Childhood toothbrushing behaviours and their association with personal and family characteristics among Pacific children in New Zealand

by

Zahraa Hanif BHSc (Oral Health)

A Dissertation submitted to

Auckland University of Technology

in partial fulfilment of the requirements for the degree of

Bachelor of Health Science (Honours)

December 2021

School of Clinical Sciences

Abstract

Early childhood caries (ECC) is the most common non-communicable disease among children worldwide. In New Zealand, ECC among Pacific children is significant and pervasive. Toothbrushing twice daily is an effective self-care measure for preventing ECC. However, no studies have investigated longitudinal patterns of toothbrushing. Additionally, no studies have investigated personal and family characteristics associated with childhood toothbrushing behaviours among Pacific children. This research aimed to investigate childhood toothbrushing behaviours among Pacific children in New Zealand and determine whether toothbrushing behaviours are associated with personal and family characteristics. The first objective of this study was to identify and describe early childhood toothbrushing trajectories among Pacific children in New Zealand. The second objective was to investigate the strengths of association between toothbrushing behaviours and personal and family characteristics.

A quantitative methodology was utilised to conduct data analysis from a birth cohort study, the Pacific Islands Families (PIF) Study. The current study analysed personal and family characteristics data from the 6-weeks postpartum, 1, 2, 4, 6 and 9-year phases of the longitudinal PIF study. Group-based trajectory modelling was used to assign children into distinct groups based on their toothbrushing frequencies reported at ages 4, 6 and 9-years. Multinomial logistic regression was performed to examine the strength of potential personal and family characteristics with the toothbrushing trajectories.

Four distinctive trajectories of toothbrushing behaviours were identified: these were characterised as ‘adoption’ (19.3%), in which children adopted the favourable behaviour of brushing twice daily; ‘cessation’ (15.7%), in which children stopped brushing twice daily; ‘consistent’ (21.9%), in which children brushed twice daily at all ages; and ‘inconsistent’ (43.1%), in which children had mixed brushing frequencies. After controlling for personal and family characteristics, children of mothers who brushed twice daily had a lower risk of following the ‘adoption’ trajectory than the ‘consistent’, which was also true for children in home-owning families. Male children had a higher risk of following the ‘inconsistent’ toothbrushing trajectory than the ‘consistent’, relative to female children. Children of

mothers brushing at least once daily, children using children's toothpaste, and children with higher maternal education had a lower risk of following the 'inconsistent' trajectory than the 'consistent'. Children of mothers who economised on fruit and vegetables at ages 4 and 9-years were significantly more likely to follow an unfavourable toothbrushing trajectory than those who never had to economise.

This study established that four distinct trajectories of toothbrushing can exist among Pacific children in New Zealand and were closely associated with parents' socioeconomic advantage and mothers' oral self-care behaviours. The findings provide stakeholders, such as policymakers, with evidence to remove financial barriers to toothbrushing. The findings also suggest that toothbrushing behaviour interventions targeting young children should focus on both the children and their caregivers, particularly novice or socioeconomically disadvantaged mothers. Further research examining toothbrushing trajectories into adulthood and associated oral health outcomes among Pacific peoples in New Zealand will help to better understand the current study's findings.

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List of Abbreviations

Abbreviation	Name
CI	Confidence interval
COHS	Community Oral Health Services
DHB	District Health Board
ECC	Early childhood caries
GA	General anaesthesia
GBTM	Group-based trajectory modelling
ICDAS	International Caries Detection and Assessment System
OHRQoL	Oral health-related quality of life
PPM	Parts per million
PIF	Pacific Islands Families
RRR	Relative risk ratio
SES	Socioeconomic status
STATA	Statistical program, a portmanteau of ‘statistics’ and ‘data’
VEG	Vegetable
WHO	World Health Organization

Attestation of Authorship

I, Zahraa Hanif, hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

31/12/2021

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Signature **Date**

Acknowledgements

I would like to express my gratitude to Colgate New Zealand and Auckland University of Technology for providing the Colgate AUT Oral Health (Honours) Scholarship, which enabled this research project.

I thank my primary supervisor, Professor Zac Morse, Department of Oral Health, Auckland University of Technology, for his constant professional guidance and warm encouragement. Thank you for all your time and patience through my novice researcher journey. You have nurtured me through the research process, shared my enthusiasm for the subject, and greatly inspired me.

I thank my secondary supervisor Leon Iusitini, Centre of Pacific Health and Development Research, Auckland University of Technology, for supporting Pacific oral health, enabling this study to be undertaken and sharing his invaluable insight into the PIF Study. Your valuable feedback throughout the research process has also been of immense help.

I thank my external advisory supervisor, Professor Jonathan Broadbent, Department of Oral Sciences, University of Otago, whose expertise with group-based trajectory modelling has been invaluable for this research project. Thank you for sharing your immense knowledge, time, and patience in helping me understand and unravel many areas of the topic and research concepts. I am truly grateful for your help with the statistical analyses and the many long, constructive, and inspiring discussions.

I would like to express my deepest appreciation to my parents, Lydia and Azeez Hanif, for their wise counsel and sympathetic ear. Your unending support has helped me complete this dissertation.

Introduction

New Zealand studies of oral health have found that proportionally more Pacific children are affected by early childhood caries (ECC) than other New Zealand children (Shackleton et al., 2018). Past research has indicated the need for further studies of oral health behavioural factors in preventing dental caries (Jamieson & Koopu, 2006). The literature will be discussed, focusing on ECC as a significant health issue, especially among Pacific children and toothbrushing as an effective preventive modifiable factor for ECC. The definition of ECC will be presented, and its aetiology will be briefly discussed. Literature on ECC in a New Zealand context will be discussed, followed by ECC among the Pacific population of New Zealand. Existing literature on the barriers and facilitators to child toothbrushing will then be explored. Lastly, behavioural trajectories will be explored to identify and consider how routine behaviours develop or evolve.

Early Childhood Caries

ECC is "*the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth in a child 71 months of age or younger"* (American Academy of Pediatric Dentistry, 2011). It is the most common non-communicable disease among children worldwide and is of public health importance (World Health Organization, 2019).

ECC has significant short- and long-term impacts on children, families, and society (Peres et al., 2019). It can affect the daily lives of children and their families through its impacts of chronic pain; chewing difficulties; speech articulation, delay and development difficulties; increased orthodontic need in the permanent dentition; general health disorders such as gastrointestinal disorders; increased absences from preschool; altered growth; psychological problems such as reduced socialisation and self-esteem; and overall poorer quality of life for the child and their family (Schluter et al., 2020; Anil & Anand, 2017; William, 2016). ECC differs from dental caries in older children and adults in its rapid development and diversity of risk factors, although almost all risk factors of ECC are modifiable (World Health Organization,

2019). The experience of ECC is a strong indicator that a child with ECC will continue to experience dental caries into adulthood (Bach & Manton, 2014).

Dental caries occurs when frequent exposure to fermentable carbohydrates results in a microbiological shift in the commensal oral microflora to an acidogenic biofilm (Pitts, 2016). The development of a carious lesion is promoted when the plaque remains undisturbed in an acidic environment with a continued supply of fermentable carbohydrates. Dental plaque can sustain an environment characterised by net mineral loss from the tooth (Pitts, 2016). The aetiology of dental caries is complex and can have various contributing factors. Due to the complex and various ever-shifting causes of dental caries, there is no single universal solution. Therefore, ECC meets the criteria to be designated as a "wicked" health promotion issue that cannot be solved internally by the healthcare system (Thomson, 2018).

Early Childhood Caries in a New Zealand Context

Dental caries (ECC) is largely preventable, yet it is the most common chronic disease of childhood among New Zealand children (Aung et al., 2019). ECC is also among the primary reasons for hospital admission of children in New Zealand (Schluter et al., 2020). In 1990, the national school dental health service data reported that 51.4% of children aged 5-years were caries-free, while 48.6% experienced caries (Ministry of Health, 2020). The latest age five national oral health data from the community oral health service was recorded in 2019, which reported 58.8% of children aged five were caries-free, while 41.2% experienced caries (Ministry of Health, 2020). This indicates that there has only been a 7.4% decrease in caries prevalence over 29 years, emphasising the persistent prevalence.

The treatment for ECC requires considerable cooperation from the patient, which is often challenging to attain from young children experiencing ECC (Bach & Manton, 2014). Therefore, it becomes a costly and time-consuming procedure. Schluter et al. (2020) state that the costs to the country are substantial and growing. In the financial year 2017/18, a total of $197.2 million was funded by District Health Boards (DHBs) for oral health; child oral health services accounted for $98.4 million (Schluter et al., 2020).

When cooperation is unattainable to treat ECC, treatment under general anaesthesia (GA) is usually required to manage high-quality, comprehensive treatment. The cost of GA has been estimated at $2400 per case at a minimum (Schluter et al., 2020). Statistics indicate that children receiving dental care under GA has risen by 67%, from 4,646 in 2004/2005 to 7,755 in 2014, with disproportionate numbers of Māori and Pacific children undergoing such treatment (Whyman et al., 2014). The persistently high prevalence of ECC is placing the DHBs under increased pressure to cope with the increasing demand for treating children with ECC (Hunt et al., 2018). Additionally, the high prevalence places a considerable burden on the country's health system, increasing resource and expertise burdens.

In recent years, significant improvements have been achieved in the proportion of New Zealand children who are still caries-free by the age of six years (Schluter et al., 2020). In 2006, the government set out a strategic vision for oral health policy for the following ten years, noting improving oral health as one of the 13 health priorities in New Zealand (Ministry of Health, 2006). The vision was an environment promoting oral health through fluoridated water, a healthy diet, publicly funded oral health services for children under 18 and a workforce that actively addresses the needs of those at high risk of poor oral health (Ministry of Health, 2006).

The World Health Organization (WHO) states that good oral health is a fundamental human right for all; however, significant inequities among different ethnic and socioeconomically disadvantaged communities persist. For example, the 2005 national Community Oral Health Services (COHS) data documented that 70% of Māori children and 64% of Pacific children aged 5-years experienced caries. In contrast, 39% of children of 'other' ethnicities experienced caries (Ministry of Health, 2005). The latest oral health data from the national COHS document that 59% of Māori, 69% of Pacific, and 32% of children of 'other' ethnicities aged 5-years were observed to have caries when dentally examined in 2019 (Ministry of Health, 2020). Although the modest decrease in caries prevalence among Māori children and children of 'other' ethnicities is a cause for celebration, the increase in caries experience among Pacific children and persistence of ethnic oral health disparities is alarming and unacceptable.

Early Childhood Caries among the Pacific Population in New Zealand

The Pacific population of New Zealand is rapidly increasing. The Pacific population was recorded to be 440,000 in 2018 and has been projected to rise to between 570,000 and 730,000 in 2043 (Statistics New Zealand, 2021). Additionally, New Zealand has the highest number of Pacific children than any other nation (Jamieson & Koopu, 2006). Pacific children in New Zealand have high levels of untreated dental caries and poor dental service attendance (Ministry of Health, 2020). As Pacific children currently carry the heaviest burden of ECC in New Zealand, there is a substantial need for more research on ECC among Pacific children. Past research has indicated insufficient published literature on Pacific oral health (Jamieson & Koopu, 2006), and currently, there is a paucity of literature that focuses on Pacific oral health.

Pacific peoples in New Zealand are likely to be in New Zealand's lowest socioeconomic status (SES) groupings (Sundborn et al., 2011). Literature indicates a strong association between low SES and increased caries experience (Bach & Manton, 2014). New Zealand studies into oral health have found that proportionally more Pacific children are affected by ECC than other New Zealand children (Shackleton et al., 2018).

Within New Zealand, there are six main Pacific ethnic groups: Samoan, Tongan, Cook Islands Māori, Niuean, Fijian, and Tokelauan (Auckland Council, 2021). Each Pacific ethnic group varies in terms of culture, language and traditions, and using a collective term to describe the population can disguise the heterogeneity within the community. Paterson et al. (2011) found Tongan children to have significantly poorer oral health outcomes than Samoan children, which is suggested to be a result of immigration patterns. Most of New Zealand's Samoan population arrived earlier than Tongan immigrants; therefore, as a group, Samoan people tend to be more established in New Zealand society and are a substantially larger population than other Pacific ethnic groups (Paterson et al., 2011). Tonga's economy is non-monetary and heavily depends on remittances from countries abroad (Takeuchu et al., 2017). Tongans have also experienced affordability barriers to toothbrushes and dentifrice in Tonga, causing them to neglect their oral health (Takeuchu et al., 2017), which may indicate why recent Tongan immigrants in New Zealand have poorer oral health.

Risks to good health, including unfavourable health-related behaviours, have occurred at higher rates among Pacific children than in other children in New Zealand (Crawley et al., 1995). A child's risk of general illness and oral disease cannot be separated from family and community disease risk (Fisher-Owens et al., 2007). This interconnectedness relates well to the Fonofale model, a Pacific conceptual model of health for the New Zealand context. The fale (house) incorporates components important for Pacific health with the floor or foundation as family, the four posts as physical, spiritual, mental and other support, and the roof as culture, encapsulated in a circle of time, context and environment (Crawley et al., 1995). A children's oral health model identifies factors influencing children's oral health outcomes at community, family, and individual levels (Fisher-Owens et al., 2007). The contextual variables that influence health beyond the individual at a community level include home, neighbourhood, community, and state characteristics. Family-level influences emphasise direct and indirect impacts on children's oral health by providing support and role modelling. Lastly, individual-level factors are shown as most forthright in their effects on oral health, with diet and oral hygiene the most amenable to modification (Fisher-Owens et al., 2007).

There are very few studies on the oral health of Pacific peoples, and there has been little focus on this ethnic group despite Pacific people persistently experiencing poorer oral health. Most of the major oral health promotion initiatives in New Zealand are based on evidence from other developed countries, which limits the application of evidence to Pacific people's oral health. There is further need for research on Pacific oral health.

Toothbrushing

Removing bacterial plaque with effective regular toothbrushing is the primary method for preventing and ceasing oral diseases like dental caries and periodontal diseases (Rajwani et al., 2020). Poor toothbrushing behaviours are a modifiable preventive risk factor for dental caries. It is an easily demonstrable behaviour that presents strong evidence as an effective strategy for preventing ECC (Huebner & Milgrom, 2015). Despite this, the literature states that a low number of parents meet the recommendation of brushing their child's teeth twice

daily with fluoridated toothpaste to reduce the risk of dental caries (Huebner & Milogrom, 2015).

New Zealand's Ministry of Health recommends people of all ages use toothpaste of at least 1000 ppm twice daily (New Zealand Guidelines Group, 2009). Findings from the 2009 New Zealand oral health survey reported that in the 2-4-year age group, 65.6% (56.3-74.9%) brushed at least twice daily, while only 15.3% (8.0-22.6%) did so with 1000+ ppm fluoride toothpaste (Ministry of Health, 2010). More recent findings from the 2020/2021 New Zealand Health Survey reported that 41.3% (36.6-46.2%) of children brushed at least twice daily with 1000+ ppm fluoride toothpaste (Ministry of Health, 2021). This change in the proportion of children brushing twice daily with 1000+ ppm fluoride toothpaste may have, at least in part, come due to the withdrawal of several low fluoride (500 ppm) children's toothpastes from the market in the intervening period. Toothbrushing twice daily with fluoridated toothpaste is especially uncommon among parents of low socioeconomic status (Shaw et al., 2009). However, oral health outcomes are amenable to change by modifying risk factors, such as poor oral hygiene.

Toothbrushing programmes can have favourable impacts on child oral health-related quality of life (OHRQoL). A school-based toothbrushing programme in Northland, New Zealand, is an example of such a study. The Northland project involved 159 children (aged 10 to 13-years from high deprivation areas) who participated in a supervised toothbrushing session each school day and 176 children who served as the control group (Clark et al., 2018). The children completed an OHRQoL questionnaire at baseline and again nine months later. The children in the intervention group were taught to spit out the toothpaste instead of rinsing it away and were also taught the modified Bass toothbrushing technique while timed by the supervisor for two minutes. The OHRQoL score improved for both groups, although the improvement was greater for children who took part in the supervised toothbrushing programme over a one-year period. Additionally, toothbrushing for two minutes daily became a routine activity at the school involved (Clark et al., 2018).

Clark et al. (2019) evaluated the efficiency of the supervised toothbrushing programme implemented in Northland, New Zealand, using the International Caries Detection

Assessment System (ICDAS) and bitewing radiographs. Throughout an entire school year, one school was the intervention school in which children took part in supervised toothbrushing with fluoride toothpaste for two minutes per day, while the other four schools were control schools. Each child had a complete clinical dental examination with dental bitewing radiographs prior to conducting the intervention and was repeated nine months later. Clark et al. (2019) found the intervention to be efficacious; on average, almost 12 surfaces of teeth per child showed tooth remineralisation in the intervention school, while the control schools had nearly nine surfaces that deteriorated throughout the entire school year. The significant predictor of incidence was found to be whether the child was in the control or intervention group. This suggested that supervised toothbrushing with fluoridated toothpaste for two minutes overcomes the sociodemographic risks that are linked to greater caries experience (Clark et al., 2019).

In line with the findings from Clark et al. (2019), a school-based toothbrushing programme observed a reduced caries experience and prevalence among primary school children in a high deprivation area in Queensland, Australia (Cakar et al., 2018). Both studies were conducted in high deprivation areas, showing that effective toothbrushing routines can achieve better oral health outcomes despite low SES and ethnicity.

Barriers and Facilitators of Childhood Toothbrushing

Children under the age of 6-years have limited manual dexterity; therefore, they cannot brush effectively to sufficiently remove plaque from their teeth without assistance (Bach & Manton, 2014). There is empirical support for adult involvement in a child's toothbrushing to be more effective than children brushing solely by themselves (Hariyani et al., 2020; Pine et al., 2004). However, this contrasts with dated findings in which no association was found between adult supervision of children's toothbrushing and ECC experience (Febres et al., 1997; Hallett & O'Rourke, 2003). According to Hubner and Milogrom (2014), effective toothbrushing requires more than knowing or being told that toothbrushing is essential. Therefore, findings from Febres et al. (1997) and Hallet & O'Rourke (2003) may have resulted from low parental oral health literacy or ineffective brushing methods. A study that did find an association between children's toothbrushing behaviour and adult supervision found that children being dental

caries-free at age 4-years was strongly associated with the onset of brushing by the parents before age 2-years. For example, those who began toothbrushing after age 2-years were significantly more likely to have caries (Pine et al., 2004). However, children living in a low-income household are more likely to begin brushing at an age above 3-years and are more likely to brush their teeth less frequently, hence increasing their risk of ECC (Thornton-Evans et al., 2019; Van den Branden et al., 2013).

It is well established that parents have important roles in assisting or supervising their children while brushing. However, the issue of the high risk of ECC among children from low socioeconomic families is not as simple as parents ensuring their children's teeth are brushed; instead, these families are more likely to experience conditions that make dental care a lower priority (Schulter et al., 2020). Hariyani et al. (2020), who also found the effectiveness of adult involvement in child toothbrushing, discussed that mothers brushing their child's teeth might come from higher-income families who often have higher opportunities to live healthier lives than lower-income families. An example of a potential condition causing dental care to be a lower priority may be a family's fret to afford to place a meal on the table. Many studies have reported positive associations between food insecurity and dental caries for both children and adults (Hill, 2020; Lee et al., 2020). Literature suggests that the inability to access sufficient and fresh food is associated with the family's SES (Bae & Obounou, 2018); hence, food insecurity may be a useful proxy for SES and may reflect on toothbrush and toothpaste affordability.

International studies have found a link between SES and toothbrushing frequencies. High-income individuals are more likely to brush their teeth than low-income individuals (Park et al., 2016). This is in line with a longitudinal New Zealand study that identified a lower toothbrushing frequency among low SES than high SES individuals (Broadbent et al., 2011). The researchers suggested that the self-care differences are unlikely to be caused by any systematic cause but rather affordability barriers of oral hygiene aids (Broadbent et al., 2011). This indicates that there could potentially be a lack of toothbrush ownership among low socioeconomic families, although there is insufficient published literature to corroborate this. However, a recent Australian study's findings suggested that despite household income, children in families renting homes have higher risks of tooth loss than children in home-

owning families. Although, the study overall concluded that children in low-income households have poorer oral health outcomes than children living in high-income households (Fleitas Alfonzo et al., 2021).

The link between low SES and lack of child toothbrushing aligns with the multilevel conceptual model for children's oral health in which individual, family, and community levels influence children's oral health outcomes (Fisher-Owens et al., 2007). The family-level influences, which include SES, family functioning and family composition, impact the likelihood that a parent will regularly brush their child's teeth. School-based toothbrushing programmes have been exemplified as effective among children from high deprivation areas (Clark et al., 2018; Cakar et al., 2018); this could be the only or a good opportunity for toothbrushing among some of these children.

Parental oral health attitudes, literacy, and health beliefs also have implications for developing oral self-care behaviours among children. For example, Pine et al. (2004) found that children who were more likely to brush their teeth twice a day had parents that had a high level of belief in the seriousness of ECC and were regular dental attenders. This suggests that caregivers with higher oral health literacy are motivated, more likely to begin introducing toothbrushing practices sooner to their children and demonstrate acceptable oral hygiene behaviours and levels of oral health education. This is in line with recent findings from Berzinski et al. (2020), who found that higher levels of parental oral health knowledge were the most significant predictor of child toothbrushing frequency. Similarly, Van den Braden et al. (2013) found that lower maternal education level was related to lower brushing frequencies among children. As parental oral health literacy appears to be a key indicator of oral health behaviours in children, emphasis should be placed on educational oral health promotion to novice mothers. For example, an oral health promotion programme provided in Australia in the form of anticipatory guidance to nulliparous women during pregnancy significantly reduced the ECC incidence in their children (Plutzer & Spencer, 2008). Targeting mothers or other primary caregivers for oral health promotion is essential, as they play vital roles in introducing and establishing oral health care for their children (Okada et al., 2002).

The associations of parental oral health literacy, child oral health, and toothbrushing behaviours could be further influenced by factors related to parental control and parental strategies implemented to perform toothbrushing successfully. Evidence indicates that a higher parental locus of control is associated with lower ECC experience (Broukal et al., 2008). In addition, Berzinski et al. (2020) suggest that when a child is resistant or uncooperative, parental confidence in their ability to implement certain behaviours plays a significant role; in this case, to implement toothbrushing behaviours. This is consistent with findings that indicate that child uncooperativeness while brushing was perceived as a barrier by mothers (Elison et al., 2014). A method to overcome this barrier could be the children viewing themselves in the mirror whilst receiving brushing assistance. This method was found to be an effective toothbrushing teaching method for preschool children (Makuch et al., 2011).

Behavioural Trajectories

Behaviours develop over time and can follow distinct trajectories. A trajectory describes the development, whether changed or stable, in an individual's behaviour over a period (Irinja et al., 2019). There is a lack of published literature on how toothbrushing behaviours are adopted and whether distinctive trajectories of oral hygiene behaviours exist during the early years of life. Developmental trajectories have been described in many different disciplines, including antisocial behaviour (Piquero et al., 2014), exercise (Irinja et al., 2019), and dental health (Heilmann et al., 2015). Still, none have considered the adoption of toothbrushing behaviours. Existing literature has established that effective toothbrushing routines during childhood are likely to endure into adulthood (Aunger, 2007). Yet, there is a lack of empirical evidence to demonstrate how toothbrushing behaviours become established.

Although there is a lack of literature on childhood toothbrushing behavioural trajectories, a New Zealand longitudinal study investigated plaque levels at ages 5, 9, 15, 18, 26 and 32-years and determined the relationship between plaque levels and oral health in adulthood (Broadbent et al., 2011). The authors found distinct dental plaque trajectories strongly associated with future oral health. Across the long term, participants in the high-plaque trajectory group had a 40% greater caries experience than those in the low-plaque trajectory group. The high plaque-trajectory group were also 3.4 times more likely to have the presence

of a decayed tooth surface, had lost 4.0 times more teeth owing to caries and were 4.8 times more likely to have lost a tooth as a result of caries than those in the low-plaque trajectory group (Broadbent et al., 2011). As dental plaque can be removed by toothbrushing, the study may suggest that a lack of toothbrushing during childhood formed the behaviour as a habit that continued during adulthood and resulted in poor oral health outcomes. However, the study did not investigate childhood toothbrushing trajectories; therefore, this claim cannot be corroborated. The study also found an association between low SES in childhood and high plaque levels at age 32-years, which depicts how unhealthy self-care behaviours affected by family-level influences may continue during adulthood.

It is given that there are benefits of long-term healthy behaviours, although the knowledge on how these behaviours develop or change over time is deficient. Studies of trajectories in screen use in early childhood indicate that screen use patterns form early in development (McArthur et al., 2020). Specifically, the high-persistence trajectory group maintained high levels of screen use across early childhood, which was established at 24 months. The key screen time influences that were associated with the high-persistence screen use trajectory identified were ethnic minority status, lower income, and high maternal screen use (McArthur et al., 2020).

Favourable oral hygiene behaviours are essential for good oral health. For example, toothbrushing at least once daily with fluoride-containing toothpaste reduces the occurrence of dental caries (Deinzer et al., 2019). New Zealand research into oral hygiene found that Pacific adolescents were less likely to brush their teeth twice or more in a day than their Asian, European, and 'other' counterparts (Areai et al., 2011). A study using data from the PIF Study found that poor maternal oral hygiene habits were significantly associated with increased odds of their child experiencing dental restorations and extractions (Paterson et al., 2011). Paterson et al. (2011) also found that Pacific children who were occasionally supervised while brushing had an increased likelihood of receiving dental restorations and extractions than children who did not receive any supervision (Paterson et al., 2011). Despite researchers urging further information on New Zealand Pacific people's oral health (Petelo et al., 2004), there is still scant published evidence of childhood oral hygiene behaviours, especially among Pacific children.

There are several reasons to investigate how and why toothbrushing behaviours develop or change during childhood. First, preventive practices established during the early ages of life are an important determinant of oral health several years later (Johnsen, 1995), and the behaviours can be perceived as the first step of an ongoing process. Second, such studies using longitudinal data to investigate behaviours that aid in preventing disease will help identify how healthy behaviours are maintained or lost over time and can also be important for public health policymakers.

Statement of the Problem

Sustained ethnic disparities in oral health remain in New Zealand, with Pacific children carrying the heaviest burden of ECC. Risk factors for ECC among these children vary greatly, but favourable toothbrushing behaviours are a key preventive modifiable risk factor. Toothbrushing is a simple and demonstrable behaviour that effectively prevents ECC, although several barriers to child toothbrushing remain. The identified barriers are linked with complex relationships between child, family and community-level influences mediated by developmental factors, as modelled in the Fisher-Owens' conceptual model of oral health. This relates and aligns to the Fonofale model, which in a New Zealand context identifies what Pacific people find most important for their health and wellbeing, with culture as the shelter and family as the foundation of life. Research gaps remain to adequately understand how toothbrushing trajectories develop during early childhood.

Disparities in the experience of ECC affecting Pacific children are significant, pervasive, and relevant to public health policy. It is anticipated that the individual, family, and community influences interrupt or expedite these children to develop healthy toothbrushing behaviours. Therefore, it is crucial to identify and describe toothbrushing behaviours among Pacific children in New Zealand and investigate how personal and family characteristics influence toothbrushing trajectories.

Significance of the Research

There is currently an absence of literature on toothbrushing trajectories, let alone toothbrushing trajectories among Pacific peoples. This study planned to generate unique

insights into toothbrushing behaviours among Pacific children in New Zealand and associated personal and family characteristics. The findings of this study can add to the limited body of literature currently existing on Pacific oral health and may help inform recommendations for public health policy concerning Pacific children's oral health.

The aim of this research was to investigate childhood toothbrushing behaviours among Pacific children in New Zealand and determine whether toothbrushing behaviours are associated with personal and family characteristics.

Objectives:

1. To identify and describe trajectories of toothbrushing frequencies over childhood.
2. To investigate the strengths of associations between toothbrushing behaviours and personal and family characteristics.

Methodology

A quantitative approach was utilised to identify toothbrushing trajectories and investigate personal and family characteristics associated with toothbrushing behaviours among Pacific children in New Zealand. Data analysis was conducted using data from the Pacific Islands Families (PIF) Study. The current study uses data from the baseline data collection phase at 6-weeks postpartum and the follow-up phases at ages 1, 2, 4, 6 and 9-years.

Pacific Islands Families Study

The Pacific population has been identified as one of the fastest-growing population subgroups in New Zealand. The PIF study is an ongoing longitudinal study tracking the health and development of a birth cohort of 1,398 Pacific children born in Auckland, New Zealand, in 2000. The inception cohort broadly represented the Pacific population as per the 1996 and 2001 New Zealand census figures (Paterson et al., 2008). The PIF Study was established to address the over-representation of Pacific peoples in numerous adverse health and social statistics, leading to higher rates of communicable and non-communicable diseases, hospitalisations, and deaths among this ethnic group.

Despite Pacific people being over-represented in adverse health statistics and the rapidly increasing ethnic population, there was a paucity of culturally specific literature to base coordinated public health interventions for Pacific peoples. The PIF study was developed and established within this context through collaboration with Pacific communities, researchers, and appropriate healthcare and social agencies (Paterson et al., 2008). Since its establishment, the PIF study has been instrumental in identifying culturally precise information regarding Pacific peoples in New Zealand. It is also the largest longitudinal health study of Pacific people globally.

The PIF study has a multi-disciplined, broad-based, and inclusive study design. The broad aims of the PIF study are to (i) identify and characterise participants experiencing negative and positive health outcomes; (ii) understand the mechanisms and processes moulding the pathways to the health outcomes; (iii) create empirically based strategic and tactical

recommendations to improve the health and wellbeing of Pacific children and thereby benefit New Zealand society as a whole (Sundborn et al., 2011).

The PIF study captures data from the child, their mothers, and their fathers at ages six weeks postpartum, 1, 2, 4, 6, 9, 11, 14, 17-years, and a subset seen at 18-years. At six weeks postpartum, a total of 1,398 mothers participated. There has been sample attrition over the years, with 1,224 mothers participating in the 1-year phase, 1,144 in the 2-year phase, 1,048 in the 4-year phase, 1,001 in the 6-year phase and 996 in the 9-year phase.

Mothers of a cohort of Pacific Island infants born between the 15th of March and the 17th of December 2000 at Middlemore Hospital in South Auckland were recruited (Paterson, 2006). All potential participants were identified through the Birthing Unit and the Pacific Islands Cultural Resource Unit at Middlemore Hospital. An infant was deemed eligible to be included in the PIF Study if at least one parent identified themselves as having a Pacific Islands' ethnicity and was a New Zealand citizen or permanent resident. Middlemore Hospital was chosen to recruit participants for the birth cohort as its maternity division homes the largest number of Pacific births in New Zealand (Paterson et al., 2008).

Interviews undertaken in the phases investigated in this study were conducted in the mother's home and her preferred language by Pacific female bilingual interviewers using paper-based questionnaires. Prior to commencing the hour-long interviews, the interviewers obtained informed consent from the mothers (Paterson, 2006). The questionnaires were created with consideration and input from Pacific researchers, and specific measures were employed to ensure their content acceptability and validity (Paterson et al., 2008).

Participant Inclusion and Exclusion Criteria

The current study identifies toothbrushing behaviours at ages 4, 6 and 9-years. Participants who reported toothbrushing behaviours for at least two of the three ages were included in the analysis, and this study analysed the data collected from them. At ages 4, 6 and 9-years, 987, 981, and 913 children had at least two or more toothbrushing frequencies recorded, respectively.

Measures

Toothbrushing Frequency

The child's toothbrushing frequency was reported at 2, 4, 6 and 9-years. At 2-years, mothers were asked to report "no" or "yes" to the following question "*Do your child's teeth get cleaned at least once a day?*". In this study, children of mothers who reported "no" were coded as 0 = less than daily and 1 = at least once daily. Next, at ages four, six and nine, mothers were asked, "*How often does your child brush his/her teeth?*". The responses were recorded categorically; 0) Never; 1) Less than once a day; 2) Once a day; 3) Twice a day or more. In the current study, responses were recorded as 1); Less than daily, 2); At least once daily; 3) At least twice daily.

Child's Sex

At 6-weeks, the child's sex was recorded as 1) Female or 2) Male.

Child's Ethnicity

The mother identified the child's ethnicity at 1-year. The mother was asked, "*What ethnic group(s) do you identify YOUR CHILD as?*". Mothers answered either "yes" or "no" to the following ethnic sub-groups; 1) Samoan; 2) Cook Island; 3) Niuean; 4) Tongan; 5) Fijian; 6) Fijian Indian; 7) Tokelauan; 8) Tuvalu; 9) Māori; 10) NZ European/ Pakeha; 11) Other. Due to the small sample sizes of Niuean, Fijian, Fijian Indian, Tokelauan, Tuvaluan and Māori participants, these ethnic subgroups were combined into an 'Other Pacific' category which also included children whose mother's identified them as Māori whilst at least one of the child's parents identified themselves as Pacific. If the mother identified her child as an ethnicity other than Pacific despite at least one of the child's parents identifying themselves as Pacific, the child was categorised as 'non-Pacific'.

Home Ownership

Home ownership in this study describes whether the child was living in a home that their parents owned. Home ownership was recorded at 2-years. The mother was asked, "*Who owns this home?*". The answers were recorded categorically; 1) owned or mortgaged (by the respondent or partner); 2) Rented from another person; 3) Rented from a State agency,

e.g., Housing NZ; 4) Other (e.g., the respondent is boarding). For this study, homeownership was categorised into two groups; 0 = Does not own a home and 1 = Owns a home.

Maternal Toothbrushing Frequency

Maternal toothbrushing frequency was collected at 4-years. Mothers were asked the following question "*How often do you brush <u>your</u> teeth?*". The answers were recorded categorically; 1) Never; 2) Less than once a day; 3) Once a day; 4) Twice a day or more.

Maternal Education Level

Maternal education level, determined by their highest education qualification attained, was recorded at 6-weeks. Mothers were asked, "*What is your HIGHEST secondary school qualification?"* and *"What is your HIGHEST qualification you have obtained since leaving school?"* The answers were collapsed down to three categories for this study: 1) No formal qualification (reported no formal qualifications), 2) secondary school qualification (secondary school qualification recorded as the highest obtained qualification) and 3) post-school qualification (reported having a post-school qualification).

Toothpaste Type Use

To determine whether children used a children's or an adult's toothpaste at 6-years, mothers were asked, "*Do they use normal (adult) toothpaste or the one specifically for kids?*". Mothers' responses were recorded as either 1) Normal or 2) Kids.

Food Security

Food security questions were asked at ages 4 and 6-years. To determine economisation on food at 4-years, mothers were asked, "*In the last 12 months, have you done any of these things not at all, a little, or a lot?".* The following two questions were separately asked: *"Bought cheaper cuts of meat or less meat than you would like to buy to help keep down cost?" and "gone without fresh fruit and vegetables to help keep down the costs?".* Mother's responses were recorded as 0) Not at all; 1) A little; 2) A lot.

At age 9-years, mothers were asked, *"In the last 12 months, have you personally gone without fresh fruit and vegetables, often so that you could pay for other things needed?"* Answers for this question were recorded as 0) No; 1); Yes. At age 9-years, mothers were also asked, *"In the last 12 months, have you personally been forced to buy cheaper food so*

that you could pay for other things you needed?". The mother's responses were recorded as either 0) No or 1) Yes.

Statistical Analysis

Statistical analyses in this study were performed with Stata IC/16 for Windows using a significance level of 0.05. Descriptive statistics (total number (n), mean, column (col) percentages, relative risk ratios (RRR) and confidence intervals (CI)) were used to present data relating to participants' personal and family characteristics. Firstly, simple tabulations were carried out to investigate and describe the brushing frequencies (less than daily, at least once daily, at least twice daily) by sex at ages 2, 4, 6 and 9-years.

Groups of distinctive trajectories were identified by applying group-based trajectory modelling (GBTM), which is a specialised application of finite mixture models. GBTM assigned study members to trajectory groups by allocating individuals into a number of small groups that present statistically similar trajectories. The individuals were assigned a probability of group membership and were assigned to a group for which they had the highest probability (Nagin, 2014). Groups of distinctive trajectories are summarised by a finite set of different polynomial functions of age or time, as determined by maximum likelihood estimation (Nagin, 1999). GBTM has been identified as superior for modelling longitudinal trajectories (Franklin et al., 2013). Most other standard statistical approaches for analysing developmental trajectories are designed to account for individual variability about a mean population trend. However, longitudinal analysis can identify subgroups within a population that follow distinctive developmental trajectories, which are unidentifiable ex-ante based on some measured set of individual characteristics (Nagin, 2014).

GBTM was used to assign study members to trajectory groups based on their toothbrushing frequencies only recorded at 4, 6 and 9-years; toothbrushing frequencies at age 2-years were excluded from the GBTM as the "yes/no" question wording was used, which made the data incompatible with subsequent years. After assigning study members to trajectory groups, simple cross-tabulations were used to examine age-specific brushing frequencies

by toothbrushing trajectory group. Simple cross-tabulations were also used to investigate associations between personal and family characteristics and the identified trajectory groups.

Multiple logistic regression was performed for the dependent outcome of toothbrushing trajectories to examine the strength of potential explanatory personal and family variables. Multinomial logistic regression is an extension of standard logistic regression that allows for more than two categories of the outcome variable (Pallant, 2016). A multivariable model adjusting for confounding variables was produced to examine associations between trajectory groups and the explanatory variables. These are presented as relative risk ratios compared to the 'consistent' toothbrushing trajectory. The 'consistent' group was chosen as the base outcome, as this group was the only group that had a stable and favourable toothbrushing behaviour of brushing twice daily at all ages. Relative risk ratios and confidence intervals describing the statistical strength between the trajectory groups and explanatory personal and family characteristics are calculated and reported.

The association between food security and toothbrushing was investigated as an additional measure. Firstly, simple cross-tabulation was carried out to investigate the association between mothers economising on fruit or vegetables when the participating child was aged 4-years and when the child was aged 9-years. Simple cross-tabulation was then utilised to examine food-security factors at both ages by toothbrushing trajectory group.

Two separate multiple logistic regression procedures utilising multivariable logistic regression models were then performed. This was performed to further examine the strength of potential explanatory food-security variables at ages 4 and 9-years for the dependent outcome of toothbrushing trajectories. The age 4-years variable was dichotomised into 'economised "a lot"' versus 'economised "a little" and "not at all"'. 'Never' economised "a lot" on fruit or vegetables was selected as the reference group for the first food security-related multiple logistic regression. To consider the contrasted risk of toothbrushing trajectory membership by food security, 'never economised "at all"' was selected as the reference group for the second food security-related multiple logistic regression.

Two separate multivariable models adjusting for confounding variables, including personal and family characteristics, were included to provide strengthened evidence of associations between trajectory groups and the explanatory age 4 and 9-year's food-security variables. These are presented as relative risk ratios compared to the 'consistent' toothbrushing trajectory. Confidence intervals describing the statistical strength between the trajectory groups and explanatory variables are also reported.

Ethical Approval

This study implements the analysis of de-identified existing data. The ethical approval for this study is covered under the PIF Study's existing ethics approval: Auckland Regional Ethics Committee X ref. 99/055, Northern X Ethics Committee ref. AKY/04/02/019, and Northern Y Regional Ethics Committee ref. NTY/08/12/119.

Results

At age 2-years, nearly one in five children (17.6%) did not have their teeth cleaned at least once daily (Table 1). This figure dropped to around one in twenty (5.4%) by 4-years and still further by 6-years (1.9%) and 9-years (2.5%). At 2, 4 and 6-years, proportionally more females (82.8%, 95.8% and 98.6%, respectively) than males (82.1%, 93.6% and 97.7%, respectively) had their teeth brushed at least once daily. However, at age 9-years, proportionally more males (97.5%) had brushed their teeth at least once daily than females (90.0%). At 4, 6 and 9-years, toothbrushing at least twice daily was also reported (this response option was not included in 2-year data collection), and proportionally, more females had brushed their teeth at least twice daily during those years. Teeth were brushed at least twice daily for around half the participating cohort at 4- (52.9%) and 9-years (49.7%), while at 6-years, two in three children did so (67.1%).

Table 1. Toothbrushing frequency by age (years) and sex

	Less than daily n (%)	At least once daily[a] n (%)	At least twice daily n (%)	Total n (col %)
Age 2	204 (17.6)	957 (82.4)		1161
Males	107 (17.9)	490 (82.1)	Not reported	597 (51.4)
Females	97 (17.2)	467 (82.8)	Not reported	564 (48.6)
Age 4	57 (5.4)	1009 (94.7)	564 (52.9)	1066
Males	35 (6.4)	508 (93.6)	281 (51.8)	543 (50.9)
Females	22 (4.2)	501 (95.8)	283 (54.1)	523 (49.1)
Age 6	19 (1.9)	1000 (98.1)	684 (67.1)	1019
Males	12 (2.3)	505 (97.7)	330 (63.8)	517 (50.7)
Females	7 (1.4)	495 (98.6)	354 (70.5)	502 (49.3)
Age 9	27 (2.5)	1047 (97.5)	534 (49.7)	1074
Males	21 (4.3)	471 (95.7)	242 (49.2)	492 (50.5)
Females	6 (1.0)	576 (90.0)	292 (50.2)	582 (49.5)

[a] Includes those brushing at least twice daily

Four trajectories were identified using the group-based trajectory modelling approach with mother-reported data on child toothbrushing frequencies at 4, 6, and 9-years. One trajectory labelled 'adoption' comprised children (19.3% of the cohort) who were not brushing twice daily at age 4-years but at age 9-years were reported to be brushing twice daily. The second trajectory comprised children (43.1%, close to half of the cohort) whose toothbrushing behaviours were 'inconsistent' as they were reported to have mixed brushing frequencies. A third trajectory, labelled 'cessation', comprised children (15.7%) who were brushing twice daily at age 4-years but by 9-years had stopped doing so (and were brushing only once daily or less). A fourth trajectory labelled 'consistent', comprised children (21.9%) who brushed twice daily at all ages. A detailed breakdown of toothbrushing behaviours within each trajectory group at each age is reported in , and these trajectories are portrayed in graphical format in Figure 1.

Table 2, and these trajectories are portrayed in graphical format in Figure 1.

Table 2. Toothbrushing frequency in each trajectory group by age (years)

Toothbrushing Trajectories		Never n (%)	Not every day n (%)	Once a day n (%)	Twice a day n (%)	Total with 2+ data n (%)
Trajectory 1	Age					
Adoption	4	1 (0.6)	22 (13.7)	138 (85.7)	0	161 (37.0)
	6	0	0	7 (4.7)	141 (95.3)	148 (34.0)
	9	0	0	0	126 (100)	126 (28.9)
Trajectory 2	4	3 (0.8)	27 (6.4)	272 (64.2)	122 (28.8)	424 (34.0)
Inconsistent	6	1 (0.2)	18 (4.3)	304 (72.0)	99 (23.5)	422 (33.9)
	9	1 (0.3)	15 (3.8)	248 (62.0)	136 (34.0)	400 (32.1)
Trajectory 3	4	0	0	0	126 (100)	126 (31.4)
Cessation	6	0	0	0	127 (100)	127 (31.7)
	9	0	6 (4.1)	142 (95.9)	0	148 (18.5)
Trajectory 4	4	0	0	0	276 (100)	276 (34.5)
Consistent	6	0	0	0	284 (100)	284 (31.0)
	9	0	0	0	239 (100)	239 (29.9)

Figure 1. Toothbrushing trajectory groups by age

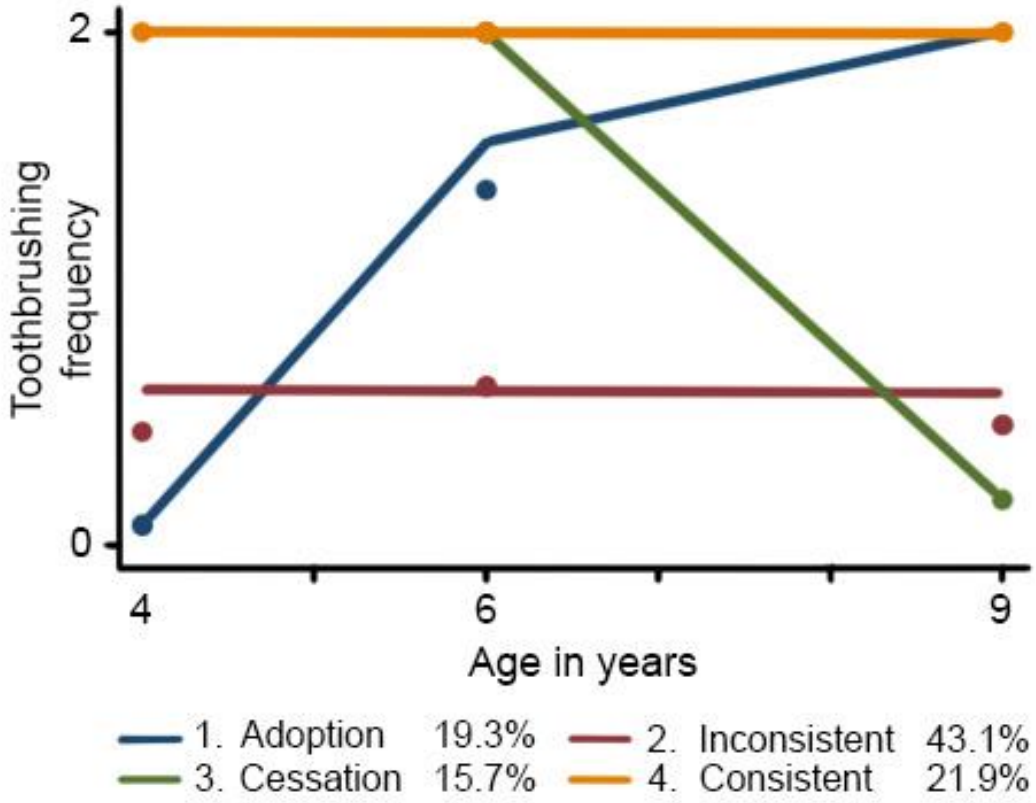

Table 3 reports the association between the trajectory groups and various sociodemographic factors and oral health behaviours. More males than females followed the inconsistent (45.5% versus 38.5%) and cessation (15.7% versus 12.3%) trajectories, while proportionally more females (17.1% and 32.1%, respectively) were in the 'adoption' and 'consistent' trajectory groups than males (13.5% and 25.3%, respectively). Proportionally, more children of mothers with no formal educational qualification (46.1%) followed the 'inconsistent' trajectory group than their peers with better-educated mothers (41.3% and 37.8%). Membership of the 'inconsistent' trajectory was also more frequent among children: who had their teeth cleaned less than once daily at 2-years (44.3%) than those who had their teeth brushed at least twice daily (44.3%); who used adult toothpaste (48.0%) than a children's toothpaste (35.7%); and whose mother's toothbrushing frequency at 4-years was less than once a day (59.2%) than children whose mothers brushed at least once daily (34.9%).

Tongan children were less likely to follow the ‘adoption’ trajectory (9.5%) than children of other ethnic groups. Proportionally, more non-Pacific children (23.5%) followed the ‘adoption’ trajectory than other ethnic groups, closely followed by Cook Islands Māori children (20.7%). Proportionally, more Tongan children also followed the ‘inconsistent’ trajectory group than children of other ethnic groups (54.7%), while Cook Islands Māori children were least likely to do so (32.6%). ‘Other’ Pacific children were more likely to follow the ‘cessation’ trajectory than other ethnic groups (15.7%), closely followed by Cook Islands Māori children (14.8%) and Samoan children (14.0%). Proportionally, fewer non-Pacific children followed the ‘cessation’ trajectory (11.8%), closely followed by Tongan children (12.9%). Proportionally, more ‘other’ Pacific children followed the ‘consistent’ trajectory than children of other ethnic groups (34.0%), while proportionally, few Tongan children did so (22.9%).

Table 3. Toothbrushing trajectory membership by participant characteristics

Factor	Trajectory 1 - Adoption n (%)	Trajectory 2 - Inconsistent n (%)	Trajectory 3 - Cessation n (%)	Trajectory 4 - Consistent n (%)	p-value	Total
Sex						
Male	72 (13.5)	243 (45.5)	84 (15.7)	135 (25.3)		534 (50.7)
Female	89 (17.1)	200 (38.5)	64 (12.3)	167 (32.1)	0.008	520 (49.3)
Ethnic group						
Samoan	72 (16.0)	181 (40.1)	63 (14.0)	135 (29.9)		451 (45.5)
Cook Islands Māori	28 (20.7)	44 (32.6)	20 (14.8)	43 (31.9)		135 (13.6)
Tongan	19 (9.5)	110 (54.7)	26 (12.9)	46 (22.9)		201 (20.3)
Other Pacific	19 (12.4)	58 (37.9)	24 (15.7)	52 (34.0)		153 (15.4)
Non-Pacific	12 (23.5)	20 (39.2)	6 (11.8)	13 (25.5)	0.007	51 (5.1)
Mother's education level						
No formal educational achievements	60 (16.0)	173 (46.1)	56 (14.9)	86 (22.9)		375 (35.6)
Secondary school qualification	56 (14.8)	156 (41.3)	47 (12.4)	119 (31.5)		378 (35.9)
Post-school qualification	45 (15.0)	114 (37.8)	45 (14.9)	97 (32.2)	0.023	301 (28.6)
Tooth cleaning frequency at age 2-years						
At least once daily	118 (14.9)	324 (41.2)	105 (13.3)	240 (30.5)		787 (81.1)
Less than once daily	29 (15.8)	81 (44.3)	33 (18.0)	40 (21.9)	0.088	183 (18.9)
Mother's toothbrushing frequency						
At least once daily	79 (12.1)	228 (34.9)	109 (16.7)	237 (36.3)		653 (66.7)
Less than once daily	80 (24.5)	193 (59.2)	16 (4.9)	37 (11.3)	<0.001	326 (33.0)
Toothpaste type use at age 6-years						
Children toothpaste	66 (16.4)	144 (35.7)	50 (12.4)	143 (35.5)		403 (41.1)

Adult toothpaste	82 (14.2)	277 (48.0)	77 (13.3)	141 (24.4)	<0.001	577 (58.2)

Several family and personal characteristics were associated with these toothbrushing trajectories. These are presented in Table 4 as relative risk ratios compared to the 'consistent' toothbrushing trajectory, both with and without adjusting for other characteristics. The 'consistent' group was selected as the base outcome. Maternal toothbrushing frequency and family home ownership were significantly associated with the 'adoption' trajectory before and after adjusting for other factors in the model. After controlling for all other factors in the model, home ownership remained a significant indicator for membership in the 'adoption' trajectory. Children of families who owned the home they were living in had 0.54 times the risk of following the 'adoption' trajectory than the 'consistent' group, relative to children of families that did not own the home they were living in. Children whose mothers brushed at least twice daily when their child was aged 4-years had 0.15 times the risk of following the 'adoption' trajectory than the 'consistent' trajectory children whose mothers did not brush at least twice daily.

Before adjusting for covariates, mother's toothbrushing frequency, type of toothpaste used by children, sex, maternal educational attainment, and family homeownership were associated with membership of the 'inconsistent' trajectory group. After adjusting for all other variables, the association between homeownership and the 'inconsistent' group was no longer statistically significant, although the direction remained consistent. Maternal brushing frequency, toothpaste type, sex, and educational attainment remained significant predictors of the 'inconsistent' trajectory group after adjusting for all other variables in the model. Children of mothers who brushed twice daily had 0.17 times the risk of following the 'inconsistent' trajectory than the 'consistent' group, relative to children whose mothers did not brush at least twice daily. Children using a child's toothpaste had 0.50 times the risk of following the 'inconsistent' trajectory than the 'consistent' group relative to children who used an adult's toothpaste. Male children had 1.61 times the risk of being in the 'inconsistent' group than the 'consistent' group relative to female children. Lastly, children whose mothers had at least a secondary school qualification had 0.66 times the risk of following the 'inconsistent' trajectory than the 'consistent' group relative to children whose mothers did not have such a qualification. Children who had their teeth brushed at least daily at 2-years and children who used children's toothpaste were less likely to be classified in the 'cessation' trajectory before adjusting for other factors in the model. However, there were no significant

associations with the 'cessation' trajectory after controlling for the other factors in the model, but the direction remained consistent.

Table 4. Risk of toothbrushing trajectory membership by key personal characteristics and behaviours

Toothbrushing Trajectories	Unadjusted RRR (95% CI)	Adjusted RRR (95% CI)
Consistent (Base outcome)	-	-
Adoption trajectory		
Brushing at least once daily at age 2 (ref less than once daily)	0.68 (0.40, 1.15)	0.67 (0.37, 1.19)
Mother brushing at least twice daily when child aged 4 years (ref less than twice daily)	0.15 (0.10, 0.25)	0.15 (0.09, 0.26)
Use of children's toothpaste (ref adult or generic toothpaste)	0.79 (0.53, 1.18)	0.79 (0.51, 1.22)
Male sex (ref female)	1.00 (0.68, 1.47)	0.95 (0.61, 1.48)
Mother secondary school qualification or higher (ref no qualifications)	0.67 (0.45, 1.01)	0.79 (0.49, 1.26)
Home ownership (ref did not own home)	0.56 (0.34, 0.94)	0.54 (0.31, 0.97)
Inconsistent trajectory		
Brushing at least once daily at age 2 (ref less than once daily)	0.67 (0.44, 1.01)	0.76 (0.47, 1.21)
Mother brushing at least twice daily when child aged 4 years (ref less than twice daily)	0.18 (0.12, 0.27)	0.17 (0.11, 0.27)
Use of children's toothpaste (ref adult or generic toothpaste)	0.51 (0.38, 0.70)	0.50 (0.35, 0.71)
Male sex (ref female)	1.50 (1.12, 2.02)	1.61 (1.14, 2.27)
Mother secondary school qualification or higher (ref no qualifications)	0.62 (0.45, 0.81)	0.66 (0.45, 0.96)
Home ownership (ref did not own home)	0.63 (0.44, 0.92)	0.77 (0.51, 1.17)
Cessation trajectory		
Brushing at least once daily at age 2 (ref less than once daily)	0.53 (0.32, 0.89)	0.58 (0.32, 1.06)
Mother brushing at least twice daily when child aged 4 years (ref less than twice daily)	1.06 (0.56, 2.00)	1.02 (0.51, 2.04)
Use of children's toothpaste (ref adult or generic toothpaste)	0.64 (0.42, 0.98)	0.80 (0.33, 1.98)
Male sex (ref female)	1.62 (1.09, 2.41)	1.41 (0.89, 2.24)
Mother secondary school qualification or higher (ref no qualifications)	0.65 (0.43, 1.00)	0.78 (0.47, 1.29)
Home ownership (ref did not own home)	0.64 (0.38, 1.06)	0.85 (0.49, 1.50)

Table 5 reports mothers' economising on fruit or vegetables when children were aged 4 and 9-years. Among mothers who did not economise on fruit or vegetables when their child was aged 4-years (39.0%), nearly one in five had begun economising on fruit or vegetables by age 9-years in order to buy other things (17.3%), and the remainder (82.7%) did not. Among mothers who economised "a little" at age 4-years (41.4%), a quarter economised at age 9-years (26.3%), and the remainder did not economise at age 9-years (73.6%). Among mothers who economised "a lot" when their child was aged 4-years (19.6%), almost two in five economised on fruits/vegetables to purchase other things when the child was aged 9-years, and the remainder (61.8%) did not economise at age 9-years.

Table 5. Mother's fruit/veg security when child aged 4 and 9-years

Mother economising on fruit/ veg when child aged 4-years	Mother went without fruit when child aged 9-years n (%)	Mother did not go without fruit when child aged 9-years n (%)	Total n (col%)
Not at all	57 (17.3)	272 (82.7)	329 (39.0)
A little	92 (26.3)	257 (73.6)	349 (41.4)
A lot	63 (38.2)	102 (61.8)	165 (19.6)
Total	212 (25.2)	631 (74.9)	843

Table 6 reports the association between mother's reported food security at ages 4 and 9-years and the child's toothbrushing trajectory membership. Proportionally, more children of mothers who did not economise on fruit or vegetables when the child was aged 4-years followed the 'consistent trajectory' than children of mothers who economised "a little" or "a lot". Proportionally, more children whose mothers economised 'a little' followed the 'adoption' trajectory than children of mothers who did not economise or economised "a lot". Proportionally, fewer children of mothers who economised "a lot" followed the 'consistent' trajectory than children of mothers who did not economise or just economised "a little".

Children of mothers who did not economise on meat when the child was aged 4-years followed the 'inconsistent' trajectory proportionally less than children of mothers who economised "a little" or "a lot". Children of mothers who economised "a little" on meat followed the 'consistent' trajectory more, while proportionally, more children of mothers who economised 'a lot' on meat followed the 'cessation' and 'inconsistent' trajectory.

Table 6. Toothbrushing trajectory membership by food security

Factor	Trajectory 1 - Adoption n (%)	Trajectory 2 - Inconsistent n (%)	Trajectory 3 - Cessation n (%)	Trajectory 4 - Consistent n (%)	p-value	Total n (%)
Mother economising on fresh fruit/veg when child aged 4-years						
Not at all	58 (36.3)	139 (32.9)	50 (39.7)	144 (52.4)		391 (39.7)
A little	72 (45.0)	183 (43.3)	48 (38.1)	98 (35.6)		401 (40.8)
A lot	30 (18.8)	101 (23.9)	28 (22.2)	33 (12.0)	<0.001	192 (19.5)
Mother economising on meat when child aged 4-years						
Not at all	15 (9.4)	48 (11.4)	27 (21.4)	60 (21.8)		150 (15.2)
A little	68 (42.5)	151 (35.7)	40 (31.8)	125 (45.5)		384 (39.0)
A lot	77 (48.1)	224 (53.0)	59 (46.8)	90 (32.7)	<0.001	450 (45.7)
Mother spending less on food when child aged 9-years						
Not personally forced to economise	57 (46.0)	152 (38.5)	52 (35.9)	120 (50.4)		381 (41.2)
Personally forced to economise	67 (54.0)	243 (61.5)	93 (64.1)	118 (49.6)	0.001	521 (57.8)
Mother went without fresh fruit when child aged 9-years						
Did not go without fresh fruit	93 (73.8)	292 (73.0)	97 (66.0)	199 (83.6)		681 (74.8)
Went without fresh fruit	33 (26.2)	108 (27.0)	50 (34.0)	39 (16.4)	0.001	230 (25.3)

Proportionally, more children of mothers who were personally forced to economise on food in order to buy other things when the child was aged 9-years followed the 'inconsistent' and 'cessation' trajectory than children of mothers who did not. Proportionally, more children whose mothers did not economise on fresh fruit and vegetables when the child was aged 9-years followed the 'consistent' trajectory than children of mothers who went without fruit.

Maternal food security was associated with the toothbrushing trajectories. The associations are presented in Table 7 and Table 8 as relative risk ratios compared to the 'consistent' trajectory, both with and without adjusting for other personal and family level characteristics. Never economising "a lot" on fruit or vegetables was initially selected as the reference group, which is reported in Table 7, and never economising "at all" was selected as the reference group for Table 8 to investigate the risk contrast of trajectory membership by food security.

Before controlling for personal and family characteristics in the model (Table 7), the factor, economising at both ages 4 and 9-years, was a significant predictor for membership in the 'adoption' group but negated after controlling for other factors in the model. Children whose mothers economised on food at age 4-years but not at age 9-years had 2.46 times the risk of being in the 'adoption' trajectory than in the 'consistent' trajectory group relative to those whose mothers never economised a lot. No significant differences were observed in the other economising groups for the 'adoption' trajectory.

Before adjusting for covariates, the factors economising at age 4 but not age 9-years, at age 9 but not age 4-years and economising at both ages were associated with a greater risk of membership in the 'inconsistent' trajectory. After adjusting for all other variables in the model, only economising at age 4 but not age 9-years and economising at both ages remained significant. Children of mothers who economised at age 4-years but not at age 9-years had 2.93 times the risk of following the 'inconsistent' trajectory than the 'consistent' relative to children whose mothers did not economise. Children whose mothers economised at both ages had 2.61 times the risk of following the 'inconsistent' trajectory than the 'consistent' relative to children whose mothers did not economise.

Before adjusting for covariates, economising at age 4 but not age 9-years, economising at age 9 but not age 4-years and economising at both ages was associated with a greater risk of membership in the 'cessation' trajectory. However, after adjusting for all other factors in the model, only economising at age 9 but not at age 4-years remained significant. Children whose mothers economised at age 9 but not at age 4-years had 3.17 times the risk of following the 'cessation' trajectory than the 'consistent' relative to children whose mothers never economised on fruit or vegetables.

Table 7. Multinomial logistic regression model for toothbrushing trajectory membership by food security[a]

Toothbrushing Trajectories	Unadjusted RRR (95% CI)	Adjusted RRR (95% CI)[a]
Consistent trajectory (Base outcome)		-
Adoption trajectory		
Never economised (a lot) on fruit/ veg (ref)		
Economised at age 4 but not at age 9	1.80 (0.82, 4.00)	2.46 (1.04, 5.80)
Economised at age 9 but not at age 4	1.76 (0.94, 3.29)	1.03 (0.48, 2.24)
Economised at both ages	3.26 (1.22, 8.73)	2.68 (0.92, 7.77)
Inconsistent trajectory		
Never economised (a lot) on fruit/ veg (ref)		
Economised at age 4 but not at age 9	2.78 (1.52, 5.09)	2.93 (1.48, 5.81)
Economised at age 9 but not at age 4	1.97 (1.21, 3.24)	1.24 (0.69, 2.25)
Economised at both ages	3.73 (1.62, 8.60)	2.61 (1.07, 6.40)
Cessation trajectory		
Never economised (a lot) on fruit/ veg (ref)		
Economised at age 4 but not at age 9	2.98 (1.42, 6.26)	2.15 (0.90, 5.16)
Economised at age 9 but not at age 4	3.06 (1.69, 5.52)	3.17 (1.64, 6.15)
Economised at both ages	3.55 (1.30, 9.72)	2.27 (0.74, 6.95)

[a] Controlling for sex, mother's qualifications, homeownership, child's brushing frequency at age 2-years, mother's brushing frequency and use of children's toothpaste

In the third multinomial logistic regression model (Table 8), before adjusting for covariates, all factors were associated with a greater risk of following the 'adoption', 'inconsistent' and the 'cessation' trajectory. After adjusting other factors in the model, all adjusted significant factors in the second model also remained significant in this model. Again, economising at age 4 but not at age 9-years was associated with a greater risk of following the 'adoption'

trajectory than the 'consistent'. Additionally, children whose mothers economised at age 9 but not age 4-years had 4.04 times the risk of following the 'adoption' than the 'consistent' trajectory than children of mothers who never economised. Children of mothers who economised at age 4 but not age 9-years and economised at both ages were again at greater risk of following the 'inconsistent' trajectory after controlling for all other factors. Children of mothers who economised at age 9 but not at age 4-years had 6.15 times the risk of following the 'cessation' trajectory than children of mothers who never economised. Additionally, children of mothers who economised at both ages had 2.65 times the risk of following the 'cessation' trajectory than the 'consistent' trajectory relative to children whose mothers had never economised on fruit or vegetables.

Table 8. Multinomial logistic regression model for toothbrushing trajectory membership by food security[a]

Toothbrushing Trajectories	Unadjusted RRR (95% CI)	Adjusted RRR (95% CI)[a]
Consistent trajectory (Base outcome)		-
Adoption trajectory		
Never economised on fruit/veg (ref)		
Economised at age 4 but not at age 9	2.07 (1.25, 3.44)	3.01(1.64, 5.51)
Economised at age 9 but not at age 4	3.21 (1.18, 8.76)	4.04 (1.21, 13.46)
Economised at both ages	2.57 (1.32, 4.99)	1.94 (0.84, 4.51)
Inconsistent trajectory		
Never economised on fruit/veg (ref)		
Economised at age 4 but not at age 9	2.26 (1.56, 3.26)	2.00 (1.28, 3.11)
Economised at age 9 but not at age 4	2.88 (1.28, 6.51)	2.03 (0.73, 5.61)
Economised at both ages	3.03 (1.84, 4.99)	1.94 (1.04, 3.12)
Cessation trajectory		
Never economised on fruit/veg (ref)		
Economised at age 4 but not at age 9	2.02 (1.23, 3.33)	1.60 (0.88, 2.89)
Economised at age 9 but not at age 4	5.05 (2.03, 12.55)	6.15 (2.12, 17.86)
Economised at both ages	3.54 (1.90, 6.57)	2.65 (1.24, 5.68)

[a] Controlling for sex, mother's qualifications, homeownership, child's brushing frequency at age 2-years, mother's brushing frequency and use of children's toothpaste

Discussion

This research investigated toothbrushing behaviours among Pacific children in New Zealand and their association with personal and family characteristics. Four distinctive trajectories of toothbrushing behaviours among Pacific children in New Zealand were described, and these were closely associated with parents' socioeconomic advantage and mothers' oral self-care behaviours.

Low maternal oral health literacy is associated with poor oral health outcomes (Divaris et al., 2012; Vann et al., 2010) and, consistent with this, we found children's inconsistent toothbrushing behaviours were associated with low maternal education levels. This aligns well with previous work from the PIF study that has reported children of better-educated mothers to be at lower risk of toothache (Paterson et al., 2015). Therefore, mothers with higher education levels may interact pertinently with the healthcare system and health initiatives to introduce and establish favourable toothbrushing behaviours with their children.

The findings from this study revealed that children whose mothers were brushing at least twice daily were less likely to follow the 'adoption' and 'inconsistent' trajectories relative to children whose mothers were not brushing twice daily. These findings align with previous research, which has found the mother's toothbrushing frequency to be a significant predictor of children's toothbrushing (Soltani et al., 2017). During early childhood, maternal influences are of great importance as children are unable to care for themselves and are dependent on their caregivers for their day-to-day care. In addition, the child's mother often influences the adoption of oral hygiene habits during childhood, as the mother provides the primary model of behaviour (Okada et al., 2002). Therefore, the caregiver can be considered the influencer of factors that could impact their child's short and long-term oral health.

Within this study, children of home-owning families had a lower risk of following the 'adoption' trajectory than the 'consistent', relative to children of non-home owning families. Māori and Pacific peoples are the two ethnic groups in New Zealand that disproportionately experience poorer housing outcomes (Statistics New Zealand, 2020). It may be implied that

children of families who own homes were among higher SES. Previous studies have found that parents from low SES households are most likely to start brushing their child's teeth at a later age and are more likely to brush their teeth infrequently (Bach & Manton, 2014). Many New Zealand studies have also found an association between low SES and poorer oral health outcomes among children and adults (Broadbent et al., 2016; Shackleton et al., 2018). This may suggest that children in higher-income families have better opportunities to adopt favourable toothbrushing behaviours, as parents are less likely to experience conditions that make oral hygiene a lower priority.

In New Zealand, proportionally, more children of Pacific ethnicity live in households where food runs out sometimes or more often than children of other ethnicities (Child Youth Wellbeing, 2021). Within this study, a time-ordered association was observed whereby children whose mothers started economising on fruit and vegetables were more likely to stop brushing as they got older. The converse was observed among those who were able to stop economising on fruit and vegetables. Those whose mothers economised on fruit and vegetables at both ages 4 and 9-years were significantly more likely to have an unfavourable toothbrushing trajectory than those who never had to economise. In line with this finding, New Zealand children aged 2 to 15-years living in food-insecure households have higher tooth extraction rates than children in food-secure households (Ministry of Health, 2019). As food insecurity reflects household SES, it may suggest that those economising on fruit or vegetables experience financial barriers to accessing oral self-care products. Having to economise on food may also be an example of why self oral care may become a lower priority.

Toothbrushing frequency at 2-years was significantly associated with the 'cessation' trajectory group before adjusting for mother's brushing frequency, toothpaste type of use, child's sex, maternal education level and homeownership. However, no statistical significance was found between the 'cessation' group and toothbrushing frequency at age two after adjusting for other factors but remained close to significant. It is reasonable to assume that the factor likely loses its significance due to the lower number of children in the group. Preventive practices established during early life are important determinants of dental health several years later.

Children using a children's toothpaste had a lower risk of following the 'inconsistent' trajectory than children in the 'consistent' group relative to children using an adult's/generic toothpaste. The American Academy of Paediatric Dentistry recommends that children under six use children's toothpaste with fluoride concentrations lower than 500ppm to avoid potential fluorosis and ingesting traces of fluoride when brushing (Sockalingam et al., 2010; Walsh et al., 2010). In the current study, less than half of the participating children, aged six, used children's toothpaste. Although this study is unable to conclude the reason behind the use of either a children's or adult's/generic toothpaste, it may be hypothesised that children using a children's toothpaste were more likely to follow the 'consistent' trajectory because their parents were aware of favourable toothbrushing recommendations and implemented the behaviours among their children.

More male than female children followed the 'inconsistent' than the 'consistent' trajectory. Other studies have also reported better oral hygiene behaviours among females than males during adolescence and adulthood (Lipsky et al., 2021; Poutanen et al., 2007), but data from early childhood is scarce. A New Zealand study reported males to be almost three times more likely to have poor lifetime dental plaque than females (Broadbent et al., 2011), suggesting that poor oral hygiene behaviours among males may continue from childhood to adulthood. It has been suggested that more females have favourable oral hygiene behaviours, as they often care more about their appearance and implement favourable oral hygiene habits to maintain or improve the appearance of their dentition (Kateeb, 2010; Poutanen et al., 2007). This may not necessarily be true for young children but rather may be due to cognitive-based factors and developmental differences between boys and girls during early childhood (Morrongiello & Rennie, 1998).

Strengths and Weaknesses of the Study

The PIF Study is the first birth cohort study to report longitudinally on the oral health behaviours of Pacific peoples; therefore, the findings presented in the current study are unique and add valuable knowledge to the relatively limited body of knowledge on Pacific oral health. Unfortunately, no comparable studies exist, and thus, it is difficult to compare the findings from this study to other studies. There is also a lack of comparable data from other

ethnic groups in New Zealand, as other cohort studies have not collected such data on toothbrushing behaviours.

Another significant strength of the study is the cultural appropriateness maintained in the procedures and methods undertaken to collect the data used in this study. Pacific input from communities, appropriate healthcare and researchers were sought and obtained at all stages of the study, allowing credibility and, importantly, cultural safety throughout the PIF study. The sample is also broadly representative of New Zealand's ethnic make-up of the Pacific population, as the inception cohort was found to be ethnically representative of the 1996 and 2001 New Zealand census figures for the Pacific population (Paterson et al., 2004).

An important limitation of this study is the reliance on self-report data on toothbrushing behaviours and related variables, as some response bias may have occurred; for example, participants may have over-reported their toothbrushing behaviours in order to project a socially desirable self-image. However, self-report is the only feasible means of collecting such data.

Implications

As poor oral health in early childhood is highly predictive of poor oral health later in life (Heilmann et al., 2015), favourable toothbrushing behaviours should be introduced and established during early childhood. To achieve favourable toothbrushing behaviours for Pacific children in New Zealand, there is a need for contemporary and collective approaches to achieving this through personal, family, community, and national levels.

Financial barriers to toothbrushing should be removed. Findings from this study indicate that toothbrushing behaviours are strongly associated with mothers' economising on food. This has important implications for health policy with respect to access to dentifrice products and presents an argument for the removal of cost as a barrier to accessing oral self-care products for children.

This study's findings lend support to the New Zealand government's recently implemented initiative to provide toothbrushes and toothpaste to New Zealand pre-schoolers. Supply of

toothbrushes and fluoride toothpaste to children as a public goodwill will likely result in better access to these essential self-care resources for the most disadvantaged children and may enable early uptake of toothbrushing behaviours. A supervised toothbrushing programme among school children should also be promoted to improve toothbrushing behaviours and should have a particular focus on male, Pacific, Māori or socioeconomically deprived children.

Findings from this study suggest that toothbrushing behaviour interventions targeting young children should focus on both the children and their caregivers, particularly novice or socioeconomically disadvantaged mothers. The health system could support this by ensuring that all health workers, whether oral health therapists, dentists, midwives, and Plunket nurses, routinely include discussion of healthy oral self-care behaviours at appointments for parents as well as for children. In educational settings, such as schools and early childhood education centres, oral self-care could be taught in order to benefit children who might otherwise miss out on this at home. South Auckland, where most of New Zealand's Pacific people reside, could be an essential area to roll out such strategies.

Further research is needed into personal, family and community-level factors associated with the toothbrushing trajectories, whether these trajectories persist into adolescence and adulthood, and the extent to which they relate to oral health outcomes. Intervention studies should be conducted to investigate effective strategies for improving outcomes for children who follow unfavourable toothbrushing trajectories. Additionally, further research using qualitative methods is also needed to determine reasons or factors contributing to economising on food and access to oral self-care products.

Conclusion

Distinct trajectories of toothbrushing, closely associated with parents' socioeconomic advantage and mothers' oral self-care behaviours, exist during the early years of life among Pacific children in New Zealand. Toothbrushing behaviours can form early in life; hence, early childhood is an ideal time point to introduce and establish favourable toothbrushing behaviours. The current study's findings can provide stakeholders, such as policymakers, with evidence to help remove financial barriers to toothbrushing and promote supervised toothbrushing programmes at schools to improve and establish favourable toothbrushing behaviours. The current study also suggests that toothbrushing behaviour interventions targeting young children should focus on both the children and their caregivers, particularly novice or socioeconomically disadvantaged mothers. Further research examining toothbrushing trajectories into adulthood and associated oral and general health outcomes among Pacific peoples in New Zealand will help to better understand the current study's long-term implications.

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