (Group 1). The remaining of the children (8.2%) had above average 'healthy' dietary pattern z-scores, throughout; however, these reduced over the study period from 18 months to 7 years of age (Group 2).

### Maternal and child characteristics according to the 'less healthy' dietary pattern trajectory groups

It was observed that mothers whose children had consistent higher adherence to the 'less healthy' dietary pattern tended to be younger, belonged to the Malay ethnic group, had lower educational attainment and lower household income compared to those mothers whose children showed consistent average adherence to this pattern (Table 1). These mothers were also more likely to have lower maternal diet quality scores, be current smokers, exposed to environmental tobacco smoke (ETS) at home during pregnancy, be concerned about infant hunger and used food to calm infant's fussiness at 15 months of age. In addition, children with consistent higher adherence to the 'less healthy' dietary pattern were breastfed



**Fig. 2** Trajectories of the ‘less healthy’ (left panel) and ‘healthy’ (right panel) dietary patterns from 18 months to 7 years of age in the GUSTO study. Solid line represents the group of children whose dietary pattern z-scores indicate average adherence (Group 1) while dotted line represents the group of children whose dietary pattern z-scores indicate higher adherence (Group 2) to the respective dietary patterns. Dotted line=95% confidence interval

**Table 2** Crude and adjusted associations between clusters of parental feeding practices and trajectories of dietary patterns in the GUSTO cohort (n = 706)

	Less healthy DP <sup>d</sup>		Healthy DP <sup>e</sup>	
Pre-schooler Feeding Questionnaire at 3 years <sup>a</sup>	Group 2 (n = 29)		Group 2 (n = 40)	
	Crude	Adjusted	Crude	Adjusted
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Adherence to Structured with autonomy support <sup>f</sup>	0.52 (0.24, 1.15)	0.63 (0.27, 1.46)	1.37 (0.71, 2.65)	1.08 (0.55, 2.13)
Adherence to Coercive control <sup>g</sup>	1.81 (0.82, 3.98)	1.39 (0.61, 3.20)	0.48 (0.24, 0.95)*	0.55 (0.28, 1.10)
Comprehensive Feeding Practices Questionnaire at 5 years <sup>a</sup>	Group 2 (n = 26)		Group 2 (n = 40)	
	Crude	Adjusted	Crude	Adjusted
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Adherence to Structured with autonomy support <sup>f</sup>	0.62 (0.27, 1.39)	0.70 (0.29, 1.66)	3.85 (1.79, 8.28)**	3.62 (1.64, 7.99)*
Adherence to Coercive control <sup>g</sup>	1.37 (0.61, 3.09)	1.35 (0.58, 3.17)	0.67 (0.35, 1.29)	0.70 (0.36, 1.38)

Models were adjusted for mother’s age at recruitment, mother’s ethnicity, mother’s highest education, and maternal HEI score

\*P<0.05, \*\*P<0.001

<sup>a</sup>Missing data: PFQ at 3 years (n=229); CFPPQ at 5 years (n=228)

<sup>d</sup>Reference: Less healthy DP Group 1 at 3 and 5 years (n=448 and n=452 respectively)

<sup>e</sup>Reference: Healthy DP Group 1 at 3 and 5 years (n=437 and n=438 respectively)

<sup>f</sup>Reference: Less adherence to “Structure with autonomy support” at 3 and 5 years (both n=240)

<sup>g</sup>Reference: Less adherence to “Coercive control” at 3 and 5 years (n=231 and n=219 respectively)

for less than a month during infancy as compared to those who had consistent average adherence to this pattern. Nonetheless, no stark differences were observed in child’s anthropometric measures between the two trajectory groups for the ‘less healthy’ dietary pattern.

**Maternal and child characteristics according to the ‘healthy’ dietary pattern trajectory groups**

Compared to children who showed consistent average adherence to the ‘healthy’ dietary pattern, those who showed consistent higher adherence to this pattern were more likely to have been breastfed for more than 6 months, have mothers not exposed to ETS at workplace when they were pregnant and were fed on a schedule as

infants at 15 months of age (Table 1). Except for a higher height at year 5 and 8, no significant differences were observed with other anthropometric measures between the trajectory groups for the ‘healthy’ dietary pattern.

**Associations between dietary patterns trajectory groups and patterns of maternal feeding practices**

Findings on the associations between dietary pattern trajectory groups and patterns of maternal feeding practices are shown in Table 2. In the crude model, children whose mothers employed a ‘coercive control’ feeding practice at 3 years of age were less likely to follow a trajectory of higher adherence to a healthy dietary pattern (Group 2) compared to children in other group [OR=0.48 (95% CI:



0.24, 0.95)]. However, after adjusting for confounding factors, this association was no longer significant [OR=0.55 (0.28, 1.10)]. No other significant associations were found between maternal feeding practices at 3 years of age and the trajectory groups of the less healthy dietary pattern.

In the crude model, children whose mothers employed a 'structured with autonomy support' feeding practice at 5 years of age were more likely to follow a trajectory of higher adherence to a healthy dietary pattern (Group 2) as compared to children in the other group [OR=3.85 (1.79, 8.28)] and this remained significant after adjusting for confounders [OR=3.62 (1.64, 7.99)]. No other significant associations were found between maternal feeding practices at 5 years of age and the trajectory groups of less healthy dietary pattern.

## Discussion

In this multi-ethnic Asian cohort, longitudinal modeling of dietary pattern z-scores from 18 months to 7 years of age suggested 2 consistent trajectory groups for each of the dietary patterns namely the 'healthy' and 'less healthy'. The majority of the children formed average adherence trajectory group for both dietary patterns. The remaining small proportions of children showed consistent higher adherence to the 'less healthy' dietary pattern and higher but decreasing adherence to the 'healthy' dietary pattern between infancy and childhood. Children who formed the higher but decreasing trajectory group for the 'healthy' dietary pattern were significantly associated with 'structured with autonomy support' maternal feeding practices.

Similar to recent studies that have examined dietary trajectories in young children, our study observed strong stability of dietary pattern trajectories over time in the majority of the children [9, 10, 12]. For example, trajectories reflecting consistent poor, medium or good diet quality over time were observed in the study by Dalrymple et al., 2021 [9], which investigated mother-offspring diet quality trajectories from as early as pre-pregnancy till mid-childhood (age 8–9 years) in the Southampton Women Survey cohort. Similarly, another study that has investigated diet quality using 2005's Healthy Eating Index in young children, reported consistency in adhering to poor diet quality between the ages of 3 and 7 years [12]. In parallel, moderate to high stable trajectories reflecting dietary patterns that are 'never healthy', 'moderately healthy', 'becoming less healthy' and 'always healthy' were reported by Gasser et al. in Australian children aged between 2 and 11 years of age [10]. While dietary pattern trajectories over 2 to 3 time points in early life were reported in these studies, it is important to note differences in the population size, dietary assessment tools and dietary pattern analyses employed between these studies. Having said that, taken together,

these findings reinforced the notion that dietary patterns are established very early in life and remain largely consistent thereafter.

In the present study, a majority of the children maintained average scores for the 'healthy' dietary pattern trajectory throughout their early childhood, while 8% of the children started well above the average but showed over time reduction between infancy and early childhood. On the other hand, concerning, nearly 5% of the children maintained higher scores for the 'less healthy' dietary pattern across infancy and early childhood. This is in line with findings observed in the study by Gasser et al. whereby a smaller proportion of children had highest adherence (always unhealthy) to the 'unhealthy' dietary pattern trajectory (4.0% in Gasser et al. vs. 4.5% in this study) [10]. Nonetheless, a larger proportion of children (44%) showed highest adherence (always healthy) to the 'healthy' dietary pattern trajectory in Gasser et al. compared to that seen in the current study (8%). Similarly, Dalrymple et al. reported only 28% of mothers and offspring dyads from pre-conception to 9 years of age had poor dietary quality measured using Diet Quality Index (DQI) [9]. The fact that a higher percentage of Australian and British children were found to have higher adherence to the 'healthy' dietary pattern as compared to our study, possibly suggesting an overall poorer average diet quality in our local children between infancy and childhood. However, this could also be due to differences in the number of food items or food groups captured, the dietary assessment method and the frequency of the dietary assessments in both studies.

Interestingly, it was also observed that a small number of children in Gasser et al. rapidly increased their z-scores for the 'unhealthy' dietary pattern (3.6%) while another group of children showed worsening 'healthy' dietary pattern z-scores (10.6%) from the age of 7 and even worse from 9 years of age onwards [10]. In the current study, no children were seen to increase their z-scores for the 'less healthy' dietary pattern, however, there were a group of children who showed deterioration for the 'healthy' dietary pattern at as early as 18 months of age. The fact that a deteriorating trend was only observed for the 'healthy' dietary pattern in our study could be due to the inclusion of the age ranged up to 7 years of age in our study. The worsening of the 'unhealthy' dietary pattern in Gasser et al. was found beyond the age of 7 years, where greater exposure to unhealthy foods is highly possible as children enter primary school and are exposed to the school environment and peer influence. Having said that, using constructed dietary scores based on weekly frequency of core and discretionary foods intakes in children from ages 4 months, 8 months, 1 year, 2 years and 3 years in the Healthy Smiles, Healthy Kids (HSHK) cohort in Australia, Manohar et al. showed that children on

unhealthy discretionary foods trajectories consumed discretionary foods as early as at 4 months of age and consistently increased these intakes up to 3 years of age [11]. This was also not observed in our study, possibly because our dietary assessments in our current study did not capture this inflection point in the early childhood period. The above suggests that frequent repeated reporting over an extended time frame has the advantage of providing a longer-term picture of children's diets and allows the capture of 'sensitive periods' or allude to 'windows' of change. It was also suggested that examining diets using various diet parameters would elucidate different aspects of diet trajectories [10, 11, 42].

Two maternal feeding practice patterns were identified at 3 and 5 years of age in the current study. The 'structured with autonomy support' feeding cluster was characterised by mothers who engaged in more structured interactions, modelling, balance and variety, teaching about nutrition, monitoring, and lower use of child control or excessively concerned about child overeating or being overweight. On the other hand, mothers in the 'coercive control' feeding cluster were characterised to be more assertive, controlling, experienced difficulties in child feeding, used food as a reward or to regulate child's emotion and were less likely to monitor child's daily intakes. The identified 'structured with autonomy support' and 'coercive control' clusters in this study appear similar to those published previously by Vaughn et al. in 2016, which defined the main feeding practice domains, regardless of instruments being used in various studies, as coercive control, structure and autonomy support [15]. The two maternal feeding practices patterns we identified are specific behaviours that describe 'authoritative' and 'authoritarian' parental feeding styles, respectively [43, 44]. Specifically, the similarities between the 'structured with autonomy support' feeding practice pattern found in this study and previously published 'authoritative' feeding style could be explained by the presence of both high demandingness (i.e. monitoring/supervision) and responsiveness (i.e. warmth and involvement) components. These combinations of factors have been linked to the development of internal eating cues for hunger and fullness in children as well as improvements in dietary intakes and nutritional outcomes such as lower levels of weight gain [44].

In the current study, mothers who adhered more to the 'structured with autonomy support' maternal feeding pattern were more likely to have children with higher but over time reduction in adherence to the 'healthy' dietary pattern. This is in line with studies which reported positive relationships between adherence to the 'authoritative' feeding style and higher child dietary quality, fruit and vegetables intakes and improved weight status [45–47]. Furthermore, based on structured feeding practices

domain, a study reported inverse associations between having parental rules and limits, modelling and availability (structured feeding practices) and lower consumption of discretionary food items such as snacks, candies and sweetened beverages [48–50]. Specifically, 4 items in CFPQ, namely 'modelling', 'teaching about nutrition', 'monitoring' and 'healthy environment' which were included in the 'structured with autonomy support' feeding pattern at age 5 years (see Additional File 5) consistently showed positive associations with higher but over time reduction in adherence to the 'healthy' dietary pattern.

There are some limitations in this study worth mentioning. First, data collected in this study were mostly self-reported and therefore subjected to bias. Secondly, the majority of mothers included in this study have attained education up to post-secondary or higher education levels, therefore limits the representation of the study findings. However, we have considered maternal education as one of the covariates in our regression models. Although adjustments for a few confounding factors were employed, residual confounding cannot be fully ruled out. While this study comprised of a population with different ethnic groups, we acknowledge that cultural differences may influence parental feeding practices. Thus, the patterns of feeding practices we found may not be generalisable to other populations. The assessment periods for dietary pattern trajectories (18 months to 7 years of age) and maternal feeding practices (3 years and 5 years) differ slightly. This discrepancy is anticipated in longitudinal studies when examining developmental processes across varying timeframes. Last but not least, the use of different feeding practice questionnaires at 15 months (IFQ), 3 (PFQ) and 5 (CFPQ) years of age may have contributed to the variances in the evaluation of the feeding practices in this study. However, a critical appraisal by Vaughn et al. in 2016 highlighted the consistent presence of main feeding practice domains regardless of instruments being used in various studies and those mostly included coercive control, structure and autonomy support (51). The identification of similar domains in the current study further affirmed the appraisal reported in Vaughn et al. (51). The study strengths include the representation of multi-ethnic groups, prospective study design and repeated measurement of dietary intakes in early childhood stage.

## Conclusions

In this multi-ethnic study, a small number of children showed high adherence to either the 'healthy' or 'less healthy' DP trajectory groups, while the majority of them showed average adherence to either the trajectories, between 18 months and 7 years of age. In addition, those children who started with a higher adherence to the 'healthy' dietary pattern trajectory showed an

overtime reduction. This suggests that further education, skills training and support for parents and caregivers to provide appropriately healthy diets to infants and young children are needed to improve their food intakes in the local setting. The association between structured with autonomy support maternal feeding practices and favourable dietary pattern trajectories further allude to the importance of guiding parents on healthy feeding practices and the development of positive eating behaviours from an early age.

#### Abbreviations

BF	Breastfeeding
BIC	Bayesian Information Criteria
CFPQ	Comprehensive Feeding Practices Questionnaire
CIs	95% Confidence Intervals
DPs	Dietary Patterns
ETS	Environmental Tobacco Smoke
FFQs	Food Frequency Questionnaires
GBTM	Growth Based Trajectory Model
GUSTO	Growing Up in Singapore Towards healthy Outcomes
HEI-SGP	Healthy Eating Index for pregnant women in Singapore
OR	Odds Ratio
PCA	Principal Component Analysis
PFQ	Preschooler Feeding Questionnaire

#### Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12937-024-01012-5>.

- Supplementary Material 1: Additional File 1: STROBE-Nut GUSTO Study.
- Supplementary Material 2: Additional File 2: GUSTO food groups and their constituents.
- Supplementary Material 3: Additional File 3: Food group loadings of identified dietary patterns (DPs) at 18 months, 5 years and 7 years in the GUSTO cohort.
- Supplementary Material 4: Additional File 4: Model fit for different number of groups in group-based trajectory modelling in the GUSTO cohort.
- Supplementary Material 5: Additional File 5: Factor loadings for domains within parental feeding practice clusters at 3 years and 5 years in the GUSTO cohort.

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#### Author contributions

The authors' responsibilities were as follows: Y.S.L., K.H.T., F.Y., K.M.G., Y.-S.C. were responsible for conceiving designing and leading the GUSTO cohort study. G.A. and M.F.-F.C. designed the present work. J.S.L., J.Y.T., M.T.T., W.L.Y., and W.W.P. contributed to the data collection. G.A., J.S.L., Y.H.Y., J.Y.T., Z.M.S., M.T.T., W.L.Y., and W.W.P. contributed to data processing and cleaning. M.F.-F.C. supervised and guided the data collection and cleaning process. G.A., J.S.L., Y.H.Y., Z.M.S., and M.F.-F.C. analyzed and interpreted the data. G.A., J.S.L. and M.F.-F.C. were responsible for drafting and finalizing the manuscript. All authors have read and agreed to the published version of the manuscript.

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#### Data availability

The datasets generated and/or analysed during the current study are not publicly available due to an ethical restriction (patient confidentiality) which was imposed by the Centralised Institutional Review Board of SingHealth but are available from the corresponding author on reasonable request.

#### Declarations

##### Ethics approval and consent to participate

All procedures in GUSTO have received ethical approval from the Institutional Review Boards at the 2 maternity units (CIRB 2018/2767; DSRB D/2009/00021, B/2014/00406) where the participants were recruited. Written informed consent was acquired from participants at study recruitment.

##### Consent for publication

Not applicable.

##### Competing interests

The authors declare no competing interests.

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