The pattern of association between early childhood caries and body mass index in pre-school children within Aotearoa | New Zealand: a national cross-sectional study.

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ORIGINAL ARTICLE

The pattern of association between early childhood caries and body mass index in pre-school children within Aotearoa | New Zealand: a national cross-sectional study

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Abstract

Objectives: The relationship between childhood anthropometric measurements and dental caries has an inconsistent evidence-base. This study investigated dental caries experience and body mass index (BMI) measurements of children aged 4 years in a national cohort, after accounting for key confounding variables.

Methods: A near whole-population cross-sectional study of children who had a health and developmental assessment, as part of the nationwide B4 School Check screening program, conducted in Aotearoa | New Zealand (ANZ) between 1 July 2010 and 30 June 2021 was studied. The extracted database included 582 820 children, of whom 572 523 (98.2%) had valid BMI and oral health records. Dental caries experience was derived from the 'lift the lip' oral health screening, and measured height and weight were used to calculate sex-specific BMI-for-age z-scores (BMIz). Analyses were adjusted for age, sex, ethnicity and area-level deprivation. Modified Poisson regression models using 2-degree fractional polynomial curves for BMIz were employed.

Results: In the extracted sample, the median age was 4.3 years (interquartile range: 4.1–4.5 years), 283 565 (48.7%) were female, 135 734 (23.4%) and 74 237 (12.8%) were identified as Māori and Pacific, respectively, and 140 931 (24.4%) lived in the most deprived areas of ANZ. Overall, 81 926 (14.2%) had dental caries identified. In unadjusted analyses, a significant J-shaped association was observed between dental caries experience and BMIz. However, in the adjusted analysis, a significant flattened S-shaped association was found; those with lower BMIz had lower predicted probabilities of dental caries experience. Large differences in predicted probabilities were observed between different sex, ethnicity and area-level deprivation groups.

Conclusions: This study found significant non-linear associations between dental caries experience and BMI in 4-year-old children. However, the inclusion of confounders importantly changed the shape of this non-linear association. Sex, ethnicity and area-level deprivation inequalities had a greater impact on dental caries experience than BMI.

KEYWORDS
anthropometric measurements, caries, children, epidemiology, inequalities, oral health, overweight and obesity

1 | INTRODUCTION

Childhood obesity and dental caries are significant and complex global health issues, fuelled by aggressive commercial determinants of health together with wide social and health inequalities.[1,2] Both these relatively common conditions have prevalence which increase with age, have life-long mental and physical health sequelae, and yet are largely preventable.[3–5] Radical action has been forcefully advocated targeting the underlying social and commercial determinants, and common risk factors shared between these and other non-communicable diseases.[5,6] Coherent and comprehensive regulation, legislation, and taxation are needed to tackle these shared risk factors, and it is critical to move from treatment dominated interventionist paradigms to culturally appropriate prevention strategies.[6,7]

While seemingly straightforward, the relationship pattern between childhood obesity and dental caries is heavily confounded and has an inconsistent evidence-base.[8] In 2015, Public Health England (PHE) published an evidence summary on the relationship between obesity and dental caries.[9] Their review found that children living with obesity had higher dental caries rates than children of a healthy weight. Moreover, an increased dental caries prevalence in underweight and overweight children was also noted.[9] This non-linear association was also noted in a 2012 systematic review.[8] A later PHE report, published in 2019, showed that underweight, overweight and very overweight children were more likely to have experienced dental caries than their healthy weight counterparts.[10] However, when controlling for deprivation, ethnicity and water fluoridation status, the likelihood of having dental caries was significantly higher only for those children who were overweight and very overweight.[10] Further conflicting this evidence-base, others elsewhere have shown no association between childhood obesity and dental caries.[8,11]

These mixed and inconsistent results have motivated yet further studies and systematic reviews. A 2015 systematic review of longitudinal studies found the evidence for the association between anthropometric measurements and dental caries was both conflicting and inconclusive.[12] A subsequent 2018 systematic review found no consensus in the relationship between body mass index (BMI) and dental caries in children, due to the varied reported associations.[13] Another 2019 systematic review of BMI and dental caries in younger children found equivocal evidence, and called for longitudinal studies to help shed light on this complex relationship.[14] Multiple study weaknesses were identified within these systematic reviews, most importantly the need to control for confounding (of which ethnic and economic variables stand-out[10]), capture the full range of BMI scores to adequately represent underweight, normal, and overweight and obese participants, consider the possibility of a non-linear association between dental caries and BMI, and employ standardized diagnostic methods for dental caries and BMI measurement so that more accurate conclusions can be drawn.[8,12–14] Until these methodological weaknesses are resolved, it has been opined that inconclusive and equivocal evidence will continue to be found.[8,14]

Like many countries, Aotearoa | New Zealand (ANZ) has a national program (named: Well Child Tamariki Ora) of health visits and support that are cost-free to all families for children from age 6 weeks to 5 years. It aims to support and promote the healthy development of children and their families. The B4 School Check (B4SC), the eighth and final contact within this program, screens 4-year-old children with a focus on identifying any social, developmental or behavioural issues which could potentially interfere with children's learning and success at school.[15] In addition to various demographic and health measures, the B4SC includes assessments of height, weight and a 'lift the lip' oral health screen using standardized procedures and instruments.[16] A subset of these B4SC data have been previously successfully used to charted significant and substantial unequal ethnic, economic and community water fluoridation gradients in dental caries experiences.[17,18] They have also been used to investigate trends in the prevalence of overweight and obesity.[19] By bring together these variables, and including an extended time-frame, this study aims to investigate the relationship between 4-year-old children's dental caries experience and BMI measurements for a near national cohort, after accounting for key confounding variables and addressing many of the previously identified limitations.

2 | METHODS

2.1 | Study design

Secondary cross-sectional data analysis of a national screening programme.

2.2 | Participants

New Zealand children aged between 4 years and 5 years 7 days who had their B4SC assessment between fiscal years (1 July until 30 June) 2010/2011 to 2020/2021, inclusive. Children with incomplete B4SC checks or who had no oral health screening records were excluded.

2.3 | Procedure

A comprehensive description of B4SC procedures is detailed elsewhere.[16] It is a free nationwide programme offering a set of wide-ranging health and development checks for 4-year-olds. In brief, after receiving informed written consent, B4SC assessments are conducted by trained registered nurses or nurse practitioners in various community locations and normally take between 45 and 60 minutes to complete. If concerns are identified, information is offered and support provided which include clinical pathways and referral processes.[16] The B4SC National Information System within the Ministry of Health (MoH) houses data relating to the child, permission, assessments and checks, issues identified and any referrals made. This system is designed to provide non-identifiable information for monitoring the performance of the B4SC programme, for tracking the population health status of 4-year-olds, and for approved research studies.[16] After ethics clearance and MoH application and approval, anonymous unit record data were released for the variables described below.

2.4 | Primary measures

The oral health screening component of the B4SC involves a 'lift the lip' assessment where children's teeth are classified, in the documentation provided to the B4SC nurses, using a series of six photographs, as: no visible dental caries (1); chalky patches and enamel breakdown (2); clearly visible decayed front teeth (3); well advanced decay (4); roots only of the top teeth remaining (5); and deep decay in back teeth (6).[16,18] Using a previously defined dichotomous classification,[17,18] dental caries experience was indicated by combining categories (2)–(6).

Anthropometric measurements were also undertaken by the nurse or practitioners, who received training and a handbook outlining best-practice protocols.[16] These included measuring the children while they were wearing light clothing with shoes removed, with the equipment stable on a levelled hard surface. Height was to be measured to the nearest 0.1 cm using a portable stadiometer (either Leicester Height Measure or a SECA 214) and weight to the nearest 0.1 kg using a SECA 862 electronic floor scale or Tanita WB 100S MA floor scale (or SECA 770 or Tanita HD-351 weighing scale; calibrated at least once every 6 months).[19] BMI was then derived by dividing each child's weight by their height squared (i.e., kg/m^2). The Centers for Disease Control and Prevention (CDC) SAS program was then used to derive sex-specific BMI for age z-scores (BMIz).[20] Output from this SAS program also contained a variable for biologically implausible BMIz values coded as −1 (for modified z-scores < -4), +1 (for modified z-scores > 8) and 0 otherwise. Aligned with the World Health Organization's Child Growth Standards,[21,22] BMIz were descriptively classified by the CDC SAS programme into five categories, namely wasted (BMIz < -2); normal ($-2 \le$ BMIz < 1); at risk of overweight ($1 \le$ BMIz < 2); overweight ($2 \le$ BMIz < 3); and obese ($3 \le$ BMIz).[20]

2.5 | Sociodemographic variables

All sociodemographic characteristics were derived from the B4SC dataset. Sex was categorized as girls and boys. Age (in months) was calculated from B4SC assessment and birth dates. Ethnicity was based on parental/caregiver report, which allows for multiple identifications.[23] Using the total response approach, whereby categories are not mutually exclusive and individuals could belong to multiple groups, ethnicity was categorized into Māori, Pacific, Asian, Middle Eastern/Latin American/African (MELAA) and European/Other groups. Māori are the descendants of indigenous inhabitants of ANZ, while the other groups are comprised of people or descendants from many nationalities and ethnicities within each region. A meshblock defined area-level deprivation measure was employed, the New Zealand Deprivation Index 2013 (NZDep2013).[24] Meshblocks are the smallest geographic unit for which statistical data are collected and processed by Statistics New Zealand. In 2013, ANZ was partitioned into 46 637 meshblock units (typically populated by 60–110 people).[25] The NZDep2013 combines 2013 census data relating to income, home ownership, employment, qualifications, family structure, housing, access to transport and communications into a single measure. Each meshblock is assigned a score, and quintile splits were used to define 1 (least deprived) through to 5 (most deprived) scores. The child's recorded residential address at their B4SC assessment was used to assign their NZDep2013 deprivation score. This assignment was undertaken within the MoH, and all addresses and meshblock identifications were removed prior to the research database release.

2.6 | Statistical analysis

Reporting of this study was informed by the STROBE and RECORDS guidelines (see Supplementary materials S1).[26] Initially, participant flow and sociodemographic characteristics were described. Because the dental caries experience outcome of interest was not rare, modified Poisson regression models (with log-link function and robust variance estimators) were used in unadjusted and adjusted analyses.[27] In these models, BMIz were related to children's oral health status using fractional polynomial curves[28] and included only biologically plausible values. Aligned with the recommendations of Royston and Sauerbrei,[29] degree-2 fractional polynomial powers of BMIz were considered from the set (−2; −1; −0.5; 0; 0.5; 1; 2; 3). To avoid negative z-score values, $\Delta = 6$ was added in these regression models. The Bayesian information criterion (BIC) was used to select between these competing models.[30] The BIC rewards for goodness-of-fit to the data but penalizes for model complexity, with the preferred model balancing these opposing demands and yielding the lowest BIC statistic. In the adjusted models, age, sex, ethnicity and deprivation score main effects were added together with all their two-factor interaction terms. Due to the large sample size, and in the spirit of Sun and colleagues,[31] the adjusted regression model was analysed without any variable selection. All analyses were performed using Stata SE version 17.0 (StataCorp), and two-tailed $\alpha = .05$ defined significance.

2.7 | Ethics

ANZ's Health and Disability Ethics Committee (HDEC) defined this study as minimal risk observational research, not needing formal ethics committee review or further participant consent. Use and release of de-identified B4SC data was approved by the MoH. All methods were performed in accordance with HDEC's and MoH's relevant guidelines and regulations.

3 | RESULTS

3.1 | Participants

As of 7 March 2022, the full B4SC data set contained information on 834 262 children. Applying the exclusion criteria, left 582 820 (69.9%) within the research database released by the MoH; see Figure 1.

3.2 | Sociodemographic characteristics

The sociodemographic characteristics of children included in the eligible sample is presented in Table 1. This eligible sample had a median age of 4.3 years (interquartile range: 4.1–4.5 years), 283 565 (48.7%) were girls, and 140 931 (24.4%) lived in the most deprived quintile. Multiple ethnic identifications were common, with 74 753 (12.9%) participants having two and 8253 (1.4%) having three or more groupings from the 581 148 participants with valid ethnicity values. Of the 364 920 children identified as European or other, only 4127 (1.1%) were originally identified as 'other'.

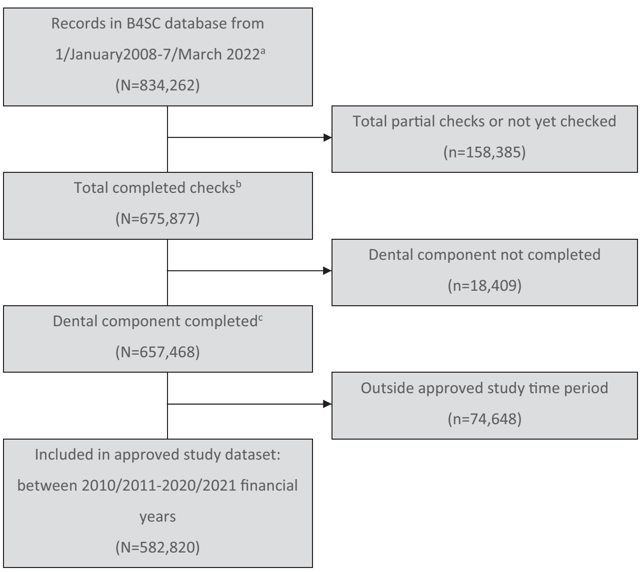

FIGURE 1 Participant flowchart. [a]sourced from the "Completed Closed Assigned" extract and reflects the total number of records where the status of the check is either "Completed", "Closed", "Assigned" or "Returned" (does not include records of children who have not yet been assigned to a B4SC provider); [b]a check is classified as completed if the child's National Health Index (NHI) has a current status of "Complete" or "Closed" (the NHI is unique identifier that is assigned to every person who uses health and disability support services in ANZ); the NHI has an assigned date first completed and the date first completed occurs while the child is between 4 years and 5 years 7 days; creflects records where there is a reported dental check outcome indication.

3.3 | Body mass index (BMI)

BMI values were calculable for 577 261 (99.0%) participants. Of these, 920 (0.2%) participants had biologically implausible value coded as −1 and 1120 (0.2%) had a code of +1. Those with implausible values had their BMI set to missing, leaving 575 221 participants with plausible BMI values. Figure 2 depicts histograms of both the BMI and BMIz for these participants. When applying the CDC SAS program derived BMIz classifications, 12 304 (2.1%) participants were defined as being wasted, 375 923 (65.4%) normal, 147 002 (25.6%) at risk of overweight, 33 043 (5.7%) overweight and 6949 (1.2%) participants as being obese.

3.4 | Oral health status

Although the completed dental component formed an integral part of the eligibility criteria (see Figure 1), the progression of decay variable contained missing or invalid data for 5875 (1.0%) participants. Using the 'lift the lip' classification, 576 945 participants had valid data of whom 495 019 (85.8%) had no visible dental caries; 44 871

TABLE 1 Sociodemographic characteristics of 582 820 children included in the eligible sample.

Characteristic	*n*	(%)
Sex[a]		
Girls	283 565	(48.7)
Boys	299 148	(51.3)
Ethnicity[b]		
Māori	135 734	(23.4)
Pacific	74 237	(12.8)
Asian	86 087	(14.8)
MELAA[c]	11 429	(2.0)
European or other	364 920	(62.8)
Level of deprivation (NZDep2013)[d]		
1 (least deprived)	112 497	(19.4)
2	107 574	(18.6)
3	106 909	(18.5)
4	110 741	(19.1)
5 (most deprived)	140 931	(24.4)

[a]107 (<0.1%) values missing or unknown.
[b]1672 (0.3%) values missing or unknown.
[c]MELAA denotes Middle Eastern/Latin American/African ethnicity.
[d]4168 (0.7%) values missing or unknown.

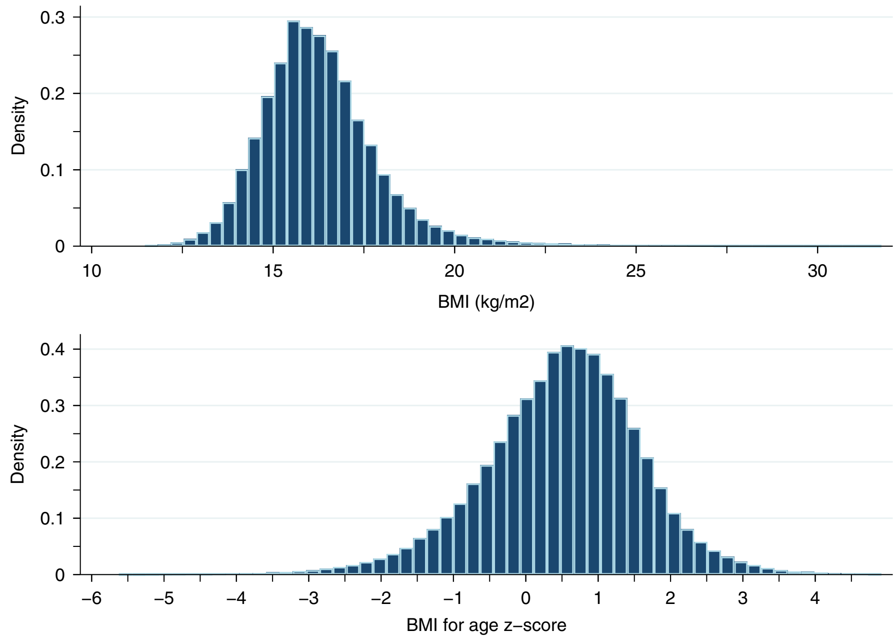

FIGURE 2 Histograms of BMI (top) and BMI for age z-scores (bottom) for 575 221 participants with valid biological plausible values.

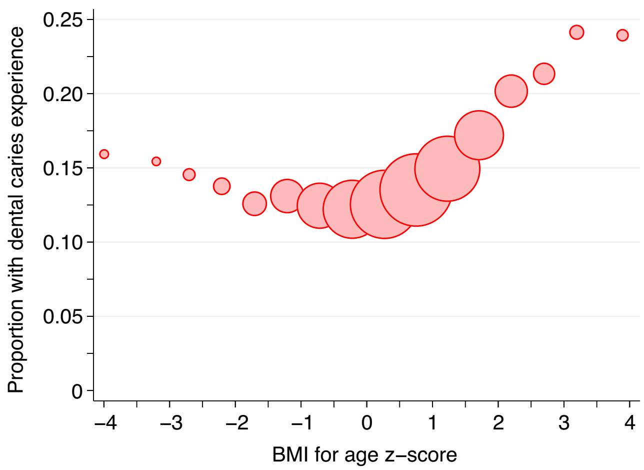

FIGURE 3 Bubbleplot of the dental caries experience proportion over BMI for age z-scores partitioned into intervals of 0.5 between −3.5 and 3.5 (along with <−3.5 and >3.5 groupings), weighted by participant numbers.

(7.8%) had chalky patches and enamel breakdown; 15 588 (2.7%) had clearly visible decayed front teeth; 6023 (1.0%) had well advanced decay; 3247 (0.6%) had roots only of the top teeth remaining; and 12 197 (2.1%) had deep decay in back teeth. Collapsing categories (2)–(6) resulted in 81 926 (14.2%) participants classified as having dental caries experience.

3.5 | Unadjusted analysis

In total, 572 523 (98.2%) participants had both valid recorded dental and biologically plausible BMI values available for analysis. Figure 3 presents a bubbleplot of the dental caries experience proportion over BMIz partitioned into intervals of 0.5 between −3.5 and 3.5 (along with <−3.5 and >3.5 groupings). The size of the bubbles reflects the relative sample numbers in each partition. Figure 3 appears to exhibit a J-shaped association between dental caries experience and BMIz, with the proportion of dental caries initially decreasing with increasing BMIz, but then increasing for BMIz values above zero. Applying degree-2 fractional polynomial powers of BMIz to modified Poisson regression models of dental caries experience supported this observation. The preferred model, with minimized BIC, included significant linear and quadratic functions of BMIz (both $p < .001$), given by:

$$\text{P(dental caries experience)} = \exp\left(0.1273 + 1.0840 \times \text{BMIz} + 1.0386 \times \text{BMIz}^2\right)$$

Figure S1 within the supplementary materials presents the predicted probabilities of dental caries experience over BMIz derived from this preferred model.

3.6 | Adjusted analysis

Degree-2 fractional polynomial powers of BMIz were then investigated in the modified Poisson regression models which also included age, sex, ethnicity and deprivation score main effects together with all their two-factor interaction terms. Complete data were available for 566 863 participants, and the preferred model included terms $(\text{BMIz}+\Delta)^3$ and $\ln(\text{BMIz}+\Delta)\times(\text{BMIz}+\Delta)^3$ with BIC = 437654.3 (d.f. = 53). This preferred model, which included all two-factor interaction terms, was superior to the preferred model which only included main effect terms (BIC = 438059.6, d.f. = 14). Coefficient estimates and associated 95% CIs of the preferred fractional polynomial multivariable modified Poisson regression models appear in Table 2.

While both BMIz terms in this adjusted model were significant ($p = .002$ and $p = .007$, respectively), their association with dental caries scores was modest, and the J-shaped association observed within the unadjusted analysis dampened considerably. Figure 4

TABLE 2 Coefficient estimates and associated 95% confidence intervals of the preferred fractional polynomial multivariable modified Poisson regression models of dental caries experience for considered main effects and two-factor interaction terms ($N = 566\,863$).

Variable	est.	(95% CI)	Variable	est.	(95% CI)	Variable	est.	(95% CI)
$(\mathrm{BMIz}+\Delta)^3$	0.0011	(0.0004, 0.0018)	Māori by sex (G)	0.028	(−0.007, 0.062)	Asian by age	0.161	(0.085, 0.237)
$\ln(\mathrm{BMIz}+\Delta)\times(\mathrm{BMIz}+\Delta)^3$	−0.0004	(−0.0007, −0.0001)	Māori by Dep.			MELAA ethnicity		
Sex			Māori × 2	−0.011	(−0.109, 0.087)	No	0	(reference)
Boy	0	(reference)	Māori × 3	0.031	(−0.059, 0.122)	Yes	−0.253	(−0.984, 0.478)
Girl	−0.237	(−0.428, −0.046)	Māori × 4	0.004	(−0.081, 0.090)	MELAA by sex (G)	0.021	(−0.074, 0.115)
Level of deprivation			Māori × 5	−0.096	(−0.177, −0.016)	MELAA by Dep.		
1 (least deprived)	0	(reference)	Māori by age	0.163	(0.105, 0.221)	MELAA × 2	−0.020	(−0.214, 0.175)
2	0.709	(0.256, 1.163)	Pacific ethnicity			MELAA × 3	−0.200	(−0.391, −0.009)
3	0.032	(−0.399, 0.463)	No	0	(reference)	MELAA × 4	−0.152	(−0.331, 0.027)
4	0.433	(0.023, 0.843)	Yes	0.405	(0.129, 0.681)	MELAA × 5	−0.318	(−0.486, −0.150)
5 (most deprived)	0.916	(0.523, 1.308)	Pacific by sex (G)	0.040	(0.004, 0.076)	MELAA by age	0.078	(−0.085, 0.241)
Sex by level of Dep.			Pacific by Dep.			Euro/O ethnicity		
Girl × 2	−0.002	(−0.059, 0.055)	Pacific × 2	0.126	(0.012, 0.241)	No	0	(reference)
Girl × 3	0.005	(−0.050, 0.060)	Pacific × 3	0.002	(−0.106, 0.110)	Yes	−1.950	(−2.236, −1.664)
Girl × 4	0.034	(−0.018, 0.087)	Pacific × 4	−0.007	(−0.109, 0.095)	Euro/O by sex (G)	−0.021	(−0.058, 0.017)
Girl × 5	0.030	(−0.019, 0.080)	Pacific × 5	−0.076	(−0.174, 0.021)	Euro/O by Dep.		
Age (years)	0.283	(0.183, 0.383)	Pacific by age	−0.008	(−0.067, 0.052)	Euro/O × 2	−0.032	(−0.131, 0.067)
Sex (G) by age	0.031	(−0.011, 0.072)	Asian ethnicity			Euro/O × 3	0.007	(−0.085, 0.099)
Dep. by age			No	0	(reference)	Euro/O × 4	0.019	(−0.068, 0.105)
2 × age	−0.110	(−0.211, −0.009)	Yes	−0.226	(−0.568, 0.116)	Euro/O × 5	0.110	(0.028, 0.191)
3 × age	0.074	(−0.021, 0.170)	Asian by sex (G)	−0.025	(−0.070, 0.020)	Euro/O By age	0.267	(0.204, 0.329)
4 × age	0.026	(−0.065, 0.117)	Asian by Dep.					
5 × age	−0.003	(−0.091, 0.084)	Asian × 2	−0.119	(−0.224, −0.014)	Constant	−3.537	(−3.983, −3.091)
Māori ethnicity			Asian × 3	−0.245	(−0.345, −0.146)			
No	0	(reference)	Asian × 4	−0.406	(−0.500, −0.312)			
Yes	−0.438	(−0.705, −0.172)	Asian × 5	−0.681	(−0.770, −0.592)			

Abbreviations: BMIz, BMI for age z-score; $\Delta = 6$; G, girl; Dep, level of deprivation; MELAA, Middle Eastern/Latin American/African; Euro/O, European/other ethnicity.

presents the predicted probability of dental caries experience for children aged 4.5 years derived from this preferred adjusted model using two scenarios: (i) the group yielding the highest risk of dental caries (girls residing in most deprived areas and identified as having Pacific ethnicity); and, (ii) the group yielding the lowest risk of dental caries (boys residing in the least deprived areas and identified as having European or other ethnicity). This figure forcefully illustrates the large inequities in predicted dental caries experience between these two sub-populations and a significant but relatively modest increase in predicted dental caries score for increasing BMIz; an increase which appears to plateau for higher z-score values.

4 | DISCUSSION

In this large, ANZ national study of 4-year-old children, when fitting a non-linear model from a flexible class of degree-2 fractional polynomial powers, a clear and significant J-shaped association between dental caries experience and BMIz was observed within the unadjusted analysis; a pattern similar to that reported in the PHE 2015 evidence summary.[9] However, with the addition of confounders and their two-factor interaction terms, this J-shaped association was dampened, and the elevated caries rates associated with the lower BMIz lost; confirming findings within the updated PHE 2019 report.[10] In the preferred adjusted model, the predicted probability of dental caries experience was lowest among children with BMIz classified as wasted (BMIz < −2), increasing through the normal to at risk of overweight classifications (−2 ≤ BMIz < 2), and then plateauing over the overweight and obesity categories (BMIz ≥ 2). This preferred model included cubic and cubic multiplied by a logarithmic

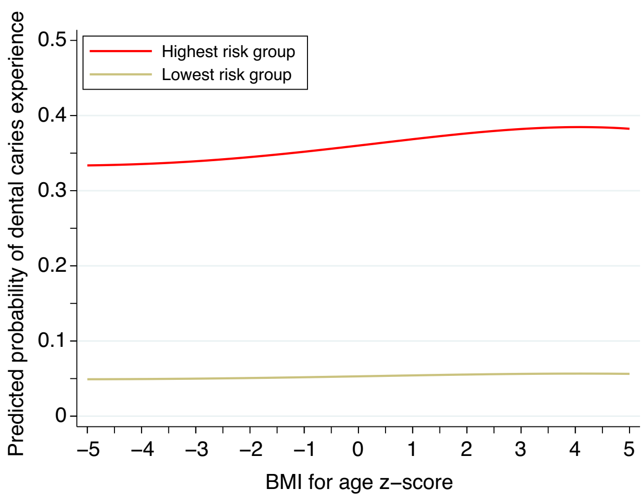

FIGURE 4 Predicted probability of dental caries experience derived from the preferred adjusted modified Poisson regression model for two scenarios with children aged 4.5 years: (i) the group yielding the highest risk of caries experience (girls residing in most deprived areas and identified as having Pacific ethnicity); and, (ii) the group yielding the lowest risk of caries experience (boys residing in the least deprived areas and identified as having European or other ethnicity).

term for BMIz—which gives a flattened S-shaped association. This underlines the call for non-linear investigations made earlier.[8,10]

While a significant non-linear pattern between dental caries experience and BMIz was identified in our findings, this statistical effect was largely overshadowed by sex, ethnicity and deprivation inequalities. For children aged 4.5 years, the predicted probability of dental caries experience in the highest risk group (girls residing in most deprived areas and identified as having Pacific ethnicity) ranged from 0.334 to 0.385 over the entire −5 ≤ BMIz ≤ 5 range, approximately 6.8 times higher than those in the lowest risk group (boys residing in the least deprived areas and identified as having European or other ethnicity) which ranged from 0.049 to 0.057. These within group predicted probability changes were negligible when compared to the between group changes. So while understanding the pattern between dental caries experience and BMIz is of considerable interest and research energy, understanding and addressing their underlying common drivers and modifiable confounders will have a profoundly larger impact.[6]

Although ethnicity was a key variable used to determine high and low risk groups, along with sex and deprivation, it must be strongly emphasized that the dental caries score and BMIz patterns observed in this study are likely predominantly, if not entirely, due to commercial and social determinants of health inequities between children rather than any intrinsic cultural or ethnic differences. While Māori and Pacific children are more likely to have early childhood dental decay,[18] and carry a disproportionate burden of overweight and obesity,[17] individually targeted health promotion or interventions alone are likely to be ineffectual set against an obesogenic environmental backdrop that includes aggressive and largely unregulated marketing of unhealthy products towards children and their parents.[1] Māori and Pacific children's relatively high dental caries rates are influenced by many social and economic factors, environmental factors, and barriers to healthcare, but also result from the negative consequences of colonization, ongoing systemic racism and blame.[32,33] For many Māori and Pacific people, this manifests in whakamā (feeling shame, self-abasement, inferiority, self-doubt, shyness, excessive modesty and withdrawal) resulting in avoidance and even distrust in dental services.[34,35] Colonization and racism, coupled with issues that afflict many families who live with socioeconomic pressures,[36] results in Māori and Pacific people engaging with dental or any health professionals only if absolutely necessary and often when in extreme discomfort. Moreover, there are mixed health messages around the importance of baby teeth which only exacerbate the ongoing dental care behaviours as children get older.[37] The solutions are complex and their pathways require application to multiple levels,[6] but at the least need to be culturally inclusive of many non-English first-language communities. It is also important to note that even in the highest risk group, the majority of children had predicted probabilities of being caries-free (ranging from 0.615 to 0.666).

The study has both strengths and weaknesses. By design, the study's primary strengths were aimed to address many of the methodological weaknesses highlighted previously.[8–10,14] It included a large national sample capturing a full range of BMIz measures, an investigation using non-linear methods, and important confounders were considered. Anthropometric measurements were also measured against a strict best-practice protocol.[16] However, the primary weaknesses included the dental caries experience variable, the cross-sectional design and the incomplete control of confounding. The dental caries experience variable was derived from the 'lift the lip' screenings. While this score has good face validity and has been used in various guises within previous studies,[17,18,38] it has yet to be clinically validated. The cross-sectional design limits any temporal investigations or causal assertions, although, in this instance, the primary aim was to investigate the relationship between dental caries assessment and BMI measurements rather than make any causal statements. Deprivation was measured using an area-level combination and weighting of variables. This geo-spatial rather than individually elicited variable may introduce bias through unaccounted clustering and the associated ecological fallacy. However, the large number of meshblocks, and the NZDep2013's rigorous derivation, likely mitigates the effect of this bias and yields an adequate proxy for participants' socioeconomic condition. Finally, other oral health and weight related confounding factors (such as diet) were unavailable. Unmeasured confounding variables can result in substantial bias in the estimated exposure-outcome relationship.[39] Study replication in different contexts, using different suites of variables and age ranges, would help produce a more consistent evidence-base for this relationship. Moreover, as has been suggested elsewhere,[12,14] high quality longitudinal designs will be useful in ascertaining whether the observed patterns remain age-invariant or change with passing years.

In conclusion, this study identified a non-linear relationship between 4-year-old children's dental caries experience and BMI measurements. In unadjusted analyses, this association appeared to be J-shaped, with children classified as wasted, at risk of overweight, overweight and obese having higher rates of dental caries. However, after controlling for key confounders, this association changed to a flattened S-shape, with children's BMIz classified as wasted having the lowest predicted probabilities of dental caries experience. These findings highlight the need for a full range of BMI measures, an investigation using non-linear methods and the inclusion of important confounders. However, the relative change in dental caries predicted probability associated with BMI paled to the changes associated with sex, ethnicity and deprivation inequalities. The findings underline the importance of addressing the commercial and social determinants of health, together with recognizing the impact of colonization and ongoing systemic racism, in stemming children's oral health and anthropometric inequalities.

AUTHOR CONTRIBUTIONS

PJS is the guarantor. PJS conceptualized and designed the study, and led the ethics application and data requests with assistance from MH, AA-D, JK and ML. SS performed the data extraction used to derive the research dataset. PJS analysed the data and led the drafting of the manuscript. All authors contributed to manuscript revisions prior to submission and during revisions. All authors have read and agreed to the published version of the manuscript.

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CONFLICTS OF INTEREST

The authors declare no competing interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the MoH but restrictions apply to the availability of these data, which were used under licence for the current study, and so are not publicly available. Data are, however, available from the authors upon reasonable request and with permission from the MoH.

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