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Income inequality and traumatic dental injuries in 12-years old children: a multi-level analysis

Abstract

Background/Aim: Contextual socioeconomic factors have been associated with traumatic dental injuries (TDIs). However, evidence concerning the role of income inequality on TDIs in children is scarce.The aim of this study was to investigate the association between contextual income inequality over a ten-year period and TDIs in Brazilian children.

Subjects and methods: The study population comprised a representative sample of 5027 children aged 12 years who participated in the Brazilian oral health survey in 2010. City-level Gini Index was used to measure contextual income inequality in the years 2000 and 2010, as well as the variation in income inequality between 2000 and 2010. Covariates were gender, ethnicity, family income, number of people per room and incisal overjet. Clinical examinations were used to assess TDIs. Multivariable multilevel ordered multinomial logistic regression was used to estimate cumulative Odds Ratio (OR) and 95% confidence intervals between income inequality and TDIs.

Results: The prevalence of children who had one tooth with TDI and two or more teeth with TDIs was 15.2% and 6.4%, respectively. The maxillary central and left lateral incisors were the teeth most affected by TDIs. Gini coefficient reduction between the years 2000 and 2010 decreased the odds of TDIs even after adjustment for demographic and socioeconomic characteristics, and incisal overjet. The likelihood of more TDIs decreased 21% for each 0.05 unit decrease in the Gini coefficient between the years 2000 and 2010. Boys, brown skin colour, overcrowding and incisal overjet greater than 5 mm remained statistically associated with TDIs in the final model.

Conclusions: The decrease in income inequality over a ten-year period was inversely associated with TDIs among Brazilian children aged 12 years.

Introduction

Traumatic dental injuries (TDIs) have become a significant public health problem that adversely affects children's quality of life.[1] In addition, treatment time and costs related to TDIs have been substantial for the individuals and their families with physical and psychological consequences.[2,3] Recent review papers have explored the occurrence of TDIs in different regions of the world and revealed that approximately 30% of preschool children have suffered a TDI to the primary dentition and 25% of schoolchildren have suffered a TDI involving the permanent dentition.[3,4] Although the prevalence of TDIs can be considered stable over recent years, a large variation of their occurrence has been reported within and between countries.[2-4] The variation of TDIs prevalence across studies can be attributed to location, environmental and socioeconomic disparities, TDIs diagnostic criteria, as well as demographic differences in the studied sample.[3-5]

Previous surveys involving schoolchildren aged nine years or more suggest that boys, overjet more than five millimeters and inadequate lip coverage are the main predisposing factors for TDIs in the permanent dentition.[6-17] Other characteristics associated with TDIs are being overweight[9], non-nuclear families, paternal punishment[10], overcrowded households[8], poor school performance[10,15] and previous dental trauma.[13] Most of these studies also investigated the possible role of socioeconomic factors on TDIs.[6,7,9,11,14-17] However, their findings regarding whether children from less privileged socioeconomic groups are more likely to have TDIs than those from better-off social groups are inconsistent. Socioeconomic indicators including family income, mother's schooling, and social class were not associated with TDIs involving the permanent dentition.[6,9,12,17] Other research has reported that children from low socioeconomic status[7,15], those from low-income families[14] and those whose mothers had low schooling[16] were more prone to TDIs. Recent systematic reviews have also highlighted the lack of consensus on the relationship between socioeconomic factors and TDIs in the primary dentition[18] and in the permanent dentition.[19]

Contextual social factors and area-level determinants have been associated with TDIs in children.[11,12,20-22] In addition, previous studies of oral health inequalities have investigated the effect of society's income inequality on a population's oral health.[23-27] The income inequality-health hypothesis argues that income distribution plays an important role in the distribution of diseases. The most egalitarian societies, where the gap separating the rich from the poor is small, have better health than those where the society's wealth is concentrated in a small proportion of the population.[28, 29] Although the income inequality-health hypothesis seems applicable to oral health research, very few studies have assessed whether contextual income inequality influences oral conditions. State-level and city-level income inequality were associated with different oral health outcomes in adults, including tooth loss,[24,27] periodontal disease[25] and oral impacts on daily lives.[26] To date, only one study has tested the income inequality hypothesis related to children's oral health. Income inequality was significantly related to dental caries in schoolchildren across 19 administrative regions of the District Federal in Brazil.[23] The possible influence of income inequality on TDIs in children was not assessed which suggests that the answer for this question remains unclear and requires further research. The aim of this study was to investigate the association between city-level income inequality over a ten-year period and TDIs in a representative sample of 12-year-old children. The possible attenuation of family income on the relationship between income inequality and TDIs in children was also assessed.

Material and methods

The project was approved by the Brazilian National Council of Ethics in Research (no. 15498). Participants were recruited from their homes where informed consent was obtained from all participants' parents before dental examination and interviews.

The present study combined individual and city-level data from the Brazilian Oral Health Survey (*SB Brasil Project*) and the Brazilian Regional Office for the United Nations Development Program, respectively.[30,31] The *SB Brasil Project* was a nationwide oral health epidemiological survey conducted in 2010 to characterise the oral health of different age groups.[30] A representative sample was obtained from 32 geographical domains, including 26 state capitals, the Federal District and five domains representing the interior municipalities of each Brazilian geographical macro-region (North, Northeast, Central-West, Southeast, and South).[32] Dental examinations were conducted by calibrated dentists under natural light with sterilized instruments following the WHO guidelines for oral health surveys involving participants from 177 municipalities of the country.[33] Demographic and socioeconomic characteristics were obtained through individual interviews using standardized questionnaires electronically configured in a Personal Digital Assistant (PDA).[30]

The studied sample consisted of children aged 12 years who participated in the *SB Brasil Project*. TDIs were measured only among 12-year-old children and thus other age groups were excluded. Children from the interior municipalities and those with missing data for any investigated variable were also excluded. The sample was considered to be representative of oral health conditions for state capitals and the Federal District.

The sample of the *SB Brasil Project* was obtained using a stratified multistage cluster sampling method. Primary sampling units were census tracts for state capitals and the Federal District. Cities were the primary sampling units for interior municipalities. Households within the census tracts for the state capitals and the Federal District and households for the interior municipalities were selected in the second sampling stage. Detailed information regarding the sampling process is available elsewhere.[32]

Ten fieldwork research teams in each state capital and the Federal District were involved in data collection. Each fieldwork research team included one dentist and one health care worker from the Brazilian Public Health Care System. All dentists participated in a 32-hour training workshop and calibration study.[30] The latter was conducted according to the consensus calibration technique to calibrate ten dentists in each state capital and the Federal District who carried out the dental examinations. Initially, the ten dentists in each city were divided into two groups and examined ten subjects for a practical discussion. Discrepancies in the diagnostic criteria were discussed with an instructor until a consensus has been reached generating a "consensus form". During the intra-examiner calibration each dentist examined 20 subjects twice with a time interval of at least 30 minutes. Then, each dentist independently examined 20 subjects and the results were compared with a "consensus form" previously agreed by the examiners in each city to evaluate inter-examiner consistency. All examiners of the main survey needed to obtain a minimum Kappa coefficient of 0.65.[33] Dentists who did not reach the acceptable Kappa were replaced.

The presence and severity of dental trauma were assessed at the *SB Brasil Project* according to the modified version of the TDI index adopted at the Children's Dental Health Survey in the UK.[34] Tooth surfaces were cleaned before dental examinations using wet gauze pads. TDIs were registered through visual examination using a plane dental mirror in all upper and lower permanent incisors, according to the following categories: 0 = no evidence of fracture or tooth missing due to trauma, 1 = fracture of the crown involving the enamel only, 2 = fracture of the crown involving the enamel and dentin, 3 = fracture of the crown involving the pulp, and 4 = missing tooth because of trauma.[34]

A contextual measure of income inequality at city-level (state capitals and the Federal District) was assessed using the Gini Index obtained from the Brazilian Regional Office for the United Nations Development Program for the years 2000 and 2010.[31] Gini Index is a single summary statistic of the income distribution and considered a reliable and sensitive measure of income inequality.[35] The variation of Gini Index between 2000 and 2010 was calculated by subtracting the respective Gini coefficients. A positive Gini coefficient difference indicated a reduction of income inequality over a ten-year period. The Gini Index is a measure of the average difference between all pairs of incomes in a population that summarizes the distribution of income across the entire range of income categories.[36] The index varies between zero and one, where the former value represents total equality and the latter value is total inequality.[31] Values were modified to indicate a change in the outcome for every increase (positive betas) or decrease (negative betas) of 5% unit in the Gini coefficient.[24,37]

Sociodemographic variables included gender, ethnicity, monthly family income, number of people per room and incisal overjet. Self-reported skin colour was used to assess ethnicity according to the Brazilian Institute of Geography and Statistics classification (white, yellow, indigenous, brown and black).[38] Monthly family income was registered in Brazilian reais (R$) according to the following categories: ≤ R$ 500, R$ 501-1500, R$ 1501-2500 and ≥ R$ 2501. The Brazilian minimal wage was R$500 and one Brazilian real corresponded to 0.586 USD when the study was conducted. The number of people per room was obtained by dividing the number of residents (excluding housemaids) by the number of bedrooms in the house to assess household's overcrowding. Incisal overjet was measured in millimeters using a periodontal probe positioned parallel to the occlusal plane. The corresponding distance between the labial surface of the more prominent maxillary central incisor and the corresponding mandibular incisor was registered and coded as ≤ 5 mm or > 5 mm.[7]

Data analyses were carried out using IBM SPSS Statistics version 22.0 (SPSS, Chicago, IL, USA) and MLWIN 2.24 (Centre for Multilevel Modelling, University of Bristol, Bristol, UK) software. The frequency of teeth with TDIs and relative frequency of TDIs per thousand incisors was estimated according to the type of tooth and TDIs categories. Participants were categorised into three TDI groups: TDI = 0, no tooth with trauma (all teeth coded zero); TDI =1, one tooth with trauma (one tooth with codes one, two, three, or four) and TDI ≥ 2; two or more teeth with trauma (two or more teeth with codes one, two, three, or four). The distribution of independent variables according to the TDI groups was described through proportions. Gini Index measures for the years 2000 and 2010 and the variation between 2000 and 2010 were described through means, standard deviations and ranges.

The multilevel structure of analysis included 5027 children (level 1) grouped into 27 cities (level 2). Multilevel models facilitate estimation of contextual-level variables by accounting for spatial clustering of individuals within areas. A two-level random intercepts and fixed-slopes model structure with individuals nested within cities was fitted, TDI as a three-level ordinal outcome, namely TDI = 0; TDI = 1; and TDI ≥ 2, and using ordered logit models to estimate the cumulative distribution probabilities of the response categories. The reference group was 'TDI = 0'. Coefficients estimated in these models indicated the likelihood of moving into a higher category of TDI ≥ 2. Fixed- and random parameter estimates for the two-level ordered logit models were calculated by marginal quasi-likelihood (MQL) procedures with first-order Taylor series expansion, RIGLS (restricted iterative generalized least squares) estimation method, as implemented within MLWIN software version 2.24. As TDI outcome has an ordinal response scale, the proportional odds assumption by fitting multilevel binary logit models with TDI at the three possible cut-off points was tested. Results are presented as odds ratios (OR) and 95% confidence intervals (95% CI).

The variance and standard error of TDIs across cities (random effects) were used to evaluate the variation in the outcome at the contextual level. The median of odds ratio (MOR) with 95% credible intervals (CrI) were calculated using the posterior distribution of the area variance as provided by the Markov ChainMonte Carlo (MCMC) procedure in MLWIN.[38] MOR equal to one suggests no variation in the TDIs between cities. The higher the MOR, the greater the city-level variation.

In the ordered multinomial logistic analysis, the log OR were interpreted as the estimated additive changes moving into a higher category of TDI ≥ 2 for a change of 5% unit in the Gini coefficient.

The multilevel ordered multinomial logistic regression was used to test the association between income inequality measures and TDIs, adjusted for individual characteristics. Independent variables showing associations with $P < 0.10$ in the bivariate analysis were selected for the multivariable analysis. Four statistical models were tested. The first model consisted of Gini Index variation between 2000 and 2010.

The contextual variable adjusted for individual demographic characteristics (gender and ethnicity) constituted the second model. Individual socioeconomic characteristics (family income and number of people per room month) were added into the third model. The final model consisted of the previous variables and the incisal overjet. Independent variables of each model were adjusted for each other.

Results

The response rates of householders and children were 91.6% and 99.4%, respectively. Children from the interior municipalities (N = 1725) and those with missing data in one or more variables (N = 497) were excluded. This resulted in a final sample of 5027 participants. Sociodemographic characteristics, TDIs and incisal overjet were similar between participants and those with missing data.

Distribution of TDI by type of tooth and severity of injury is presented in Table 1. The maxillary right central and left lateral incisors were the most common teeth affected. The most common type of TDI was fracture involving the enamel. TDIs involving the pulp and missing teeth due to TDIs were uncommon (Table 1).

The prevalence of children with one tooth with TDI and two or more teeth with TDIs was 15.2% and 6.4%, respectively. Demographic and socioeconomic characteristics, incisal overjet measures according to TDIs groups are presented in Table 2. Most participants were boys, had brown skin colour, family income between R$501 and R$1,500 and incisal overjet < 5 mm. On average, Gini index decreased across the 27 cities between the years 2000 and 2010 (Table 2). Of the 27 cities, 19 experienced a reduction on Gini coefficients between the periods.

Table 3 shows the unadjusted association of income inequality and individual independent variables with TDIs. There were significant between-city differences in TDIs prevalence (MOR = 1.34 95% CrI 1.03, 1.17) for the null model. The distribution of TDIs was significant between cities for all contextual variables since MOR remained statistically significant when city-level Gini Index measures were added to the null model. The variation of Gini index between 2000 and 2010, gender, ethnicity, number of people per room and incisal overjet were associated with TDIs ($P < 0.05$).

The variation of Gini index between 2000 and 2010 was associated with TDIs in Model 1 of the multilevel ordered multinomial logistic regression. Demographic (gender and ethnicity) and socioeconomic (family income and number of people per room) characteristics were inserted in Models 2 and 3, respectively. In the final Model, the odds of higher TDIs decreased 21% for each 0.05 unit decrease in the Gini coefficient between the years 2000 and 2010. Boys, brown skin colour, a higher number of people per room and incisal overjet > 5 mm remained statistically associated with TDIs in the final model ($P < 0.05$). The OR for the association between Gini coefficient decrease and TDIs remained similar after adjustment for family income and other covariates (Table 4).

Discussion

This study showed the influence of city-level income inequality on TDIs in a representative sample of children aged 12 years, even after taking into account individual demographic and socioeconomic characteristics, and incisal overjet. A 5% decrease in the Gini coefficient between 2000 and 2010 was associated with 21% lower odds of TDIs. Family income did not influence the association between the decrease of income inequality and TDIs. To the authors' knowledge, this is the first study that has tested the association between city-level income inequality and TDIs in children.

TDIs are a major life event in children's lives that have been related to falls, sports, accidents or physical violence.[2,3] Although living in social deprivation and poverty increase the risk of injuries in childhood,[40] few studies have analysed whether environmental characteristics and contextual social inequalities influence the occurrence of TDIs. The current findings agree with previous research on the influence of contextual social determinants on TDIs in children.[12,21,22,40] However, this is the first study to address the role of social inequalities on TDIs in children considering city-level contextual measures using a nationwide representative sample.

Children from affluent families tend to play in safer environments than those from less affluent families. Furthermore, children living in socially deprived neighbourhoods are more exposed to several environmental risks of injuries, including poor physical housing conditions and unsafe roads. Social and cultural practices are also related to children's injuries such as lack of parental supervision, sense of early independence and the non-use of safety equipment for sports.[40]

There is a large body of evidence suggesting that income inequality is a relevant determinant of population health.[28,37,41] Although epidemiologic studies on income inequality and oral health are less common, previous studies along with the current findings are consistent to demonstrate that inequalities in the wealth distribution and poor social conditions can be considered as fundamental causes of oral health disparities when different age groups and oral health outcomes were assessed.[24-27] The findings of this study argue that a decrease in income inequality has the potential to reduce children's oral health inequalities and highlight the importance of developing macrostructural measures to reduce the oral health gap between the rich and the poor.

Living in societies with more unequal distribution of income has a detrimental effect on an individual's health through different mechanisms that are applicable to TDIs in children.[28,41] Under investment in human capital, including public education and health care, is commonly observed in societies with a high-income gap.[41] This is particularly important in developing countries where the public resources are scarce. Supportive schools encompassing those with a comprehensive curriculum and better social and physical environments showed significantly lower rates of TDI than non-supportive schools in Thailand and Brazil.[11,20] The degree of implementation of healthy public policies at neighbourhood level, including those related to schools, food policies, daycare centres and dwelling conditions, was associated with TDIs in deprived areas in Brazil.[22] The influence of income inequality on oral health may be also mediated by erosion of contextual social capital.[12] Contextual social capital emphasizes the resources that can be drawn upon by individuals to pursue collective aims by being interconnected.[42] Interpersonal trust, networks and norms of mutual aid and reciprocity have been considered features of social capital, which act as resources for individuals and facilitate cooperation and collective action.[43] Boys living in areas with lower levels of social capital had a greater prevalence of TDIs than those from areas with high social capital suggesting that risk-taking behaviours are influenced by neighbourhood social connections and relationships.[12] The harmful psychosocial effects of social comparisons may also explain the influence of income inequalities on TDIs. The impact of relative deprivation on levels of frustration and striving to achieve a minimum acceptable standard of living has adverse health effects. The prevalence of TDIs was significantly higher among adolescents residing in deprived areas than those from better-off residential areas in India.[21]

There are certain methodological limitations associated with the present study that must be taken into consideration when interpreting the findings. First, causal inferences are limited due to cross-sectional data of the outcome. Second, only children aged 12 years were considered and the results should not be applied to other age groups. Third, classification bias may have occurred among participants who moved city between the years 2000 and 2010. Third, since secondary data were used in this study, potential predictors of TDIs were not addressed, including inadequate lip coverage and family structure. Finally, international comparisons must be cautious. The influence of income inequality on TDIs should be limited to countries with similar socioeconomic characteristics to Brazil.

In conclusion, the present findings suggest that children aged 12 years living in Brazilian cities that experienced a decrease in income inequality over a ten-year period were less likely to have TDIs. Dental injuries among children aged 12 years appear to be a very sensitive oral condition to environmental social changes and the impact of income inequality decrease on TDIs reinforces the need for public policies to reduce social inequalities related to oral health disparities.

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Table Legends:

Table 1. Characteristics of TDIs according to permanent incisors and type of dental injury (N = 39974 teeth).

Table 2. Distribution of TDIs according to individual and contextual variables.

Table 3. Non-adjusted association between individual and contextual variables and number of teeth with TDIs, determined using multilevel ordinal logistic regression.

Table 4. Multilevel ordinal logistic regression on the association between individual and contextual variables and number of teeth with TDIs.

Table 1. Characteristics of TDIs according to permanent incisors and type of dental injury (N = 39974 teeth).

	Frequency	Relative frequency per thousand incisors
Type of tooth		
Maxilla		
Right Lateral	130	3.3
Right Central	541	13.5
Left Lateral	435	10.9
Left Central	103	2.6
Mandible		
Right Lateral	40	1.0
Right Central	132	3.3
Left Lateral	63	1.6
Left Central	66	1.7
TDI		
Enamel fracture	1246	31.2
Enamel and dentin fracture	235	5.8
Fracture involving the pulp	17	0.4
Missing tooth because of trauma	12	0.3
Total	1510	3.8

Table 2. Distribution of TDIs according to individual and contextual variables.

Variable			Number of teeth with TDI		
			None N = 3940	1 N = 764	≥ 2 N = 323
Level 1: individual variables (N = 5027)	N	%	79.8	14.3	6.0
Gender					
Female	2512	48.7	81.9	12.5	5.6
Male	2515	51.3	77.7	16.0	6.3
Ethnicity					
White	2012	42.9	81.9	12.6	5.5
Yellow	95	1.3	80.4	8.5	11.1
Indigenous	37	0.4	78.9	18.0	3.1
Brown	2400	44.2	77.8	15.8	6.4
Black	2012	11.2	79.6	15.0	5.4
Family income (R$)					
≥ 2501	618	11.6	81.4	14.0	4.6
1501-2500	823	15.6	78.2	16.2	5.6
501-1500	2673	55.1	79.6	13.8	6.6
≤ 500	913	17.7	80.5	14.2	5.3
Incisal overjet					
≤ 5 mm	4606	91.9	80.6	13.7	5.7
> 5 mm	421	8.1	70.2	21.1	8.7
Level 2: contextual variables (N = 27)	Mean	SD	Range		
Gini coefficient 2000	0.6263	0.0266	0.5661	0.6789	
Gini coefficient 2010	0.6169	0.0335	0.5652	0.7287	
Gini coefficient variation (2000-2010)	0.0094	0.0271	-0.1042	0.0477	

Table 3. Non-adjusted association between individual and contextual variables and number of teeth with TDIs, determined using multilevel ordinal logistic regression.

Variable	Variance	MOR	β	Standard error	OR	95% CI
Null model	0.092 (0.034) *	1.34 (1.03-1.17)				
Level 2: contextual variables						
Gini coefficient 2000	0.091 (0.033)*	1.33 (1.03-1.17)	0.085	0.128	1.09	0.85 – 1.40
Gini coefficient 2010	0.083 (0.032)*	1.32 (1.02-1.16)	0.132	0.095	1.14	0.96 – 1.38
Gini coefficient variation (2000-2010)	0.069 (0.028)*	1.28 (1.01-1.13)	-0.243	0.110	0.78*	0.63 – 0.97
Level 1: individual variables						
Gender						
Female					1	
Male			0.199	0.069	1.22*	1.07 – 1.40
Ethnicity						
White					1	
Yellow			0.008	0.266	1.01	0.60 – 1.70
Indigenous			0.101	0.406	1.11	0.50 - 2.45
Brown			0.222	0.078	1.25*	1.07 – 1.46
Black			0.104	0.126	1.11	0.87 – 1.42
Family income (R$)					1	
≥ 2501						
1501-2500			0.228	0.132	1.26	0.97 – 1.63
501-1500			0.180	0.114	1.20	0.96 – 1.50
≤ 500			0.116	0.133	1.13	0.87 – 1.46
Number of people per room			0.083	0.030	1.03*	1.02 – 1.15
Incisal overjet						
≤ 5 mm					1	
> 5 mm			0.362	0.114	1.44*	1.15 – 1.80

MOR, median odds ratio

OR, odds ratios

95% CI, 95% confidence intervals

* P < 0.05

Table 4. Multilevel ordinal logistic regression on the association between individual and contextual variables and number of teeth with TDIs.

Variable	Model 1	Model 2	Model 3	Model 4
	OR 95% CI	OR 95% CI	OR 95% CI	OR 95% CI
Contextual variable (2nd level)				
Gini index variation (2000-2010)	0.78 (0.63 - 0.97)*	0.80 (0.64 - 0.99)*	0.79 (0.63 – 0.98)*	0.79 (0.64 – 0.97)*
Individual variables (1st level)				
Gender				
Female		1	1	1
Male		1.22 (1.07 – 1.40)*	1.23 (1.07 – 1.41)*	1.22 (1.06 – 1.57)*
Ethnicity				
White		1	1	1
Yellow		1.00 (0.60 – 1.68)	1.04 (0.62 – 1.75)	1.04 (0.62 – 1.74)
Indigenous		1.10 (0.50 – 2.44)	1.06 (0.48 – 2.35)	1.06 (0.50 – 2.35)
Brown		1.24 (1.07 – 1.45)*	1.21 (1.04 – 1.41)*	1.20 (1.03 – 2.40)*
Black		1.11 (0.86 – 1.42)	1.07 (0.84 - 1.38)	1.07 (0.83 – 1.37)
Family income (R$)				
≥ 2501			1	1
1501-2500			1.22 (0.94 – 1.59)	1.22 (0.94 – 1.58)
501-1500			1.12 (0.89 – 1.41)	1.12 (0.89 – 1.40)
≤ 500			1.02 (0.78 – 1.34)	1.02 (0.78 – 1.33)
Number of people per room			1.03 (1.02 – 1.15)*	1.03 (1.02 – 1.15)*
Incisal overjet				
≤ 5 mm				1
> 5 mm				1.40 (1.12 – 1.76)*
Variance at city level (Ωμ (Standard error)	0.088 (0.033)*	0.068 (0.027)*	0.068 (0.027)*	0.065 (0.027)*
MOR	1.33 (1.02-1.17)	1.28 (1.02-1.16)	1.28 (1.02-1.16)	1.28 (1.01-1.13)

OR, odds ratios

95% CI, 95% confidence intervals

* $P < 0.05$

MOR, median odds ratio