*Community Dental Health* (2014) **31,** 136–140
Received 28 October 2013; Accepted 18 January 2014

doi:10.1922/CDH_3321Polk05

# Frequency of daily tooth brushing: predictors of change in 9- to 11-year old US children

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***Objective:*** To investigate whether an increase in daily tooth brushing frequency in children was predicted by either a) having a strong intention to brush twice a day or b) their parents receiving information about their new caries experience. ***Basic Research Design:*** Secondary data analyses were conducted on two waves of data from the Aban Aya Youth Project and the Iowa Fluoride Study. ***Participants:*** The Aban Aya study included 576 10- and 11-year olds from Chicago, Illinois. The Iowa Fluoride Study included a convenience sample of 709 babies born in Iowa. The present study includes those children at age 9. ***Main Outcome Measures:*** In both studies, reported daily tooth brushing frequency was assessed twice six months apart. ***Results:*** In the Aban Aya data, compared with children with a weak intention at wave 1 to brush twice a day, children with a strong intention to brush twice a day were more likely to increase their brushing frequency by wave 2, OR 7.0, 95%CI 1.5,32.9. In the Iowa Fluoride Study, compared with children who did not have new caries at wave 1, children who had new caries experience were less likely to increase their brushing frequency by wave 2, OR 0.4, 95%CI 0.2,0.9. ***Conclusions:*** Strengthening intention to brush twice a day might increase children's brushing frequency. However, simply providing parents with information about new caries probably will not. Future studies should assess tooth brushing frequency, habit strength, intention, and situational cues at closely-spaced waves.

**Key words:** *tooth brushing, children, adolescents, intentions, caries, primary prevention, secondary prevention*

## Introduction

In children aged 5 to 16 in the US, dental caries is five times more common than asthma (U.S. Department of Health and Human Services, 2000, p. 63). Caries can lead to poor performance in school (Jackson *et al.*, 2011; Seirawan *et al.*, 2012), and, if left untreated, can cause abscesses and even death (Otto, 2007). A number of steps can be taken to reduce the risk of caries including brushing one's teeth twice a day (American Academy of Pediatric Dentistry, 2010). The benefit of brushing derives from both the mechanical removal of plaque from the teeth and the exposure of the teeth to fluoride in the toothpaste and water. Despite this relatively simple way to reduce the risk of caries, it is estimated that 17% of low income, Chicago, Illinois children in the fifth grade (average age 10 years) brush less frequently than twice a day (Koerber *et al.*, 2005). Other studies have similar findings (Addy *et al.*, 1990; Åstrøm, 2004; Åstrøm and Jakobsen, 1998; Kuusela *et al.*, 1996). Thus, as many as one child in five may not get the benefits of brushing twice a day. For these children, it is important to identify effective interventions to increase their daily brushing frequency.

For children who are old enough to be responsible for their own tooth brushing, health behaviour change theory addresses how to change a behaviour like tooth brushing frequency. According to multiple theories integrated into the Theory of Triadic Influence for tooth brushing that has not yet solidified into a consistent habit (i.e. the behaviour still requires conscious thought and is not yet automatic), the proximal cause of how often children brush is their intentions (Flay *et al.*, 2009). That is, they are more likely to brush twice a day than once a day if they intend to brush twice a day. Thus, interventions to increase brushing frequency should change intentions, either directly or indirectly. One factor that can influence intentions is social pressure. If parents learn that their children have new caries, for example, they might encourage their children to brush more frequently. This encouragement might strengthen the children's intentions to brush twice a day. Thus, for behaviour that is not yet a habit, one focus of interventions should be on intentions and factors that influence intentions.

The first objective of this paper was to determine whether children who were brushing once a day or less increased their brushing frequency if they had a strong intention to brush twice a day. We hypothesised that children would be more likely to increase their brushing frequency if their intentions to brush twice a day were strong rather than weak. We examined this issue in children first assessed at age 10 from Chicago, Illinois. Our second objective was to determine whether children who were brushing once a day or less increased their brushing frequency after their parents learned that their children had new caries experience. We hypothesised that compared with children who did not have new caries or fillings, children whose parents learned that they had new caries or fillings would be more likely to increase their brushing frequency. We examined this issue in children using brushing frequency assessed from age 9 from the Iowa Fluoride Study.

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## Methods

This study is a secondary data analysis of participants in two studies, the Aban Aya Youth Project in Chicago, Illinois (Flay *et al.*, 2004; Koerber *et al.*, 2005; 2006) and the Iowa Fluoride Study in Iowa (Levy *et al.*, 1998; 2001; 2003). Participants in the Aban Aya study were part of a cluster randomised trial testing the efficacy of two interventions designed to reduce multiple risk behaviours, including violence, substance abuse, and unsafe sexual practices among African-American youth in 12 poor metropolitan Chicago schools from 1994 to 1998 (Flay *et al.*, 2004). One of the 9 inner-city schools refused to participate and was replaced with another one from the same risk level. Under 1% of parents denied consent during grades 5 through 7, and 1.7% did so at grade 8. Survey completion rates were 93.2% of students with consent at baseline and between 89.5% and 92.7% at the other waves. Of the original 668 students in grade 5, 339 (51%) were still present at the end of grade 8. Children completed surveys in classrooms at the beginning and end of grade 5. Parents did not have access to the children's responses on the surveys. Participants in the present study included children in the master study who had been present during the first assessment (n=576) in grade 5. See Table 1 for the percentages of the sample not missing daily tooth brushing frequency at each wave.

Participants in the Iowa Fluoride Study were part of a longitudinal study designed to quantify fluoride exposures and relate them to dental fluorosis and dental caries (Levy *et al.*, 1998; 2001; 2003). Mothers of newborns were recruited from eight Iowa hospitals between 1992 and 1995. Half of those invited to participate did so. After the recruitment assessment, questionnaires were mailed to participants' homes every few months. Of the 1,882 mothers recruited, 1,389 returned questionnaires. Of those, 802 returned questionnaires at age 4 years and after. From these questionnaires, the measure of the child's daily brushing frequency at age 9 and 9½ were used in the present study. See Table 1 for the percentages of the sample not missing daily tooth brushing frequency at each wave. Dental examinations were conducted by trained dentists at ages 5 and 9 (for details about the caries assessments, see Chankanka *et al.*, 2011). From these assessments, measures of $d_2fs$ at ages 5 and 9 and $D_2FS$ at age 9 were used in the present study. Participants in the present study included children in the master study whose parent had returned questionnaires at age 4 years or older and who had at least one of the two caries assessments (n=709).

Approval for the Aban Aya study was obtained from the University of Illinois at Chicago Institutional Review Board. Parents provided consent, and students were informed that their participation was voluntary. Approval for the Iowa Fluoride Study was obtained from the University of Iowa Institutional Review Board, and appropriate informed consent procedures were used, including parent consent and child assent. Because this was a secondary analysis of anonymised data, approval for this study was not required by the University of Pittsburgh Institutional Review Board.

Regarding measures, in the Aban Aya study, the children were asked "On most days, how many times a day did you brush your teeth (in the past week)?" with responses of less than once a day, once a day, twice a day, and more than twice a day. Evidence of the validity of children's self-report of tooth brushing frequency comes from a study unrelated to the present study of children with a median age of 7.6 years (Wind *et al.*, 2005). In this study, the frequency of tooth brushing reported by the children was highly correlated with the parents' reports and the mean frequencies did not differ. In the Iowa Fluoride Study, parents were asked the following question: "How often did your child brush his/her teeth during the last 6 months?" with responses of more than three times per day, three times per day, twice per day, once per day, less than once per day, and don't know. For both studies responses were recoded as either "once per day or less often" or "twice per day or more often."

Intention to brush twice a day was assessed during wave 1 in the Aban Aya study with the following question: "In the next year (12 months), do you think you will try to brush your teeth at least twice a day?" The response options were definitely no, probably no, not sure, probably yes, and definitely yes. Prior to analysis, these were collapsed into two levels: no or not sure, *n*=25, and yes, *n*=551.

In the Iowa Fluoride Study, caries incidence was assessed in two components. In the primary teeth, it was determined whether children developed new caries ($d_2fs$) between the ages of 5 and 9. For the permanent dentition, $D_2FS$ at the age 9 assessment was used, because

**Table 1.** Minimum and maximum time in months and between each wave and mean age at each wave in the Aban Aya Youth Project and Iowa Fluoride Study, unimputed data only.

| | *Aban Aya Youth Project* | | | *Iowa Fluoride Study* | | |
|---|---|---|---|---|---|---|
| *Waves* | *Age in years (min - max)* | *Actual years since last observation (min - max)* | *Non-missing tooth brushing frequency (% of total sample)* | *Age in years (min - max)* | *Actual years since last observation (min - max)* | *Non-missing tooth brushing frequency (% of total sample)* |
| Time 0 | 9 – 12 | | 100.0 | 8.8 – 9.2 | | 72.5 |
| +6 months | 10 – 13 | 0.6 | 84.0 | 9.3 – 9.7 | 0.3 – 0.8 | 71.2 |
| +18 months | 11 – 14 | 1.0 | 74.1 | 10.3 – 10.7 | 0.7 – 1.3 | 70.2 |
| +30 months | 12 – 15 | 1.0 | 58.5 | 11.3 – 11.7 | 0.8 – 1.3 | 65.0 |
| +42 months | 13 – 16 | 1.0 | 32.6 | 12.3 – 12.7 | 0.8 – 1.2 | 65.6 |

Note. Rows indicate waves of data collection, with the months indicating time from Time 0, the starting point.

**Table 2.** Variables imputed and the percentages of observations missing values in the Aban Aya and Iowa Fluoride studies.

| *Variable* | *mean age, years* | *Observations missing, %* |
|---|---|---|
| *Aban Aya Study* | | |
| Frequency of tooth brushing at wave 2 | 10.8 | 15.9 |
| Parents' education at wave 1 | 10.2 | 13.0 |
| Family income at wave 1 | 10.2 | 20.5 |
| *Iowa Fluoride Study* | | |
| Frequency of tooth brushing at wave 1 | 9.0 | 27.6 |
| Frequency of tooth brushing at wave 2 | 9.5 | 28.8 |
| Mother's education at child's birth | | 0.3 |
| Father's education at child's birth | | 21.7 |
| Family income at child's birth | | 44.6 |
| Number of carious or filled lesions on primary teeth at child age 5 | | 0.7 |
| Number of carious or filled lesions on primary teeth at wave 1 | 9.0 | 17.0 |
| Number of carious or filled lesions on permanent teeth at wave 1 | 9.0 | 11.0 |

none of the children had $D_2FS$ at age 5. Children with either a positive caries increment in the primary dentition or any caries in the permanent dentition were scored 1, and all other children were scored 0. If a child had new caries, the parents were informed. Thus, the new caries, from ages 5 to 9, occurred before the change in brushing frequency, from ages 10 to 14.

In data analysis, to address possible problems in inference that could arise due to missing data, we used multiple imputation. See Table 2 for a list of the variables imputed and the percentage missing for each variable. Across the two studies, our general strategy was as follows. Where possible, parents' education and family income were imputed manually using information from the Bureau of Labor Statistics based on occupation. Alternatively, when education was assessed at more than one wave, we imputed the data manually from the other waves. For other variables, we fit regression models to impute missing data. To improve the accuracy of our imputation models, we used the following as predictors: 1, variables used in the analysis; 2, other variables related at $p<0.1$ to the possibility of being missing; and 3, the same variable from other waves. The latter two categories describe variables used only to enhance the quality of the imputation and were not used in analyses addressing the research question. We used sequential regression multivariate imputation (i.e. multivariate imputation using chained equations; "mi impute chained" in STATA v12.1). For each study, 100 datasets were created and used in all subsequent analyses. For the Aban Aya data, imputation was not needed for age, gender, frequency of tooth brushing at wave 1, or intention. For Iowa Fluoride Study data, imputation was not needed for race, mother's education at wave 1, and mother's tooth brushing frequency at wave 1. Where imputed variables are described, confidence intervals are provided.

In both datasets, we used logistic regression to determine whether the percentage of children who increased brushing from once a day or less to twice a day or more was significantly different from the percentage of children who continued brushing twice a day or more in wave 2 (using the total number of children brushing twice a day or more in wave 1 as the denominator to calculate the percentage in each case). In both the Aban Aya and Iowa Fluoride Study data analyses, we were examining the association of a predictor at wave 1 with an increase in brushing frequency between waves 1 and 2. With the Aban Aya study data, to determine the association between intention to brush twice a day and brushing pattern, we used logistic regression with having weak intentions to brush twice a day as the reference level for the predictor. Because intention is theorised to be the most proximal influence of behaviour, we did not include any covariates in the model. With the Iowa Fluoride Study data, to determine the association between new cavities incidence and brushing pattern, we used logistic regression with having no new caries as the reference level for the predictor. We examined gender, ethnicity, mother's brushing frequency, education of parents with the higher level of education, and annual family income as covariates, but none was significantly associated with the outcome and their inclusion in the model did not change the odds ratio, so they were not included in the model reported below.

All analyses were conducted in STATA v12.1, with $p<0.05$ considered statistically significant.

## Results

In the Aban Aya data, the age of the children at wave 1 ranged from 9 – 12 years, with most participants being 10 years old (74%). The children in Iowa Fluoride Study were mostly White (94%), whereas the children in the Aban Aya Study were mostly Black (91%). Of the parents in the Iowa Fluoride Study, most (53%, 95%CI 50, 57) were college graduates or had post-college education; whereas only 6% (95%CI 4, 8) of those in the Aban Aya study were as well educated. Of the households in the Iowa Fluoride Study, half (49%, 95%CI 45, 53) had an annual household income greater than $40,000; whereas only 11% (95%CI 8, 14) of those in the Aban Aya Study had as high an income.

In the Aban Aya data, most children reported brushing twice a day or more at both waves 1 and 2 (Table 3). Of

**Table 3.** Frequency and percentage of daily tooth brushing at wave 1 by wave 2 frequency, in the Aban Aya and Iowa Fluoride studies

| *Tooth brushing frequency at wave 1* | *Tooth brushing frequency at wave 2* | |
|---|---|---|
| | *Once a day or less, n (%)* | *Twice a day or more, n (%)* |
| *Aban Aya Study* | | |
| Once a day or less | 45 (7.8) | 53 (9.2) |
| Twice a day or more | 51 (8.9) | 427 (74.1) |
| *Iowa Fluoride Study* | | |
| Once a day or less | 254 (35.8) | 59 (8.3) |
| Twice a day or more | 45 (6.3) | 351 (49.5) |

the 17% (98 children) who reported brushing once a day or less at wave 1, 45.9% (7.8% of the whole sample) continued to brush once a day or less at wave 2 and 54.1% (9.2% of the whole sample) increased to twice a day or more. In the Iowa Fluoride Study data, the largest group of children was reported to be brushing twice a day or more at both waves (Table 3). Of the 44% (313 children) who were reported to be brushing once a day or less at wave 1, 81.2% (35.8% of the whole sample) continued to brush once a day or less at wave 2 and 18.8% (8.3% of the whole sample) increased to twice a day or more.

In the Aban Aya data, the distribution of intention to brush twice a day was highly skewed to the right, with 86% of the participants endorsing the strongest intention to brush twice a day (i.e. "definitely yes"). Relative to children with a weak intention to brush twice a day, children with a strong intention to brush twice a day were significantly more likely to increase their reported brushing frequency, OR 7.0, 95%CI 1.5, 32.9 (unimputed data: OR 7.9, 95%CI 1.6, 38.9). In the Iowa Fluoride Study data, 49% (95%CI 45%, 53%) of the children did not have any new caries incidence. Relative to children who did not develop new caries, children who developed new caries were significantly less likely to increase their reported brushing frequency, OR 0.4, 95%CI 0.2, 0.9. These results were unchanged when examined using unimputed data.

## Discussion

The purpose of this study was to investigate whether an increase in reported brushing frequency in children was predicted by either: a, having a strong intention to brush twice a day; or b, their parents receiving information about their new caries experience. Consistent with the Theory of Triadic Influence (Flay *et al.*, 2009) and many other health behaviour theories addressing non-habitual behaviour, relative to children with a weak intention to brush twice a day, children with a strong intention to brush twice a day were significantly more likely to increase their reported brushing frequency from once a day or less to twice a day or more. Thus, for children who are brushing once a day or less, increasing their intention to brush twice a day could be an effective way to increase their reported brushing frequency.

Providing information on new caries or fillings did not have the predicted result. Relative to children who did not develop new caries, children who developed new caries were *less* likely to increase their reported brushing frequency from once a day or less to twice a day or more. These results fail to support the hypothesis that telling parents their children had new caries will result in increased brushing frequency. However, this lack of support is consistent with behaviour change theory, which emphasises that information about the consequences of engaging or failing to engage in a behaviour (i.e. having new caries) may contribute but not be sufficient to change behaviour. For children without a habit, behaviour change theory suggests that intentions change when self-efficacy, social normative beliefs, and attitudes change (Flay *et al.*, 2009). Thus, interventions should target these factors.

There were both strengths and limitations to this study. Unlike cross-sectional studies, which can examine associations only at one point in time, the longitudinal nature of the Aban Aya and Iowa Fluoride studies made it possible to test whether each predictor was antecedent to a change in reported daily brushing frequency, which is one step in demonstrating a causal relationship. In addition, the brushing behaviour of this age group is unstable, suggesting that it is appropriate to develop interventions for them. However, secondary analysis of studies is useful only as far as the studies measured indicators of interest. In the Aban Aya and Iowa Fluoride studies, the degree to which tooth brushing was an automatic behaviour was not measured, so we were unable to remove children with a once a day habit from the analysis. Since the theories suggest that those children would not be likely to respond to either of our predictors, this may have had the effect of weakening the associations we obtained. In addition, in the six month span over which brushing frequency was assessed in each study, some children may have increased their brushing frequency and then dropped back. Our measures would have missed the increases of these children, which also would have the effect of weakening the associations we obtained. In addition, in both studies, the brushing frequency was reported by the respondents, but not observed. Thus, to the degree that social desirability influenced the responses from both the parents and the children, the measures may not be accurate. Finally, both populations are relatively homogeneous; thus, the generalisability of our results to other populations remains unknown.

For children who have not yet formed a habit, increasing their intention to brush twice a day could be an effective way to increase their brushing frequency. However, although it is important to inform their parents when they develop new caries, we should not expect that providing that information without any further intervention will result in long-term behaviour change. As the failure to attain lasting behaviour change in children through an intervention that attempted to improve both intentions and factors relating to habits demonstrated (Wind *et al*., 2005), we still have much to learn before we can achieve our goal of minimising caries due to infrequent brushing with fluoride toothpaste. Ideally, future studies should assess tooth brushing frequency, intentions (Ogden *et al.*, 2007), and factors relating to habits, such as habit strength (Orbell and Verplanken, 2010; Verplanken and Orbell, 2003) and situational cues (Verplanken and Wood, 2006), at each of multiple and frequent waves of data

collection. As reflected in this list of factors to assess, behaviour change theory is maturing, which holds much promise for advancing interventions to increase daily tooth brushing frequency and thereby reducing caries.

## Acknowledgements

The Aban Aya Youth Project was funded through NIH NICHD U01-HD30078 and NIDA R01-DA11019, and the Iowa Fluoride Study was funded through NIH NIDCR R01-DE09551, P30-DE10126, and M01-RR00059. DEP was supported for her work on this paper through NIH NIDCR R21-DE021572. The authors wish to thank Robert J. Weyant, MS for his assistance in determining the analytic strategy and Woosung Sohn and Robert J. Weyant, DMD, DrPH for their helpful comments.

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