Assessing association of dental caries with child oral impact on daily performance using directed acyclic graphs; a cross-sectional study of adolescents in Copperbelt province, Zambia

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Abstract

Purpose

To assess the association between dental caries and Child Oral Impact on Daily Performance (C-OIDP). Secondarily, the study evaluated psychometric properties, prevalence, and factors associated with C-OIDP.

Methods

A cross-sectional study was conducted among adolescents in Copperbelt province, Zambia. Socio-demographics, oral health behaviors, self-reported oral health, and C-OIDP were assessed using a self-administered questionnaire. Dental caries was assessed according to Caries Assessment & Treatment Spectrum (CAST). A directed acyclic graph (DAG) was used to determine a minimum set of covariates for the adjusted analysis. Data analysis was done using Stata/SE (version 17).

Results

Among 1,794 participants, 54.0% were females, while 56.0% were aged 11–14 years. Prevalence of self-reported poor teeth health, clinically assessed dental caries and, C-OIDP were 18.3%, 46.2% and 31.5%, respectively. The highest prevalence of oral impacts were with eating (26.5%), cleaning teeth (16.4%), and sleeping (12.5%). Child - OIDP Spearman's correlations of the items ranged from 0.399 to 0.641. The participants with dental caries were 2.6 times (AOR 2.6, 95% CI 2.1, 3.2) more likely to report oral impacts than those without caries. Consuming a sugary diet five times or more per day increased the odds of C-OIDP by 1.5 times (AOR 1.5, 95% CI 1.2, 1.9) while, dental visits in the past year decreased the odds of C-OIDP by 30% (AOR 0.7, 95% CI 0.6, 0.9).

Conclusions

The English version of C-OIDP is a reliable index for assessing OHRQoL among Zambian adolescents. Prevalence of C-OIDP was high, and problems with eating, cleaning teeth, and sleeping were the most frequently reported items. Dental caries was associated with increased C-OIDP. Covariates selected based on DAGs showed consuming a sugary diet more than five times per day increased the odds of C-OIDP, while dental visits at least once per year decreased the likelihood of reporting C-OIDP.

Plain Abstract

Tooth decay is the most common behavioral oral disease that affect daily activities of a child termed as Child Oral Impact on Daily Performance (C-OIDP). The disease affects eating, cleaning teeth, sleeping, speaking, smiling, emotion, school and social interactions. This study aimed at assessing relationship between dental caries and C-OIDP and how other factors such as age, and sex affect their relationship. The use of special graphs to visualize this relationship makes this study inspiring and assisted in reducing the possibilities of biased results. We examined dental caries and Child OIDP at the same time by examining teeth and asking the participants to state how often problems with their teeth caused problems with eating, cleaning teeth, sleeping, speaking, smiling, emotion, school or social interactions. Oral impacts were reported by 31.5% of the participants and the highest

impacts were with eating (26.5%), cleaning teeth (16.4%), and sleeping (12.5%). Reporting of impacts (Child -OIDP) were related to taking sugary diet five-times or more per day, painful gums, painful teeth, and dental caries. We conclude that the proportion of participants affected in their daily performance due to oral diseases was high and was related to tooth decay. Painful teeth and high consumption of sugary diet increased reporting of oral impacts while dental visit at least once per year reduced reporting impacts.

Background

The shift in perception of oral health towards a complete state of physical, mental, and social well-being and not merely the absence of diseases has led to studies assessing Oral Health-Related Quality of life (OHRQoL). Oral Impact on daily performance (OIDP) is the most common OHRQoL measurement tool assessing the extent to which an individual's daily activities may be affected by oral problems [1, 2]. A child version of the OIDP inventory, (C-OIDP), has been developed after modifications of the adult version, to fit children's cognitive level of development [3]. The C-OIDP assesses eight oral impacts, of which difficulties with eating and socializing are respectively, the most and least frequently reported impacts [2]. Child-OIDP has demonstrated satisfactory psychometric properties in various cultural contexts including Sub–Saharan Africa (SSA) [2–4], but has not yet been used in Zambia. The association of oral diseases with C-OIDP is well established [5, 6]. Adolescents with dental caries report oral impacts about one to five times more often than those without [7]. Gingivitis is also related to oral impacts as reported in some studies although to a lesser extent than dental caries [8, 9]. Independent of clinical measures of oral diseases, C-OIDP has been associated with sociodemographic, behavioral, and psychological factors in various populations, showing that the poor, socially disadvantaged, and those living in rural areas are most negatively affected (2,7,10). Females are also reported to be more affected than males [9] although some studies did not find any sex differences [10, 11]. Some studies in SSA report no age difference in the prevalence of oral impacts [10, 12] while others have found that older adolescents tend to report oral impacts more frequently than their younger counterparts [9]. Similar age distribution of C-OIDP has also been observed in studies from high-income countries [2].

The use of directed acyclic graphs, DAGs, to identify confounders and estimate unbiased relationships between oral diseases and C-OIDP has seldom been applied in oral health research [13, 14]. Directed Acyclic Graphs illustrate the relationship between exposure and outcome whilst considering the influence of other variables [15]. They are guided by causal mechanisms and are based on established conceptual frameworks, proven scientific knowledge, and previous scientific evidence [15]. Thus, DAGs can be designed and used as an aid to check for the sufficiency of confounder selection as an alternative to relying entirely on conventional statistical methods. So far, studies of children's OHRQoL globally have most frequently used conventional statistical methods to identify covariates for confounding adjustment. Although causal inference cannot be established with observational data the use of directed acyclic graphs can provide insights into the causal relevance of exposure to an outcome of interest [16]. The current study is expected to contribute to understanding important factors that affect the focal association between dental caries as an exposure and child OIDP as an outcome. Furthermore, no study has investigated the association between dental caries and C-OIDP among school-going children in Zambia. The only study done in Zambia investigated the impact of malocclusions on OHRQoL using the Child Oral Health Impact Profile short-form instrument (COHIP-SF19). However, the impacts of other prevalent oral diseases were not investigated [17]. Another small-scale cross-sectional study reported on the impact of oral diseases among individuals visiting a dental clinic in Livingstone, Zambia using the adult version of the OIDP inventory [18].

Focusing on adolescents attending public secondary schools in Zambia, this study assessed the association between dental caries and Child Oral Impact on Daily Performance (C-OIDP). Secondarily, the study assessed psychometric properties, prevalence, and sociodemographic and behavioral factors associated with C-OIDP.

Methods

Study design, population, and setting

A cross-sectional study was conducted in February-June 2021 at public secondary schools in the Copperbelt province, Zambia. We assessed 1,909 adolescents for eligibility, 115 (6.0%) were excluded due to being under fixed orthodontic treatment or lack of consent resulting in the enrollment of 1,794 participants (Fig. 1).

Sample Size And Sampling Procedure

We estimated the sample size of 1,760 by assuming: a 95% two-sided significance level, 85% power, 5% margin of error, 20% expected mean change in dental caries, 0.001 inter-cluster correlation, a cluster size of 80, and mean DMFT of 1.34 found in a previous study in Zambia [19]. To arrive at a balanced rural-urban representation of public secondary schools, the known rural-urban division of the ten districts of Copperbelt was considered during the random selection of three districts. The province has an imbalance in the number of schools and students between rural and urban districts where the urban districts have more schools and students than rural districts which led to a random selection of two rural districts and only one urban district. A total of 35 public secondary schools from the three districts in a breakdown of 21 for Ndola urban district (ratio 21/35 = 0.6), 8 for Masaiti rural district (ratio 8/35 = 0.3), and 6 for Mpongwe rural district (ratio 6/35 = 0.1) were available for selection. Due to differences in the total number of schools in the three districts, a proportionate number of schools (13/21 in Ndola, 5/8 in Masaiti, and 4/6 in Mpongwe) were randomly selected. All adolescents, 10–19 years old attending the selected schools were invited to participate in the study.

Survey Instruments And Measurements

Questionnaire

A pretested self-administered questionnaire, constructed in English was used to collect information regarding the outcome variable (C-OIDP) and covariates (sociodemographic and oral health behaviors). The questionnaire was pre-tested at one secondary school in Ndola which was not part of the study by administration to 50 adolescents.

Outcome Variable (C-OIDP)

Child -OIDP was assessed by asking participants how often during the past three months problems with their mouth and teeth caused any difficulty with eating, speaking, cleaning teeth, sleeping, smiling, emotional state, schoolwork, and social contact. Each item was scored as {0 = never, 1 = once or twice per month, 2 = once or twice per week, 3 = every day or nearly every day}. The prevalence of oral impact for each item was computed by dichotomizing scores for each of the eight items into {0 = no impact (score 0) and 1 = with impact (scores 1–3)}. The overall impact (impact based on all eight items) was obtained by first computing the total of the eight

dichotomized frequency scores (min 0, max 8) and then dichotomizing into {0 = no impact (score 0) and 1 = with impact (scores 1–8)}.

Socio-demographic Covariates

Participant's sex was recorded as {1 = male, 2 = female} while age was calculated from the date of birth and dichotomized according to World Health Organization (WHO) adolescence categories into 10–14 (early adolescence) and 15–19 years (mid and late adolescence). Parental education was recorded as {1 = no formal education, 2 = primary, 3 = secondary, 4 = college/university} and dichotomized into {1 = up to primary, 2 = secondary and above}. Socioeconomic status (SES) questions were adopted from a standardized International Wealth Index instrument (IWI) [20] and a recent demographic and health survey in Zambia [21]. The question inquired on possession of one or more of the following assets; television, refrigerator, bicycle, car, plough, phone. It also inquired on housing conditions such as the number of sleeping rooms, type of wall and roof material. Other components were the quality of a toilet, water source, and access to electricity. The total IWI scores were computed as a total of the scores for the items. The principal component (PCA) was analyzed and the first component which accounts for the largest proportion of variance was used as the wealth index. The first component scores were thereafter categorized into quantiles and later dichotomized into low to middle SES (1st to 3rd quantile) and High SES (4th quantile).

Oral Health-related Behaviors

Oral health-related behaviors were assessed in terms of frequency of tooth brushing and use of fluoridated toothpaste per day and coded as {1 = i didn't, 2 = i did but not every day, 3 = i did once a day, 4 = i did twice a day or more}, frequency of intake of sugar-containing diet in the past 30 days coded as {1 = i didn't take, 2 = occasionally per week, 3 = once per day, 4 = twice to four times per day, 5 = five times or more per day}. Tooth brushing and use of fluoridated toothpaste were combined to form one variable 'tooth brushing using fluoridated toothpaste' and recorded as {1 = less than 2 times per day and 2 = twice per day}. The frequency of intake of sugar-containing food and drinks in the past 30 days was also combined to form a variable 'frequency of intake of sugary diet' and recorded as {1 = 5 times or more per day and 2 = less than 5 times per day}. Dental visits in the previous year were coded as {1 = i didn't attend, 2 = i attended once, 3 = i attended twice or more} and dichotomized as {1 = i didn't attend and 2 = i attended once or more}. Self-reported oral health and oral symptoms Self-reported oral health in terms of the health of gums and teeth was recorded as {1 = very poor, 2 = poor, 3 = good, 4 = very good} and dichotomized as {1 = poor, 2 = good}. Self-reported oral symptoms in the past three months were recorded as {1 = no pain, 2 = pain).

Oral Clinical Examination

Oral examination was conducted inside the classrooms by four trained and calibrated dentists with adolescents sitting on a desk opposite classroom windows. Permanent teeth were examined according to Caries Assessment Spectrum and Treatment (CAST) index [2]) and coded as {0 = sound, 1 = sealant, 2 = restoration, 3 = caries in enamel, 4 = caries in dentine, 5 = caries in dentine, 6 = caries in pulp, 7 = abscess or fistula, 8 = lost due to caries, 9 = others}. Dental caries was defined according to CAST manual as any participant with one or more teeth at CAST stages 3 to 7 [21].

Statistical Analyses

Data management and statistical analysis were done using Stata/SE (version 17). A computer with a password was used to store anonymous data. Dagitty software[23] was used to select the set of covariates for adjustment in the multivariable analysis. Descriptive data on independent variables; demographics of the adolescents, parental/guardian socio-demographics, oral health-related behaviors, oral symptoms, self-reported and clinically dental caries were dichotomized and summarized as frequencies and percentages. Cohen's Kappa (n = 180) was used to evaluate the test-retest reliability of C-OIDP items by re-administering the inventory to every 10th participant at an interval of 10 days. Internal consistency reliability of C-OIDP was assessed by Cronbach's alpha. The Kappa coefficient was used to assess the intra- and inter-examiner consistency in examining dental caries. The minimal set of covariates for adjustment at a multivariate level was assessed based on DAG [Figure 2]. Hierarchical multivariate logistic regression (adjusted for clusters) was used to assess the association between dental caries and C-OIDP. Distal factors and biological factors (parental education and socioeconomic status, adolescent's age and sex) were entered at the first stage, proximal -oral health-related behaviors (tooth brushing using fluoridated toothpaste, frequency of sugary diet consumption per day and dental visits in the past one year) were entered at the second stage. The exposure (dental caries) was entered at the third stage while painful teeth in the past three months was entered at the fourth stage. The estimates from the adjusted analysis were reported using adjusted odds ratios (AOR) with a 95 % onfidence interval (CI).

Directed Acyclic Graphs (DAGs)

The study used directed acyclic graphs (Fig. 2) to illustrate the underlying association between dental caries (exposure) and C-OIDP (outcome) while considering socio-demographic, biological and individual oral health-related covariates that might influence the association [15]. In summary, dental caries was assumed to have a direct effect on C-OIDP. Proximal factors such as oral health-related behaviors in terms of tooth brushing and use of fluoridated toothpaste frequency, sugary food consumption, and dental visit frequency were assumed to have direct effects on C-OIDP, and indirect effects through dental caries. Distal socio-demographics were assumed to have indirect effects on C-OIDP mediated through more proximal individual oral health-related behaviors. A detailed description of the assumed pathways in the DAG (Fig. 2) is provided in the appendices (Appendix 1).

Results

Sample characteristics

A total of 1,794 were enrolled in this study out of 1,909 eligible adolescents at the time of the study making a participation rate of 94% (Fig. 1).

The participants were aged between 11–19 years, the mean age of 14.6 years SD (1.7). Table 1 presents the frequency distribution of participants' socio-demographic and oral health-related behaviors.

Table 1
Socio-demographic characteristics, oral health related behaviors and oral symptoms of the study participants (n = 1794)

Independent variables	Categories	% (n)
Socio-demographics		
Participants sex	Male	46.0 (825)
	Female	54.0 (969)
Participants age groups	11–14	56.0 (1004)
	15–19	44.0 (790)
Parental education	Low (Up to primary)	48.9 (876)
	Middle to High (secondary+)	51.1 (918)
Parental Socio-economic status	Low to middle	43.8 (785)
	High	56.2 (1009)
Oral health related behaviors		
Sugary consumption per day	Less than 5 times	81.8 (1468)
	5 times or more	18.2 (326)
Toothbrushing & use of fluoridated toothpaste per day	2 times or more	45.5 (816)
	Less than 2 times	54.5 (978)
Dental visit in the past 1 year	Attended	26.4 (474)
	Did not attend	73.6 (1320)

Females constituted 54.0%, 56.0% were aged 11–14 years, and 56.2% were from high SES families. The distribution of participants', oral health-related behaviors showed, 18.2% consumed sugary foods five times or more per day, 45.5% brushed their teeth using fluoridated toothpaste two times per day and 26.4% attended to a dentist in the previous year. Figure 3 presents the distribution of participants according to symptoms, self-reported, and clinically assessed dental caries.

Painful tooth or teeth in the past three months was reported by 20.2% of the participants. Prevalence of self-reported poor health of teeth and clinically assessed dental caries were 18.3% and 46.2% respectively.

Psychometric Properties And Prevalence Of C-OIDP

Test-retest reliability Kappa coefficients of C-OIDP items (n = 180) ranged from 0.960 to 1.00. Internal consistency reliability in terms of Cohen's Kappa of the C-OIDP inventory was 0.940. Inter-correlations between C-OIDP items in terms of Spearman's correlation coefficients are presented in Table 2. Spearman's correlation coefficients of the eight C-OIDP items ranged from 0.399 to 0.641. All the p values of the 28 pairwise correlations were less than the Bonferroni corrected alpha value ($p < 0.002$). Table 3 shows OIDP single item and overall C-OIDP by the self-

reported teeth health and clinically assessed dental caries. Poor self-reported health of the teeth and dental caries were associated with increased reporting of oral impacts across the eight C-OIDP items and overall C-OIDP.

Table 2
Spearman's correlation of Child -OIDP performance items

Child OIDP item	Eating	Speaking	Cleaning teeth	Sleeping	Smiling	Emotional state	School	Social Contact
Eating	1							
Speaking	0.427	1						
Cleaning teeth	0.589	0.498	1					
Sleeping	0.543	0.512	0.552	1				
Smiling	0.441	0.480	0.488	0.478	1			
Emotional state	0.399	0.482	0.473	0.550	0.564	1		
School	0.482	0.546	0.515	0.593	0.503	0.595	1	
Social Contact	0.432	0.491	0.488	0.551	0.568	0.596	0.641	1

All correlation were less than the Bonferroni corrected $\alpha = 0.05/28 = 0.002$

Table 3
Distribution of C-OIDP by single item and overall OIDP according to self-reported teeth health and clinically assessed dental caries

Variable	Individual Impacts > 0								Overall OIDP > 0
	Eating % (n)	Speaking % (n)	Cleaning teeth % (n)	Sleeping % (n)	Smiling % (n)	Emotion % (n)	School % (n)	Social Contact % (n)	
Self-reported teeth health									
Poor	61.6 (202)	26.9 (70)	39.6 (130)	31.7 (104)	26.5 (87)	21.0 (69)	22.6 (74)	22.6 (74)	69.5 (228)
Good	18.6 (273)	7.8 (119)	11.5 (168)	8.3 (122)	6.3 (92)	4.9 (72)	6.1 (89)	4.8 (71)	22.9 (336)
p value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Clinical assessed dental caries									
With caries	36.5 (302)	14.1 (117)	21.3 (176)	16.5 (137)	11.6 (96)	9.5 (79)	11.8 (98)	10.4 (86)	42.1 (349)
No caries	17.9 (173)	7.5 (72)	12.6 (122)	9.2 (89)	8.6 (83)	6.4 (62)	6.7 (65)	6.1 (59)	22.3 (215)
p value	< 0.001	<0.001	< 0.001	<0.001	0.034	0.014	<0.001	< 0.001	< 0.001

The frequency distribution of C-OIDP items is as shown in Fig. 4. The overall prevalence of oral impacts was 31.5% and the highest impacts were with eating (26.5%), cleaning teeth (16.4%), and sleeping (12.5%). Social contact (8.1%) and emotional state (7.9%) were the least reported impacts.

Minimal Set Of Covariates For Adjustment Based On Directed Acyclic Graphs

Figure 2 illustrates the relationship between dental caries as exposure and C-OIDP as an outcome. A minimum adjustment set of covariates based on DAG (Fig. 2) included: parental education, parental SES, adolescents' age, sex, frequency of tooth brushing using fluoridated toothpaste, frequency of use of sugary foods per day, dental visit in the past one year, and painful teeth in the past three months.

Final Multiple Variable Regression Analyses Adjusted For Clusters (Schools)

Table 4 shows the hierarchical logistic regression model with an adjusted odd ratio (AOR) and 95% confidence interval (95% CI) of the predictors of C- OIDP. Age was associated with C-OIDP, such that older adolescents aged 15–19 years were 1.3 times (AOR 1.3 (95% CI 1.1–1.8) more likely to report impacts than those in the age group 10–14 at stage 1. Entering oral health-related behaviors in stage 2 revealed an association between C-OIDP and age (AOR 1.4, 95% CI 1.1–1.8), sugary food frequency per day (AOR 1.8, 95% CI 1.4–2.3), and dental visit per year (AOR 0.6, 95% CI 0.5–0.8). Age and sugary food frequency-maintained association with C-OIDP after entering dental caries in stage 3. The odds of reporting oral impacts were 1.3 (AOR 1.3, 95% CI 1.1, 1.8) and 1.7 times (AOR 1.7, 95% CI 1.3, 2.2) more among participants aged 15–19 years and those consuming sugary foods five times or more per day respectively than their counterparts. A dental visit at least once per year reduced the odds of C-OIDP by 40% (AOR 0.6, 95% CI 0.4, 0.7). The participants with dental caries were 2.6 times (AOR 2.6, 95% CI 2.1, 3.2) more likely to report oral impacts than those without caries.

An association between dental caries and C-OIDP was maintained but its magnitude was reduced to 2.4 times (AOR 2.4, 95% CI (1.9, 3.0) after adjusting for confounders in the final regression model (stage 4). Consuming a sugary diet five times or more per day increased the odds of C-OIDP by 1.5 times (AOR 1.5, 95% CI (1.2, 1.9) while dental visit in the past 3 months decreased C-OIDP by 30% (AOR 0.7, 95% CI (0.6, 0.9). Adolescents who reported painful teeth in the past three months were 7 times (AOR 7.0, 95% CI 5.2, 9.4) more likely to report one or more oral impacts than those without pain.

Table 4
Hierarchical Logistic regression model of predictors of the association between dental caries and Child -OIDP (Cluster adjusted)

Covariates		Stage 1		Stage 2		Stage 3		Stage 4	
		OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Parental education	Middle to High (secondary+)	1		1		1		1	
	Low (≤ primary)	1.1 (0.8, 1.3)	0.704	1.1 (0.8, 1.3)	0.691	1.1 (0.9, 1.3)	0.590	1.0 (0.8, 1.3)	0.963
Parental SES	High	1		1		1		1	
	Low to middle	1.1 (0.8, 1.5)	0.457	1.2 (0.9, 1.6)	0.215	1.2 (0.9, 1.6)	0.271	1.3 (0.9, 1.8)	0.100
Adolescents' Sex	Male	1		1		1		1	
	Female	1.2 (0.9, 1.6)	0.179	1.2 (0.9, 1.7)	0.135	1.1 (0.9, 1.5)	0.366	1.1 (0.8, 1.4)	0.680
Adolescents' Age	10–14	1		1		1		1	
	15–19	1.3 (1.1, 1.8)	0.050	1.4 (1.1, 1.8)	0.036	1.3 (1.1, 1.8)	0.045	1.3 (1.0, 1.8)	0.095
Toothbrushing with fluoride toothpaste	2 times or more per day			1		1		1	
	Less than 2 times per day			1.3 (1.0, 1.8)	0.081	1.4 (1.1, 1.9)	0.037	1.3 (1.0, 1.7)	0.079
Sugary foods consumption per day	Less than five time per day			1		1		1	
	Five times or more per day			1.8(1.4, 2.3)	< 0.001	1.7 (1.3, 2.2)	<0.001	1.5 (1.2, 1.9)	0.001
Dental visit per year	Did not attend			1		1		1	
	Attended at least once			0.6 (0.5, 0.8)	< 0.001	0.6 (0.4, 0.7)	<0.001	0.7 (0.6, 0.9)	<0.001
Dental caries	No caries					1		1	
	With Caries					2.6 (2.1, 3.3)	< 0.001	2.4 (1.9, 3.0)	< 0.001

Covariates		Stage 1	Stage 2	Stage 3	Stage 4	
Painful tooth	No pain				1	< 0.001
	With pain				7.0 (5.2, 9.4)	

Discussion

This study assessed the association between dental caries and Child Oral Impact on Daily Performance (C-OIDP) after adjusting for confounders selected using directed acyclic graphs. In addition, the study assessed psychometric properties, prevalence, and sociodemographic and behavioral factors associated with C-OIDP. The study revealed acceptable psychometric properties of the C-OIDP index, a positive association between self-reported poor health of the teeth, and clinically assessed dental caries with all C-OIDP items as well as overall C-OIDP. Prevalence of C-OIDP was high and the most frequent impacts were related to difficulties with eating and cleaning teeth. Participants having dental caries were more likely to experience COIDP than their counterparts without dental caries experience after adjustment of confounding variables identified by the use of a DAGs. Independent of the Caries-C-OIDP association, the participants with frequent intake of sugary foods and dental visits at least once per year had respectively increased and decreased likelihood of having oral impacts. Painful tooth or teeth in the past three months was highly associated with increased oral impacts.

Interpretation of the findings needs to be done with consideration of the following limitations: This was a cross-sectional study that ascertains exposure and outcome at the same point in time and therefore causal inference cannot be established. The results on self-reported oral health-related behaviors are subject to social desirability bias similar to any other behavioral related studies [24]. Participants could have responded or chosen responses that were socially desired and therefore they might have under-reported poor oral health-related behaviors or over-reporting good oral health behaviors. An attempt to reduce this bias was done through the use of a self-administered anonymous questionnaire filled in by participants in a large classroom where they could not easily see each other's responses. Information on oral health-related behaviors is also subject to recall bias although efforts to minimize the bias were done by structuring the stem of questions to reduce the duration of recall to 1 month and the options to facilitate easy recall. The accuracy of Caries Assessment and Treatment Spectrum in the detection of none cavitated early carious lesions is limited equally between those with and without C-OIDP due to the inability to use compressed air to dry a tooth surface in the field environment. Thus, the possibilities of non-differential misclassification cannot be ignored. The findings of this study can be generalized to adolescents attending public secondary schools in Zambia but may be not to those attending private schools. A large sample size drawn from randomly selected districts and schools of Copperbelt province contributes to the strength of our findings. Training and calibration of examiners on the Caries Assessment and Treatment (CAST) tool before the collection of exposure data reduced variability and the chances of misclassifying exposure[22]. High test-retest reliability and internal consistency of the outcome variables (C-OIDP) also contribute to the strength of our findings and confirm the applicability of the tool among Zambian adolescents.

The high prevalence of C-OIDP in these adolescents is in line with their high prevalence of dental caries reported in an earlier publication [25]. This finding is consistent with some studies in SSA [11, 26]. However, considerably lower[10] and higher[7, 27, 28] prevalence of C-OIDP than those in the current study were reported among adolescents in other studies. Higher prevalence of C-OIDP up to 100% is reported in some high-income countries

[2]. Similar to other previous studies C-OIDP items related to pain and functional limitation such as difficulty with eating, cleaning teeth, and sleeping were the most frequently reported individual items of C-OIDP [2]. The higher frequencies of these items could be attributed to the fact that these daily activities are more likely to be affected in a person with a painful tooth. The order in the rank of C-OIDP items is in line with that of other previous studies in Sub–Saharan Africa [7, 10, 11, 27].

In the current study, the odds of C-ODIP were equal regardless of the levels of parental education and socioeconomic status. The influence of other factors such as peer and school and home environment which plays an equally important role in determining proximal oral health-related behaviors could explain the observed lack of association. Contrary to our finding a review of the influence of parental socioeconomic status on C-OIDP showed high income is associated with better OHRQoL [29].

The influence of biological factors such as age and sex on dental caries and C-OIDP did not reveal an association in the final model. This finding is in line with a systematic review of factors that affect oral health-related quality of life among children in Africa [7]. The review included several studies from Africa and therefore, the pooled results may reflect the true picture in the African context.

Regarding oral health-related behaviors, impacts on oral health-related quality of life were positively associated with high intake of sugar containing foods. Well-established evidence on the relationship between frequent intake of highly refined carbohydrates such as sucrose and dental caries which is the main exposure that affects C-OIDP could give a plausible explanation of this finding [30]. However, this finding is contrary to a recent systematic review [7] which did not find an impact of all oral health behaviors on C-OIDP. We used the threshold of eating behavior of “five times or more per day” as suggested by Van Loveren et al., (2019) [30] to discriminate poor and good eating behaviors in relation to dental caries which may differ from others who used a lower threshold to dichotomize the eating behaviors.

In this study dental visits reduced reporting of oral impacts. The participants who visited a dentist at least once per year were more likely to receive treatment for acute problems and get pain relief which in turn influenced C-ODIP. This finding is in line with the findings of a study that evaluated the association between the oral impact on daily performance and recent use of dental services among school children [31].

The findings of the current study call for deliberate measures by all oral health stakeholders to put in place preventive oral health services among adolescents in Zambia since the implication of the high prevalence of dental caries and C-OIDP among Zambian adolescents is likely to persist during their adulthood. Furthermore, this group consists 23% of Zambian population which is one of the highest adolescent populations in the world [32]. The deliberate measures may include addressing the problem by focusing on reducing the frequency of intake of sugary-containing foods and monitoring early cavitated teeth as primary preventive measures. Addressing dental caries in school environments such as the provision of simple restorative procedures (Atraumatic Restorative Treatment) and emergency treatment may be considered rather than waiting for adolescents to visit dental clinics.

Conclusion

Acceptable psychometric properties qualify the English version of C-OIDP as a reliable index for assessing OHRQoL among Zambian adolescents. Prevalence of C-OIDP was high and daily activities that were more likely to be affected with pain such as problems with eating, cleaning teeth, and sleeping were the most frequently reported.

Dental caries was associated with increased C-OIDP. The use of DAG facilitated the identification of parental education, socioeconomic status, adolescents' sex, age, tooth brushing using fluoridated toothpaste, frequency of consumption of sugary foods, and dental visits in the past year as possible confounders for adjustment. Consuming sugary diet more than five times per day increased the odds of C-OIDP while dental visits at least once per year decreased the likelihood of reporting C-OIDP.

List Of Abbreviations

CAST Caries Assessment and Treatment Spectrum

COHIP SF19 Child Oral Health Impact Profile Short Form 19

C-OIDP Child -Oral Impact on Daily Performance

DAG Directed Acyclic Graph

DEBS District Education Board Secretary

DHS Demographic Health Survey

IRB Institutional Review Board

IWI International Wealth Index

MUHAS Muhimbili University of Health and Allied Sciences

NHRA National Health Research Authority

OHRQoL Oral Health Related Quality of Life

OIDP Oral Impact on Daily Performance

RCFT Randomized controlled field trial

SES Socio-economic status

SSA Sub Saharan Africa

TDRC Tropical Disease Research Centre

WHO World Health Organization

Declarations

Ethical approval

Examination of the participants adhered to the Declaration of Helsinki and Zambia National Health Research Authority guidelines. The study proposal was approved by Tropical Diseases Research Centre, Zambia -IRB 00002911 FWA 00003729, MUHAS Institutional Review Board-P. MUHAS-REC-4-2020-208, Tanzania and Regional Ethical Committee Vest 191836, Norway. Eligible participants were informed on the procedures, benefits, risks and

their freedom to participate or withdraw consent at any stage of the study. Written consent was obtained from participants' parents or legal guardian(s).

Consent for publication

Not applicable

Availability of data and materials

The anonymous data will be available from the authors upon request and with permission of Zambia Health Research Authority and Muhimbili University of Health and Allied Sciences, Tanzania.

Competing interests

The authors declare no competing interests.

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Authors' contributions

The principal investigator (SA) participated in designing the study, data collection, data entry cleaning, analysis, and manuscript preparation. AA, HM, SS and FK guided the principal investigator during design, data collection, data entry and analysis and manuscript preparation. NB participated in data analysis and manuscript preparation. All the authors participated in reviewing and approving the final draft of the manuscript.

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Figures

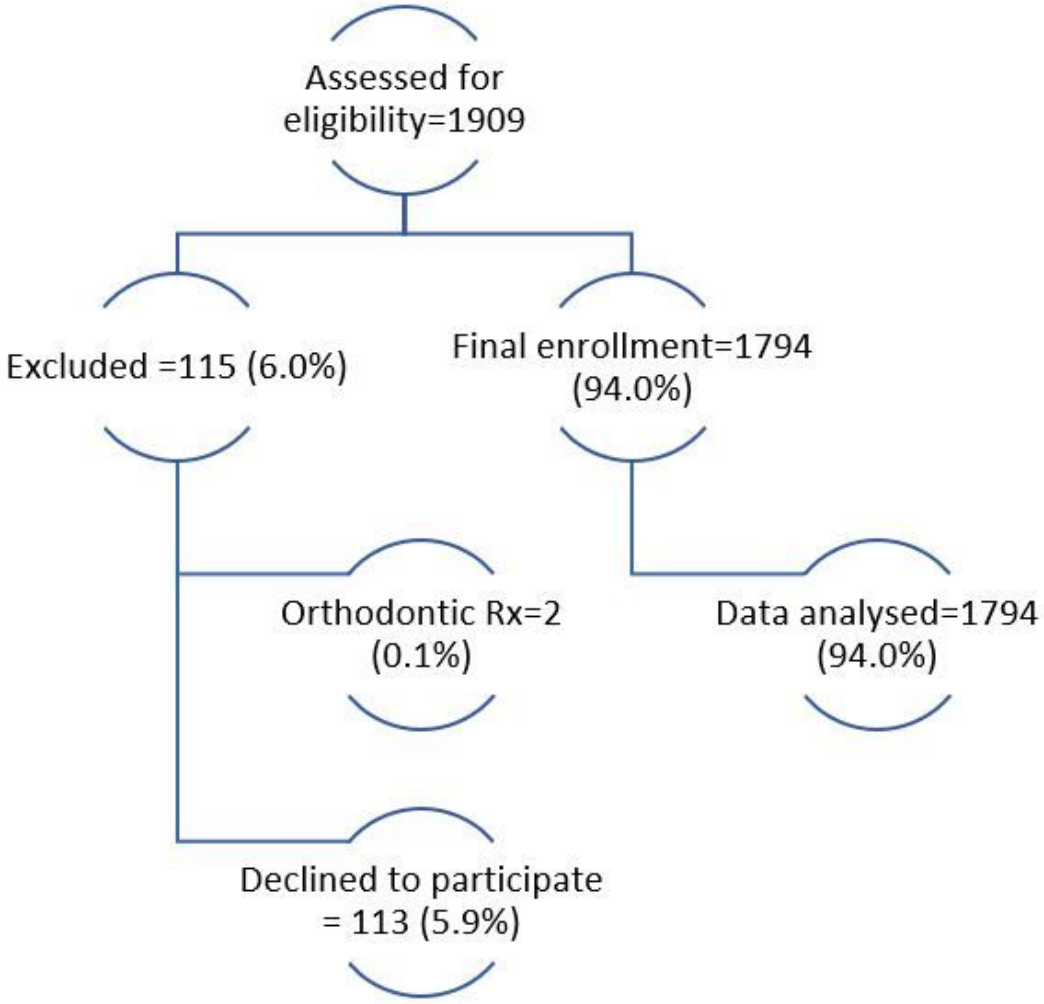

Figure 1

Participants' enrollment chart

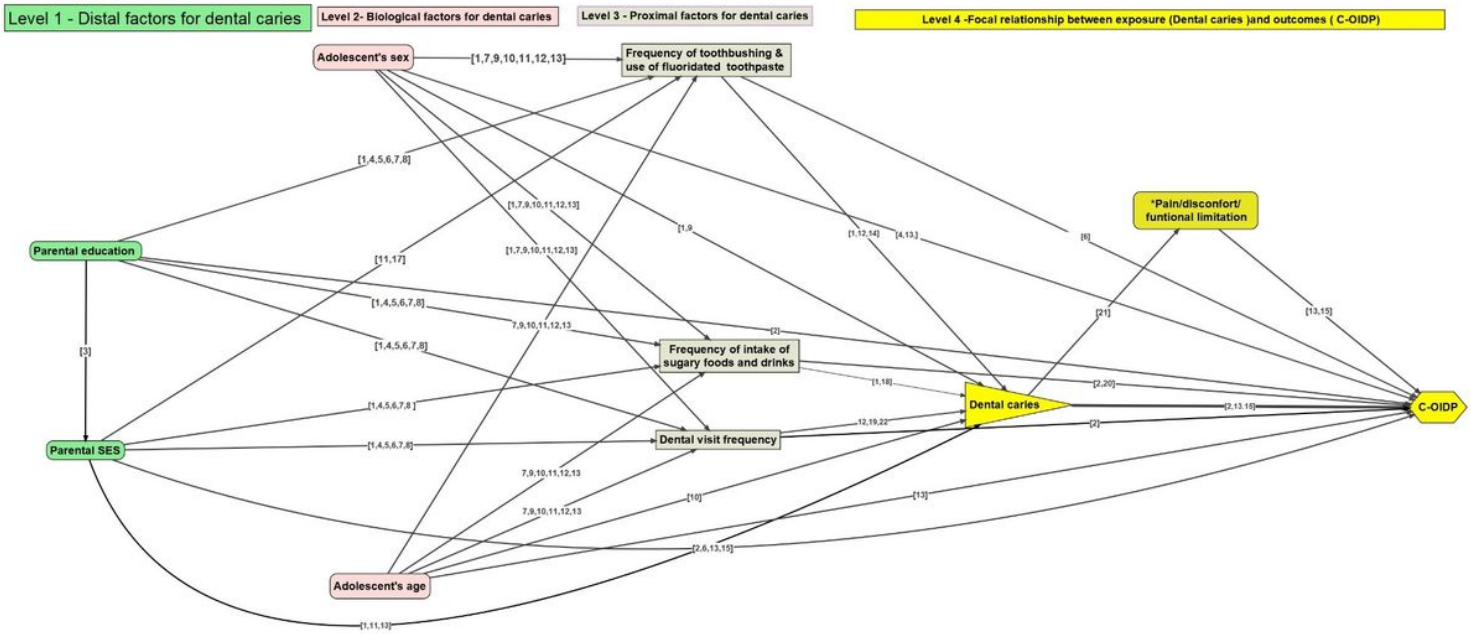

Figure 2

Directed acyclic graph (DAG) illustrating relationship between dental caries as exposure and OIDP as an outcome

In square parenthesis [ ] are the references supporting the assumed pathways during construction of the DAG (see appendix 1 for detailed description and references)

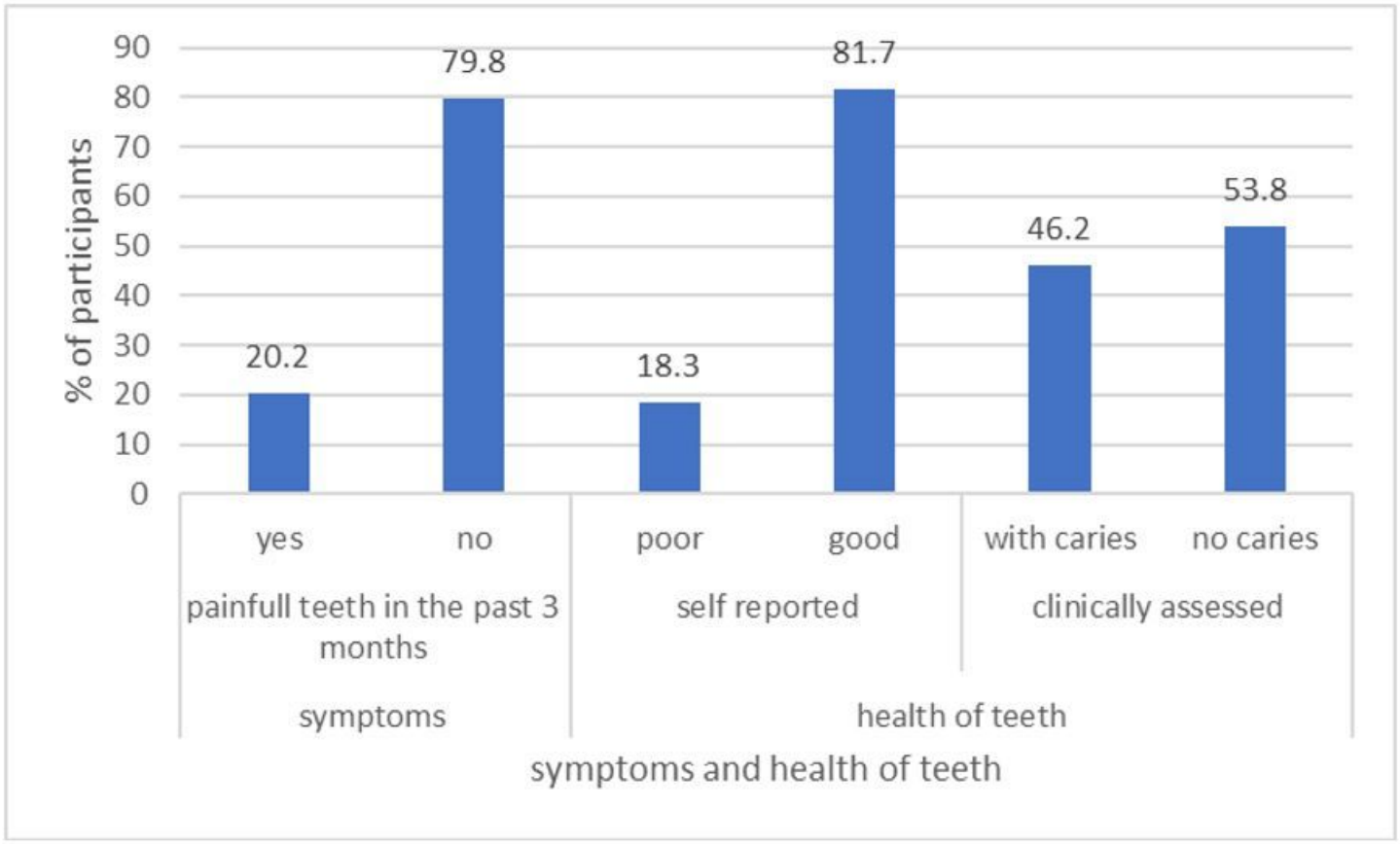

Figure 3

Distribution of participants according to symptoms, self-reported and clinically assessed heath of teeth

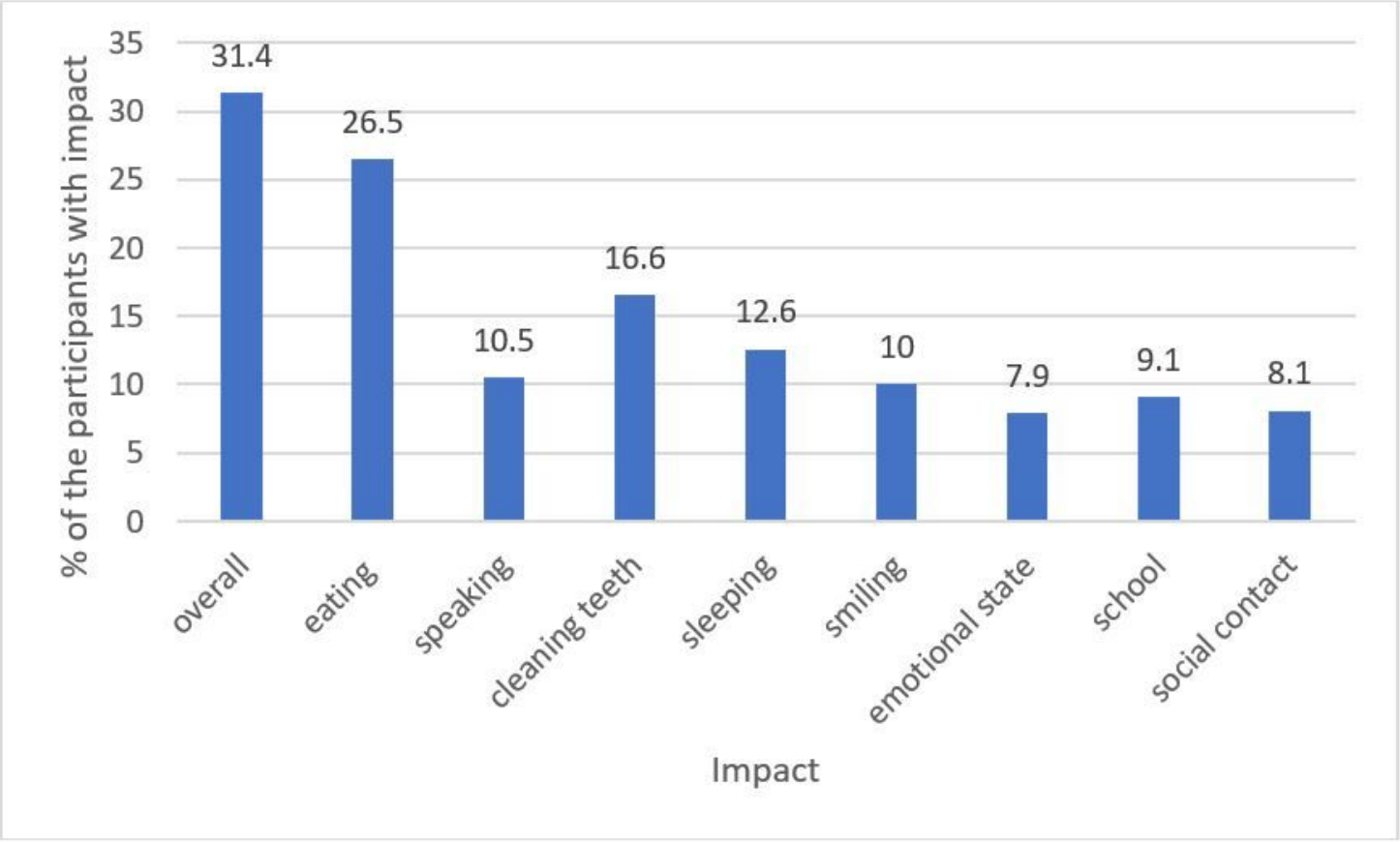

Figure 4

Distribution of overall and single OIDP items

Supplementary Files

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- DescriptionofthedirectpathsintheDAG09.02.23.docx