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## Dental caries among 12-year-old children after discontinuation of water fluoridation in Pahang, Malaysia

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## Dental caries among 12-year-old children after discontinuation of water fluoridation in Pahang, Malaysia

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### Abstract

**Background:** Water fluoridation (WF) has been a national caries prevention program in Malaysia since 1972. However, between July 2012 and December 2013, WF was discontinued in Pahang. This study aimed to compare caries prevalence and mean caries experience among Malaysian children in WF and WF-ceased areas and determine its associated risk factors. **Methods:** This cross-sectional study was conducted among 12-year-old schoolchildren in two Malaysian states: Pahang (WF-ceased) and Perak (WF-continued). Dental caries was examined using ICDAS criteria, and a questionnaire was used to collect relevant data. Associations between independent variables and dental caries were analyzed by simple logistic regression and general linear model analyses. **Results:** Dental caries (D<sub>4-6</sub>MFT) was significantly higher among children in WF-ceased areas than in communities where WF continued. Multivariate analysis demonstrated that exposure to WF remains a strong predictor of low caries experience among the study population. Moreover, children with irregular toothbrushing frequency before sleep and whose parents have lower educational attainment are associated with higher caries experience. **Conclusion:** Caries prevalence and mean caries experience were significantly higher among children in WF-ceased areas than in communities where WF continued. Multivariate analysis revealed that several factors were associated with caries experience.

*Keywords: dental caries, public health, water fluoridation*

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### Introduction

The effectiveness of water fluoridation (WF) to control caries is well established in the literature. Despite the advantages of WF, some communities and authorities have questioned its benefits and safety, resulting in its cessation in some areas such as Okinawa (Japan),<sup>1</sup> Anglesey (Wales),<sup>2</sup> Kuopio (Finland),<sup>3</sup> La Salud (Cuba),<sup>4</sup> Cheongju (South Korea),<sup>5</sup> and Calgary (Canada).<sup>6</sup> Reasons for WF cessation include lack of funding to purchase fluoride compound and equipment maintenance, technical difficulties, increased prevalence of fluorosis, and availability of other caries preventive programs, such as topical fluoride and fissure sealants.<sup>7</sup> In addition, movement of anti-fluoridation groups is reported as one of the key factors toward the discontinuation of WF.<sup>3,5</sup>

The impact of WF cessation on dental caries is not uniformly positive or negative but varies over time and is confounded by several factors. For example, the York review concluded that the prevalence of dental caries increases following WF cessation.<sup>8</sup> This York review included 8 cessation studies with a positive control (an

area continuing fluoridation) and a negative control (an area without fluoridation) that acted as reference communities. By contrast, the Cochrane review concluded that “there is insufficient information to determine the effect of stopping community water fluoridation on caries levels.”<sup>9</sup> The Cochrane review has been criticized for using stringent inclusion criteria when assessing population-based interventions such as WF.<sup>10</sup> As a result, the review only included a single study that had a positive comparison community (an area continuing fluoridation), which some authors regarded as an “empty review.”<sup>10</sup> A recent review by McLaren and Singhal reported 15 instances of WF cessation in 13 countries from 1956 to 2003, with no strict inclusion criteria.<sup>6</sup> The review reported mixed findings where earlier studies (before 1990s) reported that caries increased post-cessation, while later studies (after 1990s) reported that caries continued to decline post-cessation in an era of widespread exposure to other fluoride sources such as toothpaste.<sup>6</sup>

Nevertheless, all reviews acknowledged the difficulty in assessing the effect of WF because of the complex interactions of multiple confounders.<sup>7-9</sup> Authors

highlighted the need for more contemporary evidence with improved methodological quality. In particular, they emphasized the importance of having a positive control community and better handling of confounders via statistical analysis. Designing evaluation studies for WF intervention with an appropriate control community is challenging in some countries because fluoridation policy is enacted at the federal level and implemented for the whole country.<sup>10</sup> For example, in Hong Kong and Singapore, 100% of the population receives fluoridated water.<sup>11,12</sup> Similarly, when cessation occurs, often the entire area in the region is affected, ruling out the possibility of a comparable positive control community.<sup>10</sup>

WF was introduced in Malaysia in 1972 as a national caries prevention program. However, between July 2012 and December 2013, WF was terminated in Pahang state. The discontinuation of WF programs in the state of Pahang, Malaysia, in 2012 offers a valuable opportunity to evaluate the effect of WF cessation on dental caries.<sup>13</sup> As several states in Malaysia continue WF, this work will provide an opportunity to have a community with a positive reference point as a control group, thereby increasing the study quality. The population living in the fluoridated area was exposed to 0.5 parts-per-million (ppm) fluoride throughout their life following the downward adjustment of fluoride level in 2005.<sup>14</sup> Existing evidence was reported in areas with water fluoride concentration ranging between 0.7 and 1.0 ppm. The study aimed to compare caries prevalence and mean caries experience among Malaysian children in WF with 0.5 ppm fluoride and WF-ceased areas and determine its associated risk factors. In Pahang, the state received WF until cessation occurred in July 2012 and in some residential districts in December 2013. The reasons for the cessation were due to privatization of the state water board, lack of funding to purchase fluoride, maintenance cost of the WF program, and perceived barriers to continue WF by the state water board. The findings from this study will be valuable to fill the gap in the literature and generate important evidence for local WF policies.

## Methods

**Study design and locations.** Ethical approval for this study was obtained from the Medical Ethics Committee, Faculty of Dentistry, University of Malaya (DFCO1902/0002 [P]) and the National Medical Research and Ethics Committee of the Ministry of Health (MOH) Malaysia (NMRR-18-3309-44638). Permission to conduct this study was granted by the Ministry of Health, Ministry of Education, and State Education Department, Malaysia. Informed consent was sought from parents and assented from children prior to clinical examination. All children were given a unique individual code in all recorded measurements to maintain anonymity.

This work was a single-point cross-sectional study with comparative communities conducted in two Malaysian states, namely, Pahang (WF-ceased) and Perak (WF-continued). These two states are good-matched areas in terms of demographic profiles. On the basis of the national oral health survey for schoolchildren, caries prevalence among 12-year-old children in the year of cessation in Pahang was 38.7% (mean: 1.01) and 27.9% (mean: 0.65) in Perak.<sup>15</sup> The annual water quality report indicated that the fluoride levels in the water supply in Perak were consistent with the national standard of  $0.5 \pm 0.2$  ppm, which justified its inclusion as a comparison community. In Pahang, WF was stopped in July 2012 and in some residential districts in December 2013 due to the lack of funding to purchase the fluoride compound. Children in WF-ceased districts were exposed to fluoride in the water in the first 5–6.5 years of their life, whereas children in WF areas in Perak were exposed to fluoride in the water throughout life.

**Study population and sample size.** The study population comprised 12-year-old children in Pahang and Perak. The sample size was calculated based on the potential difference in population caries prevalence and among children in WF-ceased and WF-continued areas using G\*power software. The estimation calculated to detect a 16.5% difference in caries prevalence with 90% power and a significance level of 0.05 was 155 subjects per area. The minimal sample size was further inflated by 20% to account for non-respondents, 10% to account for non-lifelong residents, and a design effect of 2.0 calculated from a pilot study. The calculation formula was  $155 + (0.20 \times 155) + (0.10 \times 155)] \times 2.0 = 404$ . Finally, the estimated total sample size for the two areas was  $404 \times 2 = 808$ , and the number was rounded to 810.

This study used stratified cluster random sampling based on the probability proportionate to size technique to select the participants from each age group in the WF and WF-ceased areas. The sampling unit was public primary schools in both states. In the first stage, the schools were stratified into urban and rural locations and types of school (i.e., national and vernacular schools) to create individual stratum. The schools within each stratum were randomly selected by simple random sampling proportionate to the total number of children attending schools in the respective location and type of school until the sample size was fulfilled. The schools were randomly selected using simple random sampling proportionate to size and types of school. Overall, 25 schools involved in this study and only lifelong residents were included in the sample.

**Questionnaire.** A set of pre-tested questionnaires was used to collect data on oral hygiene practices, dietary habits (i.e., water intake and frequency of snacking), and demographic background. The questionnaire was adapted with modifications from a previous local

study,<sup>14</sup> and additional questions were added based on expert group discussion. The final version of the questionnaire was distributed to the parents with help from representative school teachers. Data were collected from January 2019 to June 2019.

**Dental caries examination.** To assess caries, the examiner underwent the International Caries Detection and Assessment System (ICDAS) online training module and a six-hour ICDAS workshop at the Faculty of Dentistry, University of Malaya. A calibration exercise against a gold standard was conducted after the workshop on 60 extracted teeth. Weighted kappa scores for inter-examiner and intra-examiner were 0.88 and 0.93, respectively. Duplicate clinical examinations were performed on 20 randomly selected participants in the field after a 2-week interval, with intra-examiner reproducibility of 0.89.

Caries examination was conducted on all erupted teeth in permanent dentition. The ICDAS-II index was adopted due to the ability of the system to detect cavitated and non-cavitated lesions.<sup>16</sup> The ICDAS-II index comprises a two-digit scoring method, where the first digit represents restorations and sealant codes. The second digit is related to dental caries codes. The children were asked to brush their teeth prior to the oral examination. Children were seated on the portable dental chair in supine position. Cotton roll was placed at the buccal vestibules to prevent excessive saliva flow, and gauze was used to dry the teeth.

**Data management and analysis.** This study utilized stratified cluster random sampling with different sampling ratios between strata. The data weighting process involved primary sampling unit and stratum. Data were analyzed using the Complex Sample Analysis module in SPSS version 23 considering the complex sampling method.

The ICDAS caries scores were recoded into two caries levels:  $D_{4-6}$  (dentine caries) and  $D_{1-6}$  (combination of enamel and dentine caries). Caries prevalence was defined at  $D_{4-6}MFT > 0$  and  $D_{1-6}MFT > 0$ . The recoding of ICDAS scores into decayed-missing-filled-teeth (DMFT) index was to allow comparison with other studies. Descriptive analysis was conducted to describe mean caries experience, and chi-square test was used to compare caries prevalence by area of residence. Associations between caries and independent variables from the parental questionnaire were analyzed by simple logistic regression for categorical outcomes (prevalence) and univariate general linear model for continuous outcomes (mean caries scores). The associations among risk factors, namely, demographic characteristics, oral hygiene practices, and dietary habits, were only analyzed for caries outcome at the

dentine level ( $D_{4-6}$ ). All variables ( $p < 0.30$ ) were included into a multivariate general linear model. These variables were entered into the model simultaneously. Interaction was also tested between inter-dependent factors to test their contribution to a model. The outcomes were reported as standardized coefficient, standard error, 95% confidence interval (CI), and  $p$ -value.

## Results

From the 769 questionnaires returned (95% response rate), 127 were excluded due to non-lifelong residents ( $n = 103$ ) and incomplete answers ( $n = 24$ ). A higher response rate was obtained from participants in WF areas (89.7%) than in WF-ceased areas (83.1%). No statistically significant difference was found between the two study areas in relation to demographic background. In terms of clinical examination, 620 children were available on the examination day. Data with complete clinical examination and questionnaire were used in the analysis ( $n = 620$ ).

In this paper, caries outcomes were reported at two levels, namely, dentine level ( $D_{4-6}MFT$ ) and combination of enamel and dentine levels ( $D_{1-6}MFT$ ). The prevalence and mean DMFT in the WF and WF-ceased areas are shown in Table 1. Significantly higher prevalence of dental caries was observed among children in WF-ceased areas ( $D_{4-6}MFT$ : 39%,  $D_{1-6}MFT$ : 99.3%) than in WF areas ( $D_{4-6}MFT$ : 20.9%,  $D_{1-6}MFT$ : 90%) for both outcome measures. Higher mean caries experience among children in WF-ceased area than in WF area was observed. Prevalence of caries increased when the measurement included early caries lesions at the enamel level ( $D_{1-6}$ ) for both WF-ceased (39%–99.3%) and WF areas (20.9%–90%).

In terms of socio-economic status (SES), children with mothers in the low-income group and fathers and mothers with lower educational attainment were significantly associated with higher dentine caries than their counterparts. Other demographic factors were not significantly different (Table 2).

Further associations between independent variables and caries experience were only analyzed with caries outcome at the dentine level. Table 3 shows that oral hygiene practices were not significantly associated with mean caries experience. However, children who never or occasionally brushed their teeth at night before sleeping had higher mean caries experience (mean: 0.61, SE: 0.03) than children who brushed on a daily basis (mean: 0.45, SE: 0.03). Children who used non-fluoridated toothpaste showed higher mean caries experience than their counterparts, but the difference was not significant.

**Table 1.** Caries prevalence and mean caries experience among study participants in WF and WF-ceased areas (N=620)

Outcome measures Caries prevalence	Dental caries N (%)		Unadjusted Odds Ratio <sup>a</sup> (95% CI)	<i>p</i>
	Yes	No		
<b>D<sub>4-6</sub>MFT&gt;0</b>				
WF	67 (20.9)	253 (79.1)	Ref	
WF-ceased	117 (39.0)	183 (61.0)	2.41 (1.79-3.25)	0.001*
<b>D<sub>1-6</sub>MFT&gt;0</b>				
WF	288 (90.0)	32 (10.0)	Ref	
WF-ceased	298 (99.3)	2 (0.7)	16.56 (1.36-202.19)	0.036*
Mean caries experience	Mean	S.E	95% CI	<i>p</i>
<b>D<sub>4-6</sub>MFT</b>				
WF	0.33	0.03	(0.26-0.40)	
WF-ceased	0.80	0.03	(0.72-0.87)	<0.001*
<b>D<sub>1-6</sub>MFT</b>				
WF	4.02	0.46	(2.76-5.29)	5.29
WF-ceased	8.89	0.54	(7.38-10.40)	<0.003*

n=unweighted sample count; %=weighted percentage.

<sup>a</sup>Simple logistic regression analysis

\*Statistically significant ( $p < 0.05$ )

**Table 2.** Association between mean caries experience (D<sub>4-6</sub>MFT) and demographic characteristics of study participants (N=620)

Variables	Mean caries	S.E	B <sup>a</sup>	95% CI		<i>p</i> <sup>a</sup>
				Lower	Upper	
<b>Gender</b>						
Boys	0.33	0.03	Ref			
Girls	0.36	0.01	0.03	-0.05	0.12	0.337
<b>Location</b>						
Urban	0.32	0.03	Ref			
Rural	0.36	0.01	0.03	-0.05	0.11	0.306
<b>Father monthly income</b>						
>MYR 4000	0.37	0.02	Ref			
<MYR 4000	0.30	0.02	-0.08	-0.16	0.01	0.266
No income	0.30	0.06	-0.07	-0.22	0.08	0.125
<b>Mother monthly income</b>						
>MYR 4000	0.50	0.03	Ref			
<MYR 4000	0.32	0.01	-0.18	-0.27	-0.09	0.006*
No income	0.32	0.02	-0.17	-0.27	-0.07	0.008*
<b>Father's highest education level</b>						
College/University	0.41	0.07	Ref			
High school	0.30	0.02	-0.08	-0.08	-5.74	0.009*
≤Primary school	0.38	0.02	0.03	-0.21	0.26	0.749
<b>Mother's highest education level</b>						
College/University	0.31	0.01	Ref			
High school	0.36	0.01	0.05	0.01	0.09	0.029*
≤Primary school	0.26	0.02	-0.05	-0.10	-0.00	0.057

Mean= weighted mean; B= Parameter estimates.

<sup>a</sup>Univariate analysis in Complex Sample General Linear Model

\*Statistically significant ( $p < 0.05$ )

Table 4 shows the relationship between mean caries experience and dietary habits among the study population. Children who drank more than five cups or glasses of water had fewer mean caries experience, but the difference was not significant. Drinking and eating sweet drinks and food more than four times a day were

significantly associated with elevated mean caries experience.

The number of permanent teeth with fissure sealants and sealed teeth associated with early caries is shown in Table 5. A significantly higher mean score of fissure

sealant placement was observed among children in WF areas than among children in WF-ceased areas. However, a greater number of teeth that had been sealed had early caries in WF-ceased (Mean: 0.03 to 0.04) than in WF areas (Mean: 0 to 0.07), and the difference was statistically significant.

After controlling the effect of other risk factors, WF status, parents' education level, and frequency of toothbrushing before sleep remained statistically significant in the multivariate model (Table 5). Children who had partial exposure to WF due to WF cessation had more mean caries experience ( $\beta$ : 0.28, 95% CI:

0.14–0.41,  $p$ : 0.005) than children who received lifelong exposure to WF. Children whose mothers ( $\beta$ : 0.13, 95% CI: 0.09–0.17,  $p$ : 0.001) and fathers ( $\beta$ : -0.17, 95% CI: -0.24 to -0.10,  $p$ : 0.004) went to high school had significantly higher caries experience than those children whose parents attained college or university education. Irregular toothbrushing frequency before sleeping at night remained a significant factor for high caries experience in the multivariate model ( $\beta$ : 0.14, 95% CI: 0.07–0.21,  $p$ : 0.005). Children who brushed regularly before sleep at night had lower mean caries experience than their counterparts.

**Table 3.** Association between mean caries experience ( $D_{4-6}MFT$ ) and oral hygiene practices and dietary habits among study participants (N=620)

Variables	Mean	S.E	B	95% CI		$p^a$
				Lower	Upper	
<b>Frequency of toothbrushing (n=607)</b>						
Twice/day or more	0.53	0.02	Ref			
Once/day or less	0.61	0.06	0.08	-0.07	0.23	0.194
<b>Toothbrushing before sleep at night (n=576)</b>						
Everyday	0.45	0.03	Ref			
Sometimes/never	0.61	0.03	0.16	0.01	0.30	0.043*
<b>Amount of toothpaste used (n=601)</b>						
Medium to large	0.55	0.02	Ref			
Smear/pea sized	0.45	0.04	-0.10	-0.18	-0.03	0.019
<b>Type of toothpaste used (n=580)</b>						
Fluoridated	0.55	0.02	Ref			
Non-fluoridated	0.71	0.16	0.16	-0.26	0.58	0.356
<b>Volume of plain water drank a day (n=604)</b>						
<5 cups/glasses a day	0.52	0.02	Ref			
>5 cups/glasses a day	0.56	0.04	-0.04	-0.16	0.08	0.371
<b>Frequency of sweet drinks and food consumed (n=600)</b>						
<4 times a day	0.52	0.02	Ref			
>4 times a day	0.81	0.05	0.29	0.19	0.38	0.001*
<b>Frequency of carbonated drinks consumed (n=604)</b>						
None	0.49	0.06	Ref			
At least once a day	0.57	0.02	0.08	-0.11	-0.28	0.291

Mean= weighted mean; B= Parameter estimates.

<sup>a</sup>Univariate analysis in Complex Sample General Linear Model

\*Statistically significant ( $p < 0.05$ )

Total sample in each category did not equal to n=620 due to missing data

**Table 4.** Univariate analysis of the mean score of sealed permanent teeth among study participants (N=620)

	WF-ceased				WF			
	Mean	S.E	95% CI		Mean	S.E	95% CI	
			Lower	Upper			Lower	Upper
Incomplete sealant <sup>†</sup>	0.02*	0.00	0.02	0.03	0.23	0.04	0.13	0.34
Complete sealant	0.03	0.01	0.01	0.05	0.05	0.01	0.03	0.08
Incomplete sealant with early caries	0.04*	0.00	0.03	0.05	0.07	0.01	0.04	0.09
Complete sealant with early caries	0.03*	0.01	0.02	0.05	0.00	0.00	0.00	0.01

Univariate analysis in Complex Sample General Linear Model.

<sup>†</sup>covering only parts of the teeth fissure.

\*Statistically significant ( $p < 0.05$ )

**Table 5.** Multivariate model for mean caries experience (D<sub>4-6</sub>MFT) in all participants using Complex Sample General Linear Model

	$\beta^a$	S.E	95% CI		t-statistic	$p^b$
			Lower	Upper		
Intercept	0.29	0.04	0.17	0.40	6.94	0.002*
<b>Fluoridation status</b>						
WF	Ref					
WF-ceased	0.28	0.05	0.14	0.41	5.69	0.005*
<b>Mother's highest education level</b>						
College/University	Ref					
High school	0.13	0.01	0.09	0.17	9.37	0.001*
≤Primary school	-0.12	0.05	-0.26	0.10	-2.57	0.274
<b>Father's highest education level</b>						
College/University	Ref					
High school	-0.17	0.02	-0.24	-0.10		0.004*
≤Primary school	-0.05	0.13	-0.32	0.42	0.36	1.000
<b>Toothbrushing before sleep at night</b>						
Everyday	Ref					
Sometimes/never	0.14	0.03	0.07	0.21	5.58	0.005*
<b>Type of toothpaste used</b>						
Fluoridated	Ref					
Non-fluoridated	-0.04	0.02	-0.09	0.07	-2.36	0.078

<sup>a</sup> Standardised Coefficients<sup>b</sup> Bonferroni correction conducted for multiple comparisons\*Statistically significant ( $p < 0.05$ )

## Discussion

The objectives of the study were to compare caries prevalence and mean caries experience among 12-year-old children in WF and WF-ceased areas and determine its associated risk factors. Caries prevalence and mean caries experience were significantly higher among children in WF-ceased than in WF areas. The present study confirmed existing findings that caries worsens post-cessation as reported in Okinawa, Japan,<sup>1</sup> and Tiel, the Netherlands.<sup>17</sup> However, since the late 1990s, several authors have reported that caries prevalence continued to decrease even after WF stopped.<sup>3,4</sup> A more recent study assessing the impact of WF in Alberta, Canada, reported that caries is only significantly higher in primary dentition, and no obvious changes were observed in permanent dentition among 7-year-old children in WF-ceased areas than those living in WF areas.<sup>6</sup> These findings contradicted an earlier Canadian study by Maupome *et al.* in 2001, who reported no difference in caries incidence for permanent dentition between still-fluoridating and fluoridated-ceased communities.<sup>18</sup>

This study had several limitations. First, the examiner was not blinded in terms of fluoridation status. However, this condition was difficult to achieve unless the participants were transported to another area for clinical examination. Second, the cross-sectional study design made it difficult to rule out the influence of other confounding factors in caries experience,

particularly exposure to different fluoride sources. However, efforts have been made to control potential confounders using multivariate analysis. Third, recall bias from a self-reported questionnaire may have influenced the results. Lastly, complexity was noted in selecting an ideal comparison community that is still fluoridated to match well with the WF-ceased area. Although effort was made to minimize selection bias, baseline caries prevalence in Perak (WF continued) was higher than that in Pahang. However, it was still the most suitable state in Peninsular Malaysia that fulfilled other criteria, which were consistent WF level and similar demographic profiles and median household income.

Looking at local data, the present findings support data from the National Oral Health Survey for 12-year-old schoolchildren, which indicated that caries remains high in Pahang (WF-ceased: 40.1%) in comparison to Perak (WF area: 24.0%).<sup>19</sup> The annual school dental service data from 2013 until 2019 suggested that caries prevalence declined in both states (Pahang and Perak). However, the magnitude of caries reduction was greater in WF areas (2013: 29.5%, 2019: 20.9%) than in WF-ceased areas (2013: 40.7%, 2019: 39.0%),<sup>15,20</sup> thereby implying the beneficial effect of WF.

Univariate analysis also demonstrated the positive impact of WF in teeth with sealants. A significantly greater number of teeth that have been sealed developed early caries in WF-ceased areas than in WF

areas. These findings provide evidence on the additional benefits of WF in caries prevention on fit and fissure surfaces as previous studies reported that the preventive effect of WF is mostly on smooth surface lesions.<sup>6,21</sup> However, the findings should be interpreted with caution as the ICDAS index code only allows measurement of sealants with caries for early caries lesions (Codes 1 and 2). The condition of the tooth prior to sealant placement was unknown. Regarding Code 1, this study only used gauze for drying instead of a 3-way air syringe, which is acknowledged as a limitation in epidemiology studies. The findings could also be confounded by oral hygiene practices and exposure to other sources of fluoride such as toothpaste. Univariate analysis indicated that children that used fluoridated toothpaste, brushed more than once per day, and brushed before sleep at night daily had significantly lower caries experience than their counterparts. However, only frequency of brushing before sleep at night remained significant in the multivariate model, which supported the benefits of WF even in a community with widespread use of fluoride toothpaste.

In addition, higher frequency of sweet drinks and food consumption was significantly associated with a higher caries score in univariate analysis but not significant in the multivariate model. The association between frequent consumption of sugary food products and caries prevalence has been extensively discussed in the literature.<sup>22,23</sup> Additionally, findings indicated that drinking less than 5 cups/glasses of plain water a day was related to increased caries experience. These results confirmed existing findings in the literature that drinking high volumes of plain water acts as a protective factor against caries among children aged 2–10 years old.<sup>24</sup> Drinking more water may lead to less consumption of other types of beverages such as sweetened beverages, thereby reducing the risk of developing caries.<sup>25</sup>

Other than WF status, father's and mother's education level remained a strong predictor associated with mean caries experience in the multivariate analysis. Children whose parents have lower educational attainment were associated with higher caries experience compared with children with parents that have higher education. There is established evidence that caries has an inverse relationship with SES. Parents with a high education level can influence their children's oral health practices and dietary habits, which later affects caries outcome.<sup>26,27</sup>

Findings from this study can provide more insight into WF cessation studies, particularly of having a comparison community that is still fluoridated to add rigor to the study methodology and using the ICDAS index, which allows assessment of early caries lesions.

However, the prevalence of early caries was considerably high in both areas including children exposed to WF. Previous studies have reported high caries prevalence with the inclusion of early caries lesion using ICDAS diagnostic criteria.<sup>14,28–30</sup> In addition, there is a possibility of misclassification of early caries lesion with other lesions such as white spot lesions and dental stains. Although more enamel caries were reported in the WF area than in the non-WF area, it may not have progressed to dentine caries, which implies the preventive benefit of WF. These findings led to another research question: how effective WF is in preventing early caries lesion? This question is beyond the scope of the present research and can be explored in future work. The findings from the present study are useful for local authorities in Malaysia to evaluate the effectiveness of WF in caries prevention and to build up a case for WF to resume in Pahang. Future research is needed to monitor this situation, ideally using a longitudinal study design.

## Conclusion

Caries prevalence and mean caries experience were significantly higher among children in WF-ceased areas than in communities where WF continued. After controlling for confounders, WF status, parents' education level, and regular toothbrushing before sleeping remained statistically significant in the multivariate model. Exposure to WF remained a strong predictor of low caries experience among the study population. In addition, multivariate analysis revealed that children whose parents have lower educational attainment and children with irregular brushing frequency before sleeping were associated with higher caries experience. Continuous efforts should be made to ensure regular monitoring of the population in these two states for long-term impact assessment. The data will be valuable to build a case for local authorities to reinstate WF in the state of Pahang.

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## Conflict of Interest Statement

The authors declare that they have no competing interests.



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