

# CARIES INCREMENT AMONG SCHOOLCHILDREN EXPOSED TO DIFFERENT FLUORIDE CONCENTRATIONS IN WATER: A FIVE-YEAR RETROSPECTIVE COHORT STUDY

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## Abstract

Previous studies have indicated that the cessation of community water fluoridation (CWF) leads to an increase in caries prevalence among schoolchildren. However, little is known about the rate of caries progression among schoolchildren exposed to different concentrations of fluoride in water. Hence, this study aimed to compare the mean caries increment in permanent dentition among Malaysian schoolchildren with partial exposure (in Pahang) and full exposure (in Perak) to CWF and determine its associated factors. This was a five-year retrospective cohort study using an analysis of secondary data of school dental records among schoolchildren exposed to different fluoride concentrations in the water supply. Children in Perak were exposed to CWF throughout life while children in Pahang were exposed to CWF for the first five to six years of their lives before it was discontinued. The children were followed retrospectively from 2015 (initially aged eight years old) to 2019 (12 years old). Relevant data such as demographic characteristics, caries experience and exposure to other clinical preventive dental treatments were extracted and analysed using SPSS 21.0. Descriptive, independent t-test and negative binomial regression were used to examine the data. The sample consisted of 462 school dental records in both states. The prevalence of schoolchildren with DMFT scores of 2 and  $\geq 3$  increased by 10.4% and 13.9%, respectively, in Pahang from 2015 to 2019, compared to 4.8% and 0.9% in Perak. The mean (M) and standard deviation (SD) of caries increment at tooth and surface levels in permanent dentition among schoolchildren in Pahang (M = 0.83, SD =  $\pm 1.50$  and M = 1.00, SD =  $\pm 2.10$ ) was significantly greater ( $p < 0.001$ ) compared to Perak (M = 0.18, SD =  $\pm 0.53$  and M = 0.22, SD =  $\pm 0.66$ ) over the same period. After controlling for confounders, partial exposure to CWF remained a strong predictor for mean caries increment over a five-year study period. This study showed greater mean caries increment in permanent dentition among schoolchildren in Pahang after CWF ceased. Hence, the findings from this study could be used to assist policy makers to support reimplementation and continuation of CWF in Malaysia.

**Keywords:** Caries, Community Water Fluoridation, Cessation, Preventive Dentistry, Schoolchildren

## Introduction

Dental caries is a significant public health concern globally and is the most prevalent non-communicable disease worldwide (1, 2). Approximately 2 billion individuals around the world are affected by dental caries in their permanent teeth (3). Availability to various fluoride sources such as community water fluoridation (CWF), fluoridated toothpaste coupled with better oral hygiene practices, and dietary habits have resulted in the decline of caries prevalence for the past few decades (4). Among these,

CWF is a systemic fluoride that has been recognised as one of ten greatest public health accomplishments of the 20th century (5). Unlike topical fluoride, which requires active compliance from the individuals to be beneficial, fluoridation involves drinking fluoridated water as part of daily life and has been proven to be an effective population-based caries prevention method (6, 7).

The implementation of CWF in Malaysia began in 1974 and had gradually extended to all states. However, for the Pahang state, its coverage was reduced beginning 2014,

mainly due to financial difficulties faced in purchasing fluoride compounds after the privatisation of its water treatment facilities in 2012 (8). As a result, the population coverage of CWF for Malaysia fell below the national target of 75.0% in 2018 for the first time since 2008 despite public water supplies being accessible to almost the entire (95.5%) population (9). Nonetheless, some other states in Malaysia, such as Perak, had successfully maintained good coverage of CWF since its implementation. Following the cessation of CWF in Pahang, mean caries experience remained high at 0.89 among 12-year-old schoolchildren in Pahang compared to those residing in Perak at 0.40 where CWF continued (10).

Globally, there are limited studies conducted regarding CWF cessation and this may be due to the relatively uncommon occurrence of CWF cessation, which has only happened in some areas. The situation in Malaysia thus offers a unique opportunity to evaluate the impact of CWF cessation, where there exist communities that have continuously received CWF. According to a systematic review by McLaren and Singhal in 2016, most of the studies on CWF cessation reported increases in caries levels after the discontinuation of CWF (11). This review covered 15 studies from 13 countries across a wide time frame (1956 – 2003) with only nine reviewed studies having moderate methodological quality. In addition, there is limited contemporary evidence on the mean caries increment between areas that have ceased and continued CWF. To date, only one longitudinal study could be found that assessed the effect of CWF cessation in Canada over three years (12). However, the finding of this study was inconclusive. A subsequent before-and-after study of CWF cessation in Australia reported an increase in dental caries over time in both deciduous and permanent teeth among indigenous children (13). A recently published repeated cross-sectional study by McLaren et al. (14) found a significant increase in caries experience of deciduous teeth in a CWF ceased area when compared to an area with CWF among 7-year-old children. The results for permanent teeth were less consistent since 7-year-old have not had enough time to accumulate enough caries experience in their permanent teeth for differences to be noticeable.

Locally, two published studies have utilised comparative communities, one with and one without CWF, to investigate the preventive effects of CWF on caries experience (15, 16). Abdul Karim and co-workers investigated the effect of CWF cessation on caries experience among 12-year-old schoolchildren in Pahang using a single point cross-sectional data and found that caries experience was higher among children who had partial exposure to CWF in Pahang (16). However, the existing data were based on a cross-sectional study design conducted at only one point in time, which was not able to measure the mean change in caries between an area with full and partial exposure to CWF over time. It is important to note that there are limitations with single cross-sectional studies despite the involvement of comparable communities to assess the impact of CWF cessation (17). Further research is needed

to confirm this finding using a longitudinal or cohort study design to generate evidence to advocate for policy change. Thus, this study aimed to compare mean caries increment in permanent dentition among Malaysian schoolchildren who had full and partial exposure to CWF due to cessation and determine its associated factors from 2015 to 2019. The participants were followed-up retrospectively for a period of five years. In this study, it was hypothesised that mean caries increment in permanent dentition among schoolchildren in Pahang (partial exposure to CWF) was significantly higher compared to Perak (full exposure to CWF) over five years.

## **Materials and Methods**

### **Study design and study population**

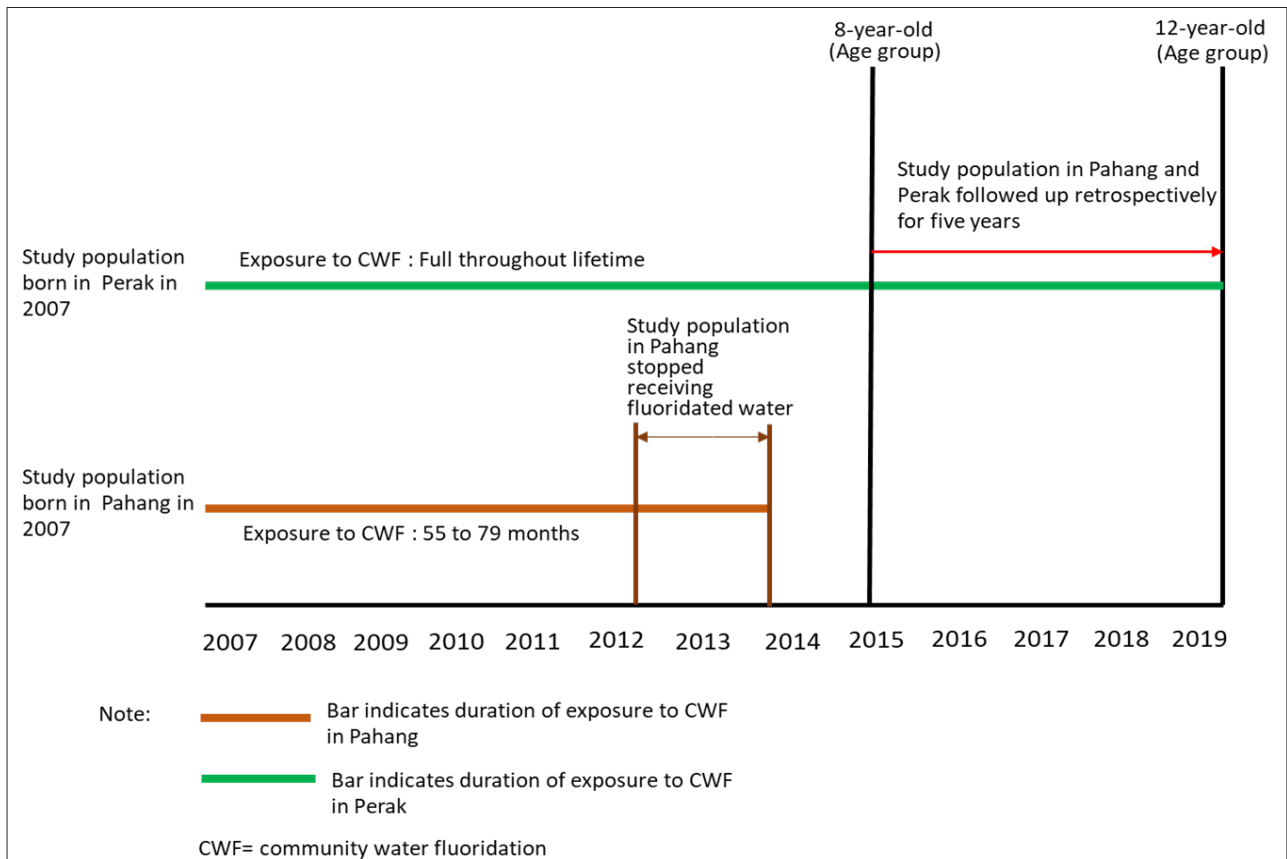
This was a retrospective cohort study involving routinely collected school dental records of schoolchildren from the districts of Temerloh, Jerantut, and Lipis in Pahang (partial exposure to CWF) and the district of Kerian in Perak (full exposure to CWF with concentration of 0.5 parts per million (ppm)) from 2015 to 2019. The schoolchildren who participated in this study were born in 2007. They were 8 years old in 2015 and 12 years old in 2019 at the end of the follow-up period. All of them were lifelong residents in Pahang and Perak. Schools from both states were selected because they were comparable in terms their sociodemographic profiles and represent mixed urban-rural districts.

### **CWF exposure measurement**

The study population in Pahang stopped receiving fluoridated water between July 2012 and December 2013 (15). As a result, these 12-year-old schoolchildren born between January 1, 2007, and December 31, 2007, had only partial exposure to water fluoridation for 55 to 79 months during their teeth development period. In contrast, schoolchildren in Perak who were born between the same dates had full exposure to CWF (0.5 ppm) throughout their lifetime. Figure 1 illustrates the duration of CWF exposure among the study population in Pahang and Perak from birth to 12 years old. Apart from CWF, fluoridated toothpaste was also widely available in both states.

### **Data source**

The school dental records were collected annually as part of the School Incremental Dental Care Programme run by the Oral Health Programme (OHP) under the Ministry of Health (MOH), Malaysia and were kept safely by the school administration. These data were collected as part of a larger water fluoridation study that assessed the impact of CWF cessation on oral health and oral health-related quality of life (18). Each school's dental records were given a unique identification code to maintain anonymity. Relevant information such as demographic data, medical history, clinical preventive dental treatment modalities, and data on caries were extracted from the school dental records for the purpose of analysis.



**Figure 1:** Duration of CWF exposure among schoolchildren lived in Pahang and Perak

Note: The green line indicates the study population in Perak had lifetime exposure to CWF. The brown line indicates partial exposure to CWF among study population in Pahang for the first 55 to 79 months of their life. The red line indicates that the study population in Perak and Pahang were followed up retrospectively for 5 years from 2015 to 2019. These study population in Pahang and Perak were 8-year-old in 2015 and 12-years-old in 2019.

**Sample size and sampling**

The estimated sample size was 104 schoolchildren based on the 1.09 difference in mean caries increment (DMFT) between children in areas with CWF (M = 3.76, SD = ±2.86) and without CWF (M = 4.85, SD = ±3.39) with 80.0% power and a significance level of 0.05 using t-test in G\*power software (19). The 104 school dental records were further inflated by 20% to account for incomplete school dental records, 10% to account for unerupted first permanent molars (FPM) and multiplied by a design effect of 2 (10). This resulted in a total estimated sample of  $270 \times 2 = 540$  school dental records for both areas. The initial sample comprised of 546 school dental records but only 231 school dental records in each area were selected after excluding incomplete school dental records, ambiguous dental charting, unerupted FPM, and schoolchildren with medical conditions such as asthma. Schoolchildren residing in areas with partial (Pahang) and full (Perak) exposure to CWF were chosen through stratified cluster random sampling based on the probability proportionate to size technique. The details of the sampling technique have been previously published, which provide further information on the methodology used for sample selection in the study (15).

**Measurement of caries outcome**

Dental caries experience in permanent dentition was examined using visual and tactile methods, and recorded in the school dental records according to World Health Organization’s (WHO) criteria, using the DMF (Decay, Missing, Filled) indices at tooth (DMFT) and surface level (DMFS) (20). This caries examination and recording were conducted by trained dental officers and dental therapists who were calibrated annually by the MOH. Decayed Teeth (DT) is defined as cavitation at the dentinal level of a tooth. Meanwhile, a tooth is considered filled (FT) when there is presence of permanent restoration without any decay and missing (MT) was used for permanent teeth that have been extracted because of decay.

**Measurement of predictor variables**

The predictor variables used in this study were demographic characteristics consisting of gender, race, and location (either urban or rural). The urban and rural classification adhered to the guidelines set by the Ministry of Education, Malaysia (21). Clinical preventive dental treatments included fissure sealant and preventive resin restoration (PRR) for selected teeth as well as fluoride varnish application for all teeth. These preventive

dental treatments (e.g., PRR and fissure sealants) were categorised separately as the indication for the treatment differs. Fissure sealant is a preventive measure to protect healthy teeth from decay by sealing deep fissures, while PRR combines preventive sealant with filling early cavities to halt the decay process (22).

**Statistical analysis**

Data were analysed using SPSS version 21. Descriptive analysis was performed to compare demographic characteristics, preventive dental treatments, and caries rate based on DMFT scores of 0, 1, 2, and ≥ 3 by type of CWF exposure. Caries severity measuring mean caries increment in both areas of CWF exposure was compared at baseline in 2015 and the final follow up in 2019 using independent t-test analysis. A negative binomial regression analysis was performed to determine factors associated with mean caries increment from 2015 to 2019. All predictor variables were included in the model. The outcomes were reported as incidence rate ratio (IRR), 95% confidence interval (CI), and p-value. The p-value was set at < 0.05.

**Results**

A total of 462 schoolchildren records were analysed. The demographic characteristics of the participants are shown in Table 1. There were nearly equal proportions of boys and girls who received partial (48.9% and 51.1%) and full (49.4% and 50.6%) exposure to CWF in Pahang and Perak. Most of the schoolchildren in both states were Malays. A higher percentage of schoolchildren with partial exposure in Pahang (74.0%) and those with full exposure in Perak (85.3%) lived in rural areas respectively. There were significant differences in the distribution of race (p < 0.001) and residency location (p < 0.001) between schoolchildren with partial and full exposure to CWF.

**Table 1:** Demographic characteristics of schoolchildren with partial (Pahang) and full (Perak) exposure to CWF (n = 462)

Variable		Partial exposure to CWF (Pahang)	Full exposure to CWF (Perak)	Total	p value
		n (%)	n (%)	n (%)	
<b>Gender</b>	Male	113 (48.9%)	114 (49.4%)	227 (49.1)	0.93
	Female	118 (51.1%)	117 (50.6%)	235 (50.9)	
<b>Race</b>	Malay	192 (83.1%)	169 (73.2%)	361 (78.1)	< 0.001
	Chinese	10 (4.3%)	44 (19.0%)	54 (11.7)	
	Indians	10 (4.3%)	18 (7.8%)	28 (6.1)	
	Aborigines	19 (8.2%)	0 (0.0%)	19 (4.1)	
<b>Location</b>	Urban	60 (26.0%)	34 (14.7%)	94 (20.3)	< 0.001
	Rural	171 (74.0%)	197 (85.3%)	368 (79.7)	

CWF=community water fluoridation  
Chi Square analysis

Table 2 shows the distribution of schoolchildren with partial and full exposure to CWF according to the DMFT score in 2015 and after the five-years follow up in 2019. The prevalence of schoolchildren with DMFT scores of 2 and ≥ 3 increased by 10.4% and 13.9%, respectively, in Pahang from 2015 to 2019, compared to 4.8% and 0.9% in Perak. The alternative hypothesis was accepted as the mean caries increment at tooth and surface levels in permanent dentition were significantly higher (p < 0.001) among schoolchildren with partial exposure to CWF in Pahang (M = 0.83, SD = ±1.50 and M = 1.00, SD = ±2.10) than Perak (M = 0.18, SD = ±0.53 and M = 0.22±, SD = ±0.66) over five years (Table 3). When mean DMFT increment was analysed according to the individual components, the mean FT increment was higher in Pahang (M = 0.53, SD = ±0.97) and Perak (M = 0.12, SD = ±0.42) compared to the mean DT increment which was 0.30±1.32 and 0.05±0.39, respectively. There was no MT in both states over the five years.

**Table 2:** Distribution of schoolchildren with partial and full exposure to CWF according to the DMFT score at baseline in 2015 and 5 years follow up in 2019.

DMFT score	Partial exposure to CWF (Pahang)		Full exposure to CWF (Perak)	
	Baseline in 2015	Follow up in 2019	Baseline in 2015	Follow up in 2019
	n (%)	n (%)	n (%)	n (%)
<b>0</b>	198 (85.7)	133 (57.6)	226 (97.8)	200 (86.6)
<b>1</b>	25 (10.8)	34 (14.7)	5 (2.2)	18 (7.8)
<b>2</b>	5 (2.2)	29 (12.6)	0 (0.0)	11 (4.8)
<b>3 and more</b>	3 (1.3)	35 (15.2)	0 (0.0)	2 (0.9)
<b>Total</b>	231 (100.0)	231 (100.0)	231 (100.0)	231 (100.0)

CWF = community water fluoridation  
DMFT = Decayed Missing Filled Teeth

Table 4 presents the distribution of preventive dental treatments among the study participants. In 2015, fissure sealant had the highest proportion (7.8%, mean of 0.13) among schoolchildren in Pahang, while in 2019, it was highest among schoolchildren in Perak (13.4%, mean of 0.25). In 2015, fluoride varnish was slightly more prevalent among schoolchildren in Pahang (0.4%) compared to Perak, where no fluoride varnish was administered. However, the prevalence of fluoride varnish in Perak (3.0%) was slightly higher compared to Pahang (2.2%) in 2019. The prevalence of PRR was higher in Pahang than Perak in both 2015 and 2019. The overall prevalence of having received any preventive dental treatment was highest in 2015 for Pahang (8.7%) and 2019 for Perak (19.5%).

**Table 3:** Comparison of mean caries increment between schoolchildren with partial (Pahang) and full exposure (Perak) to CWF at baseline in 2015 and follow up in 2019

Variable	Baseline in 2015		Follow up in 2019		2015-2019	
	Partial exposure to CWF	Full exposure to CWF	Partial exposure to CWF	Full exposure to CWF	Mean increment for partial exposure to CWF	Mean increment for full exposure to CWF
	Mean ( $\pm$ SD) 95% CI	Mean ( $\pm$ SD) 95% CI	Mean ( $\pm$ SD) 95% CI	Mean ( $\pm$ SD) 95% CI	Mean ( $\pm$ SD) 95% CI	Mean ( $\pm$ SD) 95% CI
DMFS	0.21 $\pm$ 0.63 (0.13,0.29)	0.02 $\pm$ 0.15 (0.00,0.04)	1.20 $\pm$ 2.30 (0.93,1.5)	0.24 $\pm$ 0.69 (0.15,0.33)	1.00 $\pm$ 2.10** (0.74,1.30)	0.22 $\pm$ 0.66 (0.13,0.30)
DMFT	0.19 $\pm$ 0.53 (0.12,0.26)	0.02 $\pm$ 0.15 (0.00,0.04)	1.02 $\pm$ 1.65 (0.81,1.24)	0.20 $\pm$ 0.56 (0.13,0.27)	0.83 $\pm$ 1.50** (0.63,1.02)	0.18 $\pm$ 0.53 (0.11,0.25)
DT	0.14 $\pm$ 0.46 (0.08,0.20)	0.02 $\pm$ 0.13 (0.0,0.03)	0.44 $\pm$ 1.30 (0.27,0.60)	0.07 $\pm$ 0.37 (0.03,0.12)	0.30 $\pm$ 1.32* (0.13,0.47)	0.05 $\pm$ 0.39 (0.01,0.11)
MT	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
FT	0.05 $\pm$ 0.22 (0.02,0.08)	0.00 $\pm$ 0.07 (0.00,0.01)	0.58 $\pm$ 1.00 (0.45,0.72)	0.13 $\pm$ 0.42 (0.07,0.18)	0.53 $\pm$ 0.97** (0.41,0.66)	0.12 $\pm$ 0.42 (0.07,0.18)

CI = Confidence Interval

CWF = Community Water Fluoridation

DT = Decayed Teeth

DMFS = Decayed Missing Filled Surface

DMFT = Decayed Missing Filled Teeth

FT = Filled Teeth

MT = Missing Teeth

SD = Standard Deviation

Comparison between children with different CWF exposure (partial vs full) conducted using independent t-test

Welch test is reported because Levene's test indicated that the homogeneity of variances assumption was not met for this variable

\*p &lt; 0.05, \*\*p &lt; 0.001

**Table 4:** Proportion and mean number of teeth with preventive treatments among schoolchildren with partial and full exposure to CWF in 2015 and 2019

Variable	Baseline in 2015		Follow up in 2019	
	Partial exposure to CWF	Full exposure to CWF	Partial exposure to CWF	Full exposure to CWF
	n (%) Mean ( $\pm$ SD)	n (%) Mean ( $\pm$ SD)	n (%) Mean ( $\pm$ SD)	n (%) Mean ( $\pm$ SD)
Fissure sealant	18(7.8) 0.13( $\pm$ 0.50)	10(4.3) 0.07( $\pm$ 0.38)	9(3.9) 0.09( $\pm$ 0.47)	31(13.4) 0.25( $\pm$ 0.73)
Fluoride varnish	1(0.4)	0(0.0)	5(2.2)	7(3.0)
PRR	3(1.3) 0.02( $\pm$ 0.20)	1(0.4) 0.00( $\pm$ 0.07)	12(5.2) 0.06( $\pm$ 0.30)	10(4.3) 0.06( $\pm$ 0.30)
One or a combination of preventive dental treatment	20(8.7) 0.16( $\pm$ 0.56)	11(4.8) 0.07( $\pm$ 0.38)	23(10.0) 0.15( $\pm$ 0.58)	45(19.5) 0.31( $\pm$ 0.82)

CWF = Community Water Fluoridation

NA = Not Applicable

PRR = Preventive Resin Restoration

SD = Standard Deviation

Mean was analysed at tooth level for fissure sealant, PRR and for one or a combination of preventive dental treatment

Table 5 shows that schoolchildren who had only partial exposure to CWF in Pahang had 4.9 times higher mean caries increment from 2015 to 2019 compared to those who had full exposure after controlling for confounders ( $p < 0.001$ ). Furthermore, schoolchildren who did not receive preventive dental treatment in 2015, 2016, and 2018 had 0.41, 0.37, and 0.53 times less mean caries increment, respectively, than those who did receive the treatment. Additionally, schoolchildren who were caries-free at baseline (in 2015) had a significantly lower mean caries increment than those who had already developed caries in their permanent teeth (IRR: 0.58, 95% CI: 0.35,0.96).

**Table 5:** Negative binomial regression for mean caries (DMFT) increment from 2015 to 2019 among schoolchildren (n = 462)

Variable	IRR (95.0% CI)	p-value
<b>Gender</b>		
Female	0.91 (0.64, 1.29)	0.60
<b>Male (Reference)</b>		
<b>Race</b>		
Chinese	0.67 (0.30, 1.50)	0.33
Indians	0.95 (0.42, 2.12)	0.90
Aborigines	0.83 (0.38, 1.80)	0.64
<b>Malay (Reference)</b>		
<b>Location</b>		
Rural	1.24 (0.79,1.94)	0.34
<b>Urban (Reference)</b>		
<b>Type of exposure to CWF</b>		
Partial	4.90 (3.13, 7.68)	< 0.001
<b>Full (Reference)</b>		
<b>Received either / combination of preventive treatment in 2015</b>		
No	0.41 (0.24, 0.70)	0.001
<b>Yes (reference)</b>		
<b>Received either / combination of preventive treatment in 2016</b>		
No	0.37 (0.22, 0.60)	< 0.001
<b>Yes (reference)</b>		

**Table 5:** Negative binomial regression for mean caries (DMFT) increment from 2015 to 2019 among schoolchildren (n = 462) (continued)

Variable	IRR (95.0% CI)	p-value
<b>Received either / combination of preventive treatment in 2017</b>		
No	1.71 (0.71, 4.13)	0.23
<b>Yes (reference)</b>		
<b>Received either / combination of preventive treatment in 2018</b>		
No	0.53 (0.32, 0.87)	0.01
<b>Yes (reference)</b>		
<b>Caries status in 2015</b>		
DMFT = 0	0.58 (0.35, 0.96)	0.03
<b>DMFT &gt; 1(reference)</b>		

CI = Confidence Interval  
 CWF = Community Water Fluoridation  
 DMFT = Decayed Missing Filled Teeth  
 IRR = Incidence Rate Ratio

**Discussion**

The present study highlights the comparison of the mean caries increment among 12-year-old schoolchildren with full and partial exposure to CWF and the associated factors. The results indicate that mean caries increment was significantly higher among schoolchildren with partial exposure to CWF following cessation in Pahang than those with full exposure to CWF in Perak for a period of five years. A recent longitudinal study conducted in the UK found clinically significant lower rates of caries in permanent dentition among schoolchildren who were followed from age 7 to 11 years (23). It is important to note that the UK study was conducted after the initiation of the CWF programme, while the present study was conducted after the cessation of the CWF programme. Despite these differences, findings from both studies confirmed the benefit of the CWF programme in preventing caries in permanent dentition among the cohort of schoolchildren. However, it is essential to acknowledge that other factors, such as improved parental education, income, access to fluoridated toothpaste, and better oral health behaviours, have also contributed to the prevention of caries among schoolchildren (3).

Additionally, the magnitude of mean caries increment among schoolchildren in Pahang was greater than Perak, which signified that more caries was prevented in a state with a continuous CWF programme. Similarly, high caries

preventive effect was also seen in children with lifetime exposure to CWF in Ireland, Korea, and United States when compared to those without exposure to CWF (24, 25, 26). In this study, most of the increase in mean caries was due to the FT component compared to the DT component, indicating a relatively lower burden of untreated dental caries in these two states that could be attributable to the availability of the School Dental Service (SDS) in Malaysia. SDS provides preventive, promotive, and curative dental treatments annually to all government schoolchildren aged between 7 to 17 years old.

The distinctive part of this research is that the schoolchildren in Pahang where CWF was discontinued were exposed to fluoridated water during the first five to six years of their lives. Hence, the schoolchildren in Pahang experienced the pre-eruptive effects of systemic fluoride and some post-eruptive effects of the topical fluoride on permanent teeth that have erupted during the time. There is evidence from literature regarding positive caries preventive effects of pre-eruptive exposure to CWF but they are inconclusive (27). The schoolchildren from Pahang and Perak were also exposed to fluoridated toothpaste (15). However, even with exposure to fluoride toothpaste, the mean caries increment among schoolchildren in Pahang was 4.9 times higher than Perak after adjusting for other factors. This is consistent with previous studies that have reported that the combined effects of fluoridated toothpaste and continuous exposure to CWF can significantly reduce the incidence and severity of caries in both primary and permanent teeth (14, 25).

Other than type of CWF exposure, regression analysis showed that having caries at an earlier age remains a strong predictor for mean caries increment among 12-year-old children. The finding is consistent with a previous longitudinal study conducted among primary schoolchildren in Selangor (28). In the present study, having a combination of either one or more preventive dental treatments contribute towards mean caries increment from 2015 to 2019. This unexpected finding may be attributed to several factors. For instance, it is possible that only some teeth were provided preventive dental treatment despite the child being at high caries risk during initial examinations, or that the incomplete fissure sealant on the tooth could lead to caries development. Although many clinical guidelines have recommended at least twice a year application of fluoride varnish for caries prevention (29, 30), the SDS could only cover each school once a year due to limited number of dental personnel and high number of schools. These findings reflect the challenges faced by SDS in implementing comprehensive clinical preventive management at the individual level in a resource-limited setting and highlights the importance of maintaining exposure to CWF for a population-based caries prevention strategy.

This study had several limitations. Firstly, the school dental records lacked information regarding oral hygiene practices and dietary habits of schoolchildren due to the nature of

retrospective data. Underlying social determinants such as age, gender, location of either urban or rural, and race were addressed to account for possible factors affecting these behaviours. Although socioeconomic status and parental education levels were not determined, it is worth noting that Perak and Pahang had similar median household incomes. Secondly, multiple examiners involved in the clinical examination at schools may have compromised inter-examiner reliability. However, this examiner bias was minimised as they were trained and calibrated yearly through periodical calibration training workshops organised by MOH. Thirdly, direct comparison of the impact of CWF cessation is limited due to the lack of contemporary data from cohort or longitudinal studies. Therefore, the discussion and data comparison in this study are conducted with this limitation in mind. Finally, caries data from this study were based on the DMF index which only captured the cavitated carious lesions and lacked information on early caries lesions. Further research is recommended to evaluate on the effectiveness of CWF in preventing early enamel caries lesion among schoolchildren and the impact of CWF on the progression of early lesion to cavitated caries.

### **Conclusion**

This study showed high mean caries increment in permanent dentition over a five-year study period among schoolchildren in Pahang who had less exposure to CWF due to its cessation. After controlling for confounding variables, the study found that exposure to CWF was a strong predictor of caries prevention from 2015 to 2019. The evidence generated from this study may assist policy makers to promote the reimplementation of CWF in Pahang and support the continuation of CWF in other parts of Malaysia. In addition, it is imperative to continuously monitor and evaluate the long-term effects of the CWF programme on caries prevention.

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### **Competing interests**

The authors declare that they have no competing interests.

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## Ethical Clearance

Ethical approval for this study was obtained from the Medical Ethics Committee, Faculty of Dentistry, Universiti Malaya (DF CO2101/0066 (P)) and the National Medical Research Registration, Ministry of Health Malaysia (NMRR ID: 22-00311-6CX (IIR)). Permission to conduct this study and to use the data from the school dental records was granted by the Principal Director of Oral Health Programme (OHP), Ministry of Health (MOH), Malaysia (KKM.600-56/7/2 Jld.9 (41)).

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