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ORIGINAL ARTICLE

Severe dental caries is associated with incidence of thinness and overweight among preschool Chinese children

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ABSTRACT

Objective: To examine the association of incidence and baseline prevalence of severe dental caries with incidences of thinness and overweight among pre-school Chinese children.

Materials and methods: A longitudinal study design was used. A total of 772 children recruited from 15 kindergartens in Liaoning Province who completed baseline and follow-up assessments were included. The age range of children at baseline was 24.6–71.1 months. BMI-for-age *z*-score was calculated to estimate incidence of thinness and overweight. Severe dental caries was indicated by pulpal involvement, ulceration, fistula or abscess (pufa). Baseline prevalence of severe caries included children with pufa $\geq$1, incidence included those who changed from pufa = 0 to $\geq$1 at follow-up. Logistic regression was constructed to assess the association of baseline prevalence and incidence of severe caries with each of incidence thinness and overweight.

Results: Children with incidence of severe caries had higher odds for incidence thinness (OR: 4.08; 95% CI: 1.08, 15.41). Baseline prevalence of severe caries was not significantly associated with incidence thinness. Participants with severe caries at baseline had higher odds for incidence overweight (OR: 2.33; 95% CI: 1.17, 4.63). The relationship between incidence of severe caries and incidence overweight was insignificant.

Conclusions: The findings suggest a U-shaped relationship between severe dental caries and both ends of anthropometric measures among pre-school Chinese children. The findings highlight the importance of integrating oral and general health promotion policies. Primary health care providers are encouraged to incorporate dental screening, counselling and referral for treatment for severe caries to promote appropriate growth and overall health of children.

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Introduction

The economic and nutritional transitions in China are accompanied by a shift in traditional diet from grains to meat and sugars, which has become an essential part of Chinese diet [1]. The increasing consumptions of sugars, fat and energy dense food, along with inadequate physical activities are all risk factors for obesity [2] and are linked to other life-threatening and chronic health diseases [3]. These diet-related conditions have become a major public health problem in China [2]. On the other hand, China is still facing a huge challenge of nutrition imbalance among children [4]. Dental caries is another diet-related condition and one of the most prevalent diseases in China affecting more than half of the children and majority of adults [5]. There are no national data on the prevalence or mean of severe dental caries in China. However, one study reported prevalence of teeth with pulpal involvement 38% and mean 1.2 among ethnic minority in Southwest China [6]. Untreated severe dental caries could extend to the tooth pulp leading to pulpitis and sepsis, extending to the supporting tissues and causing serious complications [7]. This is usually assessed by the number of teeth with pulpal involvement, ulcers, fistula and abscess (pufa).

Several studies suggested an association between obesity/overweight and dental caries, mainly caused by frequent and excessive consumption of sugars [8,9], a major risk factor for both conditions [10]. Others have postulated that severe dental caries could affect children's growth, practically in low income countries and communities [11–13]. Dental pain and inflammation caused by dental caries are likely to affect the child's ability to eat resulting in poorer dietary intake and stagnation of growth [7]. Severe dental caries can also affect growth through an impact on immune, endocrine and metabolic response [7]. Given that both obesity and undernutrition exist simultaneously among Chinese children, it is deemed important to identify a potential and modifiable risk factor and/or marker of both ends of anthropometric measurements. Identifying these relationships will undoubtedly inform health policies aiming at tackling both undernutrition and obesity, particularly when they coexist in the same population. The objective of this longitudinal study is to examine the association between incidences of thinness and

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overweight and incidence and baseline prevalence of severe caries among pre-school children in Liaoning, China.

Materials and methods

The preparation of this manuscript followed STROBE guidelines for cohort studies. This study obtained an ethical approval from King's College London (KCL Ethics ref.: HR-15/16-2901), and an oral consent from Shenyang Dental Hospital (Ministry of Health of People's Republic of China). Children whose parents handed in written consent forms prior to baseline and follow-up data collection were included in this study. The estimated sample size, based on a relevant study in Hong Kong [14], was 636, and the sample was increased to at least one thousand.

Study population

The study population were children enrolled at kindergartens in Shenyang, Liaoyang and Fushun, Liaoning Province, China. The age range of children at baseline was 24.6–71.1 months. We accessed kindergartens that were included in a dental screening programme organized by the Ministry of Health, China. Baseline and follow-up data collection were conducted between October 2016 and November 2017, with median and mean follow-up time 10.12 and 9.73 months (SD: 1.22), respectively. Overall, 1111 children from 15 kindergartens were included at baseline and only 772 were included at follow-up (30% dropout) (Figure 1). Those lost at follow up either left kindergarten (296), refused to participate (37) or refused clinical assessment (6).

Data collection

The questionnaire was mainly based on WHO questionnaire [15] and was amended following The Third National Oral Health Survey in China [16]. The questionnaire included questions pertaining to sociodemographic factors, dietary habits and child's general health. Family income included five groups: 0–3999 RMB, 4000–5999 RMB, 6000–9999 RMB, 10,000 RMB or above and undeclared. Children's general health was indicated as excellent or good vs. poor or others (as reported by parents) and by admission to hospital within the past year. Questions pertaining to consumption of biscuits, cake or bread, candy or chocolate, fizzy drinks and fruit juice were used to create a variable for sugar consumption. Answers for questions on dietary intake were assigned the following scores: $\geq$2/day (2), 1/day (1), 3–4 times/week (3/7 days = 0.43), 1/week (1/7 days = 0.14), 1/month (1/30 days = 0.03) and seldom or never (0) [17]. The weighted scores for the aforementioned dietary items were added up to create a variable for sugar consumption. The similar weighting method was used to create the variable for fresh fruit consumption.

Dental examination was conducted according to WHO Oral Health survey methods [15] by one dentist. The dentist was blinded to the anthropometric status of children. Intra-examiner reliability was assessed by re-examining 80 children in two different days, and the agreement (Kappa) was 0.72. The number of decayed, missing and filled teeth (dmft) and teeth with pulp involvement, ulceration, fistula and abscess (pufa) were assessed. PUFA index was designed to provide information on the clinical consequences of untreated dental caries, such as pulpal involvement, ulceration, fistula and abscess that might result in more serious symptoms than caries lesions [18]. A variable indicating whether the child has at least one tooth with pulpal involvement/ulceration/fistula/abscess was used to indicate severe dental caries.

Assessment of body measurements was conducted by a different healthcare worker who was blinded to dental examination. The weight and height of participants were measured to the nearest 0.5 kg and 0.5 cm. BMI is calculated and used to determine children's weight and height status according to the classification system [3]. However, for children, BMI should be comparable to other children of the same age and sex. BMI for age and sex *z*-score (ZBMI) was used to estimate BMI status of the children [3]. The WHO Growth Standards 2006 and 2007 were used for children aged 24–60 months and more than 60 months, respectively [19,20]. In this study, a *z*-score cut-off point >2 SD was used to classify high BMI as overweight among 0–60 months children using WHO growth reference 2006 [20]. BMI-for-age *z*-score >1 SD was set as cut-off points for overweight among children older than 60 months using WHO growth reference 2007 [19]. The cut-off points of <–2 SD was defined as thinness for all ages [21]. In this sample, the calculated overweight children were more than 5%. However, the calculated number of thin children were much fewer than 5%. For consistency, 5% of the children who had the lowest ZBMI were classified as 'thin'.

The incidence of thinness reflects the percentage of children who were not thin at baseline and became thin at follow-up according to the aforementioned definition. Incidence of overweight was calculated in the same manner using the cut-off point for overweight. This study examined whether a child's baseline prevalence of severe dental status (indicated by pufa $\geq$1) or incidence of severe dental caries (indicated by change in pufa score from 0 to 1 or more at follow) is associated with the child's worsening nutritional status over time (indicated by inadequate or excessive weight gain).

Statistical analysis

STATA 15.0 was used throughout the analysis (StataCorp, College Station, TX). First, we calculated the distribution of socioeconomic and demographic factors, parent-reported general health and hospitalization of children in the past 12 months, diet at baseline, prevalence and incidence of severe caries, and incidences of overweight and thinness.

Logistic regression models were used to analyse the relationship between each of incidence of thinness and overweight (outcomes), and each of incidence and baseline prevalence of severe caries. Three logistic regression models were constructed to assess the relationship between incidence of thinness and prevalence of severe caries. The first

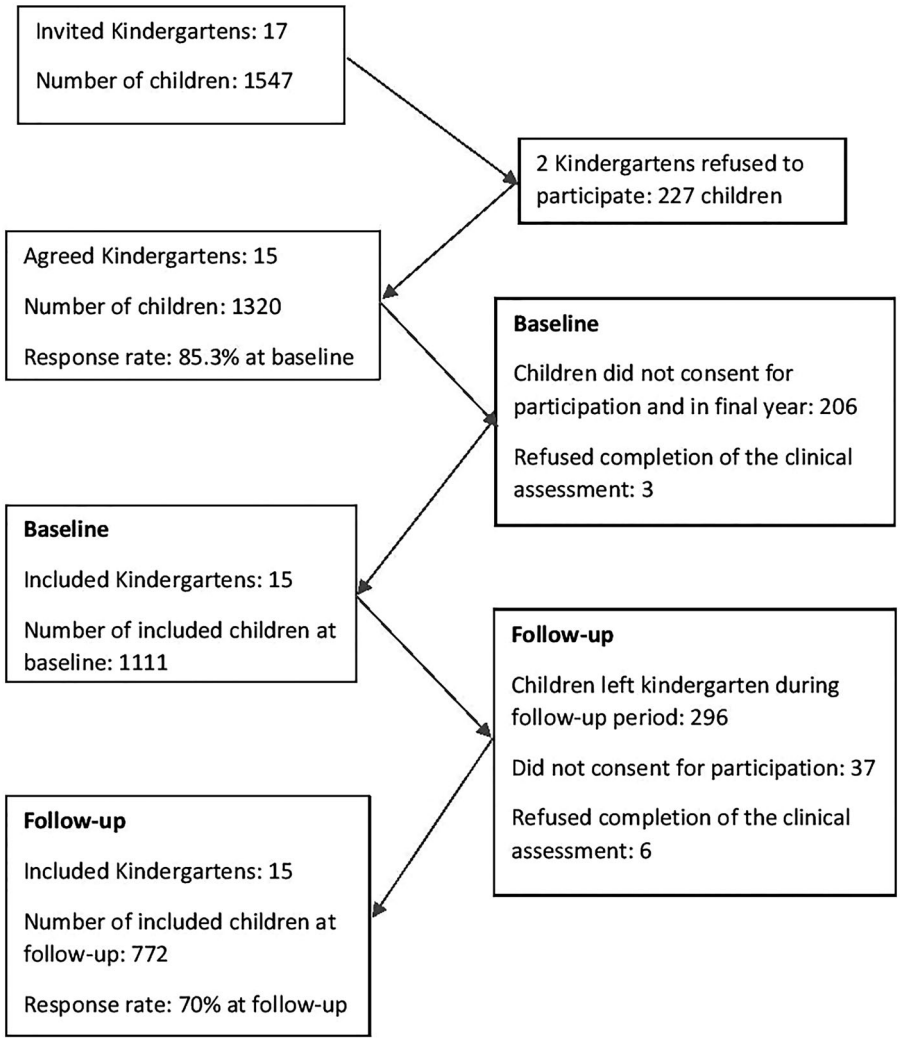

Figure 1. Flowchart of participation at baseline and follow-up.

was only adjusted for time interval, the second was additionally adjusted for age and sex, and the third was additionally adjusted for income, parent-reported children's general health, hospitalization, fresh fruit and sugar consumption. The same set of models were reconstructed only using the incidence of severe caries instead of prevalence of severe caries. Similar models were used to assess the relationship between incidence overweight (outcome) and each of prevalence and incidence of severe caries.

Results

Overall, 772 children who had data at baseline and follow-up were included in the analysis (attrition rate: 30%). Among those who were lost at follow-up, the means of age, pufa and BMI were almost identical between those who were lost at follow-up and those who completed the study in these parameters.

Table 1 shows the distribution of the variables included in the analysis. Mean age at baseline and follow-up was 50.82 and 60.55 months. The mean of actual BMI was 16.04 at baseline and decreased to 15.98 at follow-up. The means of ZBMI were 0.41 at baseline and 0.34 at follow-up. The mean pufa index was 0.50 at baseline and 0.75 at follow-up. The prevalence of thinness and overweight at baseline were 5.05 ($N = 39$) and 12.56 ($N = 97$), respectively.

Table 1. Description of all variables used in the analysis ($n = 772$).

Variables	*N*	Percentage/ mean	(95% CI)
Mean age at baseline	50.82		(50.09, 51.55)
Mean age at follow-up	60.55		(59.84, 61.26)
Gender[a]			
Male	397	51.42	(47.89, 54.95)
Female	375	48.58	(45.05, 52.11)
Income[a]			
0–3999 RMB	129	16.71	(14.25, 19.52)
4000–5999 RMB	162	20.98	(18.25, 24.01)
6000–9999 RMB	162	20.98	(18.25, 24.01)
10,000 RMB or above	108	13.99	(11.71, 16.63)
Undeclared	211	27.34	(24.30, 31.59)
Parents' reported children's general health[a]			
Excellent or good	404	52.33	(48.79, 55.85)
Poor or others	368	47.67	(44.15, 51.21)
Hospitalization past 12 months[a]			
Yes	90	11.66	(9.56, 14.13)
No	682	88.34	(85.87, 90.43)
Mean fresh fruit consumption[a]	1.41		(1.37, 1.45)
Mean sugar consumption[a]	1.03		(0.97, 1.09)
Prevalence of severe caries at baseline	110	14.25	(11.95, 16.90)
Incidence of severe caries	40	5.18	(3.82, 7.00)
Incidence of thinness	19	2.46	(1.57, 3.83)
Incidence of overweight	54	6.99	(5.39, 9.03)

[a]Baseline variable.

Table 2 exhibits the results of the logistic regression for the relationship between incidence of thinness and prevalence/incidence of severe caries. In all models, the results showed significant association between incidence of severe caries and incidence of thinness. Children who had incidence of severe caries had higher odds of becoming thin (OR: 4.08; 95% CI: 1.08, 15.41) in the fully adjusted model. However, baseline prevalence of severe caries was not significantly associated with incidence of thinness. The models for the association between incidence of overweight and incidence/prevalence of severe caries are presented in Table 3. Participants with pufa score $\geq$1 at baseline were more likely to become overweight (OR: 2.05; 95% CI: 1.07, 3.96) in the unadjusted model. The statistically significant relationship persisted after adjusting for behavioural and socioeconomic factors. There was no statistically significant relationship between incidence of overweight and incidence of severe caries. Children with severe caries at baseline were significantly more likely to have excessive weight gain over the follow-up period; and children without severe caries at baseline who developed severe caries during the follow-up period were significantly more likely to have inadequate weight gain over the follow-up period.

The associations between baseline prevalence severe dental caries and baseline prevalence of thinness/overweight were also examined. The association between baseline prevalence of severe dental caries and baseline prevalence of overweight was positive but statistically insignificant (OR: 1.11, 95% CI: 0.61, 2.02) in a model adjusted for age and sex. Similarly, the odds ratio for the relationship between baseline prevalence of severe dental caries and baseline prevalence of thinness was 1.16 (0.47, 2.90).

Discussion

The main findings of this study showed that severe dental caries is associated with both incidences of thinness and overweight among pre-school Chinese children. Incidence of severe caries was significantly and positively associated with incidence of thinness. On the other hand, baseline prevalence of severe caries was associated with incidence overweight. It is worth noting the direction of association between incidence overweight and incidence of severe caries indicated a positive relationship, though insignificant. The findings suggest that severe dental caries is associated with malnutrition among pre-school children indicated by both excessive and inadequate weight gain.

Earlier studies postulated that severe dental caries is associated with thinness among children [11,12], and that treatment of severely decayed teeth prompted weight gain among children [13]. The findings of the current study confirm that severe dental caries is associated with inadequate weight gain among Chinese children. Few longitudinal studies examined the relationship between dental caries and different measures of obesity as an outcome [8,9]. Their findings were inconclusive with caries associated with certain markers of obesity such as central obesity, but not with an increase in BMI [8,22]. On the other hand, one study suggested that caries could be a marker for lower risk of obesity [9]. This particular finding is contradictory to our findings probably because the findings were observed among Danish children whose mothers were well educated, a different population from that examined here. On the other hand, there is no known longitudinal study that examined whether severe dental caries is associated with both thinness and overweight/obesity in the same population. It is worth noting that an earlier analysis of the same data used here showed a bidirectional longitudinal association of dental caries with both of weight and height [23].

While the nutritional transition in China has undoubtedly led to changes in the diet with obesity rising among both children and adults, undernutrition is still common among children in many developing countries and deprived communities in developing countries. This study took advantage of the simultaneous existence of both obesity and undernutrition among Chinese children to uniquely examine the relationship between severe dental caries and both ends of anthropometric measures among children. Hooley et al. postulated that dental caries is associated with high and low BMI demonstrating a U-shaped relationship [24]. However, this U-shape relationship has never been tested in China or assessed using longitudinal data. The findings of the current analysis confirm the presence of this U-shaped relationship among pre-school children in China demonstrating associations between severe dental caries and both incidences of thinness and overweight.

Children's caries is associated with deeper cavities and mouth pain, which might result in inability to eat crunchy food. It is not unusual that parents use sweetened drinks or even candies to pacify a child crying from dental pain [12]. This contributes to poor dietary intake, including insufficient intake of essential nutrients, excessive and prolonged consumption of sweetened and acidic liquids [12]. While these dietary habits might result in weight gain due to greater calories intake from sugars, it could also lead to stagnation of growth due to inadequate intake of essential nutrients. While sugar consumption is an established common risk factor for both obesity and dental caries [25], different studies found a relationship between each of obesity and dental caries, and sedentary lifestyle [26,27]. Lack of physical activities and long-time watching television could also explain the relationship between dental caries and obesity [28]. Children with sedentary lifestyle are more likely to consume more snacks and soft drinks containing too many calories that lead to overweight and obesity [27]. The same behaviours could also lead to a greater risk of dental caries [26]. On the other hand, severe dental caries could impact children's growth as it leads to appetite loss, disruption of sleep and eating difficulties [12]. Others have also argued that severe dental caries and associated pain could also negatively impact height and weight gain through immune, endocrine or metabolic response [7].

In the current analysis, prevalence of severe dental caries at baseline was associated with incidence of overweight. It is possible that those children who suffered dental pain at baseline received more attention from their parents

Table 2. Logistic regression showing odds ratios (95% CI) for the relationship between incidence of thinness and baseline prevalence/incidence of severe caries ($n = 772$).

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)	Model 5 OR (95% CI)	Model 6 OR (95% CI)
Prevalence of severe caries at baseline	0.76 (0.17, 3.41)	0.76 (0.17, 3.44)	0.73 (0.16, 3.31)			
Incidence of severe caries				3.85* (1.07, 13.93)	3.92* (1.08, 14.29)	4.08* (1.08, 15.41)
Sex		0.77 (0.31, 1.95)	0.77 (0.30, 1.96)		0.74 (0.29, 1.86)	0.74 (0.29, 1.90)
Age		1.01 (0.96, 1.06)	1.01 (0.96, 1.06)		1.00 (0.96, 1.05)	1.01 (0.96, 1.06)
Income (ref: 0–3999 RMB)						
4000–5999 RMB			0.75 (0.15, 3.85)			0.81 (0.16, 4.18)
6000–9999 RMB			1.18 (0.26, 5.28)			1.26 (0.27, 5.80)
10,000 RMB or above			0.83 (0.15, 4.69)			0.98 (0.17, 5.58)
Undeclared			0.96 (0.21, 4.33)			1.19 (0.25, 5.59)
Parents' reported children's general health (ref: poor or others)						
Excellent or good			1.46 (0.52, 4.05)			1.46 (0.52, 4.10)
Hospitalization past 12 months (ref: no)						
Yes			0.46 (0.06, 3.55)			0.47 (0.06, 3.65)
Fresh fruit			1.69 (0.61, 4.69)			1.74 (0.62, 4.89)
Sugar consumption			0.91 (0.51, 1.64)			0.91 (0.50, 1.65)
Follow-up time	1.15 (0.80, 1.65)	1.17 (0.80, 1.71)	1.08 (0.72, 1.63)	1.19 (0.83, 1.70)	1.21 (0.83, 1.76)	1.11 (0.74, 1.67)

Model 1: unadjusted model for prevalence of severe caries at baseline and follow-up time; model 2: adjusted model for prevalence of severe caries at baseline, age, sex and follow-up time; model 3: model 2 + income, parents' reported children's general health, admission to hospital in the past 12 months, fresh fruit and sugar consumption; model 4: unadjusted model for incidence of severe caries and follow-up time; model 5: adjusted model for incidence of severe caries, age, sex and follow-up time; model 6: model 5 + income, parents' reported children's general health, admission to hospital in the past 12 months, fresh fruit and sugar consumption.
*$p < .05$.

Table 3. Logistic regression showing odds ratios (95% CI) for the relationship between incidence of overweight and baseline prevalence/incidence of severe caries ($n = 772$).

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)	Model 5 OR (95% CI)	Model 6 OR (95% CI)
Prevalence of severe caries at baseline	2.05* (1.07, 3.96)	1.98* (1.01, 3.86)	2.33* (1.17, 4.63)			
Incidence of severe caries				1.01 (0.30, 3.41)	0.98 (0.29, 3.34)	1.25 (0.36, 4.31)
Sex		1.06 (0.60, 1.85)	1.11 (0.63, 1.97)		1.10 (0.63, 1.91)	1.15 (0.65, 2.02)
Age		1.01 (0.98, 1.04)	1.00 (0.97, 1.03)		1.01 (0.98, 1.04)	1.01 (0.98, 1.04)
Income (ref: 0–3999 RMB)						
4000–5999 RMB			1.54 (0.57, 4.18)			1.46 (0.54, 3.95)
6000–9999 RMB			0.94 (0.30, 2.95)			0.91 (0.29, 2.87)
10,000 RMB or above			2.06 (0.65, 6.58)			1.84 (0.59, 5.79)
Undeclared			2.92* (1.16, 7.36)			2.77* (1.10, 6.95)
Parents' reported children's general health (ref: poor or others)						
Excellent or good			0.86 (0.47, 1,58)			0.88 (0.48, 1.61)
Hospitalization past 12 months (ref: no)						
Yes			0.96 (0.38, 2,42)			0.99 (0.40, 2.46)
Fresh fruit			0.85 (0.47, 1.54)			0.86 (0.47, 1.55)
Sugar consumption			0.59 (0.34, 1.04)			0.62 (0.36, 1.08)
Follow-up time	0.82 (0.63, 1.06)	0.84 (0.64, 1.09)	0.82 (0.61, 1.09)	0.79 (0.61, 1.01)	0.81 (0.62, 1.06)	0.80 (0.60, 1.07)

Model 1: unadjusted model for prevalence of severe caries at baseline and follow-up time; model 2: adjusted model for prevalence of severe caries at baseline, age, sex and follow-up time; model 3: model 2 + income, parents' reported children's general health, admission to hospital in the past 12 months, fresh fruit and sugar consumption; model 4: unadjusted model for incidence of severe caries and follow-up time; model 5: adjusted model for incidence of severe caries, age, sex and follow-up time; model 6: model 5 + income, parents' reported children's general health, admission to hospital in the past 12 months, fresh fruit and sugar consumption.
*$p < .05$.

demonstrated by seeking medical/dental care and improving diet, or possibly by providing sweets to pacify a child crying because of pain. It is worth noting that children with severe caries were more likely to be overweight at baseline. The excessive weight gain during the follow-up period could also be attributed to a continuation of overweight, not impeded by their severe caries status. On the other hand, unsurprisingly, incidence of caries had stronger association with incidence of thinness. The component of pufa used here (pulpitis, ulcer, fistula and abscess) are all acute conditions with duration of pain usually lasting for relatively short periods of time. It is possible that recent experience of inability to eat or disruption of sleep is severe enough to negatively affect child's anthropometric measurements.

The impact of severe dental caries on children's growth is more common in low income countries and communities [11–13]. In this study, family income did not influence the relationship between dental caries and anthropometric

measurement. This is probably because the children included in this study, all attending kindergartens, were not extremely deprived. Other factors, not examined here, that could have influenced the relationship between severe dental caries and anthropometric measurements include childbirth weight, maternal behaviours [29] and environmental, hereditary and genetic factors [30].

While this study took advantage of the apparent and simultaneous existence of obesity, undernutrition and dental caries in the same population in China, the findings do not only apply to Chinese children. Other countries, including high income ones, could also have a problem of undernutrition among certain pockets of the populations, particularly the most deprived. The biological and behavioural underpinning causes of the observed relationship here are also applicable to other populations where obesity, undernutrition and caries coexist. The problem could even be exacerbated in countries with limited universal and comprehensive access to dental care.

This study has the advantage of using *z*-score for BMI adjusted for age and sex, which is deemed appropriate for assessing anthropometric measurements among children. The use of cut-off points was essential to establish thinness and overweight status. While dental caries is usually used to indicate the condition of the tooth, in this study, pufa index was used for its known association with children's anthropometric measurements, particularly failure to thrive.

The study's limitations include loss of 30% of the participants at follow up. However, given that children leave kindergarten due to changes in their parents' circumstances, this was unavoidable. There were little differences between those who dropped out and those who completed the study in terms of clinical and demographic characteristics. This study was only limited to children who attended kindergartens. It is possible that those who cannot afford the cost of attending kindergartens are from more deprived families which would have a greater impact on dietary and behavioural factors that could have played a role in the current study. Finally, the follow-up time was relatively short, it is possible that greater changes in the outcome measures could have been observed with longer follow-up time. This however was inevitable due to the short period the children spend at kindergarten.

The findings of the study imply the presence of common risk factors for both dental caries and malnutrition indicated by excessive and inadequate weight gain among pre-school children. This highlights the need for developing and implementing health promotion interventions that tackle these common risk factors [31], particularly those related to healthy diet. Health policies aiming at tackling both undernutrition and obesity should be integrated. Primary health care providers are encouraged to incorporate dental screening, counselling and referral for treatment for severe dental caries to promote appropriate growth and overall health of children. Furthermore, the findings suggest that severe dental caries could be a risk factor hindering children's growth, which emphasize the importance of oral health in children's well-being [32].

Conclusions

This longitudinal study demonstrated that severe dental caries was significantly and positively associated with incidences of thinness and overweight. These findings suggest a U-shaped relationship between severe dental caries, and both ends of anthropometric measurements among pre-school children.

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Disclosure statement

The authors report no conflict of interest.

Author contributions

AS, WS conceived the research idea. EB advised on the study design. AS conducted the analysis and wrote the first draft. EB and WS advised on the statistical analysis and contributed to wring the manuscript.

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