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Investigating the Association between Healthy Eating Index and Early Childhood Caries in Iranian Preschool Children: A Case-Control Study

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ABSTRACT

Background: Early Childhood Caries (ECC) is known as a main global dental problem in childhood period, which oral diet may play an important role in the occurrence of this complication. Thus, the present study aimed to evaluate the association between dietary Healthy Eating Index (HEI) and ECC in children living in Mashhad, Iran. **Methods:** In the current case-control study, 732 preschool children (aged 3–6 years) were examined for dental caries and then categorized into two groups of children with ECC, or who were Caries-Free (CF). Then, the HEI was measured by analyzing a validated food frequency questionnaire, which their parents were requested to complete. The association between HEI score and the prevalence of ECC was determined using logistic regression analysis. **Results:** The HEI for CF group was significantly higher than ECC group (P<0.001, CI 95%: 57.58-67.93 *vs.* 51.72-65.49), respectively). The mean scores of grain, milk, fruits, vegetables, and meat groups were significantly higher in CF group (P<0.001). Children in CF group were also more compliant with recommended intake of total fat (P<0.01) and cholesterol (P<0.001). Furthermore, CF children had a significantly more diverse food item intake (P<0.001). It is noteworthy to mention that, with each unit increase in HEI score, the odds of ECC decreased by 0.04 (P=0.01, OR=0.04). **Conclusion:** Caries prevalence in preschool children could be prevented by enhancing food quality.

Introduction

Early childhood caries (ECC) refers to the presence of decayed, missing, or filled surfaces in any primary tooth, affecting over 50% of preschoolers worldwide (Lu *et al.*, 2023). The ECC not only can cause dental problems, including dentoalveolar abscesses and pain but also it is accompanied by other adverse health consequences, including nutritional deficiencies, difficulties with chewing, and impacts on overall quality of life (Krishna *et al.*, 2021). Moreover, the ECC has been recognized as one of the potential risk factors in developing caries in the permanent teeth (Lam *et al.*, 2022). It has been documented that more than 85% of Iranian children have experienced dental

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caries as an unmet oral health need (Khoshnevisan *et al.*, 2018). The implications of ECC are not only a concern for individual health but also it poses a considerable economic burden on health systems worldwide (Manchanda *et al.*, 2023). ECC is a multifactorial disease, including microorganisms, exposure to fermentable carbohydrates, inadequate nutrition, and social determinants (Anil and Anand, 2017). It has been also suggested that bedtime bottle feeding, frequent breastfeeding, frequent consumption of sugary snacks and drinks, skipping breakfast, and low intake of vegetables and fruits are listed as other possible risk factors involved in ECC (Krishna *et al.*, 2021, Vundavalli *et al.*, 2019).

Recently, numerous dietary assessment methods have been utilized, to evaluate the quality of diet. The Healthy Eating Index (HEI), developed by the United States Department of Agriculture (USDA) to monitor the American population consumption patterns, is a widely-used tool for evaluating diet quality (Kaye *et al.*, 2020). The HEI consists of ten components, in which the first five components measure the degree to which a person's diet conforms to the food guide pyramid serving recommendation for the five major food groups (grains, vegetables, fruits, milk, and meat) as expressed in servings per day. The next four components of the HEI assess the degree of adherence of several nutrients, including total fat, saturated fat, cholesterol, and sodium. The final component examines the variety of food in the person’s diet (Wang *et al.*, 2022). The diet quality indices have been shown to be reliable predictors of child growth in developing countries (Marshall *et al.*, 2014). In this regard, previous studies in Egypt, China, Turkey, and India have suggested a potential association between a lower HEI score and a higher prevalence of ECC (İnan-Eroğlu *et al.*, 2017, Priyadarshini and Gurunathan, 2020, Wang *et al.*, 2022, Zaki *et al.*, 2015). Moreover, children aged under five years who were food insecure were more likely to experience tooth decay (Sabbagh *et al.*, 2023). Given the variation in dietary habits across countries and regions, there is a distinction in recommended intake and nutritional requirements between younger children and adults (Feng *et al.*, 2022). In a study in Mashhad, it was found that most of children had a diet quality that was less than acceptable levels (Mehrabkhani *et al.*, 2016). Therefore, the current study aimed to investigate the association between the HEI and the prevalence of ECC in children living in Mashhad, Iran.

Materials and Methods

Study design and participants

The present case-control investigation was conducted on 732 children with an average age of 4.18±1.27 years, who were attending preschools in Mashhad, Iran. The preschools were selected by randomized cluster method from Mashhad city twelve districts. All parents were informed about the study objectives, and informed consent was obtained from them. The inclusion criteria were children who were healthy, had no history of systemic diseases, and had attended daycare for at least one shift. Children who were taking special medication or following a specific diet were excluded from the study. The sample size was determined based on the study by Nunn et al. (Nunn *et al.*, 2009). The mean value of HEI was considered in two groups including children with ECC and CF children. The sample size was calculated with a 95% confidence interval and an 80% power, resulting in 243 subjects for each group. However, after adjusting for a cluster sampling correction factor of 1.5, the total estimated sample size for both groups was obtained 732 participants.

Initially, an experienced dentist examined the children, and categorized them into two groups: children with ECC and CF children. The regular dietary intake of the children was assessed using an Iranian validated food frequency questionnaire. This questionnaire, which was developed specifically for the Iranian population by the Nutrition Department of Mashhad University of Medical Sciences and validated by Nematy *et al*. (Nematy *et al.*, 2013), listed 160 typical Iranian food items and their frequency of consumption. The completed questionnaires were then digitally scanned using an HP Scanjet N8420. The Iranian

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dietary composition table (Dorosty Motlagh and Tabatabaei, 2007) and Nutritionist IV software (version 3.5.2) were used to evaluate the type of consumed food items and the amount of consumption in grams.

HEI Measurement

The HEI score was determined by modifying the method proposed by Kennedy et al. (Kennedy *et al.*, 1995). This index comprises 10 components, yielding a total score ranging from 0 to 100. It assesses the consumption of 5 major food groups of food pyramid guide (bread and cereals, vegetables, fruits, meat, and dairy products), total and saturated fatty acids, cholesterol intake, and dietary diversity. Due to the lack of reliable and accurate information about sodium consumption and according to the study of Azadbakht *et al*. (Azadbakht and Esmaillzadeh, 2009), the score of this component was not calculated.

The scoring system for 5 major groups of food pyramid guide was as follows. A maximum score of 10 would be assigned if a child's intake was equal to or greater than the recommended quantity for their age group. A score of zero was assigned if a child did not consume any amount from a particular food group. Scores between zero and ten were calculated proportionally. In order to determine each food group score, the amount of each food item consumed in grams was entered into Excel software. Then, the components and the quantity of consumption were determined. USDA guidelines were used to calculate the number of servings required for each food group in each age group.

The score was determined for saturated and total fat based on the percentage of total energy derived from fat. The energy derived from fat in 1 mg of each food item was calculated and multiplied by total amount of food. A score of ten for total fat was assigned for percentages equal to or less than 30%, while a score of zero was assigned for percentages exceeding than 45%. For saturated fat, a score of ten was assigned for consuming equal to or less than 10% of total energy. Conversely, if the child's energy from saturated fat was greater than 15%, a score of zero would be given.

Consuming less than 300 mg and more than 450 mg for cholesterol is attributed to a score of ten and zero, respectively. The scores between zero and ten were calculated proportionally.

Each food item was entered into the software to calculate total fat, saturated fat, and cholesterol. The software determined 1 gram of each food item as percentages of food item energy content. The calculated values were then multiplied by the consumed amount of each food item.

Food diversity assessment

The evaluation of food diversity was measured based on major groups outlined in the food pyramid guide. These groups include bread and cereals (7 subgroups), vegetables (7 subgroups), fruits (2 subgroups), meat (4 subgroups), and dairy products (3 subgroups). In order for a food item subgroup to contribute to the diversity score, at least half of the corresponding subgroup item needed to be consumed.

Each of the five main groups could receive a maximum of 2 points out of 10. The score of the main groups was determined by the percentage of maximum possible points. The diet diversity score was calculated by adding up the total number of different food items consumed by a person per day (Azadbakht and Esmaillzadeh, 2009).

The final score for HEI was determined via summing the scores of nine components. The modified HEI score was then classified into three categories including scores above 72 indicated a healthy diet, scores between 45 and 72 suggested a diet that needed improvement, and scores below 45 represented a poor diet. Additionally, for certain data analysis, the HEI component data was divided into three levels including less than 5, between 5 and 8, and greater than 8.

Ethical considerations

The study protocol was approved by the Ethics Committee on Human Experimentation of Mashhad University of Medical Sciences (IR.MUMS.REC.1394.776).

Data analysis

All statistical analysis was performed using the Statistical Package for Social Sciences (version

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23.0; SPSS Inc). The normal distribution of the data was assessed using the Kolmogorov-Smirnov test. Given the non-normal distribution of HEI scores, the Mann-Whitney test was employed for data analysis. Comparison of the median HEI component scores between ECC and CF groups was carried out via the Kruskal-Wallis test. In addition, the Chi-Squared test was utilized for analyzing qualitative data. In order to evaluate the association between HEI score, age, and the presence of ECC, the logistic regression test was done. All differences were considered statistically significant at P≤0.05.

Results

Participants' average age was 4.18±1.27 years. Children aged 3, 4, 5, and 6 years old make up 19, 25, 39, and 17% of the population, respectively. Among the children, 36.06% were boys. It was observed that 69.4% of the children had ECC, while 30.7% were CF. **Table 1** shows the distribution of children based on age and caries experience status. There was a statistically significant association between the age of children and caries experience status (CI 95, 0.45-0.67, OR, 0.553; *P*<0.001).

Table 1. The prevalence of ECC and CF based on children's gender and age.

Age (y)	Boys			Girls			Total		
	ECC	CF	Total	ECC	CF	Total	ECC	CF	Total
3	20(40.0)[a]	30(60.0)	50(100)	43(48.3)	46(51.7)	89(100)	63(8.6)	76(10.4)	139(100)
4	46(69.7)	20(30.3)	66(100)	83(70.9)	34(29.1)	117(100)	129(17.6)	54(7.4)	183(100)
5	70(68.0)	33(32.0)	103(100)	137(74.9)	46(25.1)	183(100)	207(28.3)	79(10.8)	286(100)
6	32(71.1)	13(28.9)	45(100)	77(96.2)	3(3.8)	80(100)	109(14.9)	16(2.2)	125(100)
Total	168(63.6)	96(36.4)	264(100)	340(72.6)	129(27.6)	468(100)	508(69.4)	225(30.7)	732(100)

*[a]: n (%); **ECC**: Early childhood caries; **CF**: Caries-free.*

According to the results in **Table 2**, the mean score of HEI was significantly higher in CF group (57.58-67.93) compared to ECC group (*P*<0.001, (57.58-67.93) vs (51.72-65.49), respectively).

Table 2. Comparison of HEI between ECC and CF groups.

Study group	HEI score (95% Confidence interval)
ECC	58.30 (51.72-65.49)
C.F	61.74(57.58-67.93)
P-value[a]	≤0.001

*[a]: Obtained from the Mann-Whitney test; **HEI**: Healthy eating index; **ECC**: Early childhood caries; **CF**: Caries-free.*

Based on **Table 3**, it was detected that CF group had a higher proportion of children with a good quality diet (16.6%) compared to ECC group (6%). Conversely, a higher percentage of participants in ECC group had a poor diet compared to those in CF group (15.2% *vs.* 7%, respectively). The Chi-square test results indicated a significant difference between ECC and CF groups (*P*<0.001).

Table 3. HEI score distribution in ECC and CF groups.

HEI score[b]	ECC	CF	P-value[a]
	n (%)	n (%)	
<45	71 (15.2)	18 (7.0)	<0.001
45-72	368 (78.8)	198 (77.3)	
72<	28 (6.0)	40 (16.6)	

*[a]: Chi-square test; **HEI**: Healthy eating index; **ECC**: Early childhood caries; **CF**: Caries-free.[b]: <45(Poor diet quality); 45-72 (Diet need improvement); 72<(Good diet quality).*

Table 4 displays the interquartile range of nine components of the HEI for the two study groups. The results of Mann-Whitney test indicated that CF group achieved significantly higher scores in major food pyramid groups (*P*<0.001), total fat (*P*=0.019), and food diversity (*P*<0.001). Conversely, ECC group had a higher intake of cholesterol (*P*<0.001).

As indicated in **Table 5**, a greater percentage of children in both groups achieved scores exceeding 8 points on the seven components of HEI (P<0.001). In **Table 5**, the Kruskal-Wallis test revealed a statistically significant difference between the two groups. A higher percentage of individuals in both groups had scores greater than 8 (P<0.001). There was no significant difference between the study groups in total fat (P=0.39) and saturated fat (P=0.23) consumption. However, the frequency of children with a cholesterol score above 5 was significantly higher in CF group compared to ECC group (P<0.001). The frequency of children with food diversity scores above 8 and below 5 was higher in CF and ECC groups, respectively (P<0.001).

Table 4. Comparing the median values of HEI components in ECC and CF groups.

Group	B&C	DP	Vegetables	Fruits	Meats	TF	Cholesterol	SFA	Diversity
ECC	10a (6.8-10)	10 (6.79-10)	10 (6.45-10)	10 (5.84-10)	10 (10-10)	0 (0-3.41)	0.82 (0-10)	3.93 (0-8.18)	5.57 (4.02-6.80)
CF	10 (10-10)	10 (10-10)	10 (10-10)	10 (10-10)	10 (10-10)	0.63 (0-4.56)	0 (0-0.69)	4.45 (0-9.52)	6.94 (5.57-8.81)
P-value[b]	<0.001	<0.001	<0.001	<0.001	<0.001	0.019	<0.001	0.330	<0.001

[a]: *Data are presented as median (first quartile-third quartile);* [b]: *Obtained from the Mann-Whitney test;* ***ECC****: Early childhood caries; CF: Caries-free; B%C: Bread and cereals; TF: Total fat; SFA: Saturated fatty acid; DP: Dairy products.*

Table 5. HEI components score in ECC and CF groups.

HEI component	Component score						P-value[a]
	<5		5-8		8<		
	ECC N (%)	CF N (%)	ECC N (%)	CF N (%)	ECC N (%)	CF N (%)	
Bread and cereals	79 (16.9)	26 (10.2)	56 (12.0)	16 (6.2)	332 (71.1)	214 (83.6)	<0.001
Dairy products	91 (19.5)	22 (8.6)	72 (15.4)	6 (2.3)	304 (65.1)	228 (89.1)	<0.001
Vegetables	84 (18.0)	18 (7.0)	74 (15.8)	20 (7.8)	309 (66.2)	218 (85.2)	<0.001
Fruits	105 (22.5)	32 (12.5)	47 (10.1)	6 (2.3)	315 (67.5)	218 (85.2)	<0.001
Meat	62 (13.3)	14 (5.5)	10 (2.1)	4 (1.6)	395 (84.6)	238 (93.0)	<0.001
Total fat	376 (81.9)	194 (78.9)	39 (8.5)	30 (12.2)	44 (9.6)	22 (8.9)	0.398
Cholesterol	274 (58.7)	212 (82.8)	23 (4.9)	10 (3.9)	170 (36.4)	34 (13.3)	<0.001
Saturated fat	259 (56.4)	132 (53.7)	80 (17.4)	34 (13.8)	120 (26.1)	80 (32.5)	0.238
Diversity	198 (42.4)	52 (20.3)	219 (46.9)	114 (44.5)	50 (10.7)	90 (35.2)	<0.001

[a]: *Obtained from the Kruskal-Wallis test;* ***HEI****: Healthy eating index;* ***ECC****: Early childhood caries;* ***CF****: Caries-free.*

The logistic regression analysis revealed a significant association between three HIE components: dairy and total fat intake, food diversity, and the incidence of ECC (P<0.001, **Table 6**). For each unit increase in milk, total fat consumption, and food variety, the odds of ECC multiplied by 0.790, 0.830, and 0.680, respectively (P<0.001). Additionally, with each unit increase in HEI, the odds of caries experience, such as ECC, decreased by 0.04 (4% decrease in caries experience, P<0.01).

Discussion

To the best of our knowledge, this study was the first scientific effort to investigate the association of HEI and prevalence of ECC in Iranian children. The World Health Organization indicated that dietary patterns may undergo significant changes between the ages of 3 and 6. Finally, the study decided to concentrate on this specific age group (Krishna *et al.*, 2021).

There are few studies on the association between HEI and ECC. In the present study, most children

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had HEI with a score range of 45-72, and their diet needed improvement. This was consistent with studies from Saudi Arabia (Vundavalli *et al.*, 2019) and Turkey (Nunn *et al.*, 2009). The HEI is a measure for dietary quality assessment based on the food pyramid, in which 24 h dietary recall is used.

Regarding HEI components, the results showed that children in CF group achieved good scores in all five components of HEI scores. In addition, CF group had higher score compared to ECC group in bread and grains, dairy, fruits, vegetables, meat, total fat, cholesterol, and food diversity. Moreover, there was an association between lower HEI score and the experience of dental caries as ECC. The results of this study are in agreement with the findings of Nunn *et al*. (Nunn *et al.*, 2009), who observed higher score for HEI in CF group. Vundavalli *et al*. (Vundavalli *et al.*, 2019) also found a positive association between diet quality and ECC in children aged 4-6. Priyadarshini and Gurunathan (Priyadarshini and Gurunathan, 2020), İnan-Eroğlu *et al*. (İnan-Eroğlu *et al.*, 2017), Prince *et al*. (Prince *et al.*, 2020), Karğin *et al*. (Karğin *et al.*, 2021), and AbdelAziz *et al*. (AbdelAziz *et al.*, 2015) reported a positive relationship between diet quality and dental caries in children. According to the results of a previous investigation, it has been shown that diet was the primary etiological factor for ECC in 3-year old children (Olczak-Kowalczyk *et al.*, 2021).

Table 6. The association between the HEI and ECC.

Variables	B[c]	EXP(B)[b]	Lower	Upper	P-value[a]
Dairy products	236.0-	790.0	695.0	0.898	<0.001
Total fat	187.0-	830.0	762.0	903.0	<0.001
Diversity	386.0-	680.0	596.0	0.775	<0.001
HEI	041.0	042.1	010.1	1.075	0.001

[a]: Obtained from the regression logistic test; [b]: Odds ratio; [c]: correlation coefficient; ***HEI****: Healthy eating index;* ***ECC****: Early childhood caries;* ***CF****: Caries-free.*

The percentage of children in CF groups with meat consumption score above 8 was higher in CF group compared to ECC group (93% *vs*. 84.6%). Meat contains sufficient protein and low cariogenic potential compared to refined carbohydrates and is relatively protective against tooth decay (Krishna *et al.*, 2021). Vundavalli *et al.* found that higher scores for grain and meat consumption were associated with a reduction in prevalence of ECC (Vundavalli *et al.*, 2019).

In the present study, fruit and vegetable consumption was higher in CF children. Vegetables exhibited a protective function against caries for their fiber characteristics and self-cleaning ability due to stimulation of saliva during mastication. They also stimulate salivation during chewing while increasing its acid-neutralizing effects (Wang *et al.*, 2022). Zaki *et al*. suggested that caries experience was negatively associated with fruit consumption (Zaki *et al.*, 2015). However, some fruits, such as citrus fruits, are rich in organic acids (such as citric, malic, oxalic, and tartaric acids) that decrease the pH of saliva in the oral cavity, and excessive consumption of these fruits can lead to tooth erosion and demineralization (Wang *et al.*, 2022).

The current study showed that CF group dairy product intake was higher than ECC group. On the other hand, a negative association was observed between dairy consumption and ECC. Therefore, to reduce the risk of ECC, it is recommended to increase the consumption of dairy products. Several studies have confirmed that milk and dairy products are rich in nutrients, including proteins (e.g., casein and whey protein), minerals (e.g., calcium and phosphorus), and fats (e.g., essential and non-essential fatty acids) (Ozyurt and Ötles, 2016, Wang *et al.*, 2022). There are also many other bioactive ingredients, including casein phosphopeptides which have been shown to have remineralization potential (Ozyurt and Ötles, 2016, Rezvani *et al.*, 2015). Milk consumption was

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related to lower score of DMFT index in 3- to 5-year-old African American children (Kolker *et al.*, 2007). Johansson *et al*. observed fewer caries in children who drank milk compared to other beverages (non-sweetened or sweet) consumed with snacks (Johansson *et al.*, 2010).

CF children had better dietary diversity than ECC group. This result is in line with the study by Nunn *et al*. (Nunn *et al.*, 2009). Wang *et al.* also reported that the severity of caries in children aged 2 to 5 years decreased with increased dietary diversity, since it was positively associated with dietary micronutrient intake (Wang *et al.*, 2022). Dietary diversity is a suitable indicator for predicting the adequacy of macronutrients or micronutrients in children (Wang *et al.*, 2017). An unbalanced diet and the subsequent lack of calcium, iron, albumin, vitamin D, and protein-energy malnutrition may cause enamel hypoplasia/hypomineralization, surface roughness, plaque accumulation, and finally, post-eruptive caries (Meng *et al.*, 2018, Zhao *et al.*, 2017). A balanced diet with various food items is essential for young children, since most micronutrients are obtained from daily diet.

According to the current study, enhancing dairy intake and dietary diversity and decreasing total fat consumption, significantly increased the odds of experiencing ECC by 0.83. Well-designed nutrition education for young children can improve a family eating habits (Kostecka, 2022). Oral health care worker can consider comprehensive dietary guidelines in their oral care prevention counseling and strategies. By improving oral health-related diet, oral health care workers can incorporate comprehensive dietary guidelines into their oral care prevention counseling and strategies. Improving diet is associated not only with oral health but also with overall well-being (Kaye *et al.*, 2020).

The main strength of the current study was gathering dietary data via a validated and reliable questionnaire. Additionally, the sampling method was carried out using randomized cluster method and included twelve districts within the city of Mashhad. Therefore, the study population consisted of 3- to 6-year-old children residing in Mashhad city and is representative of this group. However, there are several limitations in the study. First, the study relied on self-reported dietary information obtained from a questionnaire. This method is susceptible for potential biases including measurement error, misclassification, and recall bias. Furthermore, the study did not consider other potential confounders, such as the socioeconomic status of families or the oral hygiene status of children.

Conclusion

The HEI was found to be higher in CF children compared to children who had experienced ECC. Increasing the intake of dairy products, promoting dietary diversity, and ensuring appropriate total fat consumption may help reduce the risk of ECC. Further long-term randomized clinical trials are required to confirm the findings.

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Conflict of interests

The authors declare no competing interest.

Authors' contributions

M Mehrabkhani and M Nematy and T Movahhed designed research; M Mehrabkhani and H Mohammadi conducted research; M Hoseinzadeh analyzed data; and M Mehrabkhani, T Movahhed and H Mohammadi wrote the paper. M Mehrabkhani had primary responsibility for final content. All authors read and approved the final manuscript.

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