Correlations between diet quality and early childhood caries among 2- to 5-year-old Chinese children A cross-sectional study

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Research Article

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Abstract

Background: Early childhood caries (ECC) is one of the most common chronic diseases among children. Diet quality assessment is better than single food or specific nutrient assessment in predicting the risk of ECC. This study is aimed to explore the correlations between diet quality and ECC among 2- to 5-year-old Chinese children.

Methods: Totally 150 two- to five-year-old children were selected in this study. The decayed, missing or filled surface (dmfs) of each child was examined and recorded. Then the children were divided by ages and dmfs scores into the caries-free group, ECC group, and severe ECC (SECC) group respectively. The information of 24-h dietary intake from each child was captured via a mobile APP. The diet quality of each child was assessed by calculating the Chinese diet balance index for preschool children (DBI_C) indicators scores, high bound score (HBS), low bound score (LBS) and diet quality distance (DQD). Correlations of HBS, LBS, DQD and scores of 10 food group indicators with ECC were evaluated using rank sum test and logistic regression analysis.

Results: The probabilities of ECC and SECC are positively correlated with HBS (OR: ECC=1.102, SECC=1.098) and with DQD (OR: ECC=1.117, SECC=1.114), but not correlated with LBS ($P>0.05$) among the 2- to 5-year-old children. The severity of caries among the 2- to 5-year-old children are positively correlated with the score of Grains (OR: ECC=1.322, SECC=2.929) and negatively with the score of Food diversity (OR: ECC=0.378, SECC=0.034), but not correlated with other indicators.

Conclusions: The possibilities of ECC and SECC among the 2- to 5-year-old children are positively correlated with the degree of excessive dietary intake and dietary imbalance. The severity of caries among the 2- to 5-year-old children is positively correlated with grains intake and negatively with food diversity.

Background

Early childhood caries (ECC) is one of the most common chronic diseases and has been threatening the health of children worldwide. ECC is defined by American Academy of Pediatric Dentistry as one or more caries decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces (dmfs) in any primary tooth in a child, who is 71 months or younger [1]. The *Global Burden of Disease Study 2016* showed that the incidence rate of deciduous teeth caries ranked 5th among the globally most epidemic diseases [2]. The *Fourth Chinese Oral Health Epidemiological Survey Report* in 2018 demonstrated that the prevalence of caries in 3-, 4- and 5-year-old children were 50.8%, 63.6% and 71.9% respectively and the severity of caries is aggravated with age; however, the therapeutic rates were only 1.5%, 2.9% and 4.1% respectively [3]. Even after treatment, about 40% of ECC cases suffer from recurrence within one year [4]. Severe ECC (SECC) not only hinders the growth, development and quality-of-life of children [5], but also may cause negative effects on the parents and the society [6]. Hence, how to prevent the occurrence and development of ECC is a challenge faced by pediatric dentists globally.

Caries is a chronic disease affected by multiple factors. Its formation starts from the microbial changes in complex bio-membranes, and is affected by salivary flow and composition, exposure to fluoride, consumption of dietary sugars, and preventive behaviors (e.g. tooth cleaning) [7]. ECC usually progresses extensively and rapidly due to the age, physical and mental development of children, and physiological anatomic structure of deciduous teeth. Its occurrence may be more closely related to cariogenic microbes, adverse feeding habits, frequent contact with fermentable carbohydrates, adverse oral hygiene habits, and a series of social variables [8]. Specifically, dietary factors are pivotal in the occurrence and development of ECC [9]. Among various foods, sucrose, and processed or hydrolyzed starchy foods are considered to have a high cariogenic potential, as they all contain fermentable carbohydrates and can be fermented by oral microbes, leading to the drop of salivary pH to 5.5 or lower and thereby inducing caries [10]. Thus, frequent intake of sugary snacks and sugary drinks will significantly increase the risk of ECC [11]. Meanwhile, the associations between other foods and ECC have also been studied. For instance, milk and dairy products, unrefined grains, and fresh vegetables and fruits all will not cause caries [12, 13].

In conventional nutritional epidemiology, single (or a few) food or nutrient is investigated to explore the relationship between dietary nutrition factors and chronic diseases. However, such research may ignore effects of other potential factors on ECC and the interactions between other potential factors [9]. Diet quality refers to the types, contents and proportions of main foods and (or) nutrients in a diet accord with the diet guideline or a healthy diets structure proved before [14]. Currently, researchers focus on analyzing the relationship between dietary factors and ECC from the perspective of diet quality, because the complex synergistic effect among foods is considered. The currently-used tools to assess diet quality of ECC patients include the healthy eating index (HEI), which assesses whether the diet quality of residents aged 2 and above accords with the federation eating guideline [15–17]. Nunn et al. (2009) observed that the probability of having severe ECC (SECC) was 44% less in those in the highest tertile of the HEI compared with the lowest tertile [12]. Besides, Nunn et al. considered HEI as a predictor of the prevalence of SECC, independent of race/ethnicity and socio-economic status [12]. Zaki et al. (2015) found the total scores of HEI-2005 among 2- to 6-year-old Egyptian children with SECC were significantly lower than those without caries [18]. Elif İnan-Eroğlu et al. (2017) reported that the incidence rate of ECC was negatively correlated with the total score of HEI-2010 [19]. Priyadarshini et al. (2020) observed that Indian children with higher total scores of HEI-2005 were less prone to ECC [20]. However, HEI has not been used to assess the diet quality among 2- to 5-year-old Chinese children with ECC. In fact, the dietary patterns differ among various countries; the recommended intake and nutrition demand for 2- to 5-year-old children differ from those of adults, and children in this age range are physiologically featured by the gradual increase of height and weight, and by the limited chewing and digestion abilities [21, 22]. For the above concerns, the Chinese diet balance index for preschool children (DBI_C) was adopted here to assess the diet quality of 2- to 5-year-old Chinese children with ECC. DBI_C involves ten food group indicators, including Grains, Vegetables, Fruits, Dairy, Beans, Animal foods, Cooking oil, Salt, Drinking water, and Food diversity. The value ranges of these indicators were all determined by referring to the *Chinese Dietary Guidelines for Preschool Children*, and *A Balanced Diet Pagoda for Chinese Preschool*

Children [22, 23]. Thus, DBI_C is more suitable and applicable for the diet quality assessment of 2- to 5-year-old Chinese children.

Accurate description of foods and accurate estimation of portion sizes are critical for assessing dietary intake. The methods used in the past (e.g. 24-h diet recall, and food frequency questionnaire) are relatively tedious and may lead to inaccurate results in diet assessment, which thereby will cause negative effects on the results and patients. Recently, along with the popularization of cameras, mobile phones and other mobile equipment, the applications based on imaging methods and mobile equipment have been developed. Specifically, all the foods consumed by a subject are captured on basis of images and recorded as the main sources of dietary intake, which are used into dietary recording and assessment [24]. Herein, the information of 24-h dietary intake from children was collected using a mobile phone APP. The guardians of the children can add images details through mobile phones, which improved the accuracy of dietary assessment. Thereby, the dietary intake of each child was recorded in real time, which avoided the memory-based input. Thus, this method is faster, more efficient and more precise than traditional approaches.

- Herein, a mobile phone APP and DBI_C were used to investigate the diet quality of 2- to 5-year-old Chinese children, and to discuss the relationship between diet quality and ECC, which will offer a scientific basis for prevention of childhood caries.

Materials And Methods

Study population

In this cross-sectional descriptive survey, 150 children were chosen by a convenience sampling method from the Stomatological Department at Hospital of Stomatology of Hebei Medical University, one urban kindergarten, and two rural kindergartens.

The inclusion criteria: age at 2–5 years; presence of only primary dentition; an informed consent was signed from the legal guardians/parents of participant.

The exclusion criteria: any mental or systemic disease that affects oral health examination or dietary intake; energy intake less than 450 kcal/d or higher than 2800 kcal/d; taking any antibiotic at 2 weeks before this research.

Sample size estimation

The determination of sample size was based on the following assumptions: ECC prevalence of 62.5% generated from *The Fourth Chinese Oral Health Epidemiological Survey Report* in 2018 [3]; the allowable error is 15% of the overall rate; the test level is 5%. Thereby, the required sample size was determined by PASS 15 (Power Analysis and Sample Size, version 15) is 111. On the assumption of random missed follow-up and the missed follow-up rate was 10%, the required sample size was 124. Finally, 150 children were included into the analysis.

Ethical considerations

This study was approved by the Ethics Committee at the Hospital of Stomatology of Hebei Medical University (No.□2018□028) and conducted in accordance with *Declaration of Helsinki*. Before the study, the legal guardians/parents were informed about the objectives of this study, the health benefits and potential harms. They signed an informed consent. All the data in this study were used only for scientific research. Furthermore, children presenting with ECC or other oral diseases were offered the necessary advice and treatment.

Dental examinations

Dental examinations were carried out under field conditions by two trained and calibrated pediatric dentists. Duplicate clinical examinations were performed to test intra-examiner reliability, with kappa values averaging 90% and 88% for the examiners themselves and between the two examiners respectively. To maximally ensure the accuracy of the examinations, we adopted two caries diagnostic criteria: International Caries Detection and Assessment System (ICDAS-□) [25] to evaluate early enamel caries without forming cavity, and Worth Health Organization (WHO) Caries Examination and Diagnostic Criteria [26] to evaluate cavitated lesions in pits, fissures, and smooth surface. After food residues were removed and teeth were dried with cotton rolls, the dacayed, missing, filled surface (dmfs) of each child was scored using an aseptic odontoscope under sufficient illumination. A community periodontal index (CPI) probe was used when it is necessary to explore the tooth surfaces and to determine the enamel surface continuity and coarseness. The 150 children were divided by age and dmfs into 3 groups: a caries-free group (n = 21), an ECC group (n = 31), and a SECC group (n = 98).

Twenty-four hours dietary intake

The data of 24-h dietary intake were collected using a mobile phone APP (Beijing Sihai Huachen Technology Co., Ltd.), which consists of a children household nutrition management micro-platform, and a children nutrition supervision micro-platform. First, 10 parents were randomly selected for testing to ensure they can use the software correctly. According to the active feedback from the parents, we thought it unnecessary to further explain how to use the software. The guardians uploaded the diets consumed by children within 24 hours, in the form of images, onto the children household nutrition management micro-platform where they can also remark and supplement the information of food intake. On the next day, the doctors obtained the details from the children nutrition supervision micro-platform. After that, we called the guardians to check and supplement any necessary detail, which ensured the effectiveness and accuracy of all data.

Assessment of diet quality

Each food item captured in the 24-h dietary was converted to the corresponding DBI_C indicators, and the score for each indicator was calculate. The values of all indicators were determined by referring to *Chinese Diet Guidance for Preschool Children* [22] and *A Balanced Diet Pagoda for Chinese Preschool*

Children. A score closer to 0 indicates the intake of a certain type of foods is closer to the recommended intake at the corresponding age group from *A Balanced Diet Pagoda for Chinese Preschool Children*.

Based on the computational method of DBI_C, high bound score (HBS), low bound score (LBS), and diet quality distance (DQD) were calculated. For these three indicators, a score closer to 0 means the dietary state is better. HBS is the absolute value of the sum of the positive scores of all the food indicators, and reflects the degree of excessive dietary intake. Its score ranges from 0 to 36: where 0 means no excessive intake; 1–7 means appropriate intake; 8–14, 15–22, and 23–36 mean low, moderate and high intake excess respectively. LBS is the absolute value of the sum of the negative scores of all the food indicators, and reflects the degree of deficient dietary intake. Its score ranges from 0 to 72: where 0 means no intake deficiency; 1–14 means appropriate intake; 15–29, 30–43, and 44–72 mean low, moderate and high intake deficiency respectively. DQD is the sum of the absolute value of each food indicator score and comprehensively reflects dietary imbalance. Its score ranges from 0 to 84, where 0 means no intake deficiency and no intake excess; 1–17 means appropriate, and 18–34, 35–50, and 51–84 mean low, moderate and high dietary imbalance respectively.

Statistical analysis

During descriptive statistics, the continuous variables in accordance with normal distribution were expressed as mean ± standard deviation (), and those not in accordance with normal distribution were recorded as median and quartile ranges. Categorical variables were expressed as percentages (%).

Ages were compared among the three groups by One-way analysis of variance (ANOVA), and genders were tested by Chi-square (χ^2) test.

Since the data did not accord with normal distribution and (or) heterogeneity of variance, the scores of DBI_C indicators, HBS, LBS, and DQD were compared among the three groups using rank sum test. The significant level was $P \leq 0.05$. Comparison between groups was conducted by Bonferroni's method to calibrate the test levels.

The effects of HBS, LBS or DQD on ECC or SECC in the two independent models were assessed through univariate logistic regression analysis.

The bivariate relationships between the presence or absence of ECC and SECC and DBI_C indicators were assessed using Mann-Whitney U test. The variables at $P < 0.1$ were enrolled into the multivariate logistic regression to clarify the significant influence factors on ECC (model 1) and on SECC (model 2). The dependent variable was encoded as caries-free (value = 0) and ECC (value = 1), or as caries-free (value = 0) and SECC (value = 1). In addition to OR and 95% confidence interval (CI), the correct percentages of the classification were calculated.

The data were processed, analyzed and plotted on SPSS 26 (SPSS Inc., Chicago, IL, USA) and Graphpad prism 9.

Results

General information

Table 1 shows the demographic data of the studied subjects. Of the 150 included children, the caries-free group, the ECC group, and the SECC group are aged 2.81 ± 0.23, 3.74 ± 0.14, and 3.73 ± 0.08 years respectively, showing significant differences among groups ($P < 0.001$). There are 71 boys (47.3%) and 79 girls (52.7%), but the gender distributions are not significantly different among groups ($\chi^2 = 0.592$, $P = 0.744 > 0.05$).

Table 1
Comparison of demographic data among the three groups

Variables	N(%) Caries-free	ECC	SECC	Total	χ^2	*P*-value
Age $\bar{x} \pm s$	2.81 ± 0.23^a	3.74 ± 0.14^b	3.73 ± 0.08^b	3.61 ± 0.07	-	< 0.001*
Gender					0.592	0.744
Male	11(52.4)	13(41.9)	47(48.0)	71(47.3)		
Female	10(47.6)	18(58.1)	51(52.0)	79(52.7)		
Different letters indicate significant differences.						
* significantly different at *P* < 0.05						

DBI_C indicators scores and HBS, LBS, DQD

The average scores of Grains and Salt among the studied children are both higher than 0, but the average scores of Vegetables, Fruits, Dairy, Beans, Drinking water, and Food diversity are all lower than 0; however, only the average scores of Cooking oil and Animal foods are both equal to 0 (Fig. 1). Comparison of scores of the 10 DBI_C indicators shows that only the scores of Grains, Vegetables, and Food diversity are significantly different among the three groups ($P < 0.05$). The P value of Grains is 0.037; the P values of Vegetables and Food diversity are 0.016 and 0.007 respectively (Fig. 1). The average scores of HBS in the caries-free group, ECC group, and SECC group are 4, 9 and 10.5 respectively, showing significant differences among groups (χ^2 = 6.593, P = 0.037 < 0.05). The average score of LBS in the caries-free group (19) is lower compared with the ECC group (21) and the SECC group (22), but without significant differences among groups (χ^2 = 1.677, P = 0.432 > 0.05). The average score of DQD in the caries-free group is 25, and is 31 in both the ECC group and the SECC group, showing significant differences among groups (χ^2 = 11.677, P = 0.003 < 0.05) (Fig. 1).

Logistic regression analysis for the effects of HBS, LBS and DQD on ECC and SECC

HBS and DQD have significant effects on both ECC and SECC (P_{HBS}: 0.039, 0.019, P_{DQD}: 0.012 and 0.002 respectively) (Table 2). In the meantime, the possibility of the 2- to 5-year-old children having ECC or SECC is positively correlated with HBS and DQD (OR_{HBS}: 1.102, 1.098, OR_{DQD}: 1.117 and 1.114 respectively), but not correlated with LBS (P > 0.05).

Table 2
Logistic regression models for the effects of HBS, LBS and DQD on ECC and SECC

Variables	Outcome	Wald χ^2	P-value	OR	95% CI
HBS	ECC	4.240	0.039*	1.102	1.005–1.208
	SECC	5.467	0.019*	1.098	1.015–1.188
LBS	ECC	1.183	0.277	1.052	0.960–1.154
	SECC	1.376	0.241	1.041	0.973–1.114
DQD	ECC	6.259	0.012*	1.117	1.024–1.219
	SECC	9.670	0.002*	1.114	1.041–1.193

* significantly different at P < 0.05

OR: odds ratio; CI: confidence interval

Variables entered in the multivariate logistic regression model

The bivariate relationships between the occurrence of ECC or SECC and DBI_C indicators were assessed using Mann-Whitney U test (Table 3). Specifically, the caries-free group and the ECC group are significantly different in the scores of Vegetables (P = 0.021) and Food diversity (P = 0.007). The caries-free group and the SECC group are significantly different in the scores of Grains (P = 0.021), Vegetables

($P = 0.017$) and Food diversity ($P = 0.002$). Due to there only a few independent variables, the indicators at $P < 0.1$ were all enrolled into the multivariate logistic regression models.

Table 3
Bivariate relationships between the occurrence of ECC or SECC and DBI_C indicators

	P-value ECC	SECC
Grains	0.079*	0.021*
Vegetables	0.021*	0.017*
Fruits	0.208	0.260
Dairy	0.614	0.211
Beans	0.540	0.495
Animal foods	0.172	0.206
Cooking oil	0.362	0.201
Salt	0.133	0.139
Drinking water	0.924	0.400
Food diversity	0.007*	0.002*

*$P < 0.1$

Multivariate logistic regression models for the effects of DBI_C indicators on ECC and SECC

Figures 2 and 3 show the multivariate logistic regression models for the effects of DBI_C indicators on ECC and SECC. The DBI_C classification accuracy rates of ECC and SECC are 80.8% and 95.8% respectively. ECC is significantly affected by Grains ($P = 0.005$) and Food diversity ($P = 0.009$) (Fig. 2). The score of Grains is an independent risk factor of ECC (OR = 1.322, 95% CI = 1.089–1.604), and the score of Food diversity is an independent protective factor of ECC (OR = 0.378, 95% CI = 0.181–0.788). The significant influencing factors of SECC are also Grains ($P < 0.001$) and Food diversity ($P < 0.001$) (Fig. 3). The score of Grains is more likely to promote SECC compared with ECC (OR: 2.929 vs. 1.322), and the score of Food diversity can better prevent SECC than ECC (OR: 0.034 vs. 0.378).

Discussion

DBI_C was used for the first time to assess the correlations between diet quality and ECC among 2- to 5-year-old Chinese children. The indicators of DBI_C all involve food groups, but no nutrients, and thus avoid the tedious calculation needed by the nutrient-based diet quality assessment methods. Thus, DBI_C can be used to easily and rapidly analyze the diet quality of individuals and populations. Moreover, these indicators are expressed as two-way scores and can better intuitively reflect the problem and degree of dietary imbalance. Besides, taking the characteristics of Chinese preschool children into consideration, DBI_C is a better choice for assessing their diet quality.

In the present study, the possibility of the 2- to 5-year-old children having ECC or SECC is positively correlated with HBS and DQD, but not correlated with LBS. The analysis of the relationships between the DBI_C indicators (grains, vegetables, fruits, dairy, beans, animal foods, cooking oil, salt, drinking water, and food diversity) and ECC showed that the severity of caries among the 2- to 5-year-old children is positively correlated with the score of Grains and negatively with the score of Food diversity. Besides, ECC is not correlated with the scores of Vegetables, Fruits, Dairy, Beans, Animal foods, Cooking oil, Salt, or Drinking water.

The severity of caries among the studied children is aggravated with age, which is consistent with the previous study [18]. This may be resulted from the bad dietary/snack habits and the chronic contact between teeth and caries-inducing foods during the growing period of children [27].

All the studied subjects suffer from low-grade diet imbalance, and suffer both insufficient diet intake and excessive intake. Nevertheless, the average scores of HBS, LBS and DQD in the caries-free group are all lower compared with the ECC group and the SECC group. These results indicate the caries-free children have higher diet quality and are more likely to follow recommendations on healthy diet. These results are consistent with other studies [18, 20] that the adherence to general health eating guidelines is significantly correlated to the lower possibility of SECC in children based on HEI-2005 scores. Owing to the rapid sociometric development, the nutrition statuses of Chinese children are improved [28, 29], but dietary imbalance is still common among Chinese children [30]. Our study shows the average intake of grains and salt by 2- to 5-year-old Chinese children are higher than the recommended intake according to *A Balanced Diet Pagoda for Chinese Preschool Children*, but the average intake of vegetables, fruits, dairy, beans, drinking water, and food diversity are all lower than the recommended intake. Moreover, the probability of developing ECC is positively correlated with the degree of dietary imbalance. Dietary imbalance will lead to malnutrition with varying degrees, which in turn will result in the hypofunction of salivary glands, and the variation in saliva composition and the decline in buffering ability of saliva, increasing the risk of ECC [31, 32]. The diet quality of preschool children will affect their diet quality both at the school age and adulthood [33], and is associated with the incidence of chronic diseases and even death at the adulthood and old age [34, 35]. Thus, the dietary imbalance problems of preschool children deserves great attention globally. Necessary intervention measures can be adopted, such as to strengthen the guardians' health consciousness [36] and to conduct popular science and propaganda about nutritional health of young children.

The average score of Grains in the ECC group and the SECC group are both significantly higher than that of the caries-free group, and the severity of caries is positively correlated with the score of Grains. This result indicates that children with more grains intake will suffer more-severe caries. However, Nunn et al. found the scores of whole grains by caries-free children were significantly higher compared with ECC patients, and the increase in the intake of whole grains was associated with a decrease in the risk of ECC [12]. In this study, DBI_C does not differentiate refined grains and whole grains. According to *Scientific Research Report on Dietary Guidelines for Chinese Residents* (2021) (abridged version) [37], the grains consumed by Chinese residents are dominated by refined rice and flour, but the intake of whole grains is deficient, which indirectly indicate that the 2- to 5-year-old Chinese children consume more refined grains than whole grains. Owing to the loss of the external bran layers and the mashing of endosperm during processing, the contents of dietary fibers, vitamins, minerals, essential fatty acids and plant chemical substances in refined grains are largely decreased [38], with the main component of refined grains as starch. Sarah Hancock et al. found that after exposure to starch- and sugar-containing processed foods, the pH of dental plaques was maintained below the critical level of 5.5 for longer time compared with the foods only containing high sucrose [39], indicating that the intake of refined grains, especially the sugary refined grains, is associated with the occurrence of caries.

In the present study, the score of Vegetables are significantly different among the three groups, but logistic regression analysis shows the score of Vegetables is not an independent influence factor of ECC or SECC, suggesting there may be other confounders. This result is opposite to two other studies [20, 40] that the intake of vegetables is significantly related to a lower ECC risk. Mastication of vegetables, which are featured with fiber characteristics and self-cleaning ability, can stimulate saliva flow and enhance the acid neutralizing ability of saliva, which help with the cleaning of oral fermentable carbohydrates [41, 42]. However, the structures, physicochemical properties and nutrition effect of dietary fibers are easily affected by the processing methods [43]. Some parents think children's chewing ability is weak because of young ages, and thus cut vegetables into fine pieces and boil them very soft, thereby altering the functions and nutrition of fibers and decreasing the anti-caries capacity of fibers. This may explain that the vegetable consumption in the present study is not significantly related to the severity of caries.

Moreover, the average score of Fruits among children with ECC or SECC is higher than that of caries-free children, but with no significant differences among the three groups, which is inconsistent with the result of a previous study that the intake of fruits is negatively correlated with the severity of caries [44]. However, some fruits such as oranges are rich in organic acids (e.g. citric acid, malic acid, oxalic acid, tartaric acid) that can decrease the oral cavity pH, and excessive intake of such fruits may induce dental erosion and demineralization [13]. The seasonal differences in the intake of fruits also affect the results.

Compared with the other two groups, the SECC group shows the highest intake of dairy, but without significant difference. Various components of dairy products are considered to be able to prevent caries, including the minerals (e.g. Ca, P), proteins (e.g. casein, lactoal-bumin) and lipids (e.g. essential fatty acids, nonessential fatty acids) in milk [45, 46], and casein phosphopeptides in yogurt and cheese [47, 48]. In vivo and in vitro demineralization / remineralization experiments also prove the low cariogenicity ability and potential caries-protective role of dairy [45]. However, to improve the taste and flavor of products, most commercial milk and milk producers add sucrose and seasoners, which complicate the research on the caries-inducing ability of dairy products. Moreover, yogurt and cheese both are sticky foods; when children eat too much such foods and do not clean teeth in time, these foods become the substrates of bacteria and may induce ECC.

Children in the caries-free group has the highest score of Food diversity compared to children in the ECC and SECC groups. The severity of caries is negatively correlated with food diversity. It is indicated that the degree of caries is lower among children consuming more diverse foods. The majority of micronutrients originate from daily diets, and food diversity is proved to be positively correlated with the intake of dietary micronutrients [49]. Thus, food diversity is a valuable indicator to predict whether the macronutrients or micronutrients taken by children are sufficient or not [50, 51]. However, For children with monophagism, deficiency in vitamin D, iron, calcium and albumin, and protein-energy malnutrition may induce enamel defects, enamel surface roughness and dental plaque accumulation, thereby leading to caries [32, 52–54]. Thus, balanced diet with diverse foods is rather necessary.

Image-based methods provide more feasible and extensive choices for diet assessment and are closer to the daily life of participants. Compared with the solo use of traditional assessment methods, the participants can supplement image details to decrease the food under-reporting, which improve the accuracy of diet assessment [24, 55]. Though many meaningful valuable results are obtained, this study still has some limitations. Firstly, in this cross-sectional study, the results only reflect associations, rather than causality. Secondly, DBI_C is a scale based on food group indicators, and cannot assess the concrete nutrient intake of children and thereby cannot analyze the relationship between nutrients and ECC. Thirdly, the image-based methods is dependent on image data, but China is huge in area and has diverse and complex dietary cultures, which make Chinese diets one of the most complex dietary systems. In the case of some unrecorded food types, it cannot be identified or analyzed.

Conclusions

Dietary imbalance is a severe health problem faced by the studied population. The possibilities of ECC and SECC among the 2- to 5-year-old Chinese children are positively correlated with the degree of excessive dietary intake and dietary imbalance. The severity of caries among the 2- to 5-year-old Chinese children is positively correlated with grains intake and negatively with food diversity. These findings will offer some scientific basis for preventing ECC. Nevertheless, large-scale prospective research is needed to validate these findings and to offer more information about the underlying causality and mechanism.

Abbreviations

ECC
early childhood caries
dmfs
decayed (non-cavitated or cavitated), missing (due to caries), and filled tooth surfaces
SECC
severe early childhood caries
DBI_C
Chinese Diet Balance Index for Preschool Children
HBS
high bound score
LBS
low bound score
DQD
dietary quality distance
AAPD
American Academy of Pediatric Dentistry
HEI
Healthy Eating Index
ICDAS
International Caries Detection and Assessment System
WHO
World Health Organization
CPI
Community Periodontal Index

Declarations

Ethics approval and consent to participate

Ethics approval was obtained from the “Hebei Medical University Dental Hospital Medical Ethics Committee”, and written informed consent was received from all the participant's legal guardian. Ethics approval code:（2018）028 . The study is conducted in accordance with the principles of the Declaration of Helsinki.

Consent for publication

Not applicable

Availability of data and materials

The data used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

HS conceived and designed the study. ZM, XL, ML, CZ trained the data collectors. XW, ML, ZM, CZ analyzed and reconciled the data. XW, FC drafted the first draft of the manuscript. HS reviewed and modified it to the final version. All authors critically revised the manuscript and approved the final version for publication.

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Figures

Figure 1

Box plots for comparison of DBI_C indicators scores, HBS, LBS and DQD among the three groups

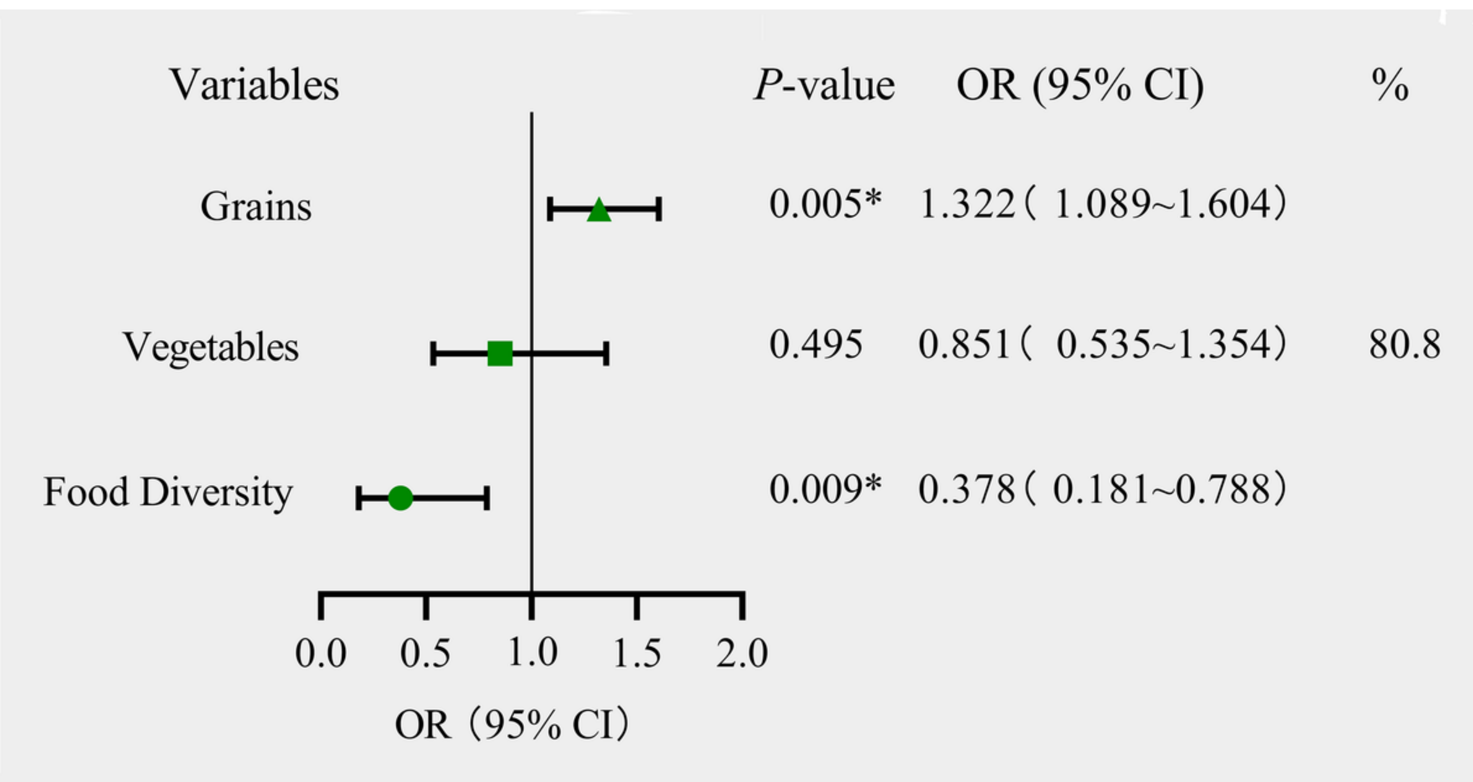

Figure 2

Multivariate logistic regression model for the effects of DBI_C indicators on ECC

* significantly different at P<0.05

The indicators enrolled into the ECC model include Grains, Vegetables, and Food diversity.

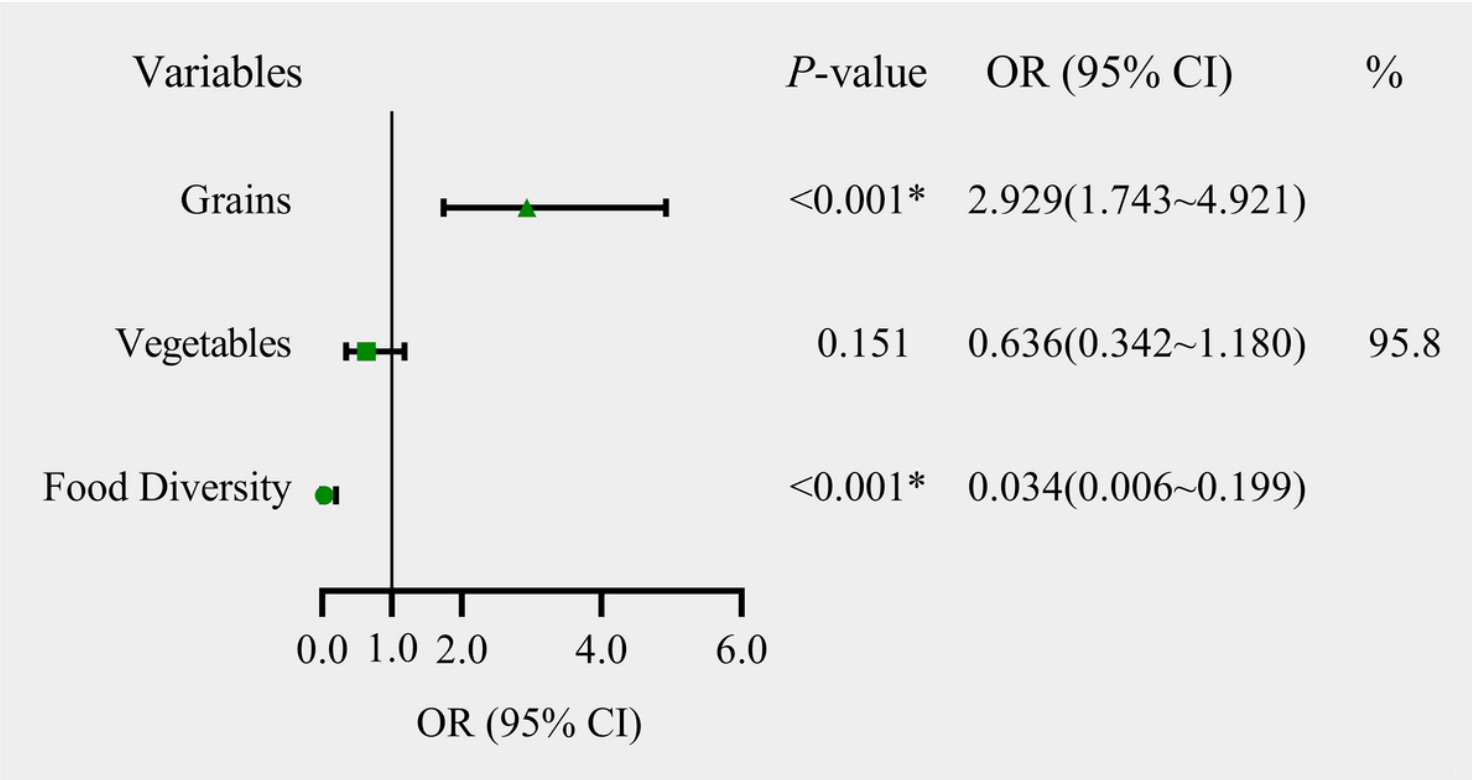

Figure 3

Multivariate logistic regression model for the effects of DBI_C indicators on SECC

* significantly different at P<0.05

The indicators enrolled into the SECC model include Grains, Vegetables, and Food diversity.