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Title
Dietary Patterns of Five-Year-Old Children and Their Correlates: Findings from a Multi-Ethnic Asian Cohort

**Short Version of Title**

**Dietary Patterns of 5-Year-Old Asian Children**

**Authors**

**R Sugianto 1, JY Toh 2, Wong SF 3, MT Tint 2,3, MT Colega 2, YS Lee 3,4, F Yap 5,6,
LPC Shek 3,4, KH Tan 5,6, KM Godfrey 7,8, YS Chong 2,3, BC Tai 1,3, MFF Chong 1,2**

1 Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore

2 Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research, Singapore

3 Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore

4 Khoo Teck Puat-National University Children's Medical Institute, National University Hospital and National University Health System, Singapore

5 Duke-NUS Medical School, Singapore

6 KK Women's and Children's Hospital, Singapore

7 NIHR Southampton Biomedical Research Centre, University of Southampton and University Hospital Southampton NHS Foundation Trust, Southampton, United Kingdom

8 Medical Research Council Lifecourse Epidemiology Unit, University of Southampton, Southampton, United Kingdom

|  |  |  |
| --- | --- | --- |
| **Name (Surname in CAPITAL)** | **Primary Affiliation** | **Secondary Affiliation** |
| Ray SUGIANTO | Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore |  |
| TOH Jia Ying | Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research, Singapore |  |
| WONG Shu Fang | Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore |  |
| Mya Thway TINT | Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research, Singapore | Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore |
| Marjorelee T COLEGA | Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research, Singapore |  |
| LEE Yung Seng | Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore | Khoo Teck Puat-National University Children's Medical Institute, National University Hospital and National University Health System, Singapore |
| Fabian, YAP Kok Peng | Duke-NUS Medical School, Singapore | KK Women's and Children's Hospital, Singapore  |
| Lynette, SHEK Pei-Chi | Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore | Khoo Teck Puat-National University Children's Medical Institute, National University Hospital and National University Health System, Singapore |
| TAN Kok Hian | Duke-NUS Medical School, Singapore | KK Women’s and Children’s Hospital, Singapore |
| Keith M GODFREY | NIHR Southampton Biomedical Research Centre, University of Southampton and University Hospital Southampton NHS Foundation Trust, Southampton, United Kingdom | Medical Research Council Lifecourse Epidemiology Unit, University of Southampton, Southampton, United Kingdom |
| CHONG Yap Seng | Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore | Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research, Singapore |
| TAI Bee Choo | Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore | Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore |
| Mary, CHONG Foong-Fong | Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore | Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research, Singapore |

**Corresponding Author:**

**Dr R Sugianto
Address: MD1 – Tahir Foundation Building, National University of Singapore,
12 Science Drive 2, #10-01, Singapore 117549
Telephone: +65 6516 4988
Email: ray.sugianto@u.nus.edu**

**Abstract**

There is limited data on the dietary patterns of 5-year-old children in Asia. The study examined childhood dietary patterns and their maternal and child correlates in a multi-ethnic Asian cohort. Based on caregiver-reported one-month quantitative food frequency questionnaires of 777 children from the Growing Up in Singapore Towards healthy Outcomes (GUSTO) cohort, cluster analysis identified two mutually exclusive clusters. Children in the “Unhealthy” cluster (43.9%) consumed more fries, processed meat, biscuits and ice cream, and less fish, fruits and vegetables compared to those in the “Healthy” cluster (56.1%). Children with mothers of lower educational attainment had twice the odds of being assigned to the “Unhealthy” cluster (adjusted OR (95% CI) = 2.19 (1.49-3.24)). Children of Malay and Indian ethnicities had higher odds of being assigned to the “Unhealthy” cluster (adjusted OR = 25.46 (15.40-42.10) and 4.03 (2.68-6.06)) respectively, relative to Chinese ethnicity. In conclusion, this study identified two dietary patterns in children, labelled as the “Unhealthy” and “Healthy” clusters. Mothers’ educational attainment and ethnicity were two correlates that were associated with the children’s assignments to the clusters. These findings can assist in informing health promotion programmes targeted at Asian children.

**Keywords:**

Children, Asian, dietary patterns, cluster analysis, correlates

# Introduction

Diet is an essential contributor to children’s health, growth and development. Establishing healthy diets early in life is important as they are the foundation for shaping the food preferences of children as they grow older(1,2). Analysis of children’s diets using a dietary pattern approach has been increasingly used, as this approach enables the evaluation of the whole diet as opposed to focusing on individual foods or nutrients.

To identify dietary patterns of a specific population, researchers have used dimension-reduction statistical methods to reduce complex dietary intake information into interpretable dietary patterns. One of the statistical methods is cluster analysis (CA), which assigns individuals into mutually exclusive clusters based on the concept of minimizing differences of food intakes within-cluster and maximizing the differences of food intakes between-clusters. CA has been widely used in several studies to identify dietary patterns of children in recent years. For example, “Processed”, “Plant-based” and “Traditional British” dietary patterns were identified in children from the Avon Longitudinal Study of Parents and Children (ALSPAC) in the United Kingdom(3). With regard to studies conducted in Asia, Choi *et al.*(4) have identified “Korean” and “Western” dietary patterns from the Gwacheon child cohort study in Korea. In the same vein, Shang *et al.*(5) have identified “Healthy”, “Transitive” and “Western” dietary patterns from children in five cities in China. In Singapore, while dietary data has been collected for five-year-old children from the ongoing Growing Up in Singapore Towards healthy Outcomes (GUSTO) multi-ethnic birth cohort, the use of CA to investigate their dietary patterns has not been attempted. This is of particular interest as the pre-school period is crucial in influencing the long-term diet preferences of children(6). Thus, the main objective of this study is to utilize CA to identify dietary patterns of five-year-old children in this multi-ethnic Asian cohort.

A second objective is to examine the maternal and child characteristics associated with the identified dietary patterns. There is evidence to suggest differences in commonly consumed local food across the three main ethnic groups (Chinese, Indian and Malay) in the multi-ethnic population of Singapore(7) and we believe this extends to the children’s diets as well. Besides ethnicity, socioeconomic status may also influence the diet of children. The ALSPAC study, for example, found that lower socioeconomic status was strongly associated with unhealthy dietary patterns in the children(3). A similar association was also reported in China(5). In addition, maternal diet might also influence the diet of children, as Bjerregaard *et al.*(8) reported that among participants of the Danish National Birth Cohort (DNBC), maternal diet quality during pregnancy was an influential factor that affected their children’s diet.

Whether similar associations hold true in this multi-ethnic Asian context, or if other characteristics are related to the identified dietary patterns are of interest and were investigated in this study.

# Material and Methods

This study utilized data from the Growing Up in Singapore Towards healthy Outcomes (GUSTO) mother-offspring cohort study. The GUSTO study recruited pregnant Singapore citizens and permanent residents aged 18 to 50 years during their first trimester visits at two major public maternity units in Singapore (National University Hospital and KK Women’s and Children’s Hospital). To be eligible, a pregnant mother and her spouse must have the same ethnic background (Chinese, Malay, or Indian, the three major ethnic groups in Singapore), and both must have parents of homogeneous ethnic background. The mothers must have had the intention to deliver in either of the two maternity units and plan to reside in Singapore for the next 5 years. Pregnant mothers with major health conditions (e.g. cancer, type 1 diabetes or psychiatric diseases) were excluded. The recruitment was conducted between June 2009 and September 2010. All recruited mothers and their spouses signed written informed consents12. Children of these mothers were followed up from birth. For the current study, data from the children participants at 5 years of age were analysed. The complete GUSTO study design and protocol have been detailed elsewhere(9), and is registered as [NCT01174875](https://clinicaltrials.gov/ct2/show/NCT01174875) at clinicaltials.gov. Ethical approval of the study was obtained from the National Health Care Group Domain Specific Review Board (D/09/021) and the SingHealth Centralized Institutional Review Board (2009/280/D).

***Dietary Assessment of Children***

The children were aged 5 years (+ 0 to 3 months) when their diets were assessed between 2015 and 2016 using a quantitative food frequency questionnaire (FFQ). The FFQ was interviewer-administered to caregivers of the children by trained researchers during the scheduled year 5 GUSTO clinic visits. The FFQ encompasses 112 items consisting of single food/beverage items and mixed dishes (e.g. burger, fish ball noodle, chicken rice). The food list was developed with reference to dietary data of GUSTO children collected at earlier points of the cohort, and a local database was consulted to obtain the food composition of mixed dishes(10). The caregivers were asked to report on the frequencies and quantities of food and beverage items consumed by their children in the previous month. The average servings of items consumed were ascertained using household measurements (e.g. slices of bread, boxes of raisins, pieces of chicken, etc.) or standard cups, spoons, and plates presented during the interview. Further details of the FFQ are described in the evaluation study of the FFQ, where the FFQ was validated and found to have a reasonable level of agreement for a number of nutrients when compared against the reference diet records among five-year-old children participants of GUSTO(11).

In addition to the FFQ, the caregivers were also asked several questions related to their children’s diets. The questions included: “Who is the primary caregiver of the child?”; “Who is the food decision-maker of the child?”; ”When purchasing food, do you read the food labels?”; and “When purchasing food, do you read the Healthier Choice Symbols?”. The Healthier Choice Symbols are front-of-pack labels that are printed on food items that meet certain guidelines set by the Singapore Health Promotion Board(12). For example, beverages with lower sugar contents and bread with higher whole grain contents would have the symbols printed on the packaging.

***Maternal and Children’s Characteristics***

Marital status, maternal education level, household income level and current pregnancy birth order were collected via interviewer-administered questionnaires during recruitment. The diet quality of the pregnancy diet, assessed during week 26-28 of gestation, was quantified with a healthy eating index for pregnant women in Singapore (HEI-SGP)(13). The HEI-SGP evaluates certain food components (total vegetables; total fruit; total rice and alternatives; total protein foods; whole grains; dark green leafy and orange vegetables; whole fruit; and dairy), nutrient compositions (percentages of energy intake from total fat and saturated fat) and the use of antenatal supplements. Mothers were subsequently classified into HEI-SGP tertiles, with mothers in the highest tertile having higher adherence to the Singapore dietary guidelines for pregnant women compared to mothers in lower tertiles. Details of the HEI-SGP can be found in Han *et al.*(13)

Sex of the children was recorded at birth. At the year 5 clinic visits, trained researchers measured the children’s height and weight (stadiometer, model 213, Seca, Germany; and digital scales, model 803, Seca, Germany, were used) in duplicates for accuracy. The children’s Body Mass Index (BMI) was calculated by dividing the body mass (in kilogram) by the square of the body height (in metre). The World Health Organization(14) age- and sex-specific BMI cut-off was used for overweight classification (BMI > 1 SD).

***Statistical Methods***

*Cluster Analysis to Identify Dietary Patterns*

Cluster analysis (CA) was performed to identify the children’s dietary patterns. Input variables were energy-adjusted food intakes from the FFQ, expressed in gram per 1000 kcal. The objective of CA is to optimally assign children into distinct, mutually exclusive clusters by minimizing differences of food intakes within-cluster and maximizing differences of food intakes across clusters(15). The CA method used was K-medoids clustering, which employed the Partitioning Around Medoids (PAM) algorithm(16). Euclidean distances (direct/shortest distance between data points) were specified as the distance measure used for the PAM algorithm. The PAM algorithm was chosen because this algorithm is known to be less sensitive to outliers(17), which are often encountered if input variables are food intake data. Eight different cluster solutions were set to be evaluated, with the final cluster solution determined by comparing the Calinski-Harabasz index (CH index) across the eight possible solutions. The solution with the highest CH index is considered the most optimal solution based on the average between- and within-cluster sum of squares(18). In addition, membership size and interpretability of the clusters were also
considered(19).

The energy-adjusted food intakes of the clusters were presented by displaying median and inter-quartile range as the food intake data were not normally distributed. Food intakes with medians of zero (i.e. consumed by less than half of children) and skewed distributions were presented by displaying their 85th percentiles followed by 75th-95th percentiles. The clusters were then named interpretatively based on the combination of the foods that characterize the clusters. The median and inter-quartile range of energy and nutrients intakes of children in each cluster were also presented. These estimates were obtained by converting one-month intakes (from FFQ) into daily intakes and analysed using Dietplan nutrient analysis software version 6 (Forestfield software, UK) which contains a local database of energy and nutrient composition of food(10). Mann-Whitney U test was used to assess the differences in food and nutrients intakes between the clusters.

*Correlates of Cluster Dietary Patterns*

Logistic regression was used to evaluate the associations of maternal and child characteristics, responses to diet-related questions, and year-5 BMI to the identified clusters. In the case of three or more clusters were to be identified, multinomial regression would alternatively have been used. The identified cluster with the largest membership was considered as a negative outcome, whereas positive outcome(s) were assignments of children to the remaining cluster(s). Bivariate strengths of associations were evaluated by computing crude Odds Ratios (OR) (or Multinomial Relative Risk Ratios (MRRR) for ≥ 3 clusters) and their 95% Confidence Intervals (95% CI). Multivariable regression was subsequently performed to compute adjusted OR (or adjusted MRRR) to account for confounding. All statistical analyses were evaluated assuming a two-sided test with an alpha of 0.05 and performed using Stata version 15 (StataCorp, TX, USA).

# Results

A total of 808 caregiver-reported FFQs assessing the five-year-old children’s intakes were collected. The majority of caregivers were the children’s mothers (92.6% of FFQ), fathers (4.3%), mother and father (0.6%), with the remaining 2.5% reported by non-parents (non-biological parents, grandparents, other family members or domestic workers). FFQs of twenty child participants were excluded as the reported energy intake were outside the predefined limits (500-4000 kcal/day)(11). Eleven FFQs were further excluded due to implausible food intakes. The remaining 777 FFQs were available for analysis (Figure 1) and this represented 76.8% of five-year-old children that were still registered in the GUSTO cohort. [Figure 1 near here]



The participants’ characteristics are displayed in Table 1. In general, almost half of the children (48.4%) were girls and were first-borns (44.8%). Slightly more than half of the children were Chinese (56.6%) with a fair representation of Malay (24.8%) and Indian (18.5%). Characteristics of the participants were largely similar to at the inception of the cohort, except for slightly lower proportions of Malay and Indian children in the present study, due to differences in loss to follow-up rates across ethnicities (9). At year-5, 18.3% of children were overweight, approximately two-thirds of children had their parents as their primary caregivers, and more than half of parents reported reading food label when making food purchases (“Yes” or “Sometimes” responses). [Table 1 near here]

***Dietary Patterns Identified by Cluster Analysis***

The two-cluster solution was chosen after evaluating the CH indexes of eight different cluster solutions. The CH indexes for two-, three- and four-cluster solutions were 365.6, 269.2 and 204.0, respectively, with CH indexes of lower than 200.0 for the remaining solutions. The clusters’ memberships of two-cluster solution were also suitable for further analysis, with the smaller cluster formed by 43.9% of children.

[Table 2 near here]

The food groups that characterized the cluster dietary patterns are displayed in Table 2. They are presented as energy-adjusted daily intakes over a thirty-day period. The identified clusters were interpretatively labelled as the “Healthy” cluster and the “Unhealthy” cluster. A total of 436 children (56.1%) were assigned to the “Healthy” cluster, while the remaining 341 children (43.9%) to the “Unhealthy” cluster. The “Unhealthy” cluster was named as such because children in this cluster consumed greater amounts of fries, processed meat, biscuits and ice cream–items with high contents of saturated fat and refined carbohydrates–compared to children in the “Healthy” cluster. Those in the “Unhealthy” cluster also consumed lesser amounts of fish, fruits and vegetables compared to those in the “Healthy” cluster. The distributions of the food groups between the clusters were found to be statistically significantly different for most of the food groups. No statistically significant differences between clusters were found for bun and ethnic bread, fried eggs, burger and pizza, low-fat milk and sugar-sweetened beverages food groups.

***Energy and Nutrients Intakes***

The energy and nutrients intakes of children assigned to the “Healthy” and “Unhealthy” clusters are displayed in Table 3. Children in the “Healthy” cluster were found to have higher levels of energy-adjusted protein, fibre, fat, monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), cholesterol, vitamin A and beta-carotene intakes compared to children in the “Unhealthy” cluster. In contrast, children in the “Unhealthy” cluster had higher intakes of energy and carbohydrate compared to children in the “Healthy” cluster. No statistically significant differences between clusters were found for saturated fat, sodium, calcium and iron intakes. [Table 3 near here]

***Correlates of Cluster Dietary Patterns***

The correlates of the “Healthy” and “Unhealthy” clusters are presented in Table 4. Lower household income, lower maternal education level, being of Indian and Malay ethnicities, second- or subsequent-born children, BMI of five-year-old children classified as overweight and lower HEI-SGP tertiles were found to increase the odds of children being assigned to the “Unhealthy” cluster in the bivariate analysis. Meanwhile, all diet-related questions were not found to be associated with the cluster dietary patterns.

Ethnicity was associated with the children’s cluster assignments, with Indian and Malay children have higher odds of being assigned to the “Unhealthy” cluster, relative to Chinese children. After adjustment for confounders, ethnicity and maternal education level were the two variables associated with children’s cluster assignments. For ethnicity, the adjusted ORs (95% CIs) for Indian and Malay were 4.03 (2.68-6.06) and 25.46 (15.40-42.10), with Chinese as reference. Mothers whose educational attainment was secondary-level or below were found to have twice the odds of children being assigned to “Unhealthy” cluster, with an adjusted OR (95% CI) of 2.19 (1.49-3.24), relative to mothers whose education were tertiary-level.

# Discussion

This study is the first to report the dietary patterns of five-year-old children of three ethnic groups in Singapore, utilizing data from the ongoing GUSTO mother-offspring cohort study. Cluster analysis identified two clusters, the “Healthy” and “Unhealthy” clusters. The dietary pattern of the “Healthy” cluster was characterised by higher intakes of fruits, vegetables and fish, and thus adheres closely to dietary recommendations(20). In contrast, the “Unhealthy” cluster appears to be the antithesis of what a healthy diet a child should follow, and consisted of higher intakes of white bread, processed meat, ice cream and sweets. Another interesting finding was that the choice of protein sources differed between the clusters. The protein sources of children in the “Healthy” cluster were mainly from fish, non-fried poultry, tofu and non-fried red meat. These food items were consumed less often by children in the “Unhealthy” cluster. The opposite was true for processed meat–considered as less healthy protein sources, due to high fat and sodium contents–with higher intakes among children in the “Unhealthy” cluster compared to the “Healthy” cluster.

When comparing our cluster findings with other cohorts of children with similar age group, some similarities and some differences in the dietary patterns’ characteristics were observed. Closely similar to the ALSPAC cohort of British children, our “Unhealthy” cluster resembled their “Processed” cluster, which was characterised by white bread, processed meat, snack food items, fizzy drinks and squash. Similarly, vegetables and fruits were important cluster-differentiating food items in both cohorts(3). In contrast, our cluster findings were less similar to two other Asian cohorts of children. The Gwacheon child cohort study in Korea similarly found bread, cookies, crackers and chips to be cluster-differentiating food items between their “Western” and “Korean” clusters. However, unlike our findings, intakes of vegetables and fish between clusters were not cluster-differentiating in Korea(4). In the Chinese Five Cities Study, children in the unhealthy “Transitive” cluster consumed relatively high amounts of processed meat accompanied by high intakes of light coloured vegetables(5), whereas in our “Unhealthy” cluster, a combination of high processed meat intakes and low vegetable intakes were found. Taken together, these comparisons highlight that while dietary patterns across different populations may be broadly generalizable into healthy and unhealthy patterns, cluster analysis is important to better understand the specific make-up of these diets, based on local diets and cultural context of the population.

In our study, observed differences in nutrients intakes between clusters provided internal validation of the dietary patterns derived from CA(21). The higher levels of dietary fibre, vitamin A and beta-carotene intakes in the “Healthy” diet were expected as they reflected the higher intake of fruits and vegetables. The “Unhealthy” cluster had higher levels of total energy and carbohydrates, as well as lower levels of healthier fats such as MUFA and PUFA, which are in line with the higher intakes of refined and processed intakes in this cluster.

Numerous studies have shown that the diet quality of children is closely related to parental socioeconomic status with higher education and income leading to better diet quality of children (22–25). We found that household income level and maternal educational attainment were related to the assignment of children to the “Healthy” or “Unhealthy” clusters in the bivariate model. However, after accounting for confounders, only educational attainment was found to be significant, with mothers who had secondary-level or below education having twice the odds of their children being assigned to “Unhealthy” cluster, relative to mothers whose education were tertiary-level. The finding might be related to how mothers perceive the importance of diet for the health of children or due to the differing ability of mothers to access health-related
information(26,27).

There is growing evidence that a mother’s diet, even during pregnancy, has a long-term influence on their children’s diet quality(8). We did find some evidence that lower maternal diet quality during pregnancy was related to children being assigned to the “Unhealthy” cluster in the bivariate analysis, although the results did not reach statistical significance in the multivariable model. There was a suggestion of interaction between the HEI-SGP tertiles and ethnicity, with higher HEI-SGP tertiles leading to lower odds of children assigned to “Unhealthy” cluster in a varying extent across ethnicities, but unfortunately, the current study was underpowered to evaluate these further. The value of HEI-SGP as a determinant of children’s diet quality should be investigated further in the future birth cohorts.

In line with other studies(27,28), ethnicity was associated with children’s assignments to either the “Healthy” cluster or the “Unhealthy” cluster. We found that children of Malay ethnicity had higher odds of being assigned to the “Unhealthy” cluster, relative to Chinese and Indian ethnicities. However, we should note that these higher odds were also due to the small number of Malay children assigned to the “Healthy” cluster. This association was slightly attenuated by educational attainment, suggesting that higher education level leads to healthier children’s diets in this ethnic group. This finding was similar to the Singapore National Nutrition Survey of adults in 2010, where adults belonging to the Malay ethnic group tended to have lower intakes of fruits and vegetables(7). It was rather difficult to compare our findings with other studies, due to the difference in children’s ethnic compositions across studies. For example, the Amsterdam Born Children and their Development (ABCD) cohort in the Netherlands consisted of Dutch, Surinamese, Turkish, Moroccan and other ethnicities(27); and the Continuing Survey of Food Intakes by Individuals (CSFII) in the US consisted of White, African American, Hispanic, and other ethnicities(29). Nevertheless, both ABCD and CSFII have suggested that the children of non-majority ethnicities were having less healthy diets(27,29). The closest similarities to GUSTO in term of ethnic composition was the Malaysia subset of the South East Asian Nutrition Survey (SEANUTS) study, with Chinese, Indian, Malay and *Orang Asli* (Malaysia indigenous ethnic groups) making up 19.1%, 6.4%, 59.1% and 15.4% of children, respectively(30). However, the study investigated the eating habits of children (e.g. irregular mealtimes, snacking, fast food intake) rather than employing the dietary pattern approach. Despite the methodological difference, the Malaysia SEANUTS bears some similarities with our findings. In Malaysia, a greater percentage of Malay children consumed fast food once or more per week (10.9% of Malay children), compared to Indian (10.6%), *Orang Asli* (8.0%) and Chinese (7.3%)(30). Thus, somewhat supporting our finding that ethnicity is associated with child assignment to the “Unhealthy” cluster. This may point to some cultural influence on food choices and would warrant health promotion efforts targeting this. Another approach is to conduct a qualitative study to identify the barriers and facilitators across different ethnicities, therefore developing a culturally sensitive nutrition support programme.

Previous studies have demonstrated that parent as primary caregiver, parent as food decision-maker, and food label reading habits lend to willingness to prioritize healthy diet during caregiving (22,23,31). In this study, however, these were not associated with how children were assigned to the “Healthy” or “Unhealthy” clusters. This finding must be interpreted with caution, as it might be possible that social desirability bias affected the responses; the responses did not translate to actual food purchases; or a combination of both occurred. Busick *et al.*(32) have suggested that tracking food purchases through the collections of food-receipts are a better way to evaluate the parental influence on pre-schoolers’ diet quality. To verify the current finding, the suggested study design may be investigated in the future.

***Strengths and Limitations***

The strength of this study lies in the use of quantitative FFQ which enables us to quantify the children intake more precisely. This enabled us to account for the differences in children’s portion sizes that affected the identification of the cluster dietary patterns. The second strength is the method used to generate the clusters. The PAM algorithm combined with the evaluation of clusters from both statistical and interpretability standpoints, as well as internal validation by nutrients would ensure that the cluster solution is reflective of the study population.

The findings in this report are subject to at least three limitations. First, the use of caregiver-reported FFQ may have introduced social desirability bias related to over-reporting of food perceived to be healthy and under-reporting of food perceived to be unhealthy. The use of direct observations method to address this limitation was not attempted due to logistical issues and potential rejections by parents, as having observers recording children’s food intakes would be considered as rather intrusive. Second, non-response bias might have occurred since we did not manage to collect all of the year-5 children’s FFQs. It is possible that some caregivers were unwilling to be interviewed if they thought their children’s diets were unhealthy. Thus, the difference between the “Healthy” and “Unhealthy” clusters might be greater if we managed to collect all FFQs. Third, the current children may not be representative of the Singapore population, given that the participants were recruited from two maternity units. However, considering that the two maternity units are the largest in Singapore, serving both private and subsidized patients, selection bias was likely to be minimal.

# Conclusion

This study utilized a cluster analysis that identified two mutually exclusive dietary patterns in five-year-old Asian children, labelled as the “Healthy” and “Unhealthy” clusters. Compared to Chinese children, children of Indian and Malay ethnicities had higher odds of being assigned to the “Unhealthy” cluster. Besides ethnicity, lower maternal education level was also associated with higher odds of children being assigned to the “Unhealthy” cluster. These findings would be valuable in informing health promotion programmes targeted to improve the diet of Asian children.

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Country: Singapore

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